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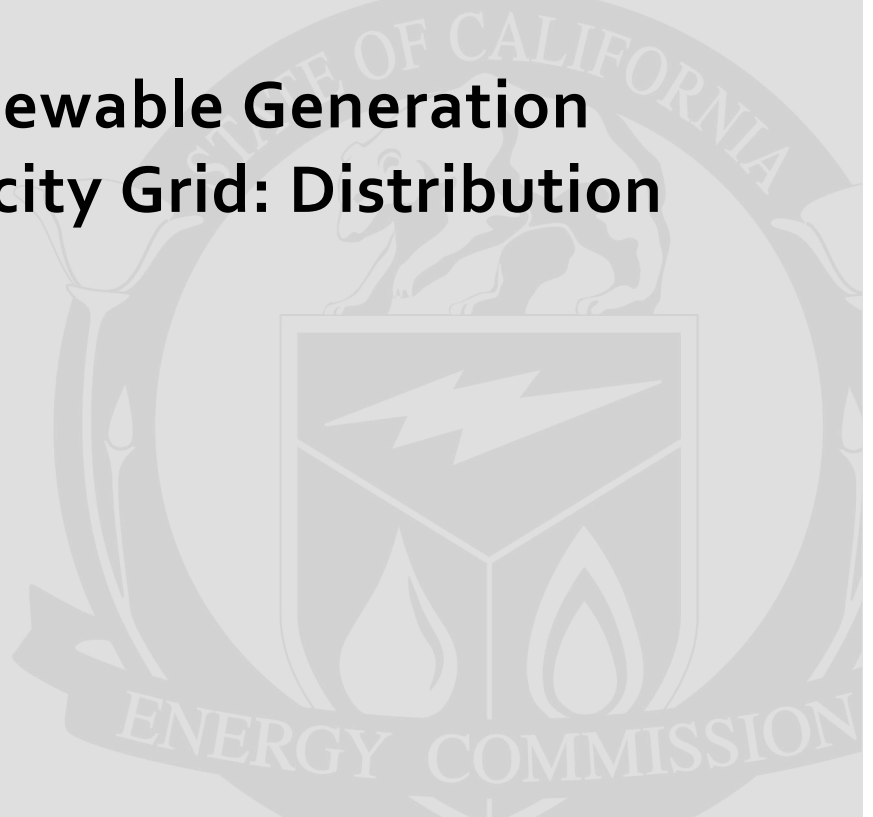https://escholarship.org/uc/item/5xq234kd

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WHITE PAPER

Integrating Renewable Generation with the Electricity Grid: Distribution System Issues

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PREFACE

The California Energy Commission Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency

- Energy Innovations Small Grants

- Energy-Related Environmental Research

- Energy Systems Integration

- Environmentally Preferred Advanced Generation

- Industrial/Agricultural/Water End-Use Energy Efficiency

- Renewable Energy Technologies

- Transportation

Integrating Renewable Generation with the Electricity Grid: Distribution System Issues is the report for the Energy Commission project Staff Workshops Forums on Integrating Renewable Generation with the Electricity Grid (contract number 500-10-055, work authorization number WA002), Task 4: White Paper on Integrating Renewable Generation with the Electricity Grid: Distribution System Issues, conducted by the California Institute for Energy and Environment. The information from this project contributes to PIER's Energy Systems Integration Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

ABSTRACT

This white paper assesses the current state of the art in electric distribution system engineering and operations; identifies the potential impacts to the distribution system from the expected level of renewable generation by 2020; and recommends the technological issues and solutions that will need to be addressed by new research efforts in order to mitigate the expected impacts. This white paper is intended to provide information that will help target future solicitations for research toward applications that will help California better reach its near-term renewable energy goals.

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Introduction

Purpose of the White Paper

The purpose of this White Paper (report) is to present the findings of the literature search and three workshops, and subsequent and associated activities, regarding electric distribution system issues that have arisen, or are anticipated to arise, from the integration of renewable generation with the electric grid at the distribution voltage levels. This work builds on the foundations of Energy Commission-funded renewable and electric grid work completed and underway. The report includes findings in the areas of issues and technology status, summary of discussions and interactions with workshop participants, and evaluation and assessment of information acquired before, during and following the workshop leading to identification of research activities needed for this focus area, including meetings with technical advisory committees, technology experts, and other stakeholders.

Integrating the Distribution System and Renewable Distributed Generation – Overview

Electric distribution systems represent the crucial connection between the high-voltage power transmission network, which extends across many states, and the individual electric customers in any given region, as well as a rapidly growing number of small distributed generators. While this distribution infrastructure is critical to society, it has not historically received much public attention. However, state mandates and incentives primarily intended to reduce greenhouse gases are driving substantial increases in the use of renewable generation at the distribution level, largely solar and wind, both of which are variable and intermittent. Simultaneously, the expected penetration of electric vehicles into the California transportation fleet will impose new and possibly extraordinary demands on the distribution system.

These changes demand a new focus on power distribution as a key area of technology and policy development. Utilities are in the process of implementing the "Smart Grid" and modernizing their distribution systems. The following descriptions are intended to provide a reference basis and context for the technical innovations and challenges likely to be associated with distribution systems experiencing high penetrations of renewable generation, especially variable solar and wind powered systems.

Distribution System Current Status

Physical Architecture

Components

To best understand the issues, and the state of the art for electric grid technologies and the technology gaps that require research and development before they can be deployed as solutions, one needs to understand the physical infrastructure of the electric delivery system. Distribution systems are composed of electric conductors (wires) and a host of associated control equipment – mainly transformers, switchgear and voltage regulation equipment – to provide a safe and dependable path of electric power flow from generation sources to consumers. The main source of electric power for a given distribution system to date is a substation, the point of interface with the transmission grid. From the substation, some number of distribution feeders branch out to cover the local territory to deliver the power to customers.

Substations are built around transformers, the interface between sections of the electric power system with different voltage levels. A transformer consists of two sets of wire coils, linked by a magnetic field through the center of both coils, which induces an alternating electric current in one coil as a result of an alternating current applied to the other. The voltage on either side is proportional to the number of wire turns in each coil; thus, by selecting an appropriate "turns" ratio, high-voltage (low-current) power is converted into low-voltage (high-current) power and vice versa. The side connected to the power source – in this case, the high-voltage side – is called the primary side of the transformer, and the load side the secondary. Transformers may be equipped with load tap changers (LTCs) that mechanically adjust the contact where the conductor taps the coil on the secondary side, thus changing the effective number of turns and thereby adjusting voltage.

The power transfer capacity of transformers, measured in kilovolt-Amperes (kVA) or megavolt-Amperes (MVA), is limited by heat produced in the windings at high current, which must not damage the wire insulation or ignite the oil in which the windings are immersed for cooling (which is meant to remain chemically and electrically inert). The oil in large transformers like those at substations is typically cooled with active air fans, in addition to passive heat sinks (fins) on the transformer's exterior. Actual maximum transformer capacity, like transmission lines, is thus technically dependent on weather, and for operating purposes, is usually capped at a fixed power rating under an assumed worse case.

Transformers also separate primary and secondary distribution. The primary system carries voltages typically on the order of tens of kilovolts, from substations to neighborhoods. Secondary distribution refers to the wires that carry voltage at the customer level, typically 120-240V. In North America, due to low load densities, it is typical for most of the distance to be covered by primary distribution systems, and for a large number of small service transformers to be installed close to loads. This design contrasts with the European style which tends to use fewer, larger transformers in the field that each serve many customers. The European design works there both because distances are smaller and secondary distribution voltage is higher, making line losses less significant.

Electrical switchgear includes various types of switches for opening and closing circuit connections, as well as protective devices whose function it is to automatically interrupt power flow in case of a fault, i.e., a dangerous electrical contact between wires, ground, trees or animals that results in an abnormal current (fault current). Protective devices include fuses (which simply melt under excessive current), circuit breakers (which are opened by a relay) and

reclosers (which are designed to re-establish contact once the fault has gone away). Standard protective devices are characterized by time-current curves, indicating the combination of magnitude (in amps) and duration (in milliseconds) of current through the device that will trip it, or cause it to open. Protection coordination involves comparing the time-current curves of all the devices on a given circuit to ensure that for any given fault scenario, the device closest to the fault will act first to isolate it from the power source, and devices farther away from the fault are set to open at later times if the primary device fails for some reason; this means assigning a protection zone to each device. These multiple layers of protection devices are designed to ensure a high level of reliability that faults on the systems will be cleared.

Utilities are required to provide voltage at every customer service entrance within permissible range, generally ±5% of nominal. Yet the laws of physics dictate that a voltage drop occurs along a distribution line, with a slope proportional to the line's electrical impedance and the current flow. Thus, in order to maintain the voltage within range for the first as well as the last customers on a given feeder, it may be necessary – especially on a long feeder and under high load – to adjust the voltage along the way. Voltage regulation equipment includes load tap changers at substation transformers (mentioned above), voltage regulators, and capacitors. Voltage regulators are essentially adjustable transformers with a small turns ratio, stepping up the voltage along a feeder.

Capacitors reduce the slope of voltage drop by locally reducing reactive power flow. This effect is counterintuitive and bears some explanation. Reactive power, measured in Volt-Amps-Reactive (VARs), is associated with a time lag between the alternating current and voltage, caused by certain loads (such as electric motors and anything containing coils of wire). This time lag results in a circulating current that does not transport useful energy, but contributes to unwanted heat on lines and equipment, as well as voltage drop. Capacitors have the property of compensating for the time lag between current and voltage; so that the lagging current associated with reactive power need only circulate between the load and the nearby capacitor on the distribution feeder, rather than circulating all the way back to a power plant. As a result, the current flow upstream from the capacitor is reduced, which also reduces the voltage drop leading to it. Note that capacitors have no effect on voltage drop associated with real or active power flow. Capacitors are therefore a preferred method of voltage regulation in situations with high reactive loads such as air conditioners (essentially motors), but not with mainly resistive loads such as space or water heaters.

A main distribution feeder typically carries one complete circuit with all three phases of alternating current (AC) power, thus using three wires like standard, high-voltage transmission lines. A fourth neutral wire is used in situations where the load is likely to be imbalanced among the three phases, thus necessitating a path for a nonzero return current. Laterals that branch off of main feeders typically carry only a single phase (obtained by connecting across any two of the three phases). Most small electric customers in the U.S. have only single-phase service. Because it is impossible in practice to distribute loads perfectly evenly among the phases, it is typical – contrary to the textbook case – for phase imbalances on the order of 10% to occur at the neighborhood level. Phase imbalance is undesirable in that it increases systemic electric energy losses and the risk of nuisance trips in protection systems; however, it is difficult and labor intensive to change retroactively. Phase imbalance is much less of an issue at the transmission level simply due to the statistics of aggregating a large number of loads.

Most overhead distribution wires are aluminum conductors, although copper wires are still found in older circuits. In some cases, mostly on primary circuits with higher current loadings, higher-strength ACSR (aluminum cable steel reinforced) conductors may be used. For economic reasons and to facilitate passive cooling, bare cable is standard on overhead lines; in some

locations, wires with polyethylene jacketing, sometimes called "tree wire," are used if incidental contact is likely from nearby objects.

At the distribution level, the ability of a line to transmit power is limited by heating and expressed as "ampacity," or current-carrying ability. While a line is usually operated with a maximum ampacity constraint set for the worst-case assumption (called its "thermal" or "static" rating), the actual maximum ampacity that produces the maximum allowed line temperature varies with ambient temperature and wind speed. To utilize this extra ampacity would require real-time knowledge of ambient conditions, and the line would be said to be operated according to its "dynamic rating."

Underground distribution is significantly more expensive than overhead distribution for a number of reasons: Obviously, it requires digging, trenching, or construction of conduits underground, which are labor-intensive and environmentally disruptive activities. Second, it must simultaneously provide for electrical insulation and heat dissipation by energized lines and equipment, necessitating a larger and more expensive insulated conductor for a given ampacity. Third, troubleshooting – in particular, locating a fault underground – is much more difficult and labor-intensive than for overhead. The advantages of underground distribution are potentially higher reliability (the result of being out of the way of most environmental hazards like tree limbs), reduced wildfire hazard, and improved aesthetics.

Topography

The most common layout of distribution systems is radial, extending outward like branches of a tree, with a clear hierarchy where power is designed to flow strictly in the outward direction. The main rationale for radial distribution design is based on its attributes of simplicity and reliability, and the comparative ease of protection coordination: that is, assuring circuit breakers will interrupt the flow of power from the "upstream" direction in the event of a fault (unintentional and hazardous electrical contact between wires, ground and/or other objects). Radial design also affords the economic advantage that smaller conductor sizes can be used toward the ends of the feeders, as the remaining load connected downstream diminishes.

The main disadvantage of a strictly radial design in California and the United States is that when any part of a feeder is isolated due to a fault or routine maintenance, the customers downstream have no electricity. Modifications to the radial design thus include loop and primary selective systems, in which an alternate path exists from the substation or main feeder to a given set of customers, which can be activated by opening and closing appropriate switches. It is important to note that loop and selective systems still operate radially at any given time; that is, one switch in a loop is opened before another is closed.

Because any such switching operations still entail momentary power interruptions for customers, the highest degree of service reliability is afforded by a spot network in which redundant paths are not only available but are kept energized at all times. This represents a fundamental departure from the radial topology, because it is now possible for power to flow in different directions within a loop. To prevent reverse flow, directional protective devices called network protectors are installed. Owing to the redundancy of wires as well as the extra sophistication in circuit protection, spot networks are significantly more expensive. Their use therefore tends to be limited to very high-density, high-value loads such as the downtown areas of major cities.

A special case of distribution system topography is the power island, or energized section of circuits that is electrically separate from the remainder of the system. An island may be sustained by one or more generators supplying local loads, at scales ranging anywhere from a

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single residence to a larger fraction of a utility's territory. The only standard use of power islands is during the process of service restoration after a widespread outage, where individual power islands are re-connected as quickly as possible in a centrally orchestrated effort. Otherwise, islanding is neither practiced nor condoned by U.S. utilities, for reasons of safety and liability. Distributed generators such as rooftop photovoltaics are thus required to disconnect from the grid in the event of an outage. At issue are electrocution hazards for linemen, the generators' ability to maintain adequate power quality within the island (frequency and voltage, for which the utility is responsible), as well as properly re-synchronizing islands without risk of equipment damage. Given the increasing prevalence of small generators along with control capabilities introduced by automation equipment, however, policies concerning islanding seem likely to be revisited and subject of some controversy in the years ahead.

Distribution versus Transmission

Administratively, transmission and distribution are separate units within an electric utility that deal with planning and operations for the respective systems. Legally, transmission and distribution are subject to different electricity market regulations. Technically, the division between transmission and distribution systems is defined by voltage level. Transmission and sub-transmission include systems at voltages higher than on the order of 100 kilovolts (kV) or somewhat below, while primary distribution voltages range from several kV to several tens of kV and lower. Technically, the transformer at the substation represents the boundary between transmission and distribution, but the entire substation where this conversion occurs would be called a distribution substation. As far as the transmission system is concerned, a distribution substation represents a single aggregate, time-varying load.

Qualitatively, key differences between transmission and distribution include topology, vulnerability to environment, and the role of local variation or idiosyncrasies. As described above, distribution systems are generally radial in structure, while the transmission grid is a network. Thus, distribution systems have a built-in directionality of power flow that transmission systems do not have, which figures prominently in all aspects of design and operation.

Because distribution equipment is physically closer to the ground, roadways and other structures, it is more exposed to all manner of environmental factors, from tree limbs to animals and drunk drivers. Consequently, events on distribution systems account for as much as 90% of customer service interruption events, much more so than large outages or system-wide generation shortages.

Distribution systems are also much more adaptive than transmission to varying local factors such as load distribution and topography. Furthermore, given that different line sections may have been completed at different times with different generations of technology, and the fact that equipment upgrades tend to occur on an as-needed basis, no two distribution systems are ever quite the same. Stated another way, any given mile of distribution circuit is vastly more data-rich than a mile of transmission line – as can be observed, for example, in the many layers of information about each circuit on the wall map at a regional distribution control center. This makes it far more challenging to plan and strategize for design changes, because so many diverse local factors need to be taken into account in order to predict how a distribution system will actually perform.

Operation

Distribution system operation essentially means making necessary adjustments whenever the system departs from a steady-state operating condition – which can be quite often. Such departures would include significant changes in customer load, faults on the system, or, in historically rare instances, supply shortages that require load shedding. Adjustments to the system primarily entail reconfiguring circuits by opening and closing switches; they also include changed settings on voltage regulating equipment. All these operations at the distribution level are coordinated by regional control centers. It is useful to distinguish operations by the time scales applicable to information transfer, decision making, and actions taken.

Service Restoration

The first line of defense against faults is the protection system, which is designed to operate automatically to isolate and de-energize faulted sections within fractions of a second. The human component of operation is obviously much slower and focuses largely on the "post-mortem" management of fault situations. This means first ascertaining that the protection system did in fact safely isolate the fault; developing and executing a plan for restoring any loads that can be safely restored right away (for example, by reconfiguring a loop system or switching some customers to a different feeder); assessing and repairing the fault damage; testing circuits; and finally restoring all customers to normal service.

It is important to note that service restoration, like all distribution switching operations, must follow a carefully managed sequence that is double-checked and signed off, with a list of safety precautions to be taken every time a circuit is energized. Parts of this sequence may reflect standard procedure from a reference manual, and parts may need to be thoughtfully improvised to address the particular situation. Any mistake such as closing switch B before opening switch A can cause not only expensive equipment failure (and thus aggravated delays) but can kill people, and the culture of distribution operations emphasizes keen awareness of this risk. As a result of this sequential process, some customers may find themselves waiting for service restoration for what seem like implausibly many hours, even as their neighbors (on a different feeder) have their lights back on. Automated switching, which would include automated algorithms and verification of restoration sequences, could theoretically accomplish the same process in a matter of minutes or seconds, but has been controversial for the safety reasons above – and because of the multi-variable nature of decision inputs, which according to operators may render many outage situations unique and ill-suited to linear, programmable algorithms.

Historically, operating distribution switches meant sending personnel on location in a truck to manually operate them. Since roughly the 1980s, U.S. utilities have been implementing SCADA (Supervisory Control and Data Acquisition) on distribution systems, piece by piece, focusing on those areas where it seemed most cost-effective. SCADA means that the operator at the regional office can observe the status of a given switch equipped with an RTU (Remote Terminal Unit) on a computer screen, and can actuate its operation by the click of a mouse, where the control signal can be carried to the RTU by wire (phone line or power line carrier) or radio.

Clearly, remote operations with SCADA can produce substantial savings in both man-hours of labor and service restoration time, theoretically allowing operations that previously took hours to be performed within minutes. Because of the serious electrocution hazard associated with high-voltage equipment, though, it is not unusual for some critical operations to be redundantly verified by a person on location. Also, as of a few years ago not every rural distribution circuit

in California has been equipped with SCADA. There remains therefore a broad range of duration for distribution outages caused by local faults, depending on the particular situation.

Voltage Regulation

As discussed above, voltage on distribution circuits is regulated by transformer LTCs at substations, and, if necessary, voltage regulators or capacitors along feeders, so as to keep the service voltage within acceptable range for every customer: not too high for those closest to the substation, but not too low for those farthest away. Because the voltage drop along a feeder is proportional to the current, settings may need to be adjusted in response to substantial changes in load. Such large changes tend to occur on a daily or seasonal basis, as the rapid, minute-to-minute changes in load tend to be smaller and more random.

From the point of view of voltage drop, distributed generation can mostly be thought of as negative load. As distributed generation (DG) subtracts from load, the voltage drop is reduced. In the event that DG exceeds local load, the voltage drop will be in the reverse direction, which is problematic. An even more likely problem is that DG output can vary substantially, and much faster than load alone. For example, if there are many kilowatts (kW) of photovoltaic (PV) sources installed on the same feeder and clouds pass over, the aggregate output could change by a significant amount, many times an hour. DG therefore introduces a profoundly greater variability in voltage drop to be addressed by voltage regulation.

To accommodate changing voltage drop conditions, LTCs and voltage regulators are adjusted by a mechanical movement of the wire connection to the transformer coil. In a situation where such an adjustment is expected to be necessary only a few times a year, it might have to be done manually. Typically, LTCs are moved automatically in response to a measurement of current flow on the secondary side, which translates into a calculated voltage drop along the feeder. This mechanism is not expected or designed to operate very frequently, though, and some distribution engineers are concerned that mechanical components might wear prematurely if LTCs are "hunting" a fluctuating voltage drop caused by DG.

Capacitors are not readily adjustable in terms of the size of their effect (which depends on their physical dimensions); they are either switched into the circuit or out. This switching operation may need to be performed manually on location, or it may be actuated remotely with SCADA. If the load pattern is predictable (such as afternoon air conditioning), capacitors can also be switched based on a simple timer.

These types of adjustments are more of an approximation than a fine-tuning, considering that most distribution feeders are not equipped to actually measure voltage on location and the controlled devices generally lack adjustability. With higher penetrations of DG, on the other hand, actual voltage measurements along distribution circuits may become necessary, and more adjustability of voltage through more flexible control devices will likely be required.

Power Quality

Power Quality is defined as the degree to which power (voltage and current) supplied by the utility conforms to a "pure" sinusoidal waveform of a constant magnitude at exactly 60 cycles per second frequency. Any variations or deviations from the pure waveforms are considered degradations of the quality of the power. Such variations include but are not limited to:

- Voltage or frequency out of acceptable ranges
- Unequal phase currents and/or voltages
- Harmonics

- Noise
- Transients
- Brief interruptions

The variable nature of wind and solar generation can strongly contribute to power quality issues, especially voltage swings of time durations from seconds to minutes. In extreme cases where, for example, the wind suddenly drops, there may simply be insufficient power available to maintain the local loads.

Reliability

Electric utility customers, by and large, have come to expect that their local electric service provider will always supply electric power whenever it is needed, at exactly the specified voltage and frequency. Any interruption of that power for whatever duration, or any corruption of the "pure" 60-Hz sine wave that characterizes that power, is considered simply unacceptable. But power companies do not guarantee customers any specific levels of reliability or power quality. There are quantifiable targets or ranges for reliability metrics, usually specified by utility regulatory commissions, as we shall discuss later. But power quality is more difficult to quantify, and currently there are no standards or regulations that quantify acceptable levels of power quality. There are, however, commonly accepted definitions and developing standards for monitoring power quality.

Reliability is defined as the ability of the system to deliver power to loads while withstanding disturbances to the system. Such disturbances include short circuits between lines or phases of lines, short circuits between lines and ground, generators failing and tripping off the system, etc., collectively called "faults." If a fault or any kind of disturbance results in an "outage," i.e., a part of the system fails and is removed from service, and the utility cannot supply power to some customers for a sustained period of time, reliability is reduced based on the length of the outage (more on this below). Reliability for a distribution facility is usually analyzed by a utility for a given feeder.

Equipment failure, trees touching lines, lightning strikes, high winds, animals contacting equipment, and car-pole accidents are some of the most likely causes of distribution outages. Most distribution systems in the US are designed with sectionalizing switches at strategic points, so that loads can be switched between feeders to restore service to customers while repairs are being made to faulted line sections. Software tools allow engineers to model the feeder as a system, and to identify the most cost-effective fixes to maintain acceptable reliability. In some cases, typically in downtown or commercial areas, distribution systems are connected in a ring or meshed arrangement, in order to provide a higher level of reliable service to customers. For public or comparison purposes, utilities normally express the reliability of their distribution systems in terms of an aggregate system average, rather than feeder or customer numbers.

From a customer's perspective, momentary outages can be merely annoying (having to reset digital clocks, e.g.), or just as bad as a sustained outage, if customer systems (industrial processes, computer networks, etc.) are intolerant of them. Thus, frequency of occurrence of transient events can be worse than infrequent, but longer, outages. The bottom line is customers will have their own opinions of the reliability of the circuits they are on, based on individual needs and perceptions.

Modeling and Simulation

Simulation tools are computer programs that contain a model of the distribution system and are capable of analyzing any arbitrary configuration of the distribution network, for purposes of determining its capacity, reliability, and other performance qualities. Distribution system

engineers, planners and operators all use various types of simulation programs, each one typically geared toward a specific aspect of the distribution system. These tools are the primary means by which the California utilities perform analysis and planning of distribution systems and the integration of renewables into distribution systems. Many of the current and emerging analysis and simulation tools used by utilities have features and capabilities that purport to be able to analyze renewable generation, electric vehicles, and other new technologies on the distribution system. The primary concern, regarding integration of renewables in distribution, is: Are these simulation tools adequate for analysis of the electric distribution system with the anticipated 2020 levels of renewables?

New simulation tools, such as GridLAB-D, an open-source model developed by Pacific Northwest National Laboratories, are emerging as possible solutions. All of these tools need to be evaluated for their effectiveness in simulating and evaluating renewable and electric vehicle impacts on distribution system capacity, operations, voltage performance, protection systems, planning, fault analysis, stability, system restoration, and power quality. This analysis could further be extended to define the new capabilities needed in simulation tools in order to meet the users' anticipated needs.

While simulation tools refer to the computer programs that run different scenarios and distribution system configurations, **models** are the mathematical descriptions of specific electric system components, such as generators, transformers, lines, motors, loads, etc., that are incorporated into the aforementioned simulation, planning and analysis tools. The accuracy of the studies performed with these simulation tools is only as good as the accuracy of the component models, i.e., how well the models represent the various pieces of equipment actually installed in the system. Models for new technologies such as wind turbines, solar photovoltaic systems, inverters, and electric vehicle charging systems must accurately represent their performance to faithfully predict their behaviors and impacts on the distribution system. Therefore, a thorough examination of the capabilities of existing models, and development of specifications for new and/or improved models for meeting users' future needs, would be beneficial.

Electric Vehicles

Electric Vehicles (EVs) come in two flavors: pure electric and plug-in hybrids. Pure electrics have no gas engine and initial offerings typically have a range of 70 to 100 miles. The Tesla models are an exception to this with ranges from 160 to 320 miles. The Chevy Volt and Toyota Prius plug-in are typical of hybrids with a total range of several hundred miles and a pure electric range of 14 to 40 miles. On average, batteries provide about 4 miles/kWh of energy, although this varies with model, accessories, and environment from about 2 to 5 miles/kWh.

Typical battery size for a pure electric is 24 – 32 kWh, although the Tesla models range from 42 to 95 kWh. Plug-in hybrids have much smaller batteries. The Chevy Volt with a 40-mile electric range has a 16 kWh battery, while the Prius with a 14-mile range has only 5.2 kWh.

Chargers

There are 4 types of charging currently planned:

- A Level 1 charger uses 120V AC with charge currents of 12 Amps (15 A circuit breaker) or 16 Amps (20 A circuit breaker). At a maximum hourly charge of about 2 kW, these chargers will require 8 – 12 hours to charge a depleted battery. Their prime feature is that they can plug into a standard wall outlet and thus be used anywhere there is power.

- Level 2 chargers operate at 240 Volts at around 30 A, but potentially up to 80 A. At 30 A, (7.2 KW), they can charge a typical battery in 4 hours. In the home, they require professional installation and may require an upgrade to the home's electrical system.

Installed costs are likely to exceed $2,000, although some auto manufacturers are offering free charger installations with the purchase. Level 2 chargers are expected to be the most common for both home and commercial installations.

- Direct current (DC) Chargers or "Fast Chargers" deliver DC directly to the battery. They operate from 3-phase power and would only be located at commercial locations. Prototypes have provided up to 250 kW and units can charge a battery to 80% in as little as 30 minutes. There is currently no standard for these chargers, and there are concerns about the impact of this type of charging on battery life.

- Battery Swapping is another alternative to shorten charging times. In a car designed for it, a discharged battery can be exchanged for a fully charged one in less than 5 minutes. GE has partnered with Better Place to set up a chain of stations in Denmark and a small demonstration program in Tokyo. Recently, Better Place has begun a demonstration program in San Francisco with a fleet of 61 taxis and 4 switching stations. Currently the only unmodified production vehicle compatible with this business model is the Renault EV. Whether other manufacturers will follow suit is unknown. In this business model, batteries are leased, not owned, reducing the purchase price of the car, but adding a lease cost.

Expectations are that Level 1 and Level 2 chargers in the home will dominate EV charging for some time to come. One exception might be if the Prius business model of a much smaller battery proves successful, then the low cost Level 1 chargers could be extensively used. Public charging stations are expected to have a much smaller impact on the California electric system as most charging is expected to be at home. DC fast chargers typically require 480V AC and are considered too dangerous for home use. No one, outside of Better Place, is forecasting that battery exchange will have a major impact.

Projected California Electric Vehicle Fleet (2012 – 2020)

No one really knows how many EVs will be sold in the next 10 years. There are wide ranges of projections, and actual sales will depend on factors such as oil/gasoline prices, government policies, cost reductions, and technological advances. There is relative agreement that California will likely lead the nation in EV sales and could account for 20% - 25% of nationwide EV sales. Various organizations have projected annual EV sales in California by 2020 to be anywhere from 3% to 15% of overall vehicle sales, currently about 1.1M vehicles per year and projected to grow to 1.7M/yr by 2020. This suggests anywhere from 50k/yr to 250k/yr annual sales of EV by 2020. The best guess seems to be that there will be a total of 10,000 – 50,000 EVs on the roads in California by 2015 and 200,000 – 800,000 by 2020.

Potential Distribution Impacts of Renewable Generation and Electric Vehicles

Sources of Impacts

The impacts of renewable generation at the distribution level are expected to arise from three major sources. First, the existence of distributed generation (DG) of any sort, whether renewable or variable or neither, at significant levels in any localized area can create issues with a system whose basic design assumed that only loads would be located there. With the possible exception of some large installations, most DG is customer owned and its status is not visible to utilities. The impact of DG is to effectively reduce the load, possibly to zero or even negative, in which case power flow is reversed (Balamurugan et al., 2012).

The primary means of voltage control is that of load tap changers on transformers (Švenda et al., 2012). The assumption is that voltage will decline as one moves outward from a substation, so that LTCs are designed to step the voltage up to compensate and are generally intended to make changes only relatively infrequently. Significant changes in loading and reverse power flow can create major problems maintaining voltage within the required limits. Reverse power flow can also cause serious issues with protective devices and systems that are designed for one-way flow and may not respond as intended.

The second source of distribution issues arises from the variable and intermittent nature of wind and solar generation, the likely dominant forms of renewable generation at the distribution level. Wind and solar have very low inertia compared to thermal power plants and their output can change very rapidly in response to clouds and wind speed variations. These changes can be far more rapid than the expected changes in load and can degrade both power quality and voltage control. In extreme cases they can result in insufficient power available to support the load (Steffel, 2010).

Third, electric vehicles and their charging systems are expected to proliferate in the near term (Aguero, et al., 2010), and clustering of vehicle purchases in neighbors can accelerate the impacts of EVs on sections of the distribution system. EVs have existed for many years, primarily manufactured by small companies for niche markets. Beginning in 2011, plug-in electric vehicles, both as hybrids and pure electrics, are entering the market as mainstream offerings by major car manufacturers. Nissan, Mitsubishi, Ford, and BMW offer pure battery-powered vehicles for sale while Chevrolet offers the Volt plug-in gas-engine-assisted hybrid. More models and manufacturers are likely to follow shortly.

Whether EVs succeed in the marketplace is an open question. There are many obstacles – high initial cost, limited range, and availability of public charging stations. At the same time, there are many perceived advantages including lower fuel costs and low emissions of carbon and other pollutants.

Projected Distribution Level Impact

For the next 10 years, it is widely believed (hoped?) that most EV charging will be done in the home during nighttime hours. The current generation of chargers incorporates timers and most are capable of interfacing with the Advanced Metering Infrastructure (AMI) which will allow charging to be sensitive to price (or demand response) signals from utilities. Outside the home, the next largest segment will be workplace charging. Here, most charging will occur in the morning hours. Charge stations are also being planned at a variety of other locations including shopping centers and gas stations. While these may well be used during peak hours, their overall impact on distribution, at least through 2020, is expected to be negligible.

There is an expectation that distribution transformers in certain areas will see significant increases in loading which will shorten their useful life or require them to be upgraded to handle the increased load. California utilities will likely track EV installations on a house-by-house basis and upgrade transformers as needed. While this may impact the cost of electricity, the technology to do so is already being incorporated into commercial utility "home energy" software and it does not appear that there are research needs around this subject. The three California IOUs are all rapidly moving forward with Smart Meter programs and preparations to handle the impact of EVs.

Summary

The net result of these impacts, which have been observed to occur to some degree already, is to complicate the utility's job to provide a safe, reliable and economic supply of power to its customers. Voltage control will be more problematic, protection systems will need to be upgraded, coordination with the transmission system and its operators will be more complicated, and generation sources controllable by the system operators must be procured to counter the intermittency and variability of the renewable generation.

Mitigating Technologies and Their Status

It should be noted here that distribution systems, in different utilities or even within a utility, vary widely in structure and "one size does not fit all." Mitigation of a renewable generation problem on a particular distribution system may well require monitoring, modeling, simulation and analysis before selecting the best alternative for a particular situation.

Sensors and Communication Systems

In order to mitigate a situation, the first issue is to be aware of it. In many distribution systems, there is insufficient situational awareness for a utility to know that there is a problem. As an example, it is not uncommon for utilities to first become aware of a power outage because customers have called by phone to complain that their service is out or causing problems. The widespread use of smart meters has provided a first level of this awareness and the use of SCADA systems has allowed utilities to be better informed about the status of equipment, at least where monitoring has been installed. However, the issues associated with renewable generation will require more sensors and expanded communications systems. While these devices and systems are generally technologically mature and commercially available, their cost dictates that utilities will only install them on a case-by-case basis as the penetration of renewables in specific areas warrants.

Energy Storage

Storage systems cover a wide range of power levels and deliver that power over time periods ranging from fractions of a second to several hours. At first glance, energy storage is an extremely attractive solution for many of the challenges to integrating renewables. Local storage, in the vicinity of a cluster of renewable generation, can largely eliminate the "flicker" due to solar variability. It can also store power when it is not needed and release it in times of high usage, smoothing out many of the voltage control issues in the process.

While the primary interest of this paper is in storage as part of the distribution system to assist in renewable integration, in reality, storage systems will likely perform additional functions not directly related to renewable integration but simply to improve the economic return. In its current state of development, storage is perceived as having tremendous benefits for renewable integration and grid reliability, but is largely inhibited by high initial cost. This is exacerbated by regulatory issues that make it difficult or impossible to operate storage to maximize its revenue stream.

Distribution sited energy storage systems fall within city load centers (< 69 kVA) at electric utility substations, near feeders, within neighborhoods, and at industrial, commercial, and residential customer locations. Such storage systems can be located on either the utility or customer side of the meter.

Applications for storage normally located within the distribution system are characterized by a primary objective (e.g. reducing power quality issues arising from variability) but may serve several markets, including those normally associated with transmission (Xu & Singh, 2011). Residential, commercial, and industrial based systems, unless aggregated and controlled, are similar to distributed PV systems and EV chargers in their effect on the utility.

Most commonly, at the distribution level, storage is in the form of batteries and many of the battery technologies, notably lithium ion, are relatively new and unproven in utility applications. Under ARRA, some distribution storage demonstrations are being conducted, but utilities, or customers or any other parties, have not committed to deploy storage in the foreseeable future other than as very limited demonstrations. Deployment is further hampered

by lack of appropriate regulatory and market mechanisms that effectively respond to the unique characteristics of storage.

Power Electronics

Solid-state electronic components of various types can replace or supplement existing electromechanical devices to control voltage, improve power quality, and handle two-way power flow. Flexible AC Transmission Systems (FACTS) devices have been used in transmission for some time and are now being considered for distribution. Inverters that can operate in all four quadrants (i.e., can output real and reactive power independently) can assist in Volt/VAR control. Smart Transformers can ease voltage control and power quality issues and may be of significant value at high penetrations of electric vehicles (see discussion on electric vehicles). Most power electronic devices intended for distribution control purposes are under development or in early stages of demonstration, and have yet to reach commercial-scale implementation.

It should be noted here that most renewable distributed generation and energy storage power conditioning for grid integration is done using power electronics, usually in the form of inverters. While inverters are generally designed to meet grid integration requirements at the time of installation, there's potential to incorporate additional design features for meeting grid integration requirements as they change to accommodate additional amounts of renewable generation penetration over time.

Distribution Management Systems

A Distribution Management System (DMS) is a comprehensive software package, usually constructed in modular form, to assist in the operation of the distribution system. It communicates with substation and field devices through a distribution SCADA communications network. With suitable modular additions, it could also communicate with smart meters (through AMI), energy storage, distributed generation, field service, and even other DMSs to provide integrated overall situational awareness and decision support for the distribution system with automatic control of many functions (Taft, 2012).

As the complexity of distribution systems grows, DMSs are being increasingly deployed, although only some of the possible capabilities are likely to be implemented. As penetration levels of renewable generation continue to increase, it is expected that DMS software will gradually replace more antiquated, less capable systems and that sensors, field devices, and expanded communication networks will be added to mitigate actual or expected issues.

Renewable Generation Forecasting

Methods for forecasting the output of renewable generation plants are a key technology for managing the impacts of their intermittency and variability on transmission system operations. Through a combination of weather sensors, forecasting algorithms and models of renewable plants, information on renewable plant output is provided in real time and estimates of future production for 5-minute, 15-minute, hour ahead or day ahead time periods are provided to system operators. This information is used to plan the system reserves (additional controllable generating units) and other ancillary services needed to work in coordination with the renewables to maintain the system's generation/load balance at all times.

While most renewable generation connected to transmission tends to be larger in size and visible to the system operator via metering or other instrumentation, most renewable generation on the distribution side tends to be smaller, predominantly PV systems, and is net-metered. The result is that distribution-side renewable generation effectively masks the load on the feeder, and system operators have little information about what, if any, renewable generation is active

on the distribution system at any given time. Forecasting technology could address this issue by giving the system operator some estimate of the level of renewables on a given feeder at times of interest.

Smart Charging

The key issue relative to the impact of electric vehicles on utilities and the California grid is when vehicles are charged. "Smart Charging" simply means that vehicle charging consumes power when it is most available and can be minimized when power is in short supply. Utilities, of course, would like customers to charge their vehicles when there is plenty of available power, especially if there is excess "must take" power. Consumers, by and large, will simply want their vehicles to be fully charged when they need them. Many will not be willing to concern themselves with utility problems unless it benefits them directly. Hence it is up to the utilities to convince or incentivize customers to allow utilities to impact time of charging.

Generally, the mechanism for smart charging is assumed to be that: a) utilities will offer a price structure based on time of use or real time power availability; b) there will be a smart meter and 2-way communication between the charger and the utility; and c) the end-use customer will be able to automatically have his/her vehicle charged at minimum cost while insuring that it will be charged when it's needed.

Even before smart charging is implemented, California utilities are already offering or even mandating special time-of use schedules for EV customers. PG&E, for example, requires EV customers to select one of two time-of-use options, either whole-house or EV only. Off-peak charging is at a rate of $0.05/kWh, while summer peak can be $0.28/kWh. The EV-only option is about 10% higher and requires a second meter.

In addition to smart meters and 2-way communications systems, smart charging requires both an end user charger with appropriate software (Gallardo-Lozano et al., 2012) and a utility level application which can aggregate customers and send appropriate signals. Both are commercially available. Coulomb Technologies' CT500 Level 2 charger appears to be typical of what is available. It is configured to accept AMI signals and can operate in both demand-response and time-of-use modes. Both commercial and residential chargers have wireless and cellular interfaces to network with utilities, business systems, or home networks.

Home energy management software is readily available for utilities from a number of companies. GridPoint, as an example, offers software that will aggregate EVs into a single load and is capable of varying that load through service requests to not only maximize charging at optimum times, but also to provide load shifting and shaping and real time increases or decreases in load as ancillary services. GridPoint has partnered with Coulomb and other charger manufacturers to insure seamless interfacing.

While commercial equipment and management systems are available and Smart Meters are already heavily deployed in California, some critical issues are still some years away from deployment. First is a pricing structure or other incentives to encourage EV users to allow the utilities to charge EVs in a way favorable to the utilities. Second is implementation of Home Area Networks and upgrades to Smart Meters to allow customers and utilities to interact in a mutually acceptable way.

Three Workshops: Distribution and Renewable Integration Aspects

Introduction

In the summer of 2012, three workshops were held by the California Energy Commission that dealt with renewable generation and distribution systems. The first, on June 11th, was an Integrated Energy Policy Report (IEPR) Workshop on Renewable Integration Costs, Requirements and Technologies. The second, held on June 21st at the California Independent System Operator (CAISO) was an advisory workshop with representatives from CAISO and the California Investor owned utilities (IOUs) to develop grid research activities that address electric grid and renewable generation integration issues particularly as related to electric distribution. On August 2nd and 3rd, the third workshop was held in Sacramento on the Electric Program Investment Charge (EPIC), of which some portions were directed to distribution and renewable generation integration.

Following are brief summary notes and key points pertaining to electric distribution and renewable integration taken from these workshops. In some instances, the summary contains notes and findings that are general enough in nature to pertain to electric distribution and transmission regardless of distinctions between these two links in the electricity value chain.

More detailed proceedings of the workshops may be found in Appendices B, C, and D.

Summary of the June 11, 2012 IEPR Workshop on Integrating Renewables and Distribution System Issues

Workshop Background

Every two years, the Energy Commission prepares an IEPR that covers a variety of energy topics and makes policy recommendations to the Governor, with an update prepared in the off years. In 2010, Governor Brown directed the Energy Commission to prepare a plan to expedite permitting of priority renewable generation and transmission projects. This was the eighth and final workshop in a series examining a spectrum of issues relating to renewable generation.

The purpose of this workshop was to seek input from experts, stakeholders, and the general public on integration issues related to increased penetration of renewables in California's electricity system, for input to the IEPR. The workshop addressed the ancillary services needed to integrate renewable resources while maintaining grid reliability and how those needs may change over time; and the integration services that could be provided by energy storage, demand response, and/or natural gas fired plants.

This public workshop was held at the California Energy Commission in Sacramento, and hosted by Commissioners Carla Peterman and Chairman Robert Weisenmiller. Commissioner Andrew McAllister and CPUC Commissioner Timothy Simon were also in attendance. Other participants included representatives of the three California IOUs, CAISO, Energy Commission, CIEE, technology vendors, and members of the general public. A number of people participated via phone or WebEx.

Meeting Highlights and Outcomes

This Workshop comprised four panel sessions addressing the challenges of renewable energy integration at the transmission and distribution levels. Highlights of these panel sessions are as follows:

Panel #1: Integration Issues Associated with Increased Renewable Penetration

This panel focused on the types and levels of ancillary services that will be needed to integrate large amounts of renewable resources, both at the transmission and at the distribution level, and the uncertainties associated with those needs.

Panelists: Jim McIntosh, CAISO
Lori Bird, NREL
Ben Kroposki, NREL

- The CAISO will need about 4,600 MW (upward) and 3,000 MW (downward) capability by about 2018 due to retirements of the once-through cooling (OTC) plants.
- Over-generation was about 5% of the hours this year, in terms of negative pricing events, but not curtailments.
- Lower system inertia will require about 700–800 MW of additional frequency-responsive generation capability.
- Load ramps (rates at which load changes) are becoming much greater, about ±700-800 MW/hour currently, with attendant cycling requirements on generators.
- The Western Governor's Association (WGA) issued a report, "Meeting Renewable Energy Targets at Least Cost: The Integration Challenge," that examines options for integrating larger amounts of renewable energy, and which ones are the least cost options.
- Dynamic transfers in the WECC system can be limited by factors such as transmission tie line limits and remedial action schemes (RAS).
- The European experience in managing renewable generation, particularly Germany's, can be instructive for the US.
- Progress is being made in the areas of regulatory and standards solutions.
- Distribution-level integration issues include:
  - potential for reverse power flow, necessitating changes in protection and control strategies
  - high variability in distribution system design, and resultant lack of "standard" solutions
  - the increasing number of requests for interconnection, and the need to reduce the complexity, expense, and length of time associated with that process

Panel #2: Operational Characteristics of Natural Gas Plants to Support Renewable Generation

This panel session focused on what natural gas-fired plants able to do today to provide the integration services that intermittent resources require, and what they will need to do in the future to meet the needs of increasing levels of renewables.

Panelists: Mark Rothleder, CAISO
Mark Smith, Calpine
Bonnie Marini, Siemens Energy, Inc.
John Kistle, AES Energy
Tom Pierson, TAS Energy, Inc.

- In general, natural gas plants should be able to:
  - ramp fast
  - start quickly (in 10-60 minutes)
  - have low minimum load capability
  - provide regulation
  - provide either inertia or some kind of frequency response and/or a voltage response
  - responsiveness to a contingency event in the local area

– unload other resources having these attributes

- Currently, the CAISO is looking at flexible ramping products and enhanced regulation capacity, and studying the requirements for improved frequency regulation and forward-looking capacity procurement mechanisms.
- Today's market does not provide enough compensation for generators to recover the going-forward costs of investments. A longer term (3-5 years) forward commitment would be better, and ideally one that is attribute-based.
- Siemens (and other manufacturers) are developing faster-ramping combined cycle combustion turbines that can meet clean air requirements. But uncertainty in the demand for these units and the lack of economic incentives are barriers to their wider use.
- Re-powering of OTC plants is technically possible, but the economics are uncertain.
- Additional capacity of the existing, flexible gas plants can be achieved with the use of inlet chilling technology. Again, economic incentives are not there.
- There don't appear to be any significant limitations to dynamic transfers on the major transmission paths in the Western grid at this point in time.
- "The technologies are out there; the markets need to be receptive to them."

Panel #3: Assessing Demand Response Potential to Provide Renewable Integration Services

Classically, Demand Response (DR) is used for peak load reduction. But this panel focused on the potential for using DR for ancillary services or for supporting renewable integration, especially as an alternative to storage or natural gas plants.

Panelists: Scott Baker, PJM Interconnection
Andy Satchwell, LBNL
John Hernandez, PG&E
Anthony McDonald, Target, Inc.
Ron Dizy, Enbala Corp.
Rick Counihan, EnerNOC
Matthew Tilsdale, CPUC
Stephen Keehn, CAISO

- PJM uses DR in its day-ahead capacity market. Changes to its regulation market are needed due to the increase in renewable technologies, and also the need for greater efficiency. These changes include:
  – new "Dynamic Regulation" signal, based on total ACE
  – Performance-based Regulation (PBR): compensation based on benefit to system control
  – lower regulation capacity requirement (from 1 MW to 100 kW)
  – sub-metering for DR regulation
  – new Curtailment Service Provider (CSP) registration: "Regulation Only"
  – new market rules would be needed

- LBNL has been working with the Western Governors Association, WECC and DOE on projects that look at DR in the context of ancillary services, and the identification of barriers related to using DR as ancillary services.
- WECC reliability rules currently prohibit DR from being used for spinning reserves or regulation reserves, although the WECC stakeholder group just passed a standard that will allow DR and other loads to function as spinning reserves.

- OpenADR can help bring DR into the market in a meaningful way. Companies like Target need consistency in how these various programs are managed and operated across the country.
- Customers can help provide DR, but it will take a lot of education and diversity outreach; third parties can play a helpful role here.
- Loads will be able to respond with sufficient speed; that's mostly an IT issue. The bigger problem is frequency: how often the load will be called to respond, and what the impacts on the load might be.
- Many barriers to DR are the legacies of rules that were created when nobody could imagine anything providing the service, except for a generator. The roadmap for DR in California has some disconnects in it that work against third-party aggregators being able to participate in CAISO-controlled markets.
- CPUC Rulemaking 701041 is proceeding, which will address the aggregation of utility customer load and bidding of that load directly into the CAISO market. Further workshops and hearings will take place this year, and a revised rule issued by the CPUC by end of this year (2012).
- The CAISO needs to know that DR will respond when called on. Therefore, the telemetry, visibility and control aspects are very important for DR utilization, and they will probably be different for transmission vs. distribution.
- The CAISO is doing a number of things to remove barriers to DR, for example:
  - developing a Proxy Demand Resource Product (PDRP), which would allow DR to bid in and be treated as a resource
  - modifications to the Ancillary Service markets to remove some of the restrictions on resource types
  - reduced the size of resources that can provide various services
  - reduced the continuous energy requirements in the Reg Up and real-time markets
  - developing the Non-generator Resource Model and the Reliability Demand Response Product (RDRP), which is an extension of PDRP and integrates utility emergency demand response products
  - conducting a Regulation Pilot project with PG&E
  - lowered the "floor" prices to provide more opportunity for customer loads (e.g., pumps and chillers) to help with the over-generation issue

Panel #4: The Role of Energy Storage in Supporting Renewable Integration
This panel will build on what was learned in previous IEPR workshops, and will also consider distribution-sited energy storage, keeping in mind the Governor's Plan for 12,000 MW of additional renewables in the distribution system.

Panelists: Todd Strauss, PG&E
        Jim Eyer, CESA
        Ali Nourai, KEMA
        Charles Vartanian, A123 Systems
        Arthur O'Donnell, CPUC
        Udi Helman, BrightSource Energy

- There are two broad elements to the cross-comparison of technologies: 1) a framework for thinking about that cross-comparison in terms of our policy, planning, procurement and operational activities, and 2) a portfolio approach.
- With respect to the framework, the policy in California is technology-based, but planning is resource-based, procurement is product-based, and operations are asset-

based. How do we create an environment in which those resources are able to compete in the market framework?

- We need to move from a technology silo, carve-out, set-aside policy to a market-based competition in the product space, using techniques, methodologies and approaches that encourage a portfolio approach, so each asset, program, transaction is valued within that portfolio context.
- Storage can be cost-effective if all its benefits are captured. Prices that reflect all the benefits, a forward-looking market, and market compensation mechanisms that attract investment and cost-effective applications are needed.
- Storage can help manage the mismatch between output and demand at the distribution level, regional generation variability, and the power quality impacts of renewable energy. For distribution-side PV, storage can also help manage localized ramping-related challenges, voltage and reactive power, harmonic, and current backflow, and it can enable microgrids and islanded operation.
- An issue with storage is ownership: depending on who owns the storage system, the regulatory treatment can be different, affecting its cost-effectiveness.
- Storage needs optimal location for highest value, and its value will be highest closest to the customers, e.g., community energy storage (CES).
- Lower costs for storage can be achieved via optimal packaging, higher efficiency, mass production and elimination of non-repeat integration costs.
- Storage can be controlled to provide inertia; the concepts were demonstrated by Southern California Edison at Chino in 1994.
- The PUC has a deadline of October 1, 2013, to adopt, as appropriate, energy storage procurement targets for the LSEs and utilities. The PUC is also considering a variety of possible policies to encourage cost-effective deployment of energy storage systems, including a refinement of existing procurement methods.
- The California Energy Commission commissioned the Storage 2020 Vision Report, which illuminated many of the issues around storage.
- Adding thermal energy storage (TES) to concentrating solar power (CSP) plants greatly improves both dispatchability and flexible operation of CSP.
- The Revenue Quality Metering Requirement is perceived as a significant barrier to storage resources that could participate in that market. While accurately measuring the renewable energy that ratepayers are paying for is necessary, feasible lower-cost methods are available.

Concluding Comments

Commissioner Peterman:

Next steps: we will be developing a list of detailed recommendations to reach the 2020 goals, as well as to position us for higher goals going forward. We'll be putting out a draft document and asking for responses. We'll also be holding an IEPR workshop where we will review this document, as well as some of the other products from this year's IEPR. Thank you to all who participated today, for your input and ideas.

Commissioner Weisenmiller:

As a scientist, I found this workshop to be very interesting from the technology point of view, especially in comparing the technology choices in terms of providing the services needed by renewable generation. In terms of moving forward, this has been helpful, and we certainly appreciate people's comments. I would also like to thank all the participants, and both CEC and CPUC Commissioners for your leadership in these workshops.

Summary of the June 21, 2012 Electric Transmission and Distribution Research Utility Technical Advisory Committee (TAC) Workshop

Workshop Background

This meeting was held at CAISO in Folsom. Participants included representatives of the three California IOUs, CAISO, Energy Commission, CIEE, and California State University Sacramento.

The TAC had met several times during the preceding year in order to advise the Energy Commission on research issues and needs of importance to utilities. This workshop was aimed at developing the grid research activities that address electric grid and renewable generation integration issues and are independent of research funding sources.

The specific objectives of the workshop were to review the outcomes of prior TAC meetings, review and advise on ongoing research as relevant to the purpose of TAC meetings, provide status on research activities for wide-area grid issues, and reassess research needs and priorities.

Meeting Highlights and Outcomes

Previous meetings had identified specific projects in both transmission and distribution. The most recent meeting on Oct 5, 2011, agreed on a distribution focus with 5 primary priorities: Volt/VAR control, Distribution Modeling, Forecasting, Ancillary Services, and Energy Storage. However, it had been also recommended that a future meeting address remaining transmission issues. Accordingly, this workshop devoted a session to transmission research needs.

The CAISO high priority needs that could benefit from research projects are: (1) ISO system inertia and frequency response monitoring system, (2) Phase 3 Wide Area Energy Management System, (3) Analysis of the ISO generation fleet to meet 33% RPS requirement, and (4) Fleet optimization.

From prior PIER and ARRA projects, the Energy Commission has concluded the following about storage:

- Storage business cases are difficult. Multiple applications are required.
- Commercial market beyond end use is a moving target.
- Government projects do not create a market without industry participation.
- Benefits can be difficult to monetize.
- Policy needs to change for real storage growth.
- There is a need for storage to be an asset class and for policies to better consider the unique characteristics of storage.
- Cost reductions are less than hoped for.

On renewables forecasting, getting the forecasts into the control rooms and translating to actionable information is still a significant issue.

With regard to Volt/VAR control, the following observations were made:

- Utilities would much prefer that any Volt/VAR system be under utility control rather than have that control be dictated by a 3rd party.
- Large inverters are the priority. Small inverters may be useful if fully automatic and could be an asset in community based systems.

Future Research Needs and Goals

- **DER for Ancillary Services**
  Accuracy of forecasting impacts the need for ancillary services. Better forecasting could reduce the pressure.
  More resources are becoming available for ancillary services. There is opportunity for aggregation. We are moving from discrete resources toward virtual resources.
- **Storage**
  Models are needed before more field testing. Dispatch algorithms are the 2nd step.

  Sac State has done some studies that show distributed storage can maximize efficiency (losses) on a system-wide basis.

General Comments by TAC members
- Appreciative of moving forward with Volt/VAR. Extremely important.
- Good to take a fresh, open look and to revisit transmission issues – transfer capacity, NASPI, DMRI, storage, etc. Encouraged by what I heard. Lot of synergy happening.
- Some interesting evaluations going on with fast solid state controllers for dynamic voltage control at SCE.
- Glad to see the cooperation and exchange between utilities and CEC. Good group. Hope to continue under EPIC. Re intellectual property (IP) – would like process to be as open access as possible. Need a collaborative with one well planned and coordinated R&D program.
- On storage, it's a hot issue, but need to be thinking about alternatives to batteries, which are expensive.
- I like the collaborative process. I hope that EPIC continues or expands on that.

Summary of the August 2 – 3 Workshop on the Electric Program Investment Charge (EPIC) Program

Workshop Background

The California Energy Commission staff conducted a two-day workshop to discuss the first triennial investment plan for the Electric Program Investment Charge Program on August 2 and August 3, 2012, respectively. It was held at the California Energy Commission, 1516 Ninth Street, Hearing Room A, in Sacramento, California.

The purpose of this workshop was to seek input from experts, stakeholders, and the general public on the development of a coordinated triennial investment plan covering 2012 through 2014 for administration of the Electric Program Investment Charge (EPIC) Program, as established by the California Public Utilities Commission (CPUC) in Rulemaking 11-10-003. At this workshop staff solicited input on funding priorities and initiatives to consider as input from this workshop together with other public comments it received to develop the First Triennial Investment Plan for Funds Administered by the California Energy Commission for the EPIC.

Meeting Highlights and Outcomes

Day 1

Day 1 of the workshop consisted of an explanatory session of EPIC conducted by the Energy Commission and the CPUC followed by 3 breakout sessions on Demand Side Management, Energy Generation, and Grid Operations (including T&D and EVs).

EPIC has 4 focus areas: Applied Research (AR), Technology Demonstration and Deployment (TD&D), Market Support, and Market Facilitation, but the 3rd one will not be covered in this planning period. There will be 3 investment periods of 3 years each through 2020. Guiding principles are that research will provide ratepayer benefits and be "mappable" to the utility value chain: operations/market design, generation, transmission and distribution, and demand side management. Of the total $162M annual budget, AR and TD&D will account for $130M with $100M of that administered by the Energy Commission administration and $30M by California IOUs.

Breakout Session 1- Demand Side Management *(Joe O'Hagan)*

Subtopics in this session included Smart Communities, Distributed Generation, Environment and Public Health, and Market Facilitation. Of particular note:

- Integration of EVs – simultaneous charging of 2 or more vehicles may trip transformers.
- There is urgent need for more data on environmental and public health impacts of climate change and electricity generation.

Commissioner Weisenmiller recommended that the potential for energy efficiency in existing buildings should have highest priority and that EPIC should lead through development of standards.

Breakout Session 2 – Energy Generation *(Beth Chambers)*

Numerous topics were discussed. Significant subjects included:

- Metrics for net zero energy projects
- Integration of clean generation and EV charging
- Improved and/or updated building codes and standards
- Streamlining of policies and regulations

Commissioner Weisenmiller suggested that previous renewable integration workshops would be a good source of research topics.

Breakout Session 3 – Grid Operations *(Jamie Patterson)*

The session was divided into 5 subsections – Grid Operations, Transmission, Distribution, EVs, and Other. After a presentation of the value proposition and policy drivers used by the Energy Commission, a number of possible research initiatives in each of the subsections were presented. These included but were not limited to:

- Grid Operations
    - Renewable operations tools
    - Synchrophasor applications development
    - Fleet flexibility
- Distribution
    - Distributed energy storage aggregation and control
    - Volt/VAR support and control
    - Integration of DG, smart inverters, and automated DR.
- EVs
    - Integrate charging with wind and solar
    - Enable 3rd party through AMI
    - Standards for interoperability in different utilities
- Transmission
    - Power flow control
    - Dynamic thermal ratings
    - Hardware
- Other
    - Price response demand program
    - Water heaters for DR

A general topic of discussion was the need for coordination of research between the 4 administrators. One suggestion was a joint IOU/Energy Commission presentation of all EPIC plans.

Day 2

Day 2 consisted of 3 panel discussions: Innovation Clusters, Regulatory Assistance/Permit Streamlining, and Workforce Development

Panel 1 – Innovation Clusters

Panelists: Gary Simon (Sacramento Regional Technology Alliance); Bill Walden (McClellan AFB); Ericka Kula (Prescience International); Josh Gould (ARPA-e); Cameron Gorguinpour (USAF).

Innovation clusters or centers are valuable in assisting entrepreneurs in funding, integrating their technology with others, and assisting in overcoming the Valley of Death. EPIC's support of innovation centers can help continue California's leadership in clean energy technologies. Innovation centers can help to identify problems and find solutions. Good filtering, such as that applied by ARPA-e is necessary to insure quality.

Panel 2 – Regulatory assistance/Permit streamlining.

Panelists: Valerie Winn (PG&E); Jennifer Barret (Sonoma County Permit and Resource Management Dept); Gary Craft (Craft Consulting); Mike Hart (Sierra Energy); Chris Calee (Office of Planning & Research); Vernon Hunt (US Navy).

Key points made were:

- Codes are old fashioned and need updating. The Energy Commission can assist in vetting new technologies. A single point of contact, an Ombudsman would be useful.
- For EPIC investments to avoid duplication, someone needs to help coordinate grants between OPR / DOE / EPIC. Efforts need to be coordinated.
- The measure of ratepayer benefits for local planning and permitting assistance should be whether the customers get the actual benefit of new technology deployment?
- For deploying new technologies, the permitting process is too burdensome any one company

Panel 3 – Workforce Development

Panelists: Barbara Halsey (California Workforce Association); Kurt Schuparra (California Labor and Workforce Development Agency); David McFeely (SolarTech); Jim Caldwell (Workforce Incubator); Mark Lennon (Department of Veteran Affairs); Blake Konczal (Fresno Workforce Investment Board).

Some key points that were raised:

- It is a mistake to create a program and then train people without first working closely with employers in order to ensure that jobs will actually be available.
- It would be valuable to have a standardized training program that could be offered regardless of provider.
- Online training and the use of social networking systems would be more beneficial than classroom training,
- Distributed PV and wind have industry recognized certifications (i.e., NABCEP). Energy Efficiency is one area where certification is needed.

Technology Gaps

Electric distribution networks operate at lower voltages than transmission, and the majority of distribution feeder circuits are radial, i.e., power typically flows in one direction, from the distribution substation to the customers (loads). However, this relatively simple model of a distribution system is changing rapidly, as the push for more renewable generation is resulting in an anticipated proliferation of distributed generation, especially in rooftop PV systems, a growing number of EVs, and other new devices, especially customer-owned digital equipment. These changes are increasing system complexity, for which the distribution system generally has not been designed, and are anticipated to give rise to a host of technical issues that will require technical solutions, as well as changes in utility planning and operational practices. New electric distribution technologies, of many different types, have the potential to address these concerns in an environmentally-friendly, reliable and economically efficient manner.

Much needs to be learned about how the distribution system will respond to high penetrations of renewable distributed generation, the potential interactions among new devices, and how the distribution system can be effectively monitored and controlled. There are a number of gaps between the state of art of distribution technology and the new technology that will be required for the modern electric power grid. Research activity to date in these areas has not been extensive, and much greater investment in research, development and demonstration of emerging technologies and their impacts is needed to ensure that renewable generation can be effectively integrated and utilized, and that distribution systems and the grid as a whole remain reliable, secure and cost-effective.

More specific technology gap descriptions are provided below with descriptions of some recommended research areas. For additional information, please see Appendix A: Literature Search. Organized by research areas as listed below, the selected references may provide more details and further avenues of investigation for the various topics.

Recommended Research Areas

Distribution System Planning and Design

Gap Analysis

Distribution systems in the US and California have historically been designed as relatively simple, radial networks: one-way power flow from the distribution substation to the customer loads, with little provision for generating systems such as renewables, advanced types of loads such as electric vehicle charging systems, etc. Utility experience with integration of renewables and other non-traditional customer-side technologies into distribution systems has, to date, consisted mainly in connecting PV systems via net-metering tariffs, and some scattered electric vehicle charging. Methodologies for determining the allowable level of renewable generation and/or DG on a given distribution feeder typically use "rules of thumb," such as an arbitrary limit of 15% of feeder load. Given the high level of variability in distribution system design, such "one size fits all" approaches are increasingly being seen as inadequate, frequently limiting renewables/DG to unnecessarily low levels or not recognizing technical factors that may dictate lower levels of renewables for reliability reasons. Extensive and detailed information and analysis are needed on impacts on operating procedures, O&M requirements, Volt/VAR control, coordination with transmission control, advanced protection systems to handle two-way power flow and detect high-impedance faults, applications of storage systems, and other impacts from renewables, and technological solutions identified. New methodologies will be needed that take into account the necessary upgrading of conductors, switches, transformers, relays and protection equipment due to higher levels of renewable generation

Research Activities for Methods for Deploying High Levels of Renewables on a Feeder

- Planning studies to investigate the impacts of, and barriers to, deployment of various high levels of renewables on distribution systems, and to identify technological gaps and research solutions to develop new technologies to address the impacts and barriers.

  - o Determining allowable levels of renewables on a feeder
  - o Assessment of distribution system capacity issues such as, upgrading of conductors, switches, transformers, relays and protection equipment
  - o Assessment of methods for advanced protection systems to handle two-way power flow, detect high-impedance faults, etc.
  - o Assessment of energy storage systems cost-effective for some applications in distribution, and the benefits in terms of control and operation, especially in reducing the requirements for mitigating intermittency and variability of renewables.

Distribution System Operations and Control

Gap Analysis

As renewable distributed generation, electric vehicles, and other customer equipment and devices proliferate on the distribution system, along with the need for new grid infrastructure architectures and operations functionalities – including microgrids, the requirements for overall distribution system control, local & global optimization, and communication/coordination with transmission system operations become very important to ensure stable and efficient operation and to allow maximum integration of renewable energy on distribution feeders. The current methods for maintaining awareness, controlling or coordinating the distribution system will not be adequate for the needs of future distribution systems: voltage and VAR control including conservation voltage reduction (CVR) schemes, switching and reconfiguration, demand response implementation, coordination with microgrids and their designs, and other functions will require new and probably intelligent operational schemes to ensure reliability and optimum efficiency. Additional ancillary services (generator ramping, spinning reserves, Volt/VAR supply, regulation, load following, etc.) will be required. New monitoring, communications, telemetry and data collection systems will be needed to acquire the necessary data for the new control and visualization methodologies.

Renewable generation forecasting is a new tool identified, and being developed and used, for transmission grid system operations as a critical need for integrating renewable generation into the electric grid. The need for such a forecasting capability at the distribution level is speculation that is getting increased attention. If found to be needed, renewable forecasting tools, both resource forecasting and the operator interface applications have not been developed specifically for distribution.

Research Activities for Control & Coordination Methodologies

- Conduct needs analyses for new distribution control and coordination methodologies.
- Where needs identified, develop a technology development roadmap, with stakeholder participation, for developing and commercializing new distribution control and coordination methodologies

Research Activities for Voltage and VAR Control Methodologies

- Assess state of the art for new technologies for automatic and/or operator-controlled systems for coordinating all voltage and VAR sources on a distribution feeder, to maintain desired voltage profiles, implement conservation voltage reduction (CVR)

schemes, and otherwise manage feeder voltage for optimum efficiency., especially under high penetrations of renewable distributed generation and electric vehicles.

- Develop, model, test and/or evaluate advanced, and where needed, demonstrate, automatic and/or operator-controlled methodologies and technologies for managing or coordinating all Volt/VAR devices on a distribution feeder.

Research Activities for Load Control & Coordination

- Assess state of the art for new technologies for advanced automatic and/or operator-controlled methodologies and technologies for managing or coordinating feeder loads within Demand Response schemes, and/or with renewables such as wind and solar in order to mitigate the intermittency and variability of renewables.
- Develop, model, test and/or evaluate, and where needed, demonstrate, advanced automatic and/or operator-controlled methodologies and technologies for managing or coordinating feeder loads within Demand Response schemes, and/or with renewables such as wind and solar in order to mitigate the intermittency and variability of renewables.

Research Activities for Interoperability Stability Issues

- Conduct scoping studies using interviews, literature searches, modeling, simulation and/or laboratory testing to determine whether and under what circumstances multiple renewable energy systems and other active devices on a distribution feeder will produce dynamic or transient frequency or voltage effects, known or unexpected.
- Identify or develop practices and procedures, existing or new, perhaps using new technologies, to avoid stability problems, and contribute to better integration of higher levels of renewables in distribution systems.

Research Activities for Ancillary Services Requirements

- Assess and analyze the potential need for additional ancillary services – levels and types – for generator ramping, spinning reserves, Volt/VAR supply, regulation, load following, black start, etc., as controllable resources required to balance the intermittency and variability of high penetrations of renewable generation on the distribution system.
- Develop methods for mitigating or reducing those requirements, e.g., via better forecasting or geographic/balancing area aggregation.
- Investigate the potential for renewables and DG to provide ancillary services to the grid, including technical and market innovations needed to recruit local resources for ancillary services.

Research Activities for Renewables Forecasting

- Solar Forecasting:
  - Cloud forecasting and tracking. This is the single most important area of research for improving solar forecasts. California has specific needs related to the marine layers on its coast, and to inversion layers inland. Current research may provide results, but additional research may be needed.
  - Ramping of solar generation. This is especially important in areas of the distribution system with high concentration of PV, where visibility of PV by system operators is poor or non-existent.
  - Development and evaluation of advanced forecasting engines. Examples include the SolAspect engine being developed at UCSD, or the Multiple Look-Ahead system developed by AWS TruePower. These engines can produce full-spectrum forecasts, rather than aggregating results from multiple forecasting engines, or other types of systems with time gaps in their forecast zones.

- Improved monitoring instrumentation and optimal location of monitors. This by itself can provide real-time measurement of plant output, giving system operators better situational awareness rather than relying on possibly outdated or inaccurate forecasts; the data also can be used to improve short-term (15-min and hour ahead) solar forecasts.
    - Improved day-ahead forecasting through numerical weather models, with a focus on marine layer clouds. Advanced algorithms to ingest satellite and ground measurements into their models, and advanced modeling parameterizations for clouds and the boundary layer should be applied. Of specific interest are ensemble forecasts integrated with machine learning tools to optimize dynamic selection of forecast models based on meteorological conditions.
- Wind Forecasting:
    - Ensemble forecasts. These have been used with some success in Europe and elsewhere, and should be investigated for applicability in California.
    - Improved instrumentation, and optimal location of monitors. As with solar, the benefits are better situational awareness for operators, and improved short-term forecasts, especially for ramp prediction.
    - Offshore wind forecasting methodologies for forecasting offshore wind and incorporating into current tools.
- General Forecasting:
    - Forecasting metrics (both wind and solar) need to be better defined, and evaluated for applications to specific uses. MAE (mean average error) and RMSE (root mean square error) are the leading candidates, but others may be needed.
    - Geographic diversity and aggregation techniques, especially across balancing areas, to achieve higher forecast accuracy.
    - Probabilistic/stochastic forecasting: new methods and tools, operator training and evaluation, to enhance weather forecasts for improved actional information for operators and automated systems.
    - Synchrophasors for data acquisition (e.g., renewable plant output, input to ramping tools, improved forecast accuracy, etc.) and model validation.
    - Applications of storage systems to smooth renewable plant output, augment forecasting methods and reduce errors.

Research Activities for Sensors and Monitoring Systems

- Survey, analyze and perform gap analysis for the need for sensors and monitoring systems in the distribution system by 2020 to determine:
    - Kinds of sensors, monitors and other data-gathering equipment that will be needed
    - Potential role of aggregators of DG to provide the needed data from behind the meter
    - Level of spatial and temporal resolution of monitoring data needed for different purposes
    - Specifications for how much and what kind of data to collect, how to process and store it, and how the various planning and operations tools will access and use the data
    - Level of processed data that will needed to be made available to the transmission system operator.
- As needs identified, develop, test and demonstrate new sensors and monitoring systems
    - Develop high-resolution, low-cost phasor measurement units (PMUs) along with phasor data aggregation and analytic techniques to create versatile diagnostic

tools that will enable new management, planning and control strategies to increase the efficiency of distribution system operation, accommodate intermittent renewables, and recruit distributed energy resources for grid services.

- o Targeted pilot studies and demonstration projects to gain field experience with pre-commercial distribution-level PMU technologies.
- Develop, lead and coordinate distribution system monitoring efforts among California's distribution owners and operators to obtain data needed by policy decision makers and other California stakeholders involved in assuring the distribution system needed for 2020.

Research Activities for Microgrid Operations & Control

- Use Case studies for new potential operating and design strategies implied by the technical capabilities of microgrids, and visualizing how these capabilities best can be recruited in service of the core grid.
- As needs identified, demonstrate aspects of microgrids to verify Use Case studies findings

Research Activities for Communications Architecture

- Assess and develop specifications for the most efficient and cost-effective method (or combination of methods) for
  - o Telemetry of data, both from the point of monitoring and to the various applications requiring the data at transmission and distribution levels.
  - o Processing and storing data for the various planning and operations tools that will access and use the data.

Distribution System Modeling & Simulation

Gap Analysis

Simulation tools, and the component models and algorithms embodied in them, are continually being developed and upgraded to keep up with the needs of distribution system operators and engineers, who need accurate tools for the real-time operation of distribution networks and to plan and design the distribution system of the future. Typically, simulation tools are designed for a specific purpose, e.g., analyzing the voltage profile, or the power flow, switching transients, etc., on a feeder. The engineer will usually need to run multiple types of software packages and aggregate results for a total picture of feeder performance. New customer devices, such as distributed generation, and electric vehicles, and new distribution technologies and subsystems, such as for high frequency usage volt/VAR control and reverse power flow management, needed to accommodate these new devices will render current component models inadequate. For example, most PV and loads are currently represented as lumped values at the distribution substation, masking what's on the system, leading to low situational awareness by operators, and lack of knowledge of the dynamic effects under faults or transient conditions. Better models are critical to system planning for high penetration of renewables and other new technologies. The differences in component behaviors, time scale of simulation, mathematical techniques and other variations will all introduce some degrees of error in the process. Likewise, new simulation tools, in addition to needing these new component modeling tools, will need to be developed for new infrastructure architectures, such as new self-healing network configurations and microgrids for special power service. For example, better simulation tools are critical to system operations and planning for high penetrations of renewables and electric vehicles, or new grid operating techniques, such as demand response.

More accurate, "holistic," probabilistic, stochastic, integrated and coordinated approaches are needed, especially ones that are capable of analyzing the distribution system of 2020 with its expected high penetration of renewables and other new customer-side technologies.

Research Activities for Development of Advanced Distribution System Component Models

- Assess expected new customer devices and distribution components, and of the state-of-the-art, new model development and verification.
- Where needs are identified, develop the algorithms needed for new device and component modeling through physical testing and monitoring for performance behaviors and applications of new mathematical techniques and empirical data analysis.

Research Activities for Development of Advanced Distribution System Simulation & Analysis Tools

- Assessment of expected new distribution configurations and functionalities and state-of-the-art, new tool development and verification.
- Where needs are identified, develop the algorithms, computer codes, computational capabilities, and component models [see above research activity] needed for new distribution architectures and functionalities.

Distribution System Standards & Regulation

Gap Analysis

New technologies and operating practices are constantly developing on the distribution system in response to increasing penetration of renewable energy generation, and the need for coordination and control both on the distribution system itself and in coordination with the wide-area grid. Current interconnection standards and practices for renewable generation do not take into account all the capabilities of the wind or PV plant, nor do they consider the real-time requirements of the distribution system. For example, anti-islanding requirements in the interconnection standard specify that the renewable plant disconnect from the grid for a voltage sag event, although experience shows that low-voltage ride-through capability would allow the plant to stay on-line and avoid overvoltages when it re-connects, contributing to system recovery rather than complicating it. Also, many inverter systems used on renewables plants have the capability to supply voltage support, but existing standards and utility practices do not allow this capability to be used. The development of microgrids further reinforces the need for more explicit operating practices, which must be implemented via regulation. Storage systems in particular suffer under current regulatory rules, which don't allow full consideration of the benefits they provide, nor adequate cost recovery for those benefits. System security and cybersecurity standards also need to be addressed and developed. New service standards and operating practices for voltage, reliability, power quality, etc., need to be developed at the regulatory level, as well.

Research Activities for Interconnection and Security Standards, and Distribution System Regulations

- Evaluate the requirements for improved and new distribution system standards and operating practices, and the need for new regulatory procedures, in light of the penetration of high levels or renewables, proliferation of EV chargers and other customer-side technologies, development of microgrids, storage technologies, and other factors.
  - o Identify the gaps in distribution system regulations for market facilitation, as they impact the integration and operation of renewables in the distribution system; identify the needed changes in regulations and operating practices.

- Collect data on device, component and system performance as needed to provide information for standards or regulation development or reform.

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ACRONYMS

A	Ampere (Amp)
AC	Alternating Current
ACSR	Aluminum Cable Steel Reinforced
AMI	Advanced Metering Infrastructure
AR	Applied Research
ARPA-e	Advanced Research Projects Administration – energy
ARRA	American Recovery and Reinvestment Act
CAISO	California Independent System Operator
CES	Community Energy Storage
CIEE	California Institute for Energy and Environment
CPUC	California Public Utility Commission
CSP	Concentrating Solar Power
CVR	Conservation Voltage Reduction
DC	Direct Current
DER	Distributed Energy Resources
DG	Distributed Generation
DMRI	Distribution Monitoring for Renewable Integration
DMS	Distribution Management System
DOE	(US) Department of Energy
DR	Demand Response
DSO	Distribution System Operator
EPIC	Electric Program Investment Charge
EV	Electric Vehicles
FACTS	Flexible AC Transmission Systems
Hz	Hertz (cycles per second)

IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEPR	Integrated Energy Policy Report
IOU	Investor Owned Utility
kV	Kilovolt
kVA	Kilovolt-Ampere
kW	Kilowatt
kWh	Kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LMP	Locational Marginal Price
LTC	Load Tap Changer
MVA	Megavolt-Ampere
NASPI	North American Synchrophasor Initiative
NREL	National Renewable Energy Laboratory
O&M	Operations & Maintenance
OTC	Once Through Cooling
PBR	Performance-Based Regulation
PDRP	Proxy Demand Resource Product
PHEV	Plug-in Hybrid Electric Vehicle
PIER	Public Interest Energy Research (Program)
PMU	Phasor Measurement Unit
PV	Photovoltaic
RAS	Remedial Action Scheme
RDRP	Reliability Demand Response Product
RPS	Renewable Portfolio Standard
RTU	Remote Terminal Unit

SCADA	Supervisory Control and Data Acquisition
TAC	Technical Advisory Committee
T&D	Transmission & Distribution
TD&D	Technology Demonstration and Deployment
TES	Thermal Energy Storage
V	Volt
VAR	Volt-Amps-Reactive
W	Watt
WGA	Western Governors Association
WECC	Western Electricity Coordinating Council

Appendix A:
Literature Search

As part of the background research for the White Paper titled *Integrating Renewable Generation with the Electricity Grid: Distribution System Issues*, a literature search was performed to find useful and current references to technological advances relating to the distribution system issues highlighted in the White Paper.

Some of these references were cited in the White Paper as particularly relevant to the topics and issues being discussed, and are included in the References section of that report to illustrate and validate the findings presented therein. There are, however, a multitude of papers, reports, presentations, journal articles, etc., relating either directly or indirectly to the issues and impacts that renewable generation may engender in distribution systems, and may be of value to the reader as sources of additional information and insight.

To that end, this Appendix to the White Paper lists a number of additional references including abstracts as appropriate, chosen for their relevance in providing supplemental information on the given topics, and grouped according to the distribution system issues listed in the White Paper. Many of these references also list additional references as sources for their findings, which may provide even more avenues of investigation to the adventurous and curious reader.

A. Distribution System and Equipment Capacity

A-1. Coddington, M.; Ellis, A.; Lynn, K.; Razon, A.; Key, T.; Kroposki, B.; Mather, B.; Hill, R.; Nicole, K.; Smith, J.: *Updating Technical Screens for PV Interconnection*, 2012 38th IEEE Photovoltaic Specialists Conference (PVSC), June 2012.

Solar photovoltaics (PV) is the dominant type of distributed generation (DG) technology interconnected to electric distribution systems in the United States, and deployment of PV systems continues to increase rapidly. Considering the rapid growth and widespread deployment of PV systems in United States electric distribution grids, it is important that interconnection procedures be as streamlined as possible to avoid unnecessary interconnection studies, costs, and delays. Because many PV interconnection applications involve high penetration scenarios, the process needs to allow for a sufficiently rigorous technical evaluation to identify and address possible system impacts. Existing interconnection procedures are designed to balance the need for efficiency and technical rigor for all DG. However, there is an implicit expectation that those procedures will be updated over time in order to remain relevant with respect to evolving standards, technology, and practical experience. Modifications to interconnection screens and procedures must focus on maintaining or improving safety and reliability, as well as accurately allocating costs and improving expediency of the interconnection process. This paper evaluates the origins and usefulness of the capacity penetration screen, offers potential short-term solutions which could effectively allow fast-track interconnection to many PV system applications, and considers longer-term solutions for increasing PV deployment levels in a safe and reliable manner while reducing or eliminating the emphasis on the penetration screen.

A-2. Falaghi, H.; Singh, C.; Haghifam, M.-R.; Ramezani, M.: *DG Integrated Multistage Distribution System Expansion Planning,* International Journal of Electrical Power & Energy Systems, Vol. 33, Issue 8, pp. 1489-1497, October 2011.

In this paper, a framework is presented to solve the problem of multistage distribution system expansion planning in which installation and/or reinforcement of substations, feeders and distributed generation units are taken into consideration as possible solutions for system capacity expansion. The proposed formulation considers investment, operation, and outage costs of the system. The expansion methodology is based on pseudo-dynamic procedure. A combined genetic algorithm (GA) and optimal power flow (OPF) is developed as an optimization tool to solve the problem. The performance of the proposed approach is assessed and illustrated by numerical studies on a typical distribution system.

A-3.   Hasani-Marzooni, M.; Hosseini, S.: *Dynamic Model for Market-based Capacity Investment Decision Considering Stochastic Characteristic of Wind Power,* Renewable Energy, Vol. 36, pp. 2205-2219, August 2011.

This paper proposes a decentralized market-based model for long-term capacity investment decisions in a liberalized electricity market with significant wind power generation. In such an environment, investment and construction decisions are based on price signal feedbacks and imperfect foresight of future conditions in electricity market. System dynamics concepts are used to model structural characteristics of power market such as, long-term firms' behavior and relationships between variables, feedbacks and time delays. For conventional generation units, short-term price feedback for generation dispatching of forward market is implemented as well as long-term price expectation for profitability assessment in capacity investment. For wind power generation, a special framework is proposed in which generation firms are committed depending on the statistical nature of wind power. The method is based on the time series stochastic simulation process for prediction of wind speed using historical and probabilistic data. The auto-correlation nature of wind speed and the correlation with demand fluctuations are modeled appropriately. The Monte Carlo simulation technique is employed to assess the effect of demand growth rate and wind power uncertainties. Such a decision model enables the companies to find out the possible consequences of their different investment decisions. Different regulatory policies and market conditions can also be assessed by ISOs and regulators to check the performance of market rules. A case study is presented exhibiting the effectiveness of the proposed model for capacity expansion of electricity markets in which the market prices and the generation capacities are fluctuating due to uncertainty of wind power generation.

A-4.   Masoum, A. S.; Moses, P. S.; Masoum, M. A. S.; Abu-Siada, A.: *Impact of Rooftop PV Generation on Distribution Transformer and Voltage Profile of Residential and Commercial Networks,* 2012 IEEE PES Innovative Smart Grid Technologies (ISGT), January 2012.

Integration of rooftop PVs in residential networks at moderate penetration levels is becoming a reality in many countries including Australia. However, the detrimental effects associated with the high penetrations levels of rooftop PVs are not fully explored to most power utilities. It is expected that the sophisticated structure and communication backbone of smart grid allow easy, safe and reliable integration of these distributed renewable energy resources at very high penetration levels in the residential networks populated with smart appliances. However, it could take several years before smart grid infrastructure is ready to support high perpetrations of distributed generations. Therefore, until smart grid communication becomes available, utilities need to explore how present-day residential networks will cope with the fast installations of rooftop PV systems. In particular, the burden on local distribution circuits such as transformers and cables, which are the critical links in distribution systems, must be investigated in the presence of PVs. This paper carries out an analysis into the impacts of rooftop PVs at different penetration levels on the performance of distribution transformers and

residential networks. Such operation may lead to an overall reduction in the reliability and economy of future smart grids. Simulation results are presented to demonstrate voltage profiles and distribution transformer stresses for a realistic 97 node residential network at various penetrations of rooftop PVs.

A-5.   Obara, S.; Watanabe, S.: *Optimization of Equipment Capacity and an Operational Method Based on Cost Analysis of a Fuel Cell Microgrid,* International Journal of Hydrogen Energy, Vol. 37, Issue 9, pp. 7814-7830, May 2012.

A microgrid requires a stable supply of electric power and heat, which is achieved by the cooperative operation of two or more pieces of equipment. The equipment capacity and the operational method of the equipment were optimized using a newly developed orthogonal array-GA (genetic algorithm) hybrid method for an independent microgrid accompanied by a fuel cell cascade system, solar water electrolysis, battery, and heat storage. This type of system had not been hardly developed until now. The objective function of the proposed system was the minimization of the total amount of equipment and fuel cost over ten years. For the first step in the proposed analysis method, the capacity of each piece of equipment and the operational method, which are considered to be close to the optimal solution of the system, are combined using the orthogonal array and factorial-effect chart, which are an experimental design technique. In the next step, the combination described above provides the initial values to the GA, and the GA searches for the optimal capacity and operational method for each piece of equipment in question. Compared with a simple GA, the convergence characteristic improves greatly using the proposed analysis method developed in this study.

A-6.   Trichakis, P.; Taylor, P. C.; Lyons, P. F.; Hair, R.: *Predicting the Technical Impacts of High Levels of Small-scale Embedded Generators on Low-voltage Networks,* IET (Institution of Engineering and Technology) Renewable Power Generation, Vol. 2, Issue 4, 2008.

The anticipated high penetrations of small-scale embedded generators (SSEGs) on public low-voltage (LV) distribution networks are likely to present distribution network operators (DNOs) with a number of technical impacts relating to power quality, distribution system efficiency and potential equipment overloads. Impact studies need to be performed using suitable case study networks in order to evaluate the effects of SSEGs on LV distribution networks and quantify allowable SSEG penetration levels. The aim is to propose a methodology for predicting the technical impacts of SSEGs on LV networks without the need for developing a detailed computer-based model of the power system and simulating a range of operating scenarios. This methodology is drawn from an analysis of the key electrical characteristics that determine the response of LV networks to the addition of SSEGs, focusing on the following technical aspects: (i) voltage regulation, (ii) voltage rise, (iii) voltage unbalance, (iv) cable and transformer thermal limits and (v) network losses. The analysis is carried out on a UK generic and a European generic LV network and simulation results for both networks are presented and discussed. The proposed methodology is then applied to an existing public UK LV network operated by E.ON UK Central Networks, indicating a good agreement between predicted and simulation results.

A-7.   Yang, N.-C.; Chen, T.-H.: *Optimization of Equipment Capacity and an Operational Method Based on Cost Analysis of a Fuel Cell Microgrid,* International Journal of Hydrogen Energy, Vol. 37, Issue 9, pp. 7814-7830, May 2012.

This paper proposes a dual genetic algorithm based approach to evaluate the maximum allowable capacity of distributed generations (DGs) connected to a distribution grid. The uncertainties in the existing deterministic approaches for evaluating the steady-state voltage deviation due to distributed generation are discussed as well. Nowadays,

deterministic approaches are widely adopted by those who propose the interconnection of DGs. However, the existing deterministic approaches overlook some operation conditions that may give rise to an incorrect result and lead to a wrong decision in practical applications. In this paper, various factors affecting steady-state voltage deviation are discussed first. Then, a maximum allowable DG capacity evaluation approach based on the dual genetic algorithm is proposed. Finally, the uncertainties of the existing deterministic approaches are discussed. It is intended as reference for utility engineers processing DG interconnection applications.

B. Voltage and VAR Control

B-1. Alonso, M.; Amarís, H.; Chindris, B.: *A Multiobjective Var/Volt Management System in Smartgrids,* Energy Procedia, Vol. 14, 2012.

This paper presents a methodology for optimal Var/Volt management of Distributed Generation (DG) and FACTS units in power networks. The methodology is based on Genetic Algorithm in order to achieve the desired system reliability requirements taking into account voltage stability limits. Results indicate that the proposed formulation could be used to determine the optimal points in which the incorporation of DG units and connection of FACTS devices would allow a voltage stability enhancement, minimizing, at the same time, real power losses and minimizing the investment cost of the FACTS devices.

B-2. Caldon, R.; Rossetto, F.; Scala, A.: *Reactive Power Control in Distribution Networks with Dispersed Generators: A Cost Based Method,* Electric Power Systems Research, Vol. 64, Issue 3, March 2003.

The reactive power service is one of the control area ancillary services that must be in place to make the electric energy delivery possible. It may be of interest to examine the advantage of providing the necessary reactive power support by local devices, namely shunt capacitors or Dispersed Generators (DG) where available. To this purpose the paper first defines costs for the service performed by these devices, then it proposes an optimal co-ordination method which allows distributors to select, for every operating condition, the more profitable combination of reactive sources in order to maintain the network voltage levels within a desired range and to minimise the regulation action global cost.

B-3. Feng, X.; Peterson, W.; Yang, F.; Wickramasekara, G. M.; Finney, J.: *Implementation of Control Center Based Voltage and Var Optimization in Distribution Management System,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

This paper presents the implementation of an online voltage and var optimization (VVO) application that runs at the control center for distribution systems. The innovative VVO application combines state of the art optimization technology with detailed and accurate modeling of distribution systems. The multi-phase, unbalanced system model can have radial or meshed circuits, single or multiple sources, wye and/or delta connected transformers, grounded or ungrounded, voltage dependent load models, ganged or unganged controls of capacitor banks and voltage regulators. This application is capable of optimizing large and complex networks with online application speed. It is designed for smart grid application to optimize distribution energy delivery efficiency by minimizing the energy loss and manage system demand.

B-4. Gaonkar, D. N.; Pillai, G. N.: *Fuzzy Logic Based Coordinated Voltage Regulation Method for Distribution System with Multiple Synchronous Generators,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

The continued interest in the distributed generation (DG) sources in recent years is leading to the growth of a number of generators connected to distribution networks. The steady-state voltage rise resulting from the connection of these generators can be a major obstacle at the lower voltage levels. Present network design practice is to limit the generator capacity to a level at which the upper voltage limit is not exceeded. This reduces the efficiency of DG system. This paper proposes a coordinated voltage control scheme using fuzzy logic based power factor controller, for distribution network with multiple Distributed generation systems. In the proposed scheme individual generators participate in voltage regulation of the distribution system, based on their participation factor determined using sensitivity analysis. The simulation results presented in the paper show the effectiveness of the method.

B-5. Jauch, E. T.: *Implementing "SMART GRID" Integrated Distribution Volt/var/kW Management,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

The optimum application of SMART GRID (SG) distribution system data will revolutionize the application and effectiveness of integrated distribution volt/var/kw management (IVVM). These SG enhancements will allow IVVM functions to expand into power quality issues of mitigation for sags, swells and harmonics, adherence to CBEMA voltage waveform criteria, as well as protection of the interties with dispersed, alternative, or green energy sources. Coordinated with the conservation efforts of power consumers, the benefits of an SG Conservation Voltage Control (CVC) program can be unprecedented.

These enhancements will allow more efficient and reliable distribution system configurations to be implemented. With rapid operating changes between configurations, control strategies must be highly adaptable and "SMART."

This paper discusses historic IVVM features and advanced features that will be required for full realization of SG benefits and timely implementation. The capabilities and placement of the SG IVVM equipment controls will determine the final results.

B-6. Krok, M. J.; Genc, S.: *A Coordinated Optimization Approach to Volt/VAr Control for Large Power Distribution Networks,* 2011 American Control Conference (ACC), July 2011.

Electric distribution networks are operated under a number of constraints in order to deliver power at a certain quality and reliability level. A distributed management system (DMS) is a supervisory control layer in the distribution system used by the utilities for managing distribution assets in a coordinated fashion. For large distribution systems (those consisting of thousands of nodes and multiple tens of capacitor banks and voltage regulators), an integrated Volt/VAr Control (IVVC), which maximizes asset lifetime, is non-trivial due to the size of the search space for determining the optimal settings of these devices. This paper presents coordinated optimization approach to IVVC for large power distribution networks that will enable a more optimal operation of the distribution network while maximizing distribution control asset lifetime through the minimization of unnecessary device switching.

B-7. Liang, R.; Chen, Y.; Chen, Y.: *Volt/Var Control in a Distribution System by a Fuzzy Optimization Approach,* International Journal of Electrical Power & Energy Systems, February 2011.

This paper presents a fuzzy optimization approach for solving the Volt/Var control problem in a distribution system with uncertainties. Wind turbines are being considered in the study distribution system. The main purpose is to find an optimum combination of tap position for the main transformer under load tap changer (ULTC) and on/off status for switched capacitors in a day to minimize the voltage deviation on the secondary bus of the main transformer, reactive power flow through the main transformer and real power loss on feeders. When performing the Volt/Var control problem in conventional methods, the hourly load and wind speed must be forecasted to prevent errors. However, actually there are always errors in these forecasted values. A characteristic feature of the proposed fuzzy optimization approach is that the forecast hourly load and wind speed errors can be taken into account using fuzzy sets. Fuzzy set notations in the load demand, wind speed, voltage deviation on the secondary bus, reactive power flow through the main transformer and total real power loss on feeders are developed to obtain the optimal dispatching schedule under an uncertain environment. To demonstrate the effectiveness of the proposed method, the Volt/Var control problem is performed in a distribution system within the service area of Yunlin District Office of Taiwan Power Company (TPC). The results show that a proper dispatching schedule for ULTC position and capacitor switching operation can be reached using the proposed method.

B-8. Malekpour, A.; Niknam, T.: *A Probabilistic Multi-objective Daily Volt/VAR Control at Distribution Networks Including Renewable Energy Sources,* Energy, May 2011.

At the moment, due to technology improvements and governmental incentives for the use of green energies, Renewable Energy Sources (RESs) appears to be a promising approach for electricity generation. This motivates the implementation of Wind Farms (WFs) and Fuel Cell Power Plants (FCPPs) over a mass scale by Distribution Companies (DisCos). As RESs become a larger and larger portion of the generation mix, many aspects of the distribution systems operation and planning has changed. In the context of Volt/Var control problem, proliferation of RESs becomes a challenging issue for DisCos. Since wind power acts as a variable energy source, probabilistic load flow techniques are going to be necessary to analyze the utility system. This paper presents a multi-objective probabilistic method to solve the Volt/Var control problem in distribution system with high wind power penetration. A probabilistic load flow approach using Point Estimate Method (PEM) is employed to model the uncertainty in load demands and electrical power generation of WFs. To regard the operational and economic assessment of system containing WFs and FCPPs, different objective functions have been taken into account. Cost of electrical power generated by WFs, FCPPs, and DisCos, electrical energy losses, emissions produced by WFs, FCPPs and DisCos for the next day are selected as objective functions. A new powerful optimization technique based on a Modified shuffled Frog Leaping Algorithm (MSFLA) is proposed to achieve the optimal values for active and reactive power of WFs and FCPPs, reactive power of capacitors and transformers tap positions for the next day ahead. In order to tackle the optimization problem with non-commensurable objectives, the objectives are fuzzified and max–min operator is employed. The results are compared with other evolutionary methods on a 69-bus distribution feeder in terms of efficiency and accuracy.

B-9. Malekpour, A.; Tabatabaei S.; Niknam, T.: *Probabilistic Approach to Multi-objective Volt/Var Control of Distribution System Considering Hybrid Fuel Cell and Wind Energy Sources Using Improved Shuffled Frog Leaping Algorithm,* Renewable Energy, March 2012.

Deregulation and restructuring in power systems, the ever-increasing demand for electricity, and concerns about the environment are the major driving forces for using Renewable Energy Sources (RES). Recently, Wind Farms (WFs) and Fuel Cell Power Plants (FCPPs) have gained great interest by Distribution Companies (DisCos) as the

most common RES. In fact, the connection of enormous RES to existing distribution networks has changed the operation of distribution systems. It also affects the Volt/Var control problem, which is one of the most important schemes in distribution networks. Due to the intermittent characteristics of WFs, distribution systems should be analyzed using probabilistic approaches rather than deterministic ones. Therefore, this paper presents a new algorithm for the multi-objective probabilistic Volt/Var control problem in distribution systems including RES. In this regard, a probabilistic load flow based on Point Estimate Method (PEM) is used to consider the effect of uncertainty in electrical power production of WFs as well as load demands. The objective functions, which are investigated here, are the total cost of power generated by WFs, FCPPs and the grid; the total electrical energy losses and the total emission produced by WFs, FCPPs and DisCos. Moreover, a new optimization algorithm based on Improved Shuffled Frog Leaping Algorithm (ISFLA) is proposed to determine the best operating point for the active and reactive power generated by WFs and FCPPs, reactive power values of capacitors, and transformers' tap positions for the next day. Using the fuzzy optimization method and max-min operator, DisCos can find solutions for different objective functions, which are optimal from economical, operational and environmental perspectives. Finally, a practical 85-bus distribution test system is used to investigate the feasibility and effectiveness of the proposed method.

B-10. Neal, R.: *The Use of AMI Meters and Solar PV Inverters in an Advanced Volt/VAr Control System on a Distribution Circuit,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

Advanced systems for the control of voltage and reactive power flow on distribution circuits offer benefits including energy savings and improved voltage regulation. Such systems require voltage sensing and control elements at numerous locations along the circuit. Advanced Metering Infrastructure (AMI) communicating meters and Smart Inverters associated with photovoltaic systems are being deployed in large numbers. Along with their other benefits, these meters and inverters can serve as the distributed voltage sensors and control elements for an Advanced Volt/VAr Control (AVVC) system. This paper describes the preliminary design of one such system.

B-11. Niknam, T.: *A New HBMO Algorithm for Multiobjective Daily Volt/Var Control in Distribution Systems Considering Distributed Generators,* Applied Energy, March 2011.

In recent years, Distributed Generators (DGs) connected to the distribution network have received increasing attention. The connection of enormous DGs into existing distribution network changes the operation of distribution systems. Because of the small X/R ratio and radial structure of distribution systems, DGs affect the daily Volt/Var control. This paper presents a new algorithm for multiobjective daily Volt/Var control in distribution systems including Distributed Generators (DGs). The objectives are costs of energy generation by DGs and distribution companies, electrical energy losses and the voltage deviations for the next day. A new optimization algorithm based on a Chaotic Improved Honey Bee Mating Optimization (CIHBMO) is proposed to determine the active power values of DGs, reactive power values of capacitors and tap positions of transformers for the next day. Since objectives are not the same, a fuzzy system is used to calculate the best solution. The plausibility of the proposed algorithm is demonstrated and its performance is compared with other methods on a 69-bus distribution feeder. Simulation results illustrate that the proposed algorithm has better outperforms the other algorithms.

B-12. Oshiro, M.; Tanaka, K.; Senjyu, T.; Toma, S.; Yona, A.; Saber, A. Y.; Funabashi, T.; Kim, C.-H.: *Optimal Voltage Control in Distribution Systems Using PV Generators,* Electrical Power and Energy Systems, Vol. 33, Issue 3, March 2011.

Recently, renewable energy technologies such as wind turbine generators and photovoltaic systems have been introduced as distributed generation. The connection of large number of distributed generators causes voltage deviation beyond the statutory range in a distribution system. In this paper, a methodology for voltage control in proposed by using the tap changing transformers and the inverters interfaced with the distributed generators. In the proposed method, information of the voltage and power is collected via a communication network. Based on these information, the optimal reference values are calculated at the control center, and sent to the transformers and the inverters. The proposed method accomplishes a coordinated operation among the control equipments and reduces the voltage deviation. Effectiveness of the proposed method is verified by the numerical simulation results.

B-13. Pappala, V. M.; Nakawiro, W.; Erlich, I.: *Predictive Optimal Control of Wind Farm Reactive Sources,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

This paper presents two different optimization models for predictive optimal control of wind farm reactive sources. The models are formulated as a reactive power dispatch problem. The objective of this optimization task is to reduce the operation cost of the on load tap changing transformers by reducing the short term tap changes using a predictive optimal control. Wind generation is predicted by neural network. The stochastic nature of the wind generation is modeled as a binary tree for the stochastic tree method. The proposed methods are tested on an offshore wind farm and solved using particle swarm optimization algorithm.

B-14. Ranamuka, D.; Agalgaonkar, A. P.; Muttaqi, K. M.: *Investigating the Operation of Multiple Voltage Regulators and DG in a Distribution Feeder,* 2011 2nd International Conference on Advances in Energy Engineering (ICAEE 2011); Energy Procedia, Vol. 14, 2012.

Integration of distributed generation (DG) in a distribution network may introduce adverse effects including control interaction, oscillatory transients and operational conflicts. This paper investigates the operation of multiple voltage regulators such as on-load tap changer (OLTC) and step voltage regulator (SVR), and DG in a medium voltage distribution feeder. Investigations have been carried out using time domain simulation studies conducted using MATLAB-SimPowerSystems. The results are reported for a case study involving radial distribution feeder, derived from New South Wales (NSW) electricity distribution network in Australia.

B-15. Švenda, G.; Simendic, Z.; Strezoski, V.: *Advanced Voltage Control Integrated in DMS,* International Journal of Electrical Power & Energy Systems, Vol. 43, Issue 1, December 2012.

The paper deals with distribution network (DN) voltage control from the network operation point of view. The basic voltage control devices, under load and no load tap-changing transformers, are specially stressed. Distributed generators (DGs) and capacitor banks are also discussed. The classical principle of single line voltage drop compensation (LDC) is treated as the base voltage control. The optimal voltage control (OVC), which appeared 15 years ago, was developed to overcome some of LDC shortcomings. After the appearance of OVC, distribution management systems (DMSs) developed intensively and were applied immensely in distribution practice. This opportunity has been taken to integrate the distribution voltage control into DMS. The integration of the voltage control with Power flow, State estimation, Medium- and Short-term load forecast is of special interest for the paper. The high quality integration is provided by application of the same DN Data base and Mathematical model. In this way, the advanced voltage control has been developed. It ultimately overcomes all shortcomings of OVC (and LDC as well).

This control is the subject of the paper and its properties are compared with LDC and OVC.

B-16. Takayama, S.; Katsuno, T.; Fukuyama, Y.: *Optimal Setting of Voltage Control Equipment and Analytical Tools Considering Interconnection of Distributed Generators,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

This paper presents two optimal setting methods for transformers with line drop compensator and step voltage regulator, and analytical tools considering interconnection of distributed generators. The optimal setting problem can be formulated as a large combinatorial optimization problem, in which the setting values of voltage control equipment is utilized as state variables. The first and original method can generate optimal setting values of voltage control equipment in distribution systems. The second and improved method can generate optimal setting values in a few minutes even when several voltage control equipment should be considered. The feasibility of the proposed methods is demonstrated on practical distribution system models with promising results. Moreover, analytical tools considering interconnection of distributed generators have been developed. The functions of the tools include fast distribution power flow calculation and the optimal setting method presented in this paper.

B-17. Zavoda, F.; Perreault, C.: *The Impact of a Volt & Var Control System (VVC) on PQ and Customer's Equipment,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

Hydro-Quebec aims saving energy by controlling the voltage level and by managing the reactive power (vars) in the distribution network. For this, it will use a VVC system, which requires a permanent surveillance of the voltage level at the end of the distribution feeder and the installation of switching shunt capacitor banks.

C. Standards

C-1. California Public Utilities Commission: *Electric Rule 21.* Available at: http://www.cpuc.ca.gov/PUC/energy/Procurement/LTPP/rule21.htm.

Electric Rule 21 is a tariff that describes the interconnection, operating and metering requirements for generation facilities to be connected to a utility's distribution system, over which the California Public Utilities Commission (CPUC) has jurisdiction. The Rule 21 tariff for each of California's large investor owned utilities (IOUs) is available on each IOU's website.

C-2. Darie, S.: *Guidelines for Large Photovoltaic System Integration,* 2012 IEEE Transmission and Distribution Conference and Exposition, May 2012.

The paper summarizes the result of a research project funded by the Department of Energy (DOE) in collaboration with the University of California at San Diego (UCSD). One presents a planning guideline and establishes interconnection criteria for integrating Photo Voltaic Generation (PVG) into the power systems (transmission and distribution). Some of the experiences/guidelines in the field of wind farm integration are used here since wind generation and PVG generation share many common power electronics devices used in their control schemes and both generation types are intermittent resources with similar degree of predictability and forecast methodology. Recommendations are given on the best practice promising standards for interconnecting large PV generation to power system.

C-3.   Hemdan, N.; Kurrat, M.: *Interconnection of Decentralized Renewable Resources into Distribution Grids: Implications and Planning Aspects*, Electric Power Systems Research, August 2012.

This work discusses the implications of interconnection of decentralized wind power generation on a real-life medium voltage distribution grid. Using measured wind generation data and simulated load profiles of the households, which are connected to the LV side at each MV substation, the impacts on voltage ranges, voltage profiles, line loading, and energy losses are analyzed. The availability to integrate a new wind mill into the grid which already contains three wind mills is examined with respect to the technical conditions for generation connection to the MV grids introduced by German Association of the Energy and Water Industries.

C-4.   Institute of Electrical and Electronics Engineers: *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems (IEEE Std 519-1992)*, April 1993.

This guide applies to all types of static power converters used in industrial and commercial power systems. The problems involved in the harmonic control and reactive power compensation of such converters are addressed, and an application guide is provided. Limits of disturbances to the AC power distribution system that affect other equipment and communications are recommended.

C-5.   Institute of Electrical and Electronics Engineers: *IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems (IEEE Std 929-2000)*, January 2003.

This recommended practice contains guidance regarding equipment and functions necessary to ensure compatible operation of photovoltaic (PV) systems that are connected in parallel with the electric utility. This includes factors relating to personnel safety, equipment protection, power quality, and utility system operation. This recommended practice also contains information regarding islanding of PV systems when the utility is not connected to control voltage and frequency, as well as techniques to avoid islanding of distributed resources.

C-6.   Institute of Electrical and Electronics Engineers: *IEEE Recommended Practice for Monitoring Electric Power Quality (IEEE Std 1159-2009)*, June 2009.

This recommended practice encompasses the monitoring of electrical characteristics of single-phase and polyphase AC power systems. It includes consistent descriptions of conducted electromagnetic phenomena occurring on power systems. This recommended practice describes nominal conditions and deviations from these nominal conditions that may originate within the source of supply or load equipment or may originate from interactions between the source and the load. Also, this recommended practice discusses power quality monitoring devices, application techniques, and the interpretation of monitoring results.

C-7.   Institute of Electrical and Electronics Engineers: *IEEE Standard for Interconnecting Distributed Resources With Electric Power Systems (IEEE Std 1547-2003)*, July 2003.

This standard is the first in the 1547 series of interconnection standards and is a benchmark milestone demonstrating the open consensus process for standards development. Traditionally, utility electric power systems (EPS--grid or utility grid) were not designed to accommodate active generation and storage at the distribution level. As a result, there are major issues and obstacles to an orderly transition to using and integrating distributed power resources with the grid. The lack of uniform national interconnection standards and tests for interconnection operation and certification, as

well as the lack of uniform national building, electrical, and safety codes, are understood. IEEE Std 1547 and its development demonstrate a model for ongoing success in establishing additional interconnection agreements, rules, and standards, on a national, regional, and state level. IEEE Std 1547 has the potential to be used in federal legislation and rule making and state public utilities commission (PUC) deliberations, and by over 3000 utilities in formulating technical requirements for interconnection agreements for distributed generators powering the electric grid. This standard focuses on the technical specifications for, and testing of, the interconnection itself. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It includes general requirements, response to abnormal conditions, power quality, islanding, and test specifications and requirements for design, production, installation evaluation, commissioning, and periodic tests. The stated requirements are universally needed for interconnection of distributed resources (DR), including synchronous machines, induction machines, or power inverters/converters and will be sufficient for most installations. The criteria and requirements are applicable to all DR technologies, with aggregate capacity of 10 MVA or less at the point of common coupling, interconnected to electric power systems at typical primary and/or secondary distribution voltages. Installation of DR on radial primary and secondary distribution systems is the main emphasis of this document, although installation of DR on primary and secondary network distribution systems is considered. This standard is written considering that the DR is a 60 Hz source. The IEEE 1547 series of standards is cited in the Federal Energy Policy Act of 2005.

C-8.   Institute of Electrical and Electronics Engineers: *IEEE Application Guide for IEEE Std 1547, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (IEEE Std 1547.2-2008)*, April 2009.

In this paper, technical background and application details to support understanding of IEEE Std 1547-2003 are provided. The guide facilitates the use of IEEE Std 1547-2003 by characterizing various forms of distributed resource (DR) technologies and their associated interconnection issues. It provides background and rationale of the technical requirements of IEEE Std 1547-2003. It also provides tips, techniques, and rules of thumb, and it addresses topics related to DR project implementation to enhance the user's understanding of how IEEE Std 1547-2003 may relate to those topics. This guide is intended for use by engineers, engineering consultants, and knowledgeable individuals in the field of DR.

C-9.   Institute of Electrical and Electronics Engineers: *IEEE Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected With Electric Power Systems (IEEE Std 1547.3-2007)*, November 2007.

This guide is intended to facilitate the interoperability of distributed resources (DR) and help DR project stakeholders implement monitoring, information exchange, and control (MIC) to support the technical and business operations of DR and transactions among the stakeholders. The focus is on MIC between DR controllers and stakeholder entities with direct communication interactions. This guide incorporates information modeling, use case approaches, and a pro forma information exchange template and introduces the concept of an information exchange interface. The concepts and approaches are compatible with historical approaches to establishing and satisfying MIC needs. This guide is primarily concerned with MIC between the DR unit controller and the outside world. However, the concepts and methods should also prove helpful to manufacturers and implementers of communications systems for loads, energy management systems, SCADA, electric power system and equipment protection, and revenue metering. The guide does not address the economic or technical viability of specific types of DR. It

provides use case methodology and examples (e.g.; examples of DR unit dispatch, scheduling, maintenance, ancillary services, and reactive supply). Market drivers will determine which DR applications become viable. This document provides guidelines rather than mandatory requirements or prioritized preferences.

C-10. Institute of Electrical and Electronics Engineers: *IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems (IEEE Std 1547.4-2011)*, July 2011.

Alternative approaches and good practices for the design, operation, and integration of distributed resource (DR) island systems with electric power systems (EPS) are provided. This includes the ability to separate from and reconnect to part of the area EPS while providing power to the islanded EPSs. This guide includes the DRs, interconnection systems, and participating EPSs.

C-11. Institute of Electrical and Electronics Engineers: *IEEE Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks (IEEE Std 1547.6-2011)*, September 2011.

Recommendations and guidance for distributed resources (DR) interconnected on the distribution secondary networks, including both spot networks and grid networks, are provided. This document gives an overview of distribution secondary network systems design, components, and operation; describes considerations for interconnecting DR with networks; and provides potential solutions for the interconnection of DR on network distribution systems. IEEE Std 1547-2003 provides mandatory requirements for the interconnection of DR with EPSs and focuses primarily on radial distribution circuit interconnections. For DR interconnected on networks, all of IEEE Std 1547-2003 needs to be satisfied. IEEE Std 1547.6-2011 was specifically developed to provide additional information in regard to interconnecting DR with distribution secondary networks.

C-12. Institute of Electrical and Electronics Engineers: *IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems (IEEE Std 1588; IEC Intl Std 61588)*, 2009.

A protocol is provided in this standard that enables precise synchronization of clocks in measurement and control systems implemented with technologies such as network communication, local computing, and distributed objects. The protocol is applicable to systems communicating via packet networks. Heterogeneous systems are enabled that include clocks of various inherent precision, resolution, and stability to synchronize. System-wide synchronization accuracy and precision in the sub-microsecond range are supported with minimal network and local clock computing resources. Simple systems are installed and operated without requiring the management attention of users because the default behavior of the protocol allows for it.

C-13. Mueller, D.; Camm, E. H.: *Power Quality Standards for Utility Wind and Solar Power Plants*, 2012 IEEE Transmission and Distribution Conference and Exposition, May 2012.

Power quality standards exist to guide the interconnection requirements of large wind and solar plants. IEEE guidelines exist for flicker and harmonics, while IEC guidelines exist for the measurement criteria of power quality phenomena and the characterization of wind turbine equipment. There are also some uniform guidelines for low voltage ride through (LVRT) of large plants. The presentation gives an overview of these standard and requirements, and also suggests some application guidelines not covered in the standards themselves.

C-14. Podmore, R.; Robinson, M. R.: *CIM Graphic Exchange Standard for Smart Grid Applications,* 2011 IEEE Power and Energy Society General Meeting, July 2011.

This paper reviews the practices that are currently used for development, maintenance and exchange of power system operating models including the data sets and display sets. The paper then describes how the various Smart Grid functions will impact how the generation, transmission and distribution systems will need to be modeled in the future. A primary conclusion is that complete synchronous interconnections will need to be modeled down to the feeder breaker level in order to accommodate the dynamic and variable response of plug-in hybrid electric vehicles, distributed generation, distributed storage, direct appliance control and real-time pricing for customers. The paper recommends that the CIM Graphic Exchange Standard (GES) be rapidly and widely adopted and implemented as critical enabler in the development, maintenance and exchange of future Smart Grid models.

C-15. Schauder, C.: *Impact of FERC 661-A and IEEE 1547 on Photovoltaic Inverter Design,* 2012 IEEE Transmission and Distribution Conference and Exposition, May 2012.

Photovoltaic (PV) inverters may be subject to different standards and interconnection requirements, depending on their size and interconnection point. PV plants connected at transmission voltage levels may be expected to ride through faults and other disturbances, as expressed in FERC Order 661-A for wind power plants. Islanding detection is not necessary, because customers are not directly served from these plants. On the other hand, PV units connected to distribution feeders are expected to trip automatically during voltage and frequency excursions, as expressed in IEEE Std. 1547. Distribution-connected PV inverters have islanding detection that is designed to meet UL 1741. These conflicting requirements may appear as "wind vs. solar" or "transmission vs. distribution" viewpoints. The impacts on utility-scale PV inverter design and specification are discussed.

C-16. Underwriters Laboratories: *UL 1741 Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources,* 2005.

These requirements cover inverters, converters, charge controllers, and interconnection system equipment (ISE) intended for use in stand-alone (not grid-connected) or utility-interactive (grid-connected) power systems. Utility-interactive inverters, converters, and ISE are intended to be operated in parallel with an electric power system (EPS) to supply power to common loads. For utility-interactive equipment, these requirements are intended to supplement and be used in conjunction with IEEE Std 1547, and the Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems, IEEE Std 1547.1. These requirements cover AC modules that combine flat-plate photovoltaic modules and inverters to provide AC output power for stand-alone use or utility-interaction, and power systems that combine other alternative energy sources with inverters, converters, charge controllers, and interconnection system equipment (ISE), in system-specific combinations. These requirements also cover power systems that combine independent power sources with inverters, converters, charge controllers, and interconnection system equipment (ISE) in system-specific combinations. The products covered by these requirements are intended to be installed in accordance with the National Electrical Code, NFPA 70.

D. Microgrids

D-1. Basu, A.; Chowdhury, S. P.; Chowdhury, S.; Paul, S.: *Microgrids: Energy Management by Strategic Deployment of DERs—A Comprehensive Survey*, Renewable and Sustainable Energy Reviews, December 2011.

Present paper reports the survey on existing research literatures in connection with various energy management issues/benefits of a microgrid arising due to strategic deployment of its DERs. Survey on regulatory issues includes various barriers, incentives, standards (IEEE 1547, UL-1741, etc.), environmental issues, ancillary services and metering. Economic benefits, like improvement of bus voltages, line loss reduction, deferral of upgrade, waste heat utilization, reduction of customer interruption cost (CIC), ancillary services, emission reduction, fuel cost minimization, etc. have been surveyed from many researchers' literatures in relation to methods of analyses, algorithms used and their quantification. A brief survey of researchers' opinion on DER technologies in their respective economic analysis has also been included. This paper also reviews the researches and studies on tariff structure, market strategy of microgrid energy (both electric and thermal).

D-2. Dimeas, A. L.; and Hatziargyriou, N. D.: *Agent Based Control for Microgrids,* 2007 IEEE Power and Energy Society General Meeting, July 2007.

This paper presents a general framework for the control of distributed energy resources organized in microgrids. The proposed architecture is based on the agent technology and aims to integrate several functionalities, as well to be adaptable to the complexity and the size of the microgrid. To achieve this, the idea of layered learning is used, where the various controls and actions of the agents are grouped depending on their effect on the environment. A novel approach called multiagent reinforcement learning is introduced in order to increase the intelligence and the efficiency of the microgrid.

D-3. Gabbar, H.; Islam, R.; Isham, M.; Trivedi, V.: *Risk-based Performance Analysis of Microgrid Topology with Distributed Energy Generation,* International Journal of Electrical Power & Energy Systems, December 2012.

World is moving towards smart grid infrastructures to increase the efficiency of power supply and use while optimizing associated costs and risks with increased profitability to all related parties. In order to support the shift from current grid to target smart grid, it is important to provide design support systems to ensure multi-objective optimization for life cycle activities for the design and operation of smart grid. This paper presents multidimensional modeling approach to evaluate the risk based performance of smart grid infrastructures and to support the design and operational engineering activities, which includes risks and cost analysis. The model integration of distributed renewable energy and storage technologies across the superstructure of smart grid will support power performance optimization in terms of load and demand management in microgrid level as well as globally in specified region. The proposed knowledge structure will support modeling and simulation activities for different design and operational tasks of smart grid and the integrated grid applications.

D-4. Hafez O.; Bhattacharya, K.: *Optimal Planning and Design of a Renewable Energy Based Supply System for Microgrids*, Renewable Energy, Vol. 45, September 2012.

Renewable energy sources are gradually being recognized as important options in supply side planning for microgrids. This paper focuses on the optimal design, planning, sizing and operation of a hybrid, renewable energy based microgrid with the goal of minimizing the lifecycle cost, while taking into account environmental emissions. Four

different cases including a diesel-only, a fully renewable-based, a diesel-renewable mixed, and an external grid-connected microgrid configurations are designed, to compare and evaluate their economics, operational performance and environmental emissions. Analysis is also carried out to determine the break-even economics for a grid-connected microgrid. The well-known energy modeling software for hybrid renewable energy systems, HOMER is used in the studies reported in this paper, a power network in which fossil-fueled microgrids and a price on CO_2 emissions are included has the highest composite sustainability index.

D-5. Lasseter, R. H.; Piagi, P.: *Extended Microgrid Using (DER) Distributed Energy Resources*, 2007 IEEE Power and Energy Society General Meeting, July 2007.

The electric power industry is in the midst of a critical period in its evolution. The re-regulation of the industry has resulted in the creation of self-locating merchant generation and wholesale electric power markets that are using the transmission system in ways for which it was not designed. This had resulted in a system operation closer to its edge. The retail customers have increasingly sophisticated energy service requirements that require much higher power quality than in the past. One way to approach these issues is to focus on robustness at the networked transmission and generation system while providing reliability locally. The distribution system should focus on providing the customer with the required level of power quality. Distributed energy resource (DER) is a way to enhance the distribution system's level of power quality.

D-6. Lo Prete, C.; Hobbs, B.; Norman, C.; Cano-Andrade, S.; Fuentes, A.; von Spakovsky, M.; Mili, L.: *Sustainability and Reliability Assessment of Microgrids in a Regional Electricity Market,* Energy, Vol. 41, Issue 1, May 2012.

We develop a framework to assess and quantify the sustainability and reliability of different power production scenarios in a regional system, focusing on the interaction of microgrids with the existing transmission/distribution grid. The Northwestern European electricity market (Belgium, France, Germany and the Netherlands) provides a case study for our purposes. We present simulations of power market outcomes under various policies and levels of microgrid penetration, and evaluate them using a diverse set of metrics. This analysis is the first attempt to include exergy-based and reliability indices when evaluating the role of microgrids in regional power systems. The results suggest that a power network in which fossil-fueled microgrids and a price on CO_2 emissions are included has the highest composite sustainability index.

D-7. Sanseverino, E.; Di Silvestre, M.; Ippolito, M.; De Paola, A.; Lo Re, G.: *An Execution, Monitoring and Replanning Approach for Optimal Energy Management in Microgrids*, Energy, Vol. 36, Issue 5, May 2011.

This work develops a new approach for optimal energy management of electrical distribution 'smart-grids.' Optimality aims at improving sustainability through the minimization of carbon emissions and at reducing production costs and maximizing quality. Input data are the forecasted loads and productions from renewable generation units, output data are a set of control actions for the actuators. The considered electrical distribution system includes storage units that must be considered over a 24 h time interval, to consider an entire charge and discharge cycle. The objectives for the optimal management of distributed (renewables and not) generation are technical, economical and environmental. It is thus required to solve a multi-objective optimization problem over a 24 h time interval considering the uncertainty associated to weather conditions and loads profiles. The novelty of the proposed approach resides in considering the optimal scheduling of generation units an automatic planning process in a dynamic, non-

deterministic and not fully observable environment, as it is, getting closer to actual conditions. The system proposed here is a planning and execution scheduler which allows the central controller to monitor the execution of a scheduling plan, interrupt the monitoring to input new information and repair the plan under execution every time interval.

D-8.	Ustun, T.; Ozansoy, C.; Zayegh, A.: *Recent Developments in Microgrids and Example Cases Around the World—A Review,* Renewable and Sustainable Energy Reviews, Vol. 15, Issue 8, October 2011.

Climate change concerns due to the rising amounts of the carbon gas in the atmosphere have in the last decade or so initiated a fast pace of technological advances in the renewable energy industry. Such developments in technology and the move towards cleaner sources of energy have made distributed generation (DG) from renewable resources more desirable. However, it is a known fact that rising penetrations of DG can have adverse impacts on the grid structure and its operation. The microgrid concept is a solution proposed to control the impact of DG and make conventional grids more suitable for large scale deployments of DG. Covering many aspects of the power systems and power electronics fields, microgrids have become a very popular research field. This paper reviews the background and the concept of a microgrid, the current status of the literature, on-going research projects, and the relevant standards. It also presents a review of the microgrid pilot projects around the world in further detail and discusses the potential avenues for further research.

E. Ancillary Services

E-1.	Alatrash, H.; Amarin, R. A.; Lam, C.: *Enabling Large-Scale PV Integration into the Grid,* 2012 IEEE Green Technologies Conference, April 2012.

The intermittent nature of photovoltaic (PV) systems poses stability challenges to the distribution grid. The integration of ancillary services into distributed generation (DG) inverters is an effective approach to mitigate challenges related to intermittency. Petra Solar's Generator Emulation Controls (GEC) technology equips DG inverters with voltage support through Volt/VAr droop, low-voltage ride-through (LVRT), and microgrid forming capabilities. This paper is focused on demonstrating the value of these features in stabilizing voltage and minimizing flicker due to PV intermittency and nuisance tripping using a laboratory-scale test-bed. A typical simplified 12kV/10MVA feeder was scaled down to its single-phase 120V/5kVA on a per-unit basis. The effectiveness of Volt/VAr support and LVRT is demonstrated by simulating cloud cover and a transient fault event. This is followed by a microgrid test where the circuit is shown to separate and continue operation as an intentional island when faced with a long-term disturbance on grid.

E-2.	Bracale, A.; Angelino, R.; Carpinelli, G.; Mangoni, M.; Proto, D.: *Dispersed Generation Units Providing System Ancillary Services in Distribution Networks by a Centralised Control,* IET Renewable Power Generation, Vol. 5, Issue 4, 2012.

This study considers a distribution system with a number of dispersed generation (DG) units interconnected to the AC grid through power electronic interfaces. Some selected DG units were able to provide energy service and system ancillary services (in particular, voltage regulation and partial compensation or elimination of some power quality disturbances, such as waveform distortions and voltage unbalances) through a proper centralised control system that provides the reference signals to the converters of the DG

units in real time. In addition, the problem of time delays owing to data acquisition and digital signal processing for reference signal calculations and the effects of these delays on compensation actions were studied. Several time-domain simulations of an actual distribution system are reported, taking into account different DG units and time-delay scenarios.

E-3.   Cagnano, A.; Torelli, F.; Alfonzetti, F.; De Tuglie, E.: *Can PV Plants Provide a Reactive Power Ancillary Service? A Treat Offered by an On-line Controller,* Renewable Energy, Vol. 36, Issue 3, March 2011.

This paper proposes an auto-adaptive controller that enables to suitably manage the reactive power supplied by the inverters of PV units wishing to provide the reactive power ancillary service on the base of standard needs or on a voluntary basis. The derived controller is based on an optimization procedure involving the sensitivity theory in conjunction with the Lyapunov function and provides control laws feeding the inverters of the PV units. The controller promptly minimizes system losses preserving the active power produced by the PV plants against the reactive one. In fact, when the PV modules do not get enough sunlight to generate active power, the proposed procedure forces the PV inverters to provide a reactive power equal to the rated power. On the contrary, in order to preserve the major economic benefits for the investor deriving from the produced active power during the sunlight hours, the method automatically reduces the injection of reactive power. The computer simulations, performed on a distribution system, demonstrate that the controller is capable to control the network in the real-time, mainly due to its ability to be auto-adaptive at any changes in the system operating conditions.

E-4.   Chen, Y.; Li, J.: *Comparison of Security Constrained Economic Dispatch Formulations to Incorporate Reliability Standards on Demand Response Resources into Midwest ISO Co-optimized Energy and Ancillary Service Market,* Electric Power Systems Research, Vol. 81, Issue 9, September 2011.

The purpose of this paper is to analyze three formulations developed to facilitate participation of demand response resource Type-1 in the Midwest ISO's co-optimized energy and ancillary service market. While these three formulations appear similar on the surface, careful analysis will show that they can have different impacts on clearing and pricing outcomes. Based on this analysis, the formulation that can maintain reserve product priority and reserve clearing price order is selected and implemented in the Midwest ISO Security Constrained Economic Dispatch (SCED) and Security Constrained Unit Commitment (SCUC) market clearing processes. A 5-bus system is used to illustrate the features of each approach. This paper focuses on SCED formulations. The impact from the discussed formulations on SCUC should be similar.

E-5.   Chuang, A. S.; Schwaegerl, C.: *Ancillary Services for Renewable Integration,* Integration of Wide-Scale Renewable Resources Into the Power Delivery System, 2009 CIGRE/IEEE PES Joint Symposium, July 2009.

Renewable portfolio targets have been established in many regions around the world. Regional targets such as 20% renewable energy by year 2020 and 30% by year 2030 are not uncommon. With increasing penetration and reliance on renewable resources have come heightened operational concerns over maintaining system balance. Ancillary services, such as operating reserves, imbalance energy, and frequency regulation, are necessary to support renewable energy integration, particularly the integration of intermittent resources. Without supporting ancillary services as identified in the paper, increased risk to system imbalance is introduced by the uncertainty of renewable generation availability, especially in systems with significant penetration of resources

powered by intermittent supply, such as wind and solar. Intermittent resources can suddenly cease supply to the grid with limited predictability, when the sun stops shining or wind suddenly stops blowing at point locations. Practical examples of such phenomena and their potential impact are identified. The described situation poses risk of disruption to grid-supplied electric service. The paper establishes procurement of ancillary services as a key component of renewable resource integration and a component of overall costs to deliver "green" power. Without ancillary services to support reliable delivery of electric service, end-use customers incur increased outage costs. Ancillary services are distinct components of electric service required to support the reliable delivery of electricity and operation of transmission systems. The paper summarizes regional definitions of ancillary services and identifies types of ancillary services competitively procured in electricity market environments. Regional estimates of ancillary service costs are researched and summarized to clarify cost adders associated with renewable integration beyond capital expansion cost. The cost adders comprise the reliability cost component of integra- ting renewable resources that are intermittent in nature. The paper provides data to establish that the costs for ancillary services are an important component of overall costs of renewable energy-supplied power. When such cost components are not explicitly recognized in overall electric service cost considerations, the full costs of integrating intermittent resources may likewise be under-recognized. The authors conclude by emphasizing the importance of accounting for reliability costs associated with renewable energy integration.

E-6.   Ge, J.; Luo, S.; Chen, C.: *Research on Ancillary Service Management Mechanism in the Smart Grid,* 2011 IEEE Power Engineering and Automation Conference (PEAM), September 2011.

Smart grid have flexible demand response patterns, adapt to multiple energy generation forms, diversify and decentralize energy supply, intellectualize energy storage ways and coordinate operation between transmission and distribution grids and micro-grid. This paper analyzes the effect of renewable energy generation, distributed generation and large scale demand response on ancillary service, and quantify reserve and peak shaving capacity when implementing Interruptible Load Management and Time-of-Use. The example results show the consumer side is equal to generation side. In the end, this article preliminarily suggests that developing smart grid should make full use of the existing resources, and firstly enhance power demand side management and improve the interaction between consumers and power grid to improve grid's ability of accommodating renewable energy and efficiency of using electrical power resources.

E-7.   Lamadrid, A. J.; Mount, T.: *Ancillary Services in Systems with High Penetrations of Renewable Energy Sources, the Case of Ramping,* Energy Economics, Vol. 34, Issue 6, November 2012.

Renewable Energy Sources (RES) are likely to continue the upward trend observed in the past decade. The change from dispatchable generation to an environment in which Independent System Operators (ISOs), Regional Transmission Operators (RTOs), Load Serving Entities (LSEs) and consumers dynamically respond to the conditions in the system and help to alleviate the uncertainty linked to RES requires appropriate tools to evaluate the social benefits and costs of different policies implemented. This paper presents a framework for evaluating the aforementioned effects using an engineering and economic optimization model. The proposed framework is applied to a stylized case study with operations on a test network that simulates a typical day. The objective of the case study is to compare the effects of (1) controllable demand, (2) on-site storage, and (3) upgrading transmission capacity. The different scenarios are evaluated in terms of (1) the percentage of potential wind generation spilled, (2) the total operating cost of production, and (3) the amount of installed capacity needed to maintain operating reliability. The

results show that controllable demand improves (reduces) all of the three criteria by alleviating congestion and mitigating wind variability. In contrast, the beneficial effects are smaller for RES's on-site storage, because it does not shift load to off-peak periods or reduce congestion, and for upgrading transmission, because it does not shift load to off-peak periods or mitigate wind variability.

E-8.   Madureir, A. G.; Peças Lopes, J. A.: *Ancillary Services Market Framework for Voltage Control in Distribution Networks with Microgrids,* Electric Power Systems Research, Vol. 86, May 2012.

In this paper, a proposal for an ancillary services (AS) market framework addressing voltage control in multi-microgrid systems is presented. This VAR market proposal for MV distribution systems can be adopted to involve Distributed Generation (DG) units and microgrids in AS provision. In the approach that was developed each player is given the opportunity to submit its bid to the VAR market and the market settlement is performed using an Optimal Power Flow (OPF) formulation in order to minimize the price of reactive power purchased by the Distribution System Operator (DSO). This market is based on VAR capacity use and runs daily after the scheduling of the generation units for a period of operation of one day.

E-9.   Pastromas, S. A.: *Grid Support by Wind Turbines and Future Trends,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

The European target of 2020 regarding the renewable energy plants including wind farms will lead to increase the contribution of wind farms to national grid systems. By this, wind farms are not considered as passive loads as were considered in the past, but as power plants which should have the same performance as conventional power plants. This means that wind turbines as components of a wind farm are requested to support the grid when the energy demand rises and during emergency situations. The latter is implemented by fault ride through capability of the wind turbines, improving grid stability. Furthermore, many national grid systems have either low infrastructure or developing new energy projects to accommodate the large penetration of wind farms. Due to this fact wind turbines should have several operation modes by controlling their active, reactive power production in some cases with quick response time. The use of power converters for the interconnection with the electrical network raises power quality issues of the power that is delivered to the grid. In summary, in this paper will be presented the way wind turbines can increase the grid stability and the power quality of national grid systems.

E-10. Rueda-Medina, A. C.; Padilha-Feltrin, A.: *Distributed Generators as Providers of Reactive Power Support—A Market Approach,* IEEE Transactions on Power Systems, Vol. 27, Issue 3, May 2012.

Traditionally, ancillary services are supplied by large conventional generators. However, with the huge penetration of distributed generators (DGs) as a result of the growing interest in satisfying energy requirements, and considering the benefits that they can bring along to the electrical system and to the environment, it appears reasonable to assume that ancillary services could also be provided by DGs in an economical and efficient way. In this paper, a settlement procedure for a reactive power market for DGs in distribution systems is proposed. Attention is directed to wind turbines connected to the network through synchronous generators with permanent magnets and doubly-fed induction generators. The generation uncertainty of this kind of DG is reduced by running a multi-objective optimization algorithm in multiple probabilistic scenarios through the Monte Carlo method and by representing the active power generated by the DGs through Markov models. The objectives to be minimized are the payments of the

distribution system operator to the DGs for reactive power, the curtailment of transactions committed in an active power market previously settled, the losses in the lines of the network, and a voltage profile index. The proposed methodology was tested using a modified IEEE 37-bus distribution test system.

E-11. Tsengenes, G.; Adamidis, G.: *A Multi-function Grid Connected PV System with Three Level NPC Inverter and Voltage Oriented Control,* Solar Energy, November 2011.

In this paper a grid connected photovoltaic (PV) system is presented. The grid integration of the PV system is carried out via a three phase three level neutral point clamped (NPC) inverter. To control the inverter a modified version of voltage oriented control (VOC) method and the space vector pulse width modulation (SVPWM) technique have been applied. With the proposed modification the PV system operates as a shunt active power filter (SAPF), a reactive power compensator, and a load's current balancer simultaneously. In this way the PV system operates more efficiently compared to the conventional PV systems and offers ancillary services to electric power system. The effectiveness of the proposed control scheme is established through simulation results with Matlab/Simulink in steady state and transient response of the electric power distribution system.

F. Sensors and Monitoring Systems

F-1. Berrutti, F.; Giusto, A.; Artenstein, M.: *Design of Power System Stabilizers in Variable Speed Wind Generators Using Remote Signals,* 2012 Sixth IEEE/PES Transmission and Distribution Latin America Conference and Exposition (T&D-LA), May 2012.

This work aims the description, modeling and simulation of the incorporation of a power system stabilizer (PSS) in variable speed wind turbines in order to dampen oscillation in power grids. The proposed PSS aims to alter the nature of the electric power injected by the wind farms to, in some sense, mimic the oscillatory behavior of synchronous generators and allows dampening these transient oscillations. The main advantage of this stabilizing action lies in the fact that the wind turbines, by decoupling the electrical frequency of the network respect its rotational speed by the inclusion of power electronic converters, allows the injection of oscillating power without risk of suffering stability issues. This allows to improve the oscillation damping between different synchronous generators. The proposed PSS has been analyzed in a grid of three areas: an area comprises the infinite bus; the second one a synchronous generator and the third one contains a synchronous generator and a wind farm. The PSS takes as reference the active power injected by the synchronous generator of the third area using synchrophasors. Finally, it is studied the performance of the PSS for a particular case of the Uruguayan power grid. In this scenario, the second area is composed by the hydro power plant Baygorria; the third area is comprised by the hydro power plant Terra and the wind farms Palmatir and Agua Leguas; finally, the first area is the rest of the power system.

F-2. De Almeida, M. C.; Costa, F. F.; Xavier-de-Souza, S.; Santana, F.: *Optimal Placement of Faulted Circuit Indicators in Power Distribution Systems,* Electric Power Systems Research, Vol. 81, Issue 2, February 2011.

Power distribution utilities often use impedance-based methods for locating faults along their feeders. For feeders with laterals, these techniques may identify different possible locations for the same fault. This leads to higher costs and longer restoration time. In order to improve impedance-based methods, faulted-circuit indicators (FCI) can be allocated along the feeder to reduce, or even eliminate, the uncertainty about the fault

location. This paper proposes a technique for optimally allocating a given number of FCIs along distribution feeders using the Chu–Beasley genetic algorithm to solve the optimization problem. The proposed objective functions measure the number of locations that are suspected to be the actual fault location or the distance among them. Additionally, it is possible to consider the presence of priority areas. We present results for the IEEE 34-bus system and for a 475-bus actual system. The results show the effectiveness of the proposed technique in improving impedance-based fault location methods.

F-3.   Mills-Price, M.; Scharf, M.; Hummel, S.; Ropp, M.; Joshi, D.; Zweigle, G.; Ravikumar, K. G.; Flerchinger, B.: *Solar Generation Control with Time-synchronized Phasors*, 2011 64th Annual Conference for Protective Relay Engineers, April 2011.

Solar-energy-based photovoltaic (PV) systems are a quickly growing source of distributed generation (DG) and connect to the power distribution system. PV-based DG poses challenges to grid reliability and power quality. One critical challenge is islanding control. Research is underway to devise best practice methods for anti-islanding for all power mismatch conditions. Synchrophasors provide an accurate means to detect islanding conditions by enabling precise, time-synchronized wide-area measurements. This paper presents an islanding detection system for PV-based DG. The system utilizes synchrophasor data collected from local and remote locations to detect the islanded condition. The paper shows how synchrophasors are used to control the DG during such conditions. It also discusses the power system modeling using a Real Time Digital Simulator (RTDS®) and closed-loop testing of the synchrophasor-based islanding detection system, which includes the PV-based inverter and the power distribution system. The effectiveness of the system was experimentally tested on a live power system.

F-4.   Ramesh, L.; Chakraborthy, N.; Chowdhury, S. P.; Chowdhury, S.: *Intelligent DE Algorithm for Measurement Location and PSO for Bus Voltage Estimation in Power Distribution System*, International Journal of Electrical Power & Energy Systems, Vol. 39, Issue 1, July 2012.

Accurate monitoring and estimating the state of the distribution system poses an immense challenge to power engineering researchers because of bidirectional distribution system. This paper is executed in two stage methodology. The initial stage is to identify the optimal location for the installation of monitoring instrument with minimal investment cost through DE and PSO. The second stage is to estimate the bus voltage magnitude where real time measurement is measured through identified meter location which is more essential for decision making in DSCADA. The hybrid Intelligent technique is applied to execute the above two algorithms. The algorithms are tested with IEEE and TNEB benchmark systems.

F-5.   Uslar, M.; Rohjans, S.; Specht, M.: *Technical Requirements for DER Integration Architectures*, Technoport RERC Research 2012; Energy Procedia, Vol. 20, July 2012.

Information and Communication technology (ICT) and the integration of Distributed Energy Resources (DER) are two of the most important parts of the future smart grid, so it is necessary to analyze their interaction. In that context, standardization plays a key role to cope with interoperability issues and to develop a sustainable solution. Internationally, the International Electrotechnical Commission (IEC) has created the IEC 61850 one of the most prominent standards identified by most roadmaps, e.g., CEN/CENELEC/ETSI, IEC, IEEE P2030 , The US National Institute of Standards and Technology (NIST) and Strong and Smart Grid China (SSGC). The overall focus of the standard family lies with substation automation and the corresponding communication. However, it has outgrown its original purpose with the part 7-420 dealing with and

focusing on the integration of DER into the power distribution grid. Since smart grids are highly complex systems consisting of various actors and components, the IEC 61850 has to be seen in context with other standards in the overall infrastructure.

F-6.   Wache, M.; Murray, D. C.: *Application of Synchrophasor Measurements for Distribution Networks,* 2011 IEEE Power and Energy Society General Meeting, July 2011.

Wide Area Monitoring with Synchrophasor Measurements has become of great interest in supervision of stability for transmission systems. With the acquisition of the phasor measurements using Phasor Measurement Units (PMU), a new quality of insight into the dynamic behavior of the electric power network has become possible. The value of this method is increasing because of more dynamic requirements for the system caused by renewable power infeed such as wind and solar and energy trade. The renewable power infeed goes to a quite high amount into the distribution networks so that at that level, also the dynamic processes are increasing. The distribution networks are taking over more tasks that have been reserved for transmission networks in the past, so the supervision is also important for the distribution level. This paper discusses applications for that. An example for the use of synchrophasors for energy accounting is given. Finally, the status of standardization is presented.

F-7.   Wang, D.; Wilson, D.; Venkata, S. S. (Mani); Jayantilal, A.: *Synchrophasor Applications for Distributed Energy Resource Connection and Efficient Grid Operation,* 2012 CIRED Workshop on Integration of Renewables into the Distribution Grid, 2012.

Phasor measurement units (PMUs) can produce synchronised measurements with high accuracy and granularity. Currently the technology is widely deployed on transmission systems for Wide Area Monitoring, but it has generally not been exploited at distribution level. This paper introduces some applications that utilise synchrophasor measurements to actively manage distribution networks and release more capacity for connecting distributed energy resources (DER). These applications are considered as part of future Distributed Energy Resources Management System, which offers a range of functions for improving the operation security and reliability of modern distribution networks with high DER penetration. The paper also outlines how each application can be used in a distributed control structure — an efficient control framework for managing smart grids.

F-8.   Woolley, N.; Avendaño-Mora, J.; Milanovic, J.: *Methodology for Robust Monitoring of Voltage Sags Based on Equipment Trip Probabilities,* Electric Power Systems Research, Vol. 90, September 2012.

This paper presents a new methodology for installing monitors into a distribution network to optimally and robustly monitor the voltage sag performance of the entire network. The developed methodology allows distribution network planners to specify budgetary requirements and future loading forecasts and output a robust set of monitoring locations for voltage sag performance monitoring. The research utilizes an artificial immune system optimization (AIS) algorithm to discover a range of near-optimal monitoring locations based on minimization of expected equipment trips at a bus. An estimate for the probable number of equipment trips is defined using a new probabilistic measure known as sag trip probability (STP). The optimized solutions are analyzed for robustness across a range of uncertain future network loading and topology scenarios. The results show the methodology applied to a 295 bus generic distribution network with uncertain load growth for the next 15 years.

F-9.   Yang, Y.; Xie, G.; Xu, X.; Jiang, Y.: *A Monitoring System Design in Transmission Lines based on Wireless Sensor Networks,* Energy Procedia, Vol. 12, 2012.

A smart grid application in monitoring the condition of transmission line with wireless sensor networks was described in this paper. ZigBee and GPRS (General Packet Radio Service) technology were adopted in this system to ensure normal transmission of signals, even in remote areas where there is no telecommunication service, and data could be transmitted over a long distance. In addition, the system provided warnings before the damage caused by meteorological disasters to ensure the line security.

F-10. Yun, S. Y.; Park, C.-H.; Song, I.-K.: *Development of Overload Evaluation System for Distribution Transformers Using Load Monitoring Data,* International Journal of Electrical Power & Energy Systems, Vol. 44, Issue 1, January 2013.

In this paper, we present an improved overload decision system for oil-immersed distribution transformers under 100 kVA using load monitoring data. Our study can be categorized into two parts: (a) improvement in the criteria for judging the overload conditions of distribution transformers and (b) development of an overload evaluation system using load monitoring data. In order to determine the overload criteria, overload experiments are performed on sample transformers; the results of these experiments are used to define the relationship between the transformer overload and the increase in the top-oil temperature. To verify the accuracy of the experimental results, field tests are performed using specially manufactured transformers, the loads and top-oil temperatures of which can be measured. For arriving at online overload decisions, we propose methods whereby the measured load curve can be converted into an overload characteristic curve and the overload time can be calculated for any load condition. The developed system is able to evaluate the overload for individual distribution transformers using load monitoring data.

G. Communication Systems

G-1. Pinomaa, A.; Ahola, J.; Kosonen, A.: *Power-line Communication-based Network Architecture for LVDC Distribution System,* 2011 IEEE International Symposium on Power Line Communications and Its Applications (ISPLC), April 2011.

In smart grids, a communication network with bidirectional data transmission between network components is required for functionalities, such as grid monitoring, control and protection. These functionalities set different requirements for communication. This paper focuses on the use of power-line communication (PLC) as a data transmission method for monitoring, control and protection functions in a proposed novel smart grid concept – low-voltage direct current (LVDC) distribution system. Hence, a PLC-based communication architecture for the LVDC system is proposed, its feasibility analyzed theoretically and verified by measurements. Channel capacity and practical data transmission tests are performed in a laboratory environment. Finally, the suitability of the proposed network architecture for the LVDC system and its compliance with the set requirements are analyzed.

G-2. Qianjun, Y.; Guichu, W.; Fenqun, Y.; Hongyan, X.: *Design and Applications of Intelligent Low Voltage Distribution System Based on ZigBee,* 2011 International Conference on Electronics, Communications and Control (ICECC), September 2011.

In this paper, the advantages of ZigBee wireless communication technology which application in low-voltage distribution system were introduced. The protocol framework and network architecture of ZigBee was analyzed. ZigBee, as a wireless technology low in cost, power, data rate, and complexity, is more suitable for low-voltage distribution system applications. In view of the characteristics of low-voltage distribution system, we

introduce ZigBee wireless communication technology into the low-voltage distribution system. Through a variety of electric power parameters of distribution system being acquisitioned, it can achieve real-time monitoring, remote control, fault alarm and so on. In addition, the composition, software design and applications of intelligent low-voltage distribution system were expounded.

G-3.	Rafiei, M.; Eftekhari, S. M.: *A Practical Smart Metering Using Combination of Power Line Communication (PLC) and WiFi Protocols,* 2012 Proceedings of 17th Conference on Electrical Power Distribution Networks (EPDC), May 2012.

Recently, smart metering has attracted much attention. Electricity distribution utilities are rapidly replacing traditional mechanical meters with so called smart meters. to provide a suitable smart metering system, variety of communication protocols have been proposed. Power-line communication (PLC) is a cost effective and secure communication protocol and does not require a separate communication line. In this paper a practical smart metering approach using combination of PLC and WiFi protocols is presented. The proposed approach can be used for both type of automatic meter reading (AMR) and advanced metering infrastructure (AMI).

G-4.	Sucic, S.; Dragicevic, T.; Capuder, T.; Delimar, M.: *Economic Dispatch of Virtual Power Plants in an Event-driven Service-oriented Framework Using Standards-based Communications,* Electric Power Systems Research, Vol. 81, Issue 12, December 2011.

The accelerated evolution of power systems and the associated new trends, such as Smart Grids, has stimulated the development of various approaches in handling the problems of increased electricity demands, power market (de)regulation and power systems reliability. One of the new key concepts is the virtual power plant (VPP), which represents a controllable portfolio of distributed energy resources (DERs). Such a portfolio can be operated in various modes, each with a set of unique control requirements.

An open framework providing robust solution for large scale DERs integration and control is one of the key issues in Smart Grid development. This paper proposes an approach for solving this problem by utilizing standards-based power system communications, application modeling based on event-driven information services and algorithms for optimized VPP control. The applicability of the proposed technical solution is demonstrated and analyzed via simulation of the developed economic dispatch algorithm.

G-5.	Uslar, M.; Rohjans, S.; Specht, M.: *Technical Requirements for DER Integration Architectures,* Technoport 2012 - Sharing Possibilities and 2nd Renewable Energy Research Conference (RERC2012), Energy Procedia, Vol. 20, 2012.

Information and Communication technology (ICT) and the integration of Distributed Energy Resources (DER) are two of the most important parts of the future smart grid, so it is necessary to analyze their interaction. In that context, standardization plays a key role to cope with interoperability issues and to develop a sustainable solution. Internationally, the International Electrotechnical Commission (IEC) has created the IEC 61850 one of the most prominent standards identified by most roadmaps, e.g.; CEN/CENELEC/ETSI, IEC, IEEE P2030 [1], The US National Institute of Standards and Technology (NIST) and Strong and Smart Grid China (SSGC). The overall focus of the standard family lies with substation automation and the corresponding communication. However, it has outgrown its original purpose with the part 7-420 dealing with and focusing on the integration of DER into the power distribution grid. Since smart grids are

highly complex systems consisting of various actors and components, the IEC 61850 has to be seen in context with other standards in the overall infrastructure.

G-6.   Vallejo, A.; Zaballos, A.; Selga, J. M.; Dalmau, J.: *Next-generation QoS Control Architectures for Distribution Smart Grid Communication Networks*, IEEE Communications Magazine, Vol. 50, Issue 5, May 2012.

This article presents a proposal for applying the ITU-T end-to-end QoS control architecture for next-generation networks to the distribution smart grid communication networks. We propose the use of a QoS broker device to enhance the QoS in the smart grid electrical distribution access domains by providing a centralization of QoS management. Our proposal takes decisions based on current network data traffic flows, existing QoS policies and customer service level agreements and facilitates interoperability with other technology domains in order to achieve seamless end-to-end QoS. The key feature of this end-to-end QoS control is the mapping of QoS parameters mainly between broadband power line and wireless technologies that principally serve the distribution smart grid, but it can be applied to other communication technologies as well.

H. System Control

H-1.   Brown, H.; Haughton, D. A.; Heydt, G. T.; Suryanarayanan, S.: *Some Elements of Design and Operation of a Smart Distribution System*, 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

This paper relates to several specific aspects of design and operation of a 'smart' power distribution system. The emphasis is on automation in design, reliability enhancement, operations, and reconfiguration after a disturbance. The use of network incidence or connectivity matrices is shown and examples indicate the potential operational capabilities of a 'smart distribution system'. An algorithm described as a sequential feeder approach is illustrated.

H-2.   Calderaro, V.; Galdi, V.; Piccolo, A.; Massa, G.: *Optimal Fuzzy Controller for Voltage Control in Distribution Systems*, 2011 11th International Conference on Intelligent Systems Design and Applications (ISDA), May 2011.

The increasing diffusion of distributed generation plants in recent years highlights problems concerning voltage regulation in medium voltage (MV) radial distribution networks. Among various possible control techniques able to regulate voltage profiles, intelligent systems based ones seems to be very promising. In particular, fuzzy control techniques are very interesting for a wide range of applicative fields like power distribution systems control, allowing regulation of voltage profiles handling uncertainty/vagueness and imprecise information. This paper presents a decentralized fuzzy based control technique finalized to realize a local regulation of voltage profiles at buses where wind power generators are connected, in order to avoid their disconnection. Validation of the proposed control system has been carried out by simulations conducted on a real MV Italian radial distribution system.

H-3.   Calderaro, V.; Conio, G.; Galdi, V.; Piccolo, A.: *Reactive Power Control for Improving Voltage Profiles: A Comparison Between Two Decentralized Approaches,* Electric Power Systems Research, Vol. 83, Issue 1, February 2012.

This paper is concerned with a local regulation of the voltage profiles at buses where wind power distributed generators are connected. In particular, the aim of the work is to

compare two voltage control methods: the first based on a sensitivity analysis and the second on the designing of a fuzzy control system. The two methods are tested by means of simulations on a real distribution system and the results indicate that both methods allow the voltage profiles to be regulated at the wind generator connection bus within voltage standard limits, by taking into account the capability curves of the wind generators. Nevertheless, the fuzzy method presents more advantage in comparison with the sensitivity method. In fact, (i) it provides a gentler action control with a lower reactive power consumption during control operations as the reactive power profile follows better the voltage variations; (ii) the design of the fuzzy controller is independent from the knowledge of network parameters and its topology.

H-4. California Independent System Operator (CAISO): *Final Report for Assessment of Visibility and Control Options for Distributed Energy Resources*, prepared by KEMA Corp.; June 2012.

While Distributed Energy Resources provide local power resources, management of load and environmental benefits, DER also creates variability in its offering – both from the nature of the resource and the uncertainty in response to various programs. Variability in distributed energy resources comes from a variety of different sources in distributed resources examined in this report (solar, temperature, load conditions and economics associated with DER). Uncertainty of each distributed resource relates to forecasted responses and is associated with DER monitoring to improve capabilities to forecast DER responses. Indirect control relates only to those distributed energy resources that the ISO (California ISO) provides price instructions and meters responses. Some DER are directly controlled by distribution providers or third parties working with the distribution provider so the ISO receives benefits from efforts by these agents. The KEMA Team only examined the benefits from indirect control of DER in this report.

Operational impacts are addressed by examining the effects of distributed energy resources on reserve requirements as well as technical requirements for monitoring and controlling those resources. To quantify the market impacts1 from increased DER visibility, the KEMA Team built forecast models for six DER2 technologies and compared the results with a high and low forecast model errors. We then simulated production costs for California and CAISO members with and without the impacts of forecasting/monitoring DER for the high and low forecast model error cases. We also examined the impacts of indirect control of price responsive demand response.

H-5. Chen, R.; Chen, Y.; Wang, Z.: *The Reactive/Voltage Hybrid Optimization Control of Distribution Power Grid Based on the Switching System*, 2011 International Conference on Electrical and Control Engineering (ICECE), July 2011.

To satisfy the demand for high-quality and uninterrupted electricity service increases, advanced automatic voltage control systems of distribution power grid are highly required. Based on the hybrid control method of power systems, a new automatic voltage control system named as D-HAVC is proposed in this work. To handle fast changing daily load, the D-HAVC system adopts the switching control method to design control subsystem. Moreover, for each control subsystem, the fuzzy method is used to unify the value of different operation indexes, which helps to setup a practical multi-objective reactive/voltage optimization problem. Finally, the event-driven control strategy is applied in each control subsystem, which generates the control action by solving the multi-objective optimization problem after discovering violations of the operation indexes. Tasking the Shenzhen power grid as the test system, the effeteness and efficiency of the proposed method are verified.

H-6. DongLi, J.; XiaoLi, M.; XiaoHui, S.: *Study on Technology System of Self-healing Control in Smart Distribution Grid,* 2011 International Conference on Advanced Power System Automation and Protection (APAP), October 2011.

Smart distribution grid is an important part of smart grid, which connects the main network and user-oriented supply. As an "immune system," self-healing is the most important feature of smart grid. Major problem of self-healing control is the ''uninterrupted power supply problem,'' that is, real-time monitoring of network operation, predicting the state power grid, timely detection, rapid diagnosis and elimination of hidden faults, without human intervention or only a few cases. First, the paper describes major problems, which are solved by self-healing control in smart distribution grid, and their functions. Then, it analysis the structure and technology components of self-healing control in smart distribution grid, including the base layer, support layer and application layer. The base layer is composed of the power grid and its equipments, which is the base for smart grid and self-healing control. The support layer is composed of the data and communication. High-speed, bi-directional, real-time and integrated communications system is the basis of achieving power transmission and the use of high efficiency, reliability and security, and the basis for intelligent distribution network and the key steps of self-prevention and self-recovery in distribution grid. The application layer is composed of Monitoring, assessment, pre-warning/analysis, decision making, control and restoration. Six modules are interconnected and mutual restraint. The application layer is important means of self-prevention and self-recovery in distribution grid. Through the research and analysis on the relationship and the technical composition of six modules in the application layer, the paper divides running states of smart grid distribution grid having self-healing capabilities into five states, which are normal state, warning state, critical state, emergency state and recovery state, and defines the characteristics and the relationship of each state. Through investigating an- applying self-healing control in smart distribution grid, smart distribution grid can timely detect the happening or imminent failure and implement appropriate corrective action, so that it does not affect the normal supply or minimize their effects. Power supply reliability is improved observably and outage time is reduced significantly. Especially in extreme weather conditions, the distribution grid will give full play to its self-prevention and self-recovery capability, give priority to protecting people's life and provide electricity for the people furthest.

H-7. König, J.; Franke, U.; Nordström, L.: *Probabilistic Availability Analysis of Control and Automation Systems for Active Distribution Networks,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

The future smart electricity grids will exhibit tight integration between control and automation systems and primary power system equipment. Optimal and safe operation of the power system will be completely dependent on well functioning information and communication (ICT) systems. Considering this, it is essential that the control and automation systems do not constitute the weak link in ensuring reliable power supply to society. At the same time, studies of reliability when considering complex interdependencies between integrated ICT systems becomes increasingly difficult to perform due to the large amount of integrated entities with varying characteristics involved. To manage this challenge there is a need for structured modeling and analysis methods that accommodate this characteristics and interdependencies. In other fields, the analysis of large interconnected systems is done using models that capture the systems and its context as well as its components and interactions. This paper addresses this issue by combining enterprise architecture methods that utilize these modeling concepts, with fault tree analysis and probabilistic relational models. This novel approach enables a holistic overview thanks to the use of formalized models. It also allows use of rigorous

analysis thanks to the adaptation of the models to enable Fault Tree Analysis. The paper is concluded with an example of application of the analysis method on a proposed smart grid function in a distribution network.

H-8.   Saric, A. T.; Rankovic, A.: *Load Reallocation Based Algorithm for State Estimation in Distribution Networks with Distributed Generators*, Electric Power Systems Research, Volume 84, Issue 1, March 2012.

In this paper is proposed a novel branch flow and weighted least square (WLS) based algorithm for state estimation in three phase distribution networks with distributed generation (DG) units. The basic formulation is simplified by the use of radial property of distribution network and later will be extended to meshed networks. Unmonitored (or partially monitored) loads are initially estimated from normalized daily load profiles (NDLPs) with lower weights (treated as the pseudo measurements). Also, the different types of monitored, partially monitored, or unmonitored DG units are included in state estimation. Their initial power outputs are calculated on the basis of external inputs, such as wind, sun and water inflow forecasts etc. (depending on DG unit type) or by normalized daily generation profiles (NDGPs) obtained from historical generation data. The pseudo measurements obtained by Initial Load/Generation Allocation are re-adjusted additionally by Optimal Load/Generation Reallocation procedure to fit real-time measurements inside WLS-based state estimation. The results and practical aspects of the proposed methodology are demonstrated on two real-life distribution networks.

H-9.   Taft, J. D.: *Emerging Smart Grid Control Trends and Implications for Control Architecture*, 2012 IEEE PES Transmission and Distribution Conference and Exposition (T&D), May 2012.

While the smart grid concept is beginning to achieve a degree of maturity, there are areas in which emerging trends imply significant impacts on utility systems and processes. In particular, control system architecture must still go through a degree of evolution to accommodate new models for system control, especially as the penetration of Renewable Energy Resources, Distributed Energy Resources, and smart load interactions reaches and surpasses critical thresholds.

H-10.   Vyatkin, V.; Zhabelova, G.; Higgins, N.; Schwarz, K.; Nair, N.-K. C.: *Towards Intelligent Smart Grid Devices with IEC 61850 Interoperability and IEC 61499 Open Control Architecture*, 2010 IEEE PES Transmission and Distribution Conference and Exposition (T&D), April 2010.

In this paper we report on developments and experiments conducted to prove the feasibility of using decentralized multi-agent control logic in the automation of power distribution networks. The utility network is modelled as communicating logical nodes following IEC 61850 standard's architecture, implemented by means of IEC 61499 distributed automation architecture. The system is simulated in an IEC 61499 execution environment combined with Matlab and proven to achieve simple fault location and power restoration goals through collaborative behaviour and interoperable devices.

H-11.   Zeljkovic, C.; Rajakovic, N.: *Cost-saving Potential of Customer-driven Distributed Generation*, Electric Power Systems Research, Volume 92, November 2012.

Utilization of distributed generation (DG), in combination with the traditional supply from the grid, may help industrial and commercial customers to decrease their energy bills. The full cost-saving potential of DG would be released only in case when all inputs were known for the overall billing period in advance. Under the realistic conditions, where a set of important input variables exhibit a stochastic change and where the customers are billed not only for energy but also for the monthly peak demand, it remains to search for dispatch solutions capable of bringing the savings as close as

possible to the theoretical maxima. In this paper, we propose a novel real-time near-optimal DG dispatching algorithm, which takes into account all the input parameters recognized up to now as respectable. The algorithm has been extensively tested showing an excellent performance over a wide range of operating conditions.

I. System Security and Cybersecurity

I-1.   Dolezilek, D.; Hussey, L.: *Requirements or Recommendations? Sorting Out NERC CIP, NIST, and DOE Cybersecurity*, 2011 64th Annual Conference for Protective Relay Engineers, April 2011.

Oil and gas, water and electric power – all of these essential services rely on SCADA (supervisory control and data acquisition), protection, and monitoring systems that use communications networks. The use of communications networks makes these systems potentially vulnerable to cyberattack. Over the past decade, faced with an increase in computer hacking and the recognition of the importance of these services to health and welfare, economic stability, and national security, the United States federal government has been increasingly involved in efforts to assist utilities in improving their security posture. Smart grid has become synonymous with asynchronous, nonmission-critical information exchange applications. Smart grid infrastructure describes the existing, yet largely unrecognized, mission-critical control applications that enable generation and delivery of power. Smart grid infrastructure applications require deterministic and synchronous message exchange, including automation and teleprotection. Today, utilities are faced with a confusing array of cybersecurity guidance, standards, and regulatory requirements. Electric utilities operating bulk power system assets must comply with eight NERC (North American Electric Reliability Corporation) CIP (Critical Infrastructure Protection) standards that are in the process of being revised. Federal entities are required by the FISMA (Federal Information Security Management Act of 2002) to comply with NIST (National Institute of Standards and Technology) standards. Under the Energy Independence and Security Act of 2007, Congress gave NIST the task of developing a framework of interoperability and cybersecurity for smart grid applications. To date, the framework has been primarily focused on smart grid information exchange applications that use asynchronous data flow, including metering, demand response, and the near realtime elements of substation and distribution automation. These automation elements and other smart grid infrastructure applications that require deterministic synchronous data exchange, including teleprotection and synchrophasor state measurement, remain a future endeavor. This paper discusses various cybersecurity requirements and presents a clear picture of work being done by NIST to explain what is required and recommended and what utilities should expect to see in the near future as NERC and NIST work continues.

I-2.   Fovino, I.; Guidi, L.; Masera, M.; Stefanini, A.: *Cyber Security Assessment of a Power Plant*, Electric Power Systems Research, Volume 81, Issue 2, February 2011.

Critical infrastructures and systems are today exposed not only to traditional safety and availability problems, but also to new kinds of security threats. These are mainly due to the large number of new vulnerabilities and architectural weaknesses introduced by the extensive use of information and communication technologies (ICT) into such complex systems. In this paper we present the outcomes of an exhaustive ICT security assessment, targeting an operational power plant, which consisted also of the simulation of potential cyber attacks. The assessment shows that the plant is considerably vulnerable to malicious attacks. This situation cannot be ignored, because the potential outcomes of an induced plant malfunction can be severe.

I-3.   Issicaba, D.; Lopes, J. A. P.; da Rosa, M. A.: *Adequacy and Security Evaluation of Distribution Systems with Distributed Generation,* IEEE Transactions on Power Systems, Vol. 27, No. 3, August 2012.

This paper presents an adequacy and security evaluation of electric power distribution systems with distributed generation. For this accomplishment, bulk power system adequacy and security evaluation concepts are adapted to distribution system applications. The evaluation is supported by a combined discrete-continuous simulation model which emulates the distribution system operation. This model generates a sequence of operation states which are evaluated from a steady-state perspective using AC power flow computations. Frequency and voltage stability are also assessed using dynamic simulation in order to verify the feasibility of islanded operation. Simulation results are presented for the RBTS-BUS2-F1 as well as an actual feeder from the South of Brazil. The results emphasize the need to consider adequacy and security aspects in the distribution system assessments, mainly due to the ongoing integration of distributed energy resources.

I-4.   Kim, J.; Ahn, S.; Kim, Y.; Lee, K.; Kim, S.: *Adequacy and Security Evaluation of Distribution Systems with Distributed Generation,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

AMI is the totality of systems and networks used to measure, collect, store, analyze, and use energy usage data. The industry and technology surrounding AMI has been evolving at a very fast pace for the past several years. In this paper, we propose new key establishment and security algorithm based on public key cryptography to solve AMI network security problems. We evaluate the performance of the proposed key establishment procedure compared with existing algorithm, and we find that the performance of proposed algorithm.

I-5.   Kim, J.; Ahn, S.; Kim, Y.; Lee, K.; Kim, S.: *Adequacy and Security Evaluation of Distribution Systems with Distributed Generation,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

AMI is the totality of systems and networks used to measure, collect, store, analyze, and use energy usage data. The industry and technology surrounding AMI has been evolving at a very fast pace for the past several years. In this paper, we propose new key establishment and security algorithm based on public key cryptography to solve AMI network security problems. We evaluate the performance of the proposed key establishment procedure compared with existing algorithm, and we find that the performance of proposed algorithm.

I-6.   Nicholson, A.; Webber, S.; Dyer, S.; Patel, T.; Janicke, H.: *SCADA Security in the Light of Cyber-Warfare,* Computers and Security, Vol. 31, Issue 4, June 2012.

Supervisory Control and Data Acquisition (SCADA) systems are deployed worldwide in many critical infrastructures ranging from power generation, over public transport to industrial manufacturing systems. Whilst contemporary research has identified the need for protecting SCADA systems, these information are disparate and do not provide a coherent view of the threats and the risks resulting from the tendency to integrate these once isolated systems into corporate networks that are prone to cyber attacks. This paper surveys ongoing research and provides a coherent overview of the threats, risks and mitigation strategies in the area of SCADA security.

I-7.   Wallnerstrom, C. J.; Hilber, P.: *Vulnerability Analysis of Power Distribution Systems for Cost-Effective Resource Allocation,* IEEE Transactions on Power Systems, Vol. 27, No. 1, February 2012.

This paper proposes a method to allocate resources in power distribution planning and also introduces a new reliability index category, RT, flexibility to adjust to different laws or distribution system operator (DSO) policies of long outages. Possible legal consequences for distribution system operators are first identified and studied. A vulnerability-analysis method is introduced, including a statistical validation. The overall idea is to identify and evaluate possible states of power distribution systems using quantitative reliability analyses. Results should thus indicate how available resources (both human recourses and equipment) could be better utilized, e.g.; in maintenance and holiday scheduling and in evaluating whether additional security should be deployed for certain forecasted weather conditions. To evaluate the method, an application study has been per- formed based on hourly weather measurements and about 65 000 detailed failure reports over eight years for two distribution systems in Sweden. Months, weekdays, and hours have been compared and the vulnerability of several weather phenomena in these areas has been evaluated. Of the weather phenomena studied, only heavy snowfall and strong winds, especially in combination, significantly affect the reliability. Temperature (frost), rain, and snow depth have a relatively low or no impact.

J. Storage

J-1.   Hill, C. A.; Such, M. C.; Chen, D.; Gonzalez, J.; Grady, W. M.: *Battery Energy Storage for Enabling Integration of Distributed Solar Power Generation*, IEEE Transactions on Smart Grid, Vol. 3, Issue 2, June 2012.

As solar photovoltaic power generation becomes more commonplace, the inherent intermittency of the solar resource poses one of the great challenges to those who would design and implement the next generation smart grid. Specifically, grid-tied solar power generation is a distributed resource whose output can change extremely rapidly, resulting in many issues for the distribution system operator with a large quantity of installed photovoltaic devices. Battery energy storage systems are increasingly being used to help integrate solar power into the grid. These systems are capable of absorbing and delivering both real and reactive power with sub-second response times. With these capabilities, battery energy storage systems can mitigate such issues with solar power generation as ramp rate, frequency, and voltage issues. Beyond these applications focusing on system stability, energy storage control systems can also be integrated with energy markets to make the solar resource more economical. Providing a high-level introduction to this application area, this paper presents an overview of the challenges of integrating solar power to the electricity distribution system, a technical overview of battery energy storage systems, and illustrates a variety of modes of operation for battery energy storage systems in grid-tied solar applications. The real-time control modes discussed include ramp rate control, frequency droop response, power factor correction, solar time-shifting, and output leveling.

J-2.   Jewell, W.; Hu, Z.: *The Role of Energy Storage in Transmission and Distribution Efficiency*, 2012 IEEE PES Transmission and Distribution Conference and Exposition, May 2012.

Energy storage systems that are properly placed on the transmission system can be used to relieve transmission congestion. Similarly, storage on distribution can be used to reduce peak loads. The reduction in currents produced by congestion relief and peak reduction may also result in a decrease in line losses. Further efficiency improvements could be realized by optimizing the placement and scheduling of energy storage for loss reduction and efficiency improvement. The efficiency of the storage systems themselves, however, may limit their use in loss reduction or system efficiency improvement. Typical round-trip efficiencies for bulk storage systems are 70-85% for pumped hydro and 70-

90% for electrochemical batteries. Comparing this with North American transmission and distribution efficiencies that usually exceed 90%, the case for using storage to improve overall efficiency may be difficult to make. This presentation will examine the issues, comparing storage efficiencies with transmission and distribution efficiencies. It will examine selected cases to address the feasibility of optimizing the placement and scheduling of energy storage to improve system efficiency and reduce greenhouse gas emissions. Efficiency improvement will then be discussed in the context of the other potential benefits and costs of storage.

J-3. Papadimitriou, C.; Vovos, N.: *Integration of a Hybrid Fuel Cell-Battery System to a Distribution Grid,* Electric Power Systems Research, Vol. 81, Issue 7, July 2011.

In order to integrate a proton exchange membrane type (PEM) fuel cell system (FCS) combined with a battery bank to a distribution grid; this paper proposes a local controller based on fuzzy logic. The proposed system provides primary frequency control and local bus voltage support to the local grid. This opposes the passive distributed generation of the present that do not provide auxiliary services, such as back-up power, voltage support and reliability of supply as they operate under constant power factor equal to 1 at all times. During network disturbances, the distributed generations of the present are disconnected until normal operation is reestablished. When the distributed generation penetration is high this may lead to system instability. The microgrid concept is the effective solution for the control and quality improvement of grids with high level of DG penetration. So, the proposed system, also, can be an active controllable microsource of a microgrid in the future that cooperates with other microsources in order to cover the local load demands for active and reactive power either under grid-connected mode or under islanding operating mode. In cases where the distribution grid (working as microgrid) is forced to operate in islanded mode, the hybrid system provides the demanded active and reactive power. The FCS is connected to a weak distribution grid so that the system performance is studied under the worst conditions. The simulation results are obtained using MATLAB software under a severe step load change where the grid is still connected and under islanded operation. In both cases the system presents a good performance.

J-4. Wade, N. S.; Taylor, P. C.; Lang, P. D.; Jones, P. R.: *Evaluating the Benefits of an Electrical Energy Storage System in a Future Smart Grid,* Energy Policy, Vol. 38, Issue 11, November 2010.

Interest in electrical energy storage systems is increasing as the opportunities for their application become more compelling in an industry with a back-drop of ageing assets, increasing distributed generation and a desire to transform networks into Smart Grids. A field trial of an energy storage system designed and built by ABB is taking place on a section of 11 kV distribution network operated by EDF Energy Networks in Great Britain. This paper reports on the findings from simulation software developed at Durham University that evaluates the benefits brought by operating an energy storage system in response to multiple events on multiple networks. The tool manages the allocation of a finite energy resource to achieve the most beneficial shared operation across two adjacent areas of distribution network. Simulations account for the key energy storage system parameters of capacity and power rating. Results for events requiring voltage control and power flow management show how the choice of operating strategy influences the benefits achieved. The wider implications of these results are discussed to provide an assessment of the role of electrical energy storage systems in future Smart Grids.

J-5. Xu, Y.; Singh, C.: *Distribution Systems Reliability and Economic Improvement with Different Electric Energy Storage Control Strategies,* 2011 IEEE Power and Energy Society General Meeting, July 2011.

With the rapid development of electric energy storage (EES) technologies, there is a growing interest in integrating these into distribution systems to improve their reliability and economy. Different control strategies of EES have corresponding reliability and economic impacts on the system. In this paper, the reliability and economy of radial distribution system integrated with EES are assessed. The control strategy of utilizing EES as a standby backup energy resource is analyzed. This standby backup control strategy improves system reliability the most but falls short on economy improvement. A novel MPC-based control strategy is presented, which can maximize distribution system economy but could not improve reliability as much as the standby backup control strategy. A hybrid control strategy of balancing the reliability and economy improvement by combining the standby backup control strategy and MPC-based control strategy is presented. The reliability and economic analysis of distribution system integrated with EES using proposed control strategies illustrates the effectiveness of the proposed method. It also illustrates that even with the same EES integrated into the distribution system, different control strategies have very different reliability and economic impact on the system. In order to accurately assess the impact of the implemented control strategies, sequential Monte Carlo Simulation is used and implemented EES control operations are included in the simulation.

J-6.   Zillmann, M.; Yan, R.; Saha, T. K.: *Regulation of Distribution Network Voltage Using Dispersed Battery Storage Systems: A Case Study of a Rural Network,* 2011 IEEE Power and Energy Society General Meeting, July 2011.

The drive for power networks throughout the world to utilize clean, green renewable generation poses a number of issues for distribution and transmission companies. Two of the most popular forms of renewable generation, wind and photovoltaic (PV) face large fluctuations in their generation profile. This variation means that peak generation and peak customer demand are often greatly divergent. Battery energy storage can help to buffer wind and PV generation, capturing a portion of the energy produced during light load and exporting it back onto the network as required. Moreover, energy storage can be utilized to load shift and regulate network voltage. This paper investigates the use of battery storage in regulating network voltage, in particular, the different strategies which may be employed in controlling the storage unit. Simulations are coupled with real data, taken from a rural single wire earth return (SWER) network, showing that battery storage is capable of boosting the network voltage.

K. Forecasting

K-1.   Ding, N.; Besanger, Y.; Wurtz, F.; Antoine, G.; Deschamps, P.: *Time Series Method for Short-term Load Forecasting Using Smart Metering in Distribution Systems,* 2011 IEEE Trondheim PowerTech, June 2011.

Recently, the research community gave a particular attention to the "smart grid" concept since it enables a higher efficiency to answer users' energy needs. Smart grid networks relying on the exploitation of smart meters enable the design of more accurate forecasting models on the distribution grid. Within this context, this paper presents a time series forecasting model based on real measurements. It basically relies on the description of the power load through two components: a trend component and a cyclic (periodic) component. The two components are identified separately using, on the one hand a regression algorithm and on the other hand spectral techniques. The carried out simulations are based on real measurements collected from the French distribution network. These results are promising and show better results compared to a naive model.

K-2.   Fan, S.; Wu, Y.-K.; Lee, W.-J.; Lee, C.-Y.: *Comparative Study on Load Forecasting Technologies for Different Geographical Distributed Loads,* 2011 IEEE Power and Energy Society General Meeting, July 2011.

For a power system covering large geographical area, a single forecasting model for the entire region cannot guarantee the satisfactory forecasting accuracy. One of the major reasons is because the load diversity and weather diversity throughout the region. For such a system, multi-region load forecasting will be a feasible and effective solution to generate more accurate forecasting results. However, some technical issues arise when performing the multi-region load forecasting, the major challenge is how to optimally partition/combine the regions to achieve better forecasting results, especially under transient weather conditions. On the other hand, load forecasting for small areas, especially for a distribution feeder or micro grid, is also difficult because load variation in local areas is larger than that of a large system. In addition, the correlation between weather variables and small area loads would be unstable. Therefore, a two-stage load forecasting module could be utilized to improve the forecasting accuracy, and the risk assessment of local load forecasting uncertainty could be studied. This paper discusses respectively a large geographical load forecasting in Midwest US and a small area load forecasting in a UK distribution feeder. For the load forecasting at the large geographical area, a multi-region forecasting system that can find the optimal region partition in both stationary and transient weather and load conditions is discussed. For the load forecasting at the small feeder, a two-stage combination module is discussed; furthermore, risk evaluation technologies based on time-domain and frequency-domain methods are also proposed to assess the uncertainty of load forecasting.

K-3.   Foley, A. M.; Leahy, P. G.; Marvuglia, A.; McKeogh, E. J.: *Current Methods and Advances in Forecasting of Wind Power Generation,* Renewable Energy, Vol. 37, Issue 1, January 2012.

Wind power generation differs from conventional thermal generation due to the stochastic nature of wind. Thus wind power forecasting plays a key role in dealing with the challenges of balancing supply and demand in any electricity system, given the uncertainty associated with the wind farm power output. Accurate wind power forecasting reduces the need for additional balancing energy and reserve power to integrate wind power. Wind power forecasting tools enable better dispatch, scheduling and unit commitment of thermal generators, hydro plant and energy storage plant and more competitive market trading as wind power ramps up and down on the grid. This paper presents an in-depth review of the current methods and advances in wind power forecasting and prediction. Firstly, numerical wind prediction methods from global to local scales, ensemble forecasting, upscaling and downscaling processes are discussed. Next the statistical and machine learning approach methods are detailed. Then the techniques used for benchmarking and uncertainty analysis of forecasts are overviewed, and the performance of various approaches over different forecast time horizons is examined. Finally, current research activities, challenges and potential future developments are appraised.

K-4.   Giebel, G.; Brownsword, R.; Kariniotakis, G.; Denhard, M.; Draxl, C.: *The State-of-the-Art in Short-Term Prediction of Wind Power,* European Commission, January 2011.

This paper will give an overview over past and present attempts to predict wind power for single turbines, wind farms or for whole regions, for a few minutes up to a few days ahead. It was first produced for the ANEMOS project, which brought together many groups from Europe involved in the field, with up to 15 years of experience in short-term forecasting. The follow-up project ANEMOS.plus, which concentrates on the best possible integration of the ANEMOS results in the work flow of end users, financed a

thorough revision of this report. The literature search involved has been extensive, and it is hoped that this paper can serve as a reference for all further work.

K-5. Hamlyn, A.; Cheung, H.; Wang, L.; Yang, C.; Cheung, R.: *Distributed Monitoring and Centralized Forecasting Network for DG-connected Distribution Systems,* 2008 IEEE Power and Energy Society General Meeting, July 2008.

Dispersed generations (DGs) from renewable energy resources are becoming popular and start to show benefits, but their connection to distribution systems brings operation challenges and supply uncertainty that must be carefully monitored and forecasted to provide data for correct controls of the systems. This paper proposes a distributed monitoring and centralized forecasting strategy for distribution systems connected with DGs. The paper illustrates functional implementations for the distributed monitoring and centralized forecasting operations utilizing high-speed digital signal processing (DSP) technology and network classified data transmission (CDT) algorithm. The design of a new DSP-based network monitoring architecture is provided. This architecture is fault tolerant and has features from classical cascading, star, and ring architectures. The paper presents the CDT-based real-time data acquisition and DSP-based data post-processing strategy, design, and implementation in three levels: cell units for monitoring feeder-node circuits including DG circuit connected on the feeder, domain unit for a section of the distribution circuit, and station unit for the complete distribution circuit.

K-6. Modica, G. D.; d'Entremont, R.; Mlawer, E.; Gustafson, G.: *Short-range Solar Radiation Forecasts in Support of Smart-grid Technology,* 90th American Meteorological Society Annual Meeting, August 2009.

Solar and wind energy generation assets are fast emerging as sources that will eventually supply a greater share of domestic electricity needs. The US power grid will require new infrastructure to connect these power generation facilities with consumers, as well as smarter controls to better match fluctuating supply and demand cycles. For example, solar energy generation facilities will be impacted by changes in the local cloud distribution. If these intra-day changes could be detected and forecast, the information could be used to order increases (decreases) in power production (consumption) from elsewhere.

In this paper we describe a prospective solar radiation forecast system that integrates cloud analysis, prediction, and radiative transfer technologies to provide the smart grid with this valuable information. The proposed system combines imager data from ground- and space-based remote sensing systems, a cloud forecast model to provide a detailed forecast of various cloud properties for time periods of minutes up to an hour or more, and a radiative transfer model for computation of downwelling solar irradiance in the appropriate waveband at the solar collector. In later sections we describe the components of the forecast system in further detail and illustrates some of its capabilities.

K-7. Porter, K.; Rogers, J.: *Survey of Variable Generation Forecasting in the West – August 2011 - June 2012,* National Renewable Energy Laboratory (NREL), April 2012.

This report surveyed Western Interconnection Balancing Authorities regarding their implementation of variable generation forecasting, the lessons learned to date, and recommendations they would offer to other Balancing Authorities who are considering variable generation forecasting. Our survey found that variable generation forecasting is at an early implementation stage in the West. Eight of the eleven Balancing Authorities interviewed began forecasting in 2008 or later. It also appears that less than one-half of the Balancing Authorities in the West are currently utilizing variable generation forecasting, suggesting that more Balancing Authorities in the West will engage in variable generation forecasting should more variable generation capacity be added.

K-8. Qin, Z.; Li, W.; Xiong, X.: *Estimating Wind Speed Probability Distribution Using Kernel Density Method,* Electric Power Systems Research, Vol. 81, Issue 12, December 2011.

Accurate estimation of long term wind speed probability distribution is a fundamental and challenging task in wind energy planning. This paper proposes a nonparametric kernel density estimation method for wind speed probability distribution. The proposed method is compared with ten conventional parametric distribution models for wind speed that have been presented in literatures so far. The results demonstrate that the proposed non-parametric estimation is more accurate and has better adaptability than any conventional parametric distribution for wind speed.

K-9. Vaccaro, A.; Bontempi, G.; Ben Taieb, S.; Villaccia, D.: *Adaptive Local Learning Techniques for Multiple-step-ahead Wind Speed Forecasting,* Electric Power Systems Research, Vol. 83, Issue 1, February 2012.

A massive deployment of wind energy in power systems is expected in the near future. However, a still open issue is how to integrate wind generators into existing electrical grids by limiting their side effects on network operations and control. In order to attain this objective, accurate short and medium-term wind speed forecasting is required. This paper discusses and compares a physical (white-box) model (namely a limited-area non hydrostatic model developed by the European consortium for small-scale modeling) with a family of local learning techniques (black-box) for short and medium term forecasting. Also, an original model integrating machine learning techniques with physical knowledge modeling (grey-box) is proposed. A set of experiments on real data collected from a set of meteorological sensors located in the south of Italy supports the methodological analysis and assesses the potential of the different forecasting approaches.

L. Electric Vehicles

L-1. Aguero, J. R.; Chongfuangprinya, P.; Shao, S.; Xu, L.; Jahanbakhsh, F.; Willis, H. L.: *Integration of Plug-in Electric Vehicles and Distributed Energy Resources on Power Distribution Systems,* 2012 IEEE International Electric Vehicle Conference (IEVC), March 2012.

The utility industry is expecting a proliferation of Plug-in Electric Vehicles (PEV). This has prompted increasing interest in evaluating the potential impacts of PEVs on power distribution system planning and operations, as well as in proposing mitigation approaches that allow their seamless integration. In addition, there is a noticeable growth in the number of solar photovoltaic distributed generation (PV-DG) being interconnected to distribution feeders in North America and other regions. The rising penetration of PV-DG may also lead to important impacts on power distribution systems, particularly due to the intermittent nature of its output caused by cloud cover. As an emerging technology, Distributed Energy Storage (DES) aims to improve the reliability, efficiency, and controllability of the power distribution system and to facilitate the integration of distributed generations. This paper discusses the integration of all these technologies from a technical perspective and investigates how DES may be used as a means for mitigating the impacts of PEV charging and PV-DG interconnection. Results of simulations conducted on an actual distribution feeder are presented and discussed.

L-2. Dong, J.; Lin, Z.: *Within-day Recharge of Plug-in Hybrid Electric Vehicles: Energy Impact of Public Charging Infrastructure,* Transportation Research Part D: Transport and Environment, Vol. 17, Issue 5, July 2012.

This paper examines the role of public charging infrastructure in increasing the share of driving on electricity that plug-in hybrid electric vehicles might exhibit, thus reducing their gasoline consumption. Vehicle activity data obtained from a global positioning system tracked household travel survey in Austin, Texas, is used to estimate gasoline and electricity consumptions of plug-in hybrid electric vehicles. Drivers' within-day recharging behavior, constrained by travel activities and public charger availability, is modeled. It is found that public charging offers greater fuel savings for hybrid electric vehicles s equipped with smaller batteries, by encouraging within-day recharge, and providing an extensive public charging service is expected to reduce plug-in hybrid electric vehicles gasoline consumption by more than 30% and energy cost by 10%, compared to the scenario of home charging only.

L-3.   Electric Power Research Institute: *Transportation Electrification: A Technology Overview,* 2011 Technical Report, July 2011.

This report provides a detailed status on the commercial rollout of plug-in vehicles. It describes the key vehicle and infrastructure technologies and outlines a number of potential roles for electric utilities to consider when developing electric transportation readiness plans. These roles have been formulated with the objectives of enabling utilities to demonstrate regional leadership in planning for transportation electrification, to support customer adoption of plug-in vehicles and their supporting charging infrastructure, and to understand and minimize the system impacts from vehicle charging.

L-4.   Gallardo-Lozano, J.; Milanés-Montero, M.; Guerrero-Martínez, M.; Romero-Cadaval, E.: *Electric Vehicle Battery Charger for Smart Grids,* Electric Power Systems Research, Vol. 90, September 2012.

This paper presents a smart grid compatible electric vehicle on-board battery charger. Based on a novel control strategy, the charging equipment can operate bi-directionally, demanding or injecting a balanced and sinusoidal with no harmonics current into the grid, regardless of the grid voltage quality, minimizing the losses in the power flow. The control strategy of the charger tries to fulfill the recent IEEE Standard 1459-2010, with the objective of maximizing the use / injection of AC power from / into the grid, and reducing the load harmonic factor and load unbalanced factor. Simulation and experimental results are included to test the charger under different source voltage conditions.

L-5.   Mallette, M.; Venkataramanan, G.: *The Role of Plug-In Hybrid Electric Vehicles in Demand Response and Beyond,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

As the electric utility industry continues to move towards becoming more of a deregulated entity, demand response programs are playing a much larger role. Plug-in hybrid electric vehicles (PHEVs) have the potential to increase the ability of residential customers to participate in demand response programs. However, there may need to be changes made in order to incorporate the spatially mobile aspect of PHEVs as new charging infrastructure enables vehicles to charge in many locations. New demand response programs may also be needed to take advantage of the storage potential inherent in the batteries of PHEVs. This paper explores the potential impact of PHEV market penetration on demand response in order to outline the most effective manner of using these resources.

L-6.   O'Connell, N.; Wu, Q.; Østergaard, J.; Nielsen, A.; Cha, S.; Ding, Y.: *Day-ahead Tariffs for the Alleviation of Distribution Grid Congestion from Electric Vehicles,* Electric Power Systems Research, Vol. 92, November 2012.

An economically efficient day-ahead tariff (DT) is proposed with the purpose of preventing distribution grid congestion resulting from electric vehicle (EV) charging scheduled on a day-ahead basis. The DT concept developed herein is derived from the locational marginal price (LMP), in particular the congestion cost component of the LMP. A step-wise congestion management structure has been developed whereby the distribution system operator (DSO) predicts congestion for the coming day and publishes DTs prior to the clearing of the day-ahead market. EV fleet operators (FOs) optimize their EV charging schedules with respect to the predicted day-ahead prices and the published DTs, thereby avoiding congestion while still minimizing the charging cost. A Danish 400 V distribution network is used to conduct case studies to illustrate the effectiveness of the developed concept for the prevention of distribution grid congestion from EV charging. The case study results show that the concept is successful in a number of situations, most notably a predicted system overload of 155% can be successfully alleviated on the test distribution network.

L-7.   Pleat, G.: *Allowing for Off-peak Price Incentives to Reduce Electric Vehicle Distribution Grid Congestion,* The Electricity Journal, Vol. 25, Issue 6, November 2012.

Maryland legislators have set in motion financial investments, tax incentives and Public Service Commission directives to encourage and accommodate electric vehicle market expansion in the state. To combat potential capacity reliability disruptions caused by EVs, electric utilities must begin to design residential electricity price signals that will incentivize EV users to plug in their vehicles off-peak, where demand congestions are least likely to occur.

L-8.   Van, Q.-D.; Bae, J.-H.; Lee, J.-D.; Lee, S.-J.: *Monitoring of Power Allocation in Centralized Electric Vehicle Charging Spot System,* Energy Procedia, Vol. 17, Part B, February 2012.

Plug-in Hybrid Electric Vehicle and Electric Vehicle (PHEV/EV) are taking a greater share in the personal automobile market, their high penetration levels may bring potential challenges to electric utility especially at the distribution level. Thus, there is a need for a flexible charging management strategy to compromise the benefits of both PHEV/EVs owners and power grid side. There are many different management methods that depend on objective function and the constraints caused by the system. In this paper, the schema and dispatching schedule of centralized PHEV/EV charging spot network are analyzed. Also, we proposed and compared three power allocation strategies for centralized charging spot network. The first strategy aims to maximize state of charge (SoC) of vehicles at plug-out time, the rest methods are equalized allocation and prioritized allocation based on vehicles SoC. The simulation shows that each run of the optimized algorithms can produce good results.

M. Modeling and Simulation

M-1.   Bedir, A.; Ozpineci, B.; Christian, J. E.: *The Impact of Plug-in Hybrid Electric Vehicle Interaction with Energy Storage and Solar Panels on the Grid for a Zero Energy House*, 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

Renewable energy sources and plug-in hybrid electric vehicles (PHEVs) are becoming very popular in research areas, as well as in the market. The aim of this paper is to demonstrate how a solar powered building interacts with energy storage and how it can be used to power a PHEV and to support the grid with peak shaving, load shifting, and reducing annual energy usage. A net zero energy house (ZEH5) is selected as the base house for this experiment. Oak Ridge National Laboratory (ORNL) is developing

simulation models and energy management scenarios using the actual solar production and residential energy usage data, and a PHEV. The system interaction with the grid is evaluated after getting all the data from PHEV charging, photovoltaic (PV) power production, and residential load.

M-2. Chang, J.; Madjarov, K.; Baldick, R.; Alvarez, A.; Hanser, P. Q.: *Renewable Integration Model and Analysis*, 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

The integration of significant amounts of renewable resources poses a number of challenges for system planners. We formulated a methodology that quantifies the amount of conventional generation resources and the associated fixed and variable costs necessary to integrate portfolios of renewable resources. We designed and developed a model, The Renewable Integration Model (RIM) that provides system planners a range of flexibility to simulate and estimate the system impact associated with renewable generation based on resource-specific characteristics. From there, RIM can be used to estimate the incremental operational costs associated with accommodating variable generation resources like wind and solar energy.

M-3. Coster, E. J.; Ishchenko, A.; Myrzik, J. M. A.; Kling, W. L.: *Modeling, Simulating and Validating Wind Turbine Behavior During Grid Disturbances*, 2007 IEEE Power and Energy Society General Meeting, July 2007.

Due to the liberalized energy market distributed generation, DG, is increasing. At this moment, most of the power produced by DG is generated by CHP-plants and variable speed wind turbines. Integration of wind turbines have impact on several aspects of power systems such as power system stability, protection and power quality. This paper focuses on the effect of wind farms on power quality phenomena during and after a grid disturbance. A dynamic model of a modern wind turbine will be presented in order to simulate grid disturbances. The results of the simulations are validated by measurements.

M-4. Farag, H. E.; El-Saadany, E. F.; El Shatshat, R.; Zidan, A.: *A Generalized Power Flow Analysis for Distribution Systems with High Penetration of Distributed Generation*, Electric Power Systems Research, Vol. 81, Issue 7, July 2011.

In this paper, the element incidence matrix has been extended to develop a comprehensive three-phase distribution system power flow program for radial topology. Three-phase overhead or underground primary feeders and double-phase or single-phase line sections near the end of the feeder laterals have been considered. Unbalanced loads with different types including constant power, constant current and constant impedance are modeled at the system buses. Substation voltage regulator (SVR) consisting of three single-phase units connected in wye or two single-phase units connected in open delta are modeled to satisfy the desired voltage level along the feeder. The mathematical model of distributed generation (DG) connected as PQ and PV buses are integrated into the power flow program to simulate the penetration of DGs in the distribution systems. The proposed method has been tested and compared with different IEEE test feeders result. The developed algorithm has been used to study the impact of both SVR and high penetration of DG on voltage profile and system power losses.

M-5. Goswami, A.; Gupta, C.; Singh, G.: *Minimization of Voltage Sag Induced Financial Losses in Distribution Systems Using FACTS Devices,* Electric Power Systems Research, Vol. 8, Issue 3, March 2011.

Voltage sag can have significant economic consequences for different types of industries. Flexible AC Transmission System (FACTS) is originally developed for transmission

networks but similar ideas are now starting to be applied in distribution systems. FACTS devices have become popular as a cost effective solution for the protection of sensitive loads from voltage sag. This paper presents the modeling of FACTS devices to minimize the voltage sag induced financial losses. The overall system financial losses due to voltage sag could be significantly reduced depending on the type of FACTS devices used. The short circuit analysis approach is used to incorporate the effect of these devices on financial losses. Voltage sag produced by balanced and unbalanced short circuits is analyzed by means of an analytical approach using system impedance matrix (ZBus) which incorporates FACTS devices. Two types of FACTS devices, which are most often used in practical applications, are considered in this study: Distribution Static Compensator (D-STATCOM) and Static VAR Compensator (SVC). Case studies based on a real Indian distribution system are used to illustrate the modeling method and the effectiveness of these devices in minimization of financial losses.

M-6. Jensen, M.; Louie, R.; Etezadi-Amoli, M.; Fadali, M. S.: *Model and Simulation of a 75kW PV Solar Array*, 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

This paper proposes a model for an actual photovoltaic solar array and a method for estimating total power output. The array is analyzed by modeling individual panels and calculating their cumulative effect. The system model is then used to estimate future power output based on stochastic inputs. The paper includes a system description, system model, and computer simulations.

M-7. Mihet-Popa, L.; Koch-Ciobotaru, C.; Isleifsson, F.; Bindner, H.: *Development of Tools for Simulation Systems in a Distribution Network and Validated byMeasurements*, 2012 13th International Conference on Optimization of Electrical and Electronic Equipment (OPTIM), May 2012.

The increasing amount of DER components into distribution networks involves the development of accurate simulation models that take into account an increasing number of factors that influence the output power from the DG systems. This paper presents two simulation models: a PV panel model using the single-diode four-parameter model based on data sheet values and a VRB system model based on the efficiency of different components and the power losses. The models were implemented first in MATLAB/Simulink and the results have been compared with the data sheet values and with the characteristics of the units. Moreover, to point out the strong dependency on ambient conditions and its influence on array operation and to validate simulation results with measured data, a complex model has also been developed. A PV inverter model and a VRB inverter model, using the same equations and parameters as in MATLAB/Simulink, has also been developed and implemented in [DigSILENT] Power Factory to study load flow, steady-state voltage stability and dynamic behavior of a distribution power system.

M-8. Noda, T.; Kabasawa, Y.; Fukushima, K.; Tokuda, H.; Ishikawa, H.; Ichihara, J.; Kato, S.; Kakigano, H.; Sekisue, T.; Kato, T.; Kimura, N.; Kuroe, Y.; Saito, R.; Shimomura, J.; Matsui, M.: *Present State and Future Plan of Standard Model Development for Smart Grid Simulations*, 2012 IEEE 13th Workshop on Control and Modeling for Power Electronics (COMPEL), June 2012.

The government of Japan assumes that a large portion of renewable energy in the near future will be provided by photovoltaic generation systems installed at end consumers. Thus, smart grids in Japan will be established mainly at the distribution and the end-consumer level of power systems. Considering this situation, the Smart Grid Working Group, created inside the Cooperative Study Group on Applications of Power Electronic

Simulations of IEEJ (Institute of Electrical Engineers of Japan), is currently discussing and developing standard simulation models for components of the distribution and the end-consumer-level power systems. These components include distribution substations, distribution lines, voltage regulation equipment, pole-mounted transformers, photovoltaic panels, power conditioning systems, Li-ion batteries, and small and micro wind power generation systems. The purpose of developing the standard models is to use in transient simulations related to smart grids. This paper describes the present state and the future plan of the development of the standard models.

M-9. Pezeshki, H.; Wolfs, P. J.; Johnson, M.: *Multi-agent Systems for Modeling High Penetration Photovoltaic System Impacts in Distribution Networks*, 2011 IEEE PES Innovative Smart Grid Technologies Asia (ISGT), November 2011.

This paper reviews the use of multi-agent systems to model the impacts of high levels of photovoltaic (PV) system penetration in distribution networks and presents some preliminary data obtained from the Perth Solar City high penetration PV trial. The Perth Solar City trial consists of a low voltage distribution feeder supplying 75 customers where 29 consumers have roof top photovoltaic systems. Data is collected from smart meters at each consumer premises, from data loggers at the transformer low voltage (LV) side and from a nearby distribution network SCADA measurement point on the high voltage side (HV) side of the transformer. The data will be used to progressively develop MAS models.

M-10. Schneider, K. P.; Fuller, J. C.; Chassin, D. P.: *Multi-State Load Models for Distribution System Analysis*, IEEE Transactions on Power Systems, November 2011.

Recent work in the field of distribution system analysis has shown that the traditional method of peak load analysis is not adequate for the evaluation of emerging distribution system technologies. Voltage optimization, demand response, electric vehicle charging, and energy storage are examples of technologies with characteristics having daily, seasonal, and/or annual variations. In addition to the seasonal variations, emerging technologies such as demand response and plug-in electric vehicle charging have the potential to receive control signals that affects their energy consumption. To support time-series analysis over different time frames and to incorporate potential control signal inputs, detailed end-use load models that accurately represent loads under various conditions, and not just during the peak load period, are necessary. This paper will build on previous end-use load modeling work and outline the methods of general multi-state load models for distribution system analysis.

M-11. Smith, J. W.; Dugan, R.; Sunderman, W.: *Distribution Modeling and Analysis of High Penetration PV,* 2011 IEEE Power and Energy Society General Meeting, July 2011.

The interconnection of distributed resources on the electric grid has steadily been growing over the past few years with distribution planners seeing a significant number of requests for distributed wind and solar PV. In order to effectively evaluate renewable resources on the distribution system, either large-scale or small-scale projects at high-penetration levels, certain characteristics unique to this resource must be considered in the system impact and planning processes, namely the time-varying nature of the renewable resource and location-based impacts. This panel paper describes a modeling and analysis approach used to capture these important factors when performing distribution impact studies as well as the Open Distribution System Simulator (OpenDSS) software tool that can be used to perform such studies.

M-12. Wang, D. de Wit, B.; Parkinson, S.; Fuller, J.; Chassin, D.; Crawford, C.; Djilali, N.: *A Test Bed for Self-regulating Distribution Systems: Modeling Integrated Renewable Energy and*

Demand Response in the GridLAB-D/MATLAB Environment, 2012 IEEE PES Innovative Smart Grid Technologies (ISGT), January 2012.

This paper discusses the development of a simulation test bed permitting the study of integrated renewable energy generators and controlled distributed heat pumps operating within distribution systems. The test bed is demonstrated in this paper by addressing the important issue of the self-regulating effect of consumer-owned air-source heat pumps on the variability induced by wind power integration, particularly when coupled with increased access to demand response realized through a centralized load control strategy.

M-13. Zhao, L.; Prousch, S.; Hübner M.; Moser, A.: *Simulation Methods for Assessing Electric Vehicle Impact on Distribution Grids*, 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

Against the background of raising noise and exhaust emissions and the tendency of ever-increasing oil prices, there is a growing interest in electric vehicles (EV) as replacement for conventional vehicles with combustion engine. Since the EV affects neither local tailpipe nor remarkable noise emissions, the EV can improve the ecological situation especially in municipal areas all over the world. Furthermore, due to recent technical advancements and extensive political incentives, the supply of renewable energies—especially wind and photovoltaic energy—is increasing. Since existing distribution grids are not designed for high penetration levels of dispersed generation, or for large scale integration of EVs, extensive network expansion is necessary. Therefore, the question arises if EVs can be used as mobile storage devices or standalone energy sources to counter the aforementioned development and relieve the increasing stress on distribution grids. To answer that question a simulation method based on a comprehensive model of the distribution grid, its conventional as well as the aforementioned new costumers is developed to allow an evaluation of systems of large scale at municipal extent with high penetration of dispersed generation and EVs.

N. Demand Response

N-1. Asano, H.; Takahashi, M.; Yamaguchi, N.: *Market Potential and Development of Automated Demand Response System,* 2011 IEEE Power and Energy Society General Meeting, July 2011.

Active participation of Distributed Energy Resources (DER) such as controllable load and battery storage is expected to reduce costs of large penetration of photovoltaic (PV) generation systems connected to a distribution system. This paper assesses the market potential of demand response (DR) programs using questionnaire survey data in Japan. The sum of potential is about 4.7% of estimated peak load of commercial and industrial customers and about 2.3% of the system peak load (56,405 MW) in Tokyo Electric Power Company's area in 2009. We also conducted a preliminary field experiment of peak-cutting demand response control of air conditioning and lighting in an office space located in Tokyo during 2009 summer to develop automated demand response system. Thermal environment of the controlled space and worker comfort were also surveyed in parallel with electric load measurement of controlled equipment. Experiment results showed that two DR control strategies could reduce about 10% and 23% of a peak demand of the office space during DR period, respectively. However, the adopted DR control strategies affected worker's comfort and their subjective working efficiency evidently. We are developing more acceptable control strategy.

N-2. Gyamfi, S.; Krumdieck, S.: *Scenario Analysis of Residential Demand Response at Network Peak Periods,* Electric Power Systems Research, Vol. 93, December 2012.

Electricity demand response refers to consumer actions that change the utility load profile in a way that reduces costs or improves grid security. Residential demand response (RDR) can be treated as an energy resource which can be assessed and commercially developed. RDR prospectors require more detailed information about usage patterns and penetration for specific electrical appliances during system peak load. The electric utilities normally measure electricity consumption data aggregated over many households and other users on a feeder and do not have information on household end-use behaviour. This paper describes a bottom-up diversified demand model that can be used to estimate load profile of residential customers in a given region. The model has been calibrated by a stated preference demand response survey and used to estimate the voluntary demand response potential for the residential customers in Christchurch, New Zealand, where winter peak demand is becoming increasingly difficult to meet on a capacity-constrained network.

N-3. Jia, W.; Kang, C.; Chen, Q.: *Analysis on Demand-side Interactive Response Capability for Power System Dispatch in a Smart Grid Framework,* Electric Power Systems Research, Vol. 90, September 2012.

In a smart grid framework, relations between the system operator (SO) and terminal consumers will become interactive and demand-side response capacities can be integrated as dispatch-able resources. This paper proposes a systematic analysis on demand-side response mechanism in smart grid. A multi-agent (MA) system is established to describe interactive relations between the SO and different kinds of consumers. On this basis, a novel mechanism is proposed to reflect the process of interactive response, which consists of three schemes: data clustering and release scheme, demand-side interactive response capability (DIRC) submission scheme, and submission correction scheme. Then, a standard data format is defined to formulate the submission of DIRC from basic consumers and a fuzzy-C-mean clustering method is implemented to generate and release typical interactive response modes (IRM) for different kinds of consumers. Moreover, a correction method based on similarity identification is developed to modify submission of DIRC by taking into account deviations between historical submissions and real performances. Finally, a simulation case verifies the effectiveness and rationality of the proposed mechanism, models and methods.

N-4. Lu, S.; Samaan, N.; Diao, R.; Elizondo, M.; Jin, C.; Mayhorn, E.; Zhang, Y.; Kirkham, H.: *Centralized and Decentralized Control for Demand Response,* 2011 IEEE PES Innovative Smart Grid Technologies (ISGT), January 2011.

Demand response has been recognized as an essential element of the smart grid. Frequency response, regulation and contingency reserve functions performed traditionally by generators are now starting to involve demand side resources. Additional benefits from demand response include peak reduction and load shifting, which will defer new infrastructure investment and improve generator operation efficiency. Technical approaches designed to realize these functionalities can be categorized into centralized control and decentralized control, depending on where the response decision is made. This paper discusses these two control philosophies and compares their response performances in terms of delay time and predictability. A distribution system model with detailed household loads and controls is built to demonstrate the characteristics of the two approaches. The conclusion is that the promptness and reliability of decentralized control should be combined with the controllability and predictability of centralized control to achieve the best performance of the smart grid.

N-5. Schneider, K. P.; Fuller, J. C.; Chassin, D.: *Analysis of Distribution Level Residential Demand Response,* 2011 IEEE/PES Power Systems Conference and Exposition (PSCE), March 2011.

Control of end use loads has existed in the form of direct load control for decades. Direct load control systems allow a utility to interrupt power to a medium to large size commercial or industrial customer a set number of times a year. With the current proliferation of computing resources and communications systems the ability to extend the direct load control systems now exists. Demand response systems now have the ability to not only engage commercial and industrial customers, but also the individual residential customers. Additionally, the ability exists to have automated control systems which operate on a continual basis instead of the traditional load control systems which could only be operated a set number of times a year. These emerging demand response systems have the capability to engage a larger portion of the end use load and do so in a more controlled manner. This paper will examine the impact that demand response systems have on the operation of an electric power distribution system.

N-6. Shahnia, F.; Wishart, M. T.; Ghosh, A.; Ledwich, G.; Zare, F.: *Smart Demand Side Management of Low-voltage Distribution Networks Using Multi-objective Decision Making,* IET Generation, Transmission & Distribution, Vol. 6, Issue 10, October 2012.

A novel intelligent online demand side management system is proposed for peak load management in low-voltage distribution networks. This method uses low-cost controllers with low-bandwidth two-way communication installed in customers' premises and at distribution transformers to manage the peak load while maximising customer satisfaction. A multi-objective decision making process is proposed to select the load(s) to be delayed or controlled. The efficacy of the proposed control system is verified by simulation of three different feeder types.

O. Protection Systems

O-1. Aslan, Y.; Türe, S.: *Location of Faults in Power Distribution Laterals Using Superimposed Components and Programmable Logic Controllers,* Electrical Power and Energy Systems, Vol. 33, Issue 4, May 2011.

In this study, a digital fault location and monitoring technique using programmable logic controller (PLC) for primary overhead power distribution networks is presented. This technique employs pre- and post-fault current and voltage information along with data from the laterals. By using lateral current data transferred through shielded coaxial cables to the substation, the possibility of multiple fault point locations are eliminated. The effectiveness of this method is verified through Electromagnetic Transients Program (EMTP) simulations.

O-2. Chowdhury, S. P.; Chowdhury, S.; Crossley, P.A.: *Islanding Protection of Active Distribution Networks with Renewable Distributed Generators: A Comprehensive Survey,* Electric Power Systems Research, Vol. 79, Issue 6, June 2009.

Anti-islanding protection schemes currently enforce the renewable distributed generators (RDGs) to disconnect immediately and stop generation for grid faults through loss of grid (LOG) protection system. This greatly reduces the benefits of RDG deployment. For preventing disconnection of RDGs during LOG, several islanding operation, control and protection schemes are being developed. Their main objectives are to detect LOG and disconnect the RDGs from the utility. This allows the RDGs to operate as power islands suitable for maintaining uninterruptible power supply to critical loads. A major challenge for the islanding operation and control schemes is the protection coordination of

distribution systems with bi-directional flows of fault current. This is unlike the conventional overcurrent protection for radial systems with unidirectional flow of fault current. This paper presents a comprehensive survey of various islanding protection schemes that are being developed, tested and validated through extensive research activities across the globe. The present trends of research in islanding operation of RDGs are also detailed in this paper.

O-3.   Conti, S.: *Analysis of Distribution Network Protection Issues in Presence of Dispersed Generation,* Electric Power Systems Research, Vol. 79, Issue 1, January 2009.

The presence of a significant dispersed generation (DG) capacity in existing distribution systems would cause in most cases some conflicts with correct network operation. This is mainly due to conceiving a distribution system as a "passive" radial network, with neither generators operating in parallel nor power flow control. Issues such as voltage regulation, system protection, and, generally speaking, power quality are still being investigated by researchers in order to maintain adequate service to customers in presence of DG. The present paper illustrates an analysis of the relevant malfunctioning problems that may take place in distribution networks protection schemes in presence of DG. In particular, operation conflicts between distribution protection and DG are discussed with reference to unforeseen increase in short circuit currents, lack of coordination in protection schemes, ineffectiveness of line reclosing after a fault using automatic reclosing devices, undesired islanding and untimely tripping of DG interface protections. The present study aims at highlighting the need for changes, with respect to current distribution protection philosophies, which should be made by planners and distribution operators in order to increase DG penetration in distribution networks and to provide improved service continuity to customers.

O-4.   El-Zonkoly, A. M.: *Fault Diagnosis in Distribution Networks with Distributed Generation,* Electric Power Systems Research, Vol. 81, Issue 7, July 2011.

The penetration of distributed generation (DG) in distribution power system would affect the traditional fault current level and characteristics. Consequently, the traditional protection arrangements developed in distribution utilities are difficult in coordination. Also, the reclosing scheme would be affected. With the rapid developments in distribution system automation and communication technology, the protection coordination and reclosing scheme based on information exchange for distribution power system can be realized flexibly. This paper proposes a multi-agent based scheme for fault diagnosis in power distribution networks with distributed generators. The relay agents are located such that the distribution network is divided into several sections. The relay agents measure the bus currents at which they are located such that it can detect and classify the fault, and determine the fault location. The proposed technique uses the entropy of wavelet coefficients of the measured bus currents. The performance of the proposed protection scheme is tested through simulation of two systems. The first system is a benchmark medium voltage (MV) distribution system and the second system is practical 66 kV system of the city of Alexandria.

O-5.   Javadian, S. A. M.; Haghifam, M.-R.; Bathaee, S. M. T.; M. Firoozabad, M. F.: *Adaptive Centralized Protection Scheme for Distribution Systems with DG Using Risk Analysis for Protective Devices Placement,* International Journal of Electrical Power & Energy Systems, Vol. 44, Issue 1, January 2013.

Conventional electric distribution systems are radial in nature, supplied at one end through a main source. These networks generally have a simple protection system usually implemented using fuses, re-closers, and over-current relays. Recently, great attention has been paid to applying Distributed Generation (DG) throughout electric

distribution systems. Presence of such generation in a network leads to losing coordination of protection devices. Therefore, it is desired to develop an algorithm which is capable of protecting distribution systems that include DG, through diagnosis and isolation of faults. A new approach for the protection of distribution networks in the presence of DGs is presented in this paper. The algorithm is based on dividing an existing distribution network into several zones, each capable of operating in island operation. In the suggested method, risk analysis is used to optimize the protection zones by optimal placement of protective devices. Multilayer Perceptrons (MLPs) neural networks are used for determination of faults. The proposed scheme has been implemented on a selected part of a real distribution network of a large city and a MATLAB based developed software has been used to implement the proposed algorithm on the real network data.

O-6.   Jiadong, H.; Zeyun, Z.; Xiaobo, D.: *The Influence of the Distributed Generation to the Distribution Network Line Protection and Countermeasures,* 2012 International Conference on Applied Physics and Industrial Engineering; Physics Procedia, Vol. 24, Part A, 2012.

This paper analyses the impact of distributed generation on the sensitivity and selectivity of distribution network line protection, proposes the method of using impedance current limiter in solving the impact of the increased current that distribution generation provides on the protection selectivity. Also, gives the position of limiting impedance location and the selection method of the scheme, the feasibility of scheme is verified through an example.

O-7.   Khederzadeh, M.: *Integration of Renewables into the Distribution Grid Needs New Software Tools for Coordination of Protective Relays,* 2012 CIRED Workshop on Integration of Renewables into the Distribution Grid, 2012.

Traditional software tools developed for distribution system simulation and overcurrent protection coordination need to be revised to cope with the progressive integration of renewable distributed energy resources (DERs) in distribution grid to achieve better relay protection and coordination. Meanwhile, adoption of the microgrid concept results in certain problem for the protective relays using conventional techniques because of the downstream sources that can feed the fault and also the appreciable difference between the utility-grid connected mode and autonomous (islanded) mode. Traditional distribution grid protection is based on the overcurrent scheme with the flow of fault current from the upstream sources. However, the protection confronts with two main issues: firstly, the radial configuration of the distribution network is jeopardized by the distributed resources; and secondly the DERs have a stochastic nature and the contribution of fault current from the downstream is no longer a certain parameter that could be evaluated at the design stage. This paper analyzes the new requirements and strategies expected to be included in the traditional software tools in order to be applicable for the complex future distribution grids.

O-8.   Lin ,X.; Dong, X.; Lu, Y.: *Application of Intelligent Algorithm In Island Detection of Distributed Generation,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

In the grid-connection, the distributed generation system in the status of the islanding is liable for damage to equipment, affecting the performance of the utility. Seriously, island may create a hazard for utility line-worker. Islanding detection methods for distributed generation system are reviewed. Characterized by high efficiency and performance, C4.5 decision-tree is particularly applicable to the condition of large amounts of mining data. The paper proposes a new approach based on C4.5 decision-tree for islanding detection in distributed generation system. Without any negative effect on the power quality, this

novel method greatly reduces the damage to the utility resulting from the islanding running state, and also highly enhances the capability of detecting islands of the protection relay. How to construct C4.5 decision-tree on the basis of past operation data of an existed distributed generation system was introduced in detail firstly. And this method was tested on a typical distribution system with multiple distributed recourses by using Matlab/Simulink tools. The simulation results show that C4.5 decision-tree is effective and the island operating mode of DGs can be totally forecasted by this new algorithm.

O-9. Mora-Flòrez, J.; Meléndez, Carrillo-Caicedo, G.: *Comparison of Impedance Based Fault Location Methods for Power Distribution Systems,* Electric Power Systems Research, Vol. 78, Issue 4, April 2008.

Performance of 10 fault location methods for power distribution systems has been compared. The analyzed methods use only measurements of voltage and current at the substation. Fundamental component during pre-fault and fault are used in these methods to estimate the apparent impedance viewed from the measurement point. Deviation between pre-fault and fault impedance together with the system parameters are used to estimate the distance to the fault point. Fundamental aspects of each method have been considered in the analysis. Power system topology, line and load models and the necessity of additional information are relevant aspects that differentiate one method from another. The 10 selected methods have been implemented, tested and compared in a simulated network. The paper reports the results for several scenarios defined by significant values of the fault location and impedance. The estimated error has been used as a performance index in the comparison.

O-10. Shahriari, S. A. A.; Abapour, M.; Yazdian, A.; Haghifam, M. R.: *Minimizing the Impact of Distributed Generation on Distribution Protection System by Solid State Fault Current Limiter,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

Connection of new distributed generation (DG) to the existing distribution network increases the fault current and disturbs the existing distribution protection system. In this paper a solid state fault current limiter (SSFCL) application is proposed to minimize the effect of the DG on the distribution protection system in a radial system during a fault. The protection problems at distributed generation presence are studied in detail to determine the effectiveness of the SSFCL for the proposed application. The effectiveness of the proposed SSFCL in protection problems mitigation is determined and examined in the test system. Simulation is accomplished in PSCAD/EMTDC. The proposed method is fully validated on test system.

O-11. Voima, S.; Kauhaniemi, K.: *Benefits of Using Telecommunication Based Protection with DG,* 2012 CIRED Workshop on Integration of Renewables into the Distribution Grid, 2012.

As the number of distributed generation (DG) units connected to medium voltage (MV) networks increases the structure of networks is changing and getting more complex. As a result the requirements for protection are getting more and more complicated and are playing an increasingly important role. Protection of DG units with traditional protection schemes causes performance degradation and in some cases sufficient protection levels may become unattainable. In this paper the issues with traditional protection are addressed. The benefits of using of using telecommunication based protection schemes with DG are presented from which the most important advantages are improved selectivity and decreased fault clearing times.

O-12. Zayandehroodi, H.; Mohamed, A.; Shareef, H.; Farhoodnea, M.: *A Novel Neural Network and Backtracking Based Protection Coordination Scheme for Distribution System with Distributed Generation,* Electric Power Systems Research, Vol. 78, Issue 4, April 2008.

With the increased installation of renewable energy based distributed generations (DGs) in distribution systems, it brings about a change in the fault current level of the system and causes many problems in the current protection system. Hence, effective protection schemes are required to ensure safe and selective protection relay coordination in the power distribution system with DG units. In this paper, a novel adaptive protection scheme is proposed by integrating fault location with protection relay coordination strategies. An automated fault location method is developed using a two stage radial basis function neural network (RBFNN) in which the first RBFNN determines the fault distance from each source while the second RBFNN identifies the exact faulty line. After identifying the exact faulty line, then protection relay coordination is implemented. A new protection coordination strategy using the backtracking algorithm is proposed in which it considers the main protection algorithm to coordinate the operating states of relays so as to isolate the faulty line. Then a backup protection algorithm is considered to complete the protection coordination scheme for isolating the malfunction relays of the main protection system. Several case studies have been used to validate the accuracy of the proposed adaptive protection schemes. The results illustrate that the adaptive protection scheme is able to accurately identify faulty line and coordinate the relays in a power distribution system with DG units. The developed adaptive protection scheme is useful for assisting power engineers in performing service restoration quickly so as to decrease the total down time during faults.

P. General

P-1. Balamurugan, K.; Srinivasan, D.; Reindl, T.: *Impact of Distributed Generation on Power Distribution Systems,* PV Asia Pacific Conference 2011, Energy Procedia, Vol. 25, 2012.

In order to reduce the green house gas emissions all over the world the investment on renewable energy infrastructure is increasing particularly in the distribution network. The penetration of generating sources in the distribution network changes the characteristics of distribution system and will have impact on various technical parameters based on its size and location in the network. This paper modeled the IEEE 34 Node distribution test feeder using the commercial software package DIgSILENT power factory version 14. Solar photovoltaic generators are introduced as Distributed Generators (DGs) at various nodes and the impacts that DG produces on real and reactive power losses, voltage profile, phase imbalance and fault level of distribution system is studied. Simulated results obtained using load flow and short circuit studies are presented and discussed.

P-2. Flinn, D.; Korinek, D.; Tutaj, C.: *PV Impacts on Distribution Feeders,* 2011 DistribuTECH Conference and Exhibition, February 2011.

In addition to providing energy over the course of the year, PV facilities impact the distribution systems of California's electrical grid. PV systems reduce loading on the distribution lines by displacing remote sources of energy. Reduced line loading at the time of peak demand alleviates the need to expand the transmission and distribution (T&D) infrastructure. Moreover, by reducing the amount of energy that needs to be delivered to the grid, PV facilities may lower the risk of overloads, which in turn increases overall system reliability. This paper presents the impacts of PV facilities on California's investor-owned utilities' (IOU) distribution systems and sorts these impacts

into groups by selected feeder characteristics. This paper is based on a technical assessment performed by KEMA, Inc. (in conjunction with Itron, Inc.) to determine the impacts of the California Solar Initiative on the state's T&D systems in 2009.

P-3.   Gaviano, A.; Weber, K.; Dirmeier, C.: *Challenges and Integration of PV and Wind Energy Facilities from a Smart Grid Point of View,* PV Asia Pacific Conference 2011, Energy Procedia, Vol. 25, April 2012.

The increasing share of renewable energies, especially solar photovoltaic (PV) and wind, will require coordinated efforts in order to adapt them to the future grid infrastructure. For that, the communication between electronic devices is a key technology. Although there is an international communication standard with IEC 61850 and the required models for energy systems are already specified, they face an existing heterogeneous system structure in reality. Therefore a migration concept is required in order to integrate today's fragmented devices. Standardised communication and certified products are required to ensure security, safety and reliability in a diversified future grid infrastructure.

P-4.   Kato, T.; Inoue, T.; Suzuoki, Y.: *Impact of Large-scale Penetration of Photovoltaic Power Generation Systems on Fluctuation Property of Electricity Load,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

Power output fluctuation of photovoltaic power generation systems (PVSs) may cause negative impact on the load frequency control of existing electric power system when the penetration of PVSs is quite large. For the cost-effective mitigation, the proper evaluation of apparent electricity load fluctuation property is very important, taking PVSs power output into account as negative load. Considering the independency of fluctuation patterns of insolation among various locations, this study evaluates the standard deviation of total power output fluctuation of PVSs by using the multi-point observation data of insolation. The diversity of PVSs penetration in the wide area is taken into account based on the statistical data of distribution of residences. Then, by taking the standard deviation of electricity load into account, this study discusses the impact of large-scale penetration of PVSs on the load frequency control.

P-5.   Lew, D.; Piwko, R.: *Western Wind and Solar Integration Study,* National Renewable Energy Laboratory, May 2010.

The focus of the Western Wind and Solar Integration Study (WWSIS) is to investigate the operational impact of up to 35% energy penetration of wind, photovoltaics (PVs), and concentrating solar power (CSP) on the power system operated by the WestConnect group of utilities in Arizona, Colorado, Nevada, New Mexico, and Wyoming. WWSIS was conducted over two and a half years by a team of researchers in wind power, solar power, and utility operations, with oversight from technical experts in these fields. This report discusses the development of data inputs, the design of scenarios to address key issues, and the analysis and sensitivity studies that were conducted to answer questions about the integration of wind and solar power on the grid.

P-6.   Steffel, S. J.: *Distribution Grid Considerations for Large Scale Solar and Wind Installations,* 2010 IEEE PES Transmission and Distribution Conference and Exposition, April 2010.

The distribution power grid paradigm has changed. Renewable energy installations are becoming increasingly popular due to incentives created by public policy, environmental consciousness and the desire by the end user to reduce energy costs. A recent industry report indicates that cumulative grid-tied PV capacity in the U.S. grew to 792 MW by the end of year 2008, with an 81% increase in new grid-tied PV installations in 2008 over 2007 and 53% in 2007 over 2006. The distribution grid is now viewed as a two-way pathway

for power, although it was built to carry power in one direction. Small scale, renewable systems are being added to the grid without modeling; however, large scale solar and wind require special power system modeling and analysis to insure the installation does not create voltage violations or protection issues for the distribution grid.

APPENDIX B

Proceedings of the June 11, 2012 IEPR Workshop on Renewable Integration Costs, Requirements and Technologies

Introduction

The purpose of this workshop was to seek input from experts, stakeholders, and the general public on integration issues related to increased penetration of renewables in California's electricity system. The workshop addressed the ancillary services needed to integrate renewable resources while maintaining grid reliability, and how those needs may change over time; and the integration services that could be provided by energy storage, demand response, and/or natural gas fired plants.

This workshop provided information needed to implement the overarching strategy to address barriers to renewable development that was identified in the Energy Commission's *Renewable Power in California: Status and Issues* report, of which the primary objective was to:

> "Develop a strategy that minimizes interconnection costs and time, and also minimizes integration costs and requirements at the distribution level (such as the use of remote telemetry and other smart grid technologies) and the transmission level (such as improved forecasting, the development of an energy imbalance market, and procurement of dispatchable renewable generation), and that strives for cost reductions and improvements to integration technologies, including storage, demand response, and the best use of the state's existing natural gas-fired power plant fleet."

It was stated that the Lead (Energy) Commissioner would consider input from this workshop together with other information from the 2012 IEPR Update Proceeding to develop specific strategies and action items to facilitate renewable integration at both the distribution and transmission level to support meeting California's renewable energy goals for 2020 and beyond.

Meeting Notes

Introduction

Suzanne Korosec, Manager of the Energy Commission's Integrated Energy Policy Report (IEPR) Unit, welcomed the participants to this workshop on Renewable Integration Costs, Requirements and Technologies. Commissioner Carla Peterman noted that this was the eighth and final workshop in a series examining a spectrum of issues relating to renewable generation, and this one would focus on the technical issues with integration of renewables in the electric system. Specifically, there are three pillars of success for integration: natural gas plants, demand response, and storage. Each was examined in turn, and the Workshop participants were asked to contribute their views and ideas for better methods and systems for investing in, going forward.

Commission Chair Robert Weisenmiller expressed his appreciation for the participants' efforts in discussing the operational characteristics of, and cross-comparing, the three areas of technology that Commissioner Peterman mentioned as critical to the integration efforts of renewable generation Commissioner Andrew McAllister was also in attendance, and the CPUC was represented by Commissioner Timothy Simon, who noted the significance of California as the site of cutting-edge research and technology development in renewables integration.

Renewable Integration Costs, Requirements, and Technologies

Presenter: Suzanne Korosec, Manager, Energy Commission IEPR Unit.

Every two years, the Energy Commission prepares an Integrated Energy Policy Report that covers a variety of energy topics and makes policy recommendations to the Governor, with an update prepared in the off years. In 2010, Governor Brown directed the Energy Commission to prepare a plan to expedite permitting of priority renewable generation and transmission projects. To provide the foundation for that plan, the Energy Commission developed the *Renewable Power in California: Status and Issues Report* as part of the 2011 IEPR, which described the status of renewable development in California, some of the challenges to future renewable development, and current efforts to address those challenges. The report also established five high level strategies as the basis for a more comprehensive Renewable Strategic Plan that will be part of the 2012 IEPR Update. Chapter 6 of the Report addressed Distribution-Level Integration Issues. Three types of infrastructure were identified as "Partners for Success" in addressing these issues: natural gas generating plants, demand response programs, and energy storage systems.

Distribution-level integration issues included the potential for power backflow, islanding, voltage variations, the lack of coordinated transmission/distribution system planning, and the need for uniform/open standards for distribution. Notable efforts to address these issues include, among others, smart grid development (e.g., Senate Bill 17, utility smart-grid deployment plans), utility investments in infrastructure upgrades, PIER research on voltage, power flow, and harmonics effects from distributed PV, a SMUD pilot to demonstrate inverter communications, and a KEMA, Inc. study of distributed generation in Europe.

The Workshop comprised four panel sessions: 1) Addressing Integration Challenges at the Transmission and Distribution Levels, 2) The Role of Natural Gas Plants in Providing Integration Services, 3) The Role of Demand Response Programs, and 4) The Role of Energy Storage Systems. Time was allotted at various points for public comment.

Written comments were due to the Commission by close of business, June 18.

Panel #1: Integration Issues Associated with Increased Renewable Penetration
Moderator was Melissa Jones, CEC. This panel focused on discussing the types and levels of ancillary services that are going to be needed to integrate large amounts of renewable resources, both at the transmission and at the distribution level. It also addressed some of the uncertainties associated with those needs.

Strategies to Minimize Renewable Integration Costs and Requirements and Improve Integration Technologies
Presenter: Mark Rothleder, Executive Director for Market Analysis and Development, CAISO.

The CAISO's renewable integration studies have produced some results in terms of indicating the operational requirements for the system with renewable generation. *Those results reported here essentially pertained to transmission-level issues.*

Meeting Renewable Energy Targets in the West at Least Cost: The Integration Challenge
Presenter: Lori Bird, NREL.

The Western Governor's Association (WGA) is coming out with a new report titled, *Meeting Renewable Energy Targets at Least Cost: The Integration Challenge*, that goes through a number of options that states could use to integrate larger amounts of renewable energy, and which ones are the least cost options. It's not a quantitative analysis; it's based on existing literature and studies that have been done. *Remarks made essentially pertained to transmission-level issues.*

Understanding Distribution-Level Integration Challenges
Presenter: Ben Kroposki, Director, Energy Systems Integration, NREL.

California has a goal of 12,000 MW of localized energy generation or distributed generation, which poses a unique challenge to the grid. Most technical concerns with interconnection of renewable energy at the bulk level have been solved with modern inverters and grid codes; technical concerns at the distribution level have been identified, but the solution set is not standard and small renewables have not been fully integrated into planning and operations. But these concerns are solvable.

Distribution integration issues:

- The current electrical grid is designed to move electricity in one direction: from central-station generators to substations to customers.
- However, as more distributed generation is added to the system, power generated by these resources may exceed demand and flow backward into circuits or substations, requiring new protection and control strategies to avoid damaging the electric system.
- There is a high variability in distribution system design, construction and sometime operating practice. This does not make a standard solution easy.
- There are an increasing number of requests for interconnection, and consequently there is a need to reduce the complexity, expense, and length of time associated with that process.

Germany has installed a considerable amount of PV on its distribution system, due to incentives and low PV costs, and is clearly the world leader in distribution-level grid integration of renewable energy sources. They have experienced 100 to 200% PV penetration in some locations, much higher than the 15% rule of thumb in the US. So Germany's experience can provide some lessons for us, in that they have dealt with these issues during a fast ramp-up in PV capacity. NREL is also working with California utilities on a number of studies to address the abovementioned challenges.

NREL's Energy Systems Integration Facility provides a user test-bed for conducting research and development of clean energy technologies in a systems context at deployment scale.

Potential technology solutions include:
- Distribution system upgrades
- Inverter technologies with advanced functionality (volt/VAR control, fault ride through, remote communications, power curtailment)
- Standardized control and communications interfaces
- Standard methods to identify best locations for integration
- Integration of local load control and energy storage

Standards and regulatory solutions include:
- Updated interconnection requirements to include advanced inverter functionality
- Updated industry standards: IEEE 1547, UL 1741, SGIP, WDAT, Rule 21
- Streamlined interconnection process based on rigorous screens
- Streamlined and digitized permitting process

Panel #2: Operational Characteristics of Natural Gas Plants to Support Renewable Generation
Moderator: David Vidaver, CEC. This panel session focused on what natural gas needs to do to provide the services that increasing levels of intermittent resources require, what gas is able to do now, and where it needs to go forward to provide the needed services.

Panelist: Mark Rothleder, Executive Director for Market Analysis and Development, CAISO

Ideal resources can ramp fast, start quickly (in 10-60 minutes), have low minimum load capability, can provide regulation, can provide either inertia because they have a rotating mass, or can provide some kind of frequency response and/or a voltage response. Currently, the CAISO is looking at flexible ramping products and enhanced regulation capacity, and studying the requirements for improved frequency regulation and forward-looking capacity procurement mechanisms. *While these remarks were directed to transmission-level integration, they have some relevance to integration of renewables at the distribution level.*

Panelist: Mark Smith, Calpine
Mark Smith stated that he agreed with Mr. Rothleder on the points he made. He added that Calpine supports the CAISO's recent efforts to look at the disincentives, things like the way costs are recovered through bid cost recovery; it's a detail, but it's an important detail to offer incremental flexibility.

But the issue is that the current market does not provide enough compensation for generators to recover the going-forward costs of these investments. A longer term forward commitment makes sense, maybe 3-5 years, and ideally one that is attribute-based. The best solution would be to create a market where people can bid what their true costs are, and allow that market to find a way to meet those demands. *While these remarks were directed at transmission-level integration, they will likely have increasing relevance to integration of renewables at the distribution level at high penetration levels in general.*

Siemens Flexible Generation for Renewable Integration
Presenter: Bonnie Marini, Director, 60 Hz Product Line, Siemens Energy, Inc.

Siemens has been working on developing flexible combined cycles to integrate renewables for more than a decade now. Siemans' Flex-Plant™ 10 combined cycle unit was designed to be a peaking plant that could ramp fast and still meet emissions requirements.

There are challenges to getting these technologies into the market. One is how to provide cost incentives, because right now there is little pay-off in many regions for flexibility and adding these capabilities to the cycle. Another here in California is that the entire process for putting in and choosing these cycles is very long, and that adds some challenges to implementing the latest technologies. There is also the uncertainty in demand for new natural gas units in the next five years or so. *While these remarks were directed at transmission-level integration, they will likely have increasing relevance to integration of renewables at the distribution level at high penetration levels in general.*

Panelist: John Kistle, AES Energy
AES owns and operates a number of older, gas-fired, once-through cooled units in the LA basin that will need to be repowered in the near future. *While these remarks were directed at transmission-level integration, there might be instances where these issues and those of integration of renewables at the distribution level interact.*

Generation Storage: Integrating Renewables with California's Hidden, Flexible, Peak Capacity
Presenter: Tom Pierson, Founder & CTO, TAS Energy, Inc.

California has about 1,500 MW of additional capability in its existing gas plants, which can be accessed via Generation Storage. Gas turbines lose efficiency at higher temperatures, which is exactly when one doesn't want to lose fleet capacity. But this lost power can be regained by using renewable generation to chill water, which is stored and then used to regulate the inlet temperature.

The main barrier is: what's the incentive to invest in this, i.e., how do the investment costs get recouped in today's markets? In California, it could definitely play in the 5-minute ramping

market. *These remarks have relevance to the integration of a specific application of distributed generation co-located with each thermal fossil plant.*

Panel #2 Discussion and Comments:

Q: What factors go into defining "restrictive" or "receptive" transmission lines for the purpose of dynamic transfers?

A: CAISO did some studies looking at dynamic transfers, and concluded there would not be any significant limitations on the major paths due to the expected level of renewables. Studies with other balancing authorities are being done to identify any other limitations, e.g., due to voltage control devices. *While these remarks were directed at transmission-level integration, they will likely have increasing relevance to integration of renewables at the distribution level at high penetration levels in general.*

Panel #3: Assessing Demand Response Potential to Provide Renewable Integration Services
Moderator: Mike Gravely, CEC.

This panel focused on using demand response (DR) for ancillary services or for supporting renewable integration, especially as an alternative to storage or natural gas plants. Classically, DR is used for peak load reduction, but this meeting's focus was on using it for integration of renewables.

Renewable Integration in PJM: Wholesale Market Developments
Presenter: Scott Baker, Business Solutions Analyst, PJM Interconnection.

PJM expects to have 14% renewable energy by 2026. Scott Baker's presentation focused on PJM's regulation market and how it's changing because of the new technologies, and on the demonstrations that PJM has done to help accommodate these new technologies. The other reason for making changes to PJM's regulation market is to increase the efficiency of that market as we move to a performance-based regulation market, which means that resources will be compensated based on their contribution to system control.

PJM has about 14 GW of DR capability, mostly in the day-ahead capacity market. Changes in market rules and technology improvements would be needed to use it in the hour-ahead markets for renewable integration. *While these remarks were directed at transmission-level integration, integration of renewables at the distribution level will likely need to be factored into the use of DR for providing renewable integration service in general.*

Framework to Identify and Address Barriers for Demand Response as Ancillary Services
Presenter: Andy Satchwell, Lawrence Berkeley National Laboratory (LBNL).

LBNL has been working with the Western Governors Association, WECC and DOE on projects that look at DR in the context of ancillary services, and the identification of barriers related to using DR as ancillary services. Simply put, what's the business case for these types of resources?

Overcoming these barriers requires policymakers and regulators to consider encouraging the development of fast DR in both the short- and the long-term. For example, customers have more short-term DR capability than the utility usually needs, but barriers prevent it from being used effectively. Notable is the problem of compensation; there needs to be a consistent value function to encourage and incent customer participation. *While these remarks were directed at transmission-level integration, integration of renewables at the distribution level will likely need to be factored into the use of DR for providing renewable integration service in general.*

Panelist: John Hernandez, PG&E
PG&E is a strong supporter of OpenADR, as it can help bring DR into the market in a meaningful way. But right now, DR cannot provide the desired level of service. Also, DR needs

to be implemented in a cost-effective manner. There are also capacity issues on the wires side of the utility with consumption-based DR.

It needs to be realized that customers aren't power plants. Customers can help provide DR, but it will take a lot of education and diversity outreach; third parties can play a helpful role here. *While these remarks were directed at transmission-level integration, integration of renewables at the distribution level will likely need to be factored into the use of DR for providing renewable integration service in general.*

Panelist: Anthony McDonald, Target

Target has DR at about 800 locations around the country, participates in about 23 markets, and is able to shed about 55 MW of load at any one time. Target utilizes ADR technology, and OpenADR in California. Response time is under 3 minutes, currently. That's a function mostly of network speed, and Target is hoping to improve on it.

Target is also looking for consistency in how these various programs across the country are managed, and how they're operated. Target participates in standard DR programs across the state; for participation in California Fast Demand Response Programs, having OpenADR consistent across the state would be a boon to greater Target participation. *These remarks apply for either transmission or distribution level renewable integration.*

Smart Grid Solutions That Pay
Presenter: Ron Dizy, Enbala Corp.

To run a power market, three things are needed: energy, capacity and flexibility. There are ways for load to participate in all of those markets. However, because loads in general use electricity to do something important, it is Enbala's opinion DR in energy markets will always be somewhat limited. Most of what loads have done so far has been in capacity markets, but much of North America isn't capacity constrained right now. The really big opportunity is in "Flexibility," the need for which is growing as more renewables are introduced and parts of the generation fleet are retired that used to supply that flexibility.

Loads will be able to respond with sufficient speed; that's mostly an IT issue, and solvable. The bigger problem is frequency: how often the load will be called to respond, and what the impacts on the load might be. Traditional DR, curtailment four or five times a year, is basically operating reserve; in today's markets it might get called 3-4 times per month. But with renewables in the system, DR might get called upon multiple times a day, so maybe thousands of times a year. And if DR is used for frequency regulation, which is every 4 seconds, it could get called up to 7-8 million times a year. So the communication implications are great.

Loads aren't always 100% available; the system needs to find a way to use the loads with the limited amount of flexibility and availability they have. An intelligent IT system that can work with the various loads in real time can be a very economical solution.

Rules changes approved by FERC allow PJM to use smaller loads for DR, use submetering to access some small parts of big loads, and regulation-only service providers. *While these remarks were directed at transmission-level integration, they will likely have increasing relevance to integration of renewables at the distribution level at high penetration levels in general.*

Panelist: Rick Counihan, EnerNOC

EnerNOC is a curtailment services provider; that works with commercial customers only, no residential. It is active in emergency DR, e.g., when a line falls down. EnerNOC is also active in economic DR, i.e., when prices are high, and ancillary services: spinning, non-spinning, load following, reservation, and synchronized reserves.

Many of the barriers to DR are the result of legacies of rules that were created when nobody could imagine anything providing the service, except for a generator. For example, telemetry

typically required for a generator is not cost-effective for small loads, so communications and rules that recognize the nature of the demand resource are needed. The roadmap for DR in California has some disconnects in it that work against third-party aggregators being able to participate in CAISO-controlled markets. *While these remarks were directed at transmission-level integration, they will likely have increasing relevance to integration of renewables at the distribution level at high penetration levels in general.*

Panelist: Matthew Tilsdale, CPUC
Update on CPUC Rulemaking 701041: Progress was being made on this proceeding last year to set up the Commission's rules for what would be allowed in terms of aggregation of utility customer load and bidding of that load directly into the CAISO market. The tariff CAISO proposed to FERC was rejected, so further workshops and hearings will take place this year, and a revised rule issued by the CPUC by end of this year. *While these remarks were directed at transmission-level integration, they will likely have increasing relevance to integration of renewables at the distribution level at high penetration levels in general.*

Demand Response Potential to Provide Renewable Integration Services
Presenter: Stephen Keehn, Senior Advisor, Market and Infrastructure Policy.

DR is one of a number of tools we have to balance markets. And DR can address a number of different types of needs. If we set the markets up fairly, Market and Infrastructure Policy believes that provides the best incentives and the most accurate prices, and those are going to drive what's needed. We need to know that DR will respond when we send instructions; that means we have to measure what that response is so that we can control the grid. Therefore, the telemetry, the visibility and control aspects are very important, and they will probably be different for transmission vs. distribution.

Panel #4: The Role of Energy Storage in Supporting Renewable Integration
Moderator: Pramod Kulkarni, Electricity Analysis Office, CEC.

This panel built on what was learned in previous IEPR workshops, and some of the ideas presented earlier in the workshop. It also included distribution-sited energy storage, keeping in mind the Governor's Plan for 12,000 MW of additional renewables in the distribution system.

CEC Renewable Integration Workshop – Energy Storage Panel
Presenter: Todd Strauss, PG&E

Todd Strauss talked a bit more broadly, and in particular, in terms of the cross-comparison of technologies that was mentioned earlier. That's actually critical when thinking about renewable integration. There are two broad elements to this: 1) a framework for thinking about that cross-comparison in terms of our policy, planning, procurement and operational activities, and 2) a portfolio approach and, in particular, what PG&E, the Energy Commission, the Public Utilities Commission, and the State might do, in terms of the portfolio approach.

With respect to the framework, the policy in California is technology-based, but planning is resource-based, procurement is product-based, and operations are asset-based.

He summed up with: California needs to move from a technology silo, carve-out, set-aside policy to a market-based competition in the product space, and the Commission and the State of California should encourage that approach. We should use techniques, methodologies and approaches that encourage a portfolio approach, so each asset, program, transaction is not valued strictly on its own, but in that portfolio context.

Renewable Integration in California
Presenter: Jim Eyer, California Energy Storage Alliance (CESA).

CESA challenged the notion that storage is not cost-effective; it is (cost effective), if all the benefits are captured. But prices that reflect all the benefits are required, as is a forward-looking market, and we need compensation mechanisms that attract investment and cost-effective applications. An inclusive, applications-based approach is needed to fully evaluate the cost-effectiveness of storage. There is a diverse array of types of storage, which can address the requirements of many different applications, and can also optimize operation of the conventional generation fleet, which facilitates renewables integration directly.

At the distribution level, where it's mostly PV, output and demand are mis-matched, and ramping is a concern. Storage can help manage the mismatch between output and demand, regional generation variability, and the power quality impacts of renewable energy. For distribution-side PV, storage can also help manage localized ramping-related challenges, voltage and reactive power, harmonic, and current backflow, and it can enable microgrids and islanded operation.

He offered these suggestions: Next, we need continuing innovation and more evidence that can only be derived by demonstrations, including software dispatch storage for optimized benefits. Secondly, we need electricity market design with modern rules, ease of access, and long term contracting that accommodates the range of ownership models. And fortunately, the CPUC is making some excellent and timely progress in that regard. CESA urges the CEC to provide analytical and technical support for the PUC's storage rulemaking, especially with respect to benefit quantification for cost-effectiveness and valuation of the flexibility of storage.

Buffering the Adverse Impacts of PV and EV on Distribution Circuits with Community Energy Storage
Presenter: Ali Nourai, KEMA.

Ali Nourai observed that there are two key emerging challenges that distribution circuits are facing are renewables, particularly residential PV; and electric vehicles, particularly multiple units in the same neighborhood. While there are benefits to these developments, they come with "adverse impacts" on the local power system that need to be mitigated. Storage systems can buffer these adverse impacts.

Storage needs optimal location for highest value, and its value will be highest closest to the customers. Storage also needs optimal packaging for lowest cost. The cost won't come down, though, until storage can be mass-produced and non-repeat integration costs eliminated. Lower costs, higher round-trip efficiency, smaller size, and longer discharge times will be the keys to cost-competitiveness.

Community Energy Storage (CES) is usually sited at the distribution substation or transformer, providing local benefits to multiple customers. There are a number of manufacturers marketing storage systems for the CES market, so competition is happening.

A123 Systems' Energy Storage Projects & Applications Overview
Presenter: Charles Vartanian, A123 Systems.

Charles Vartanian stated that technology and cost are not barriers to storage, although cost does limit the opportunities somewhat. It's the regulatory treatment of storage that needs work.

A123 has a number of storage projects around the world that have demonstrated energy storage as an ancillary service asset, a help to inform some of the incremental market rule changes that are needed to broaden the access to energy storage as a participating technology, a frequency regulation service, a grid-side wind integration demo, providing wind ramp rate control, freeing up 12 MW of baseload generation that was used for regulation, so that 12 MW could be more economically used for providing energy, while the storage system did the regulation and could also provide spinning reserve..

Storage can be controlled to provide inertia; the concepts were demonstrated by Southern California Edison at Chino in 1994. If deployed at large scale, Advanced Energy Storage could help mitigate or prevent future blackouts in California.

While these remarks regarding demonstrated applications of energy storage were directed at transmission-level integration, they will likely have increasing relevance to integration of renewables at the distribution level at high penetration levels in general.

Energy Storage at CPUC
Presenter: Arthur O'Donnell, CPUC.

Arthur O'Donnell pointed out that one of the big drivers has been enactment of legislation, AB 2514, adopted in late 2010, which directed the Public Utilities Commission to look into whether utilities ought to be ordered to procure storage. The PUC has a deadline of October 1, 2013, to adopt energy storage procurement targets for the LSEs and utilities, if those targets are determined to be appropriate. The PUC was also ordered to consider a variety of possible policies to encourage cost-effective deployment of energy storage systems, including a refinement of existing procurement methods.

On the storage front, there has been a lot of preliminary work, notably the California Energy Commission's Storage 2020 Vision Report, which was seminal in helping us understand many of the issues around storage. Much of 2011 was spent in workshops trying to understand issues like the barriers to storage, what kind of regulatory issues are being faced by storage providers. This led to a staff proposal issued at the end of 2011 that laid out a course for us to follow in Phase 2, to examine storage applications to support renewable energy integration, to avoid or defer distribution system upgrades, to provide demand-side management services, and to provide ancillary services.

The CPUC has tried to focus on the most valuable uses of storage for utility generation for distribution and for customer-side, what we call Use Cases. Two that O'Donnell highlighted were Community Energy Storage with the primary benefit of local reliability, and Variable Energy Resource-sited for renewables integration.

Next Steps: The ALJ is currently writing a Proposed Decision to close out Phase 1 and formally introduce the Staff Proposal into the record, and to lay out the steps for Phase 2, which will include another scoping memo. The CPUC expects to have workshops this summer which will refine the Use Case Analysis, and staff will then identify potentials for specified targets and develop a roadmap for long-term action.

Integration Analysis and Value of Concentrating Solar Power with Thermal Energy Storage
Presenter: Udi Helman, BrightSource Energy.

Udi Helman explained that by adding thermal energy storage (TES) to BrightSource's concentrating solar power (CSP) plant, it (will) provide both dispatchability and flexible operation. Plus, there isn't the difficulty of how to analyze it with production simulation models that you might have with storage that's fed from the grid, with differentials for on-peak and off-peak energy costs.

TES allows the elimination of much of the uncertainty with forecasting the next day's production, to smooth output on cloudy days, and to slow down the solar ramp rates, which helps reduce the need for peaker plants. It also allows the plant to be used for spinning reserve, as BrightSource is demonstrating at SCE.

Concluding Comments

Commissioner Peterman:

She pointed out that there has been a full series of seven workshops. We (CEC) came up with five high-level strategies in the 2011 IEPR, and then conducted seven workshops to try to flesh out these strategies.

As far as next steps, we (CEC) will be developing a list of detailed recommendations to reach the 2020 goals, as well as to position us for higher goals going forward. We'll be putting out a draft document and asking for responses. We'll also be holding an IEPR workshop where we

Commission Chair Weisenmiller:

He added that, at the end of the day, it comes back to what are the values, and postulated that we were trying to frame this as a way of comparing some of our technology choices to provide some of those values for us, or some of the services

APPENDIX C

Proceedings of the June 21, 2012 Electric Transmission and Distribution Research Utility Technical Advisory Committee (TAC) Workshop

Introduction

The TAC had met several times during the preceding year in order to advise the Energy Commission on research issues and needs of importance to utilities. This workshop was aimed at developing the grid research activities that address electric grid and renewable generation integration issues and are independent of research funding sources.

Context for the meeting was (1) Electric T&D with high penetrations of utility- and distributed-scale renewable generation. (2) Governor's Brown's 12,000 MW of renewable DG. (3) Focus on Distributed Energy Resource Characterization research.

Objectives of the meeting were to review the outcomes of prior TAC meetings, review and advise on ongoing research as relevant to the purpose of TAC meetings, provide status on research activities for wide-area grid issues, and reassess research needs and priorities.

Attendees were representatives of the three California IOUs, CAISO, CEC, CIEE, and CSUS.

Meeting Notes

Update on Past TAC Meetings: Priorities Identified by TAC
Presenter: Merwin Brown

Previous meetings had identified specific projects in both transmission and distribution. The most recent meeting on Oct 5, 2011, agreed on a distribution focus with 5 primary priorities: Volt/VAR control, Distribution Modeling, Forecasting, Ancillary Services, and Energy Storage. However, it had been also recommended that a future meeting address remaining transmission issues. Accordingly, this workshop devoted a session to transmission research needs.

Status of Wide Area Issues Research

Presenter: Merwin Brown

Merwin briefly summarized each of a dozen recently completed transmission projects and distributed a summary report on ten PIER-funded research projects.

Reassess Wide-area Grid Issues: Discussion on Needs and Priorities

Presenter: Peter Klauer

Peter reported that CAISO had concluded that there are high priority needs that could benefit from research projects: (1) ISO system inertia and frequency response monitoring system, (2) Phase 3 Wide Area Energy Management System, (3) Analysis of the ISO generation fleet to meet 33% RPS requirement, and (4) Fleet optimization.

Distribution Issues Related to High-Pen Renewables: Research Updates and Highlights of Accomplishments to Date
Presenters: Jamie Patterson/Michael Sokol

Most of the PIER projects have focused on integrating high-penetration of renewables:

- Working with manufacturers, developed a 4 quadrant inverter for PV systems.
- Started a Volt/VAR project with PG&E.

- Funded a suite of solar and wind forecasting programs aimed at improving accuracy with a variety of technologies. One includes AWS Truepower looking at intra-hour to day ahead forecasting.
- Two battery storage projects and a thermal storage study with KEMA.
- Community projects include a demonstration project at UC Davis and an exploratory one in Humboldt County.

Several projects are in the area of energy storage. PIER has a history of working with DOE going back to 2002. Projects have involved flywheels, various battery chemistries, flow batteries, and microgrid - ultracapacitors. Some general lessons learned:

- Storage business cases are difficult. Multiple applications are required.
- Commercial market beyond end use is a moving target.
- Government projects do not create a market without industry participation.
- Benefits can be difficult to monetize.
- Policy needs to change for real storage growth.
- Business case needs to be more straightforward.

ARRA projects in California totaled $1.2B for Smart Grid and energy storage. Some lessons include:

- Commercial business case still difficult
- There is a need for storage to be an asset class and for policies to better consider the unique characteristics of storage.
- Cost reductions are less than hoped for.

The Energy Storage Vision 2020 is available on the Commission website.

A contract with LLNL uses high performance computing to determine storage needs in and beyond 2020.

Update on CIEE Activity; Discussion and Feedback from the TAC
Presenters: Lloyd Cibulka, Sascha Von Meier, Larry Miller

The last TAC meeting had defined a number of priorities. The presenters provided a review of work being done on those priorities.

- **Renewables Forecasting** (Lloyd Cibulka)
  There was a December Commission workshop on forecasting and another workshop in February by UVIG in Tucson. Lloyd reported that CIEE was doing an analysis and follow up on the workshops. It would assess state of the art and develop a white paper summarizing and defining further research needs, particularly related to distribution system impacts.

Discussion:
Getting the forecasts into the control rooms and translating to actionable information is still a significant issue.

- **Volt-VAR Optimization** (Sascha Von Meier)

  First the state-of-the art of what is really available needs to be assessed. What products can actually help to regulate voltage? How do we build a business case and what are the research gaps? We are looking to the TAC to find out what is working, what isn't, what are the issues, etc. Sascha explained that CIEE was at the beginning of this study, and would need TAC members' help in connecting with the right people in each of their companies.

  Discussion:

  On inverters, for example, there can be a huge gap between what people are asking for and what utilities really need. I don't think utilities have any real interest. We're simply not going to try to regulate systems behind the meter.

  Utilities would much prefer that any Volt/VAR system be under utility control rather than have that control be dictated by a 3rd party.

  This is true at the residential level, but for large commercial, we need to understand what potential there is.

  At the last meeting, there was agreement that large inverters are the priority.

  Small inverters may be useful if fully automatic and could be an asset in community based systems.

- **Distribution Modeling and Simulation** (Lloyd Cibulka)

  Lloyd pointed out that there are several types of models and simulations. The first step is to assess the current state. Are the tools available suitable for looking forward to 2020? He explained that this project would accumulate enough basic information to recommend needed research. The study was in the process of refining the scope of work. He explained that CIEE would need TAC members' help in connecting with the right people in each of their companies.

  Discussion:

  Q: What is the time frame? This is a need for the IEPR.

  A: Probably about a year.

  Comment: Use models for interconnection of DG, understanding the what and the why by using simulation.

Discussion of Future Research Needs and Goals

- **DER for Ancillary Services** (Sascha Von Meier)

  A question was asked: Is there still a need for research in this area? The TAC had discussed a number of possible areas for research.

  Discussion:

  Accuracy of forecasting impacts the need for ancillary services. Better forecasting could reduce the pressure.

  More resources are becoming available for ancillary services. There is opportunity for aggregation.

  We are moving from discrete resources toward virtual resources.

- **Storage** (Larry Miller)

  This was a brief review of the recent history of storage projects and the recommendations of the Energy Storage Vision 2020 report. Recognizing that energy storage was 5th on the

TACs priority list, The TAC was asked whether storage was still a priority and what projects should be considered.

Discussion:

Models are needed before more field testing. Dispatch algorithms are the 2nd step.

There is a question of who owns it, what are the priorities. Can they have multiple contracts (i.e. to provide multiple ancillary services)?

There are so many storage technologies, you need to pick one to study – which one is the best. Also, there are many potential applications for storage, several of which need to be addressed for a storage project to be cost-effective.

Best application is pumped storage, for backing up aggregated loads. But pumped storage is maxed out – maybe CAES is the next best. Below-ground sites (salt caverns) for bulk storage, but above-ground tanks should be feasible too, located at substations. The Marine Corps base north of San Diego is a good place to test. It may be easier to work with a large system.

PG&E has a 300 MW, $330 M CAES, DOE project – looking for a good geologic site.

Sac State has done some studies that show distributed storage can maximize efficiency (losses) on a system-wide basis.

Question re: storage models – how many would need to be developed?

Answer: It shouldn't be any more complicated than generator models.

Talking about models in terms of how they can respond to ancillary services: ramp up, ramp down, etc.

IEC 61850 protocol defines information models for storage.

A Sandia study suggests that CAES or Liquid Air Storage might be next after pumped hydro on the economic viability list.

Distribution Monitoring for Renewables Integration – Update on Working Group Meetings, Contract Status, Next Steps
Presenter: Sascha Von Meier

We have a contract for the 1st phase regarding pooling available data from utilities, creating a shared repository, and looking to determine what we actually have. Using the data for some analysis, phase 2 will supplement with new data to fill the gaps.

General Discussion
- **Updates by TAC members**
  This was an opportunity for TAC members to provide updates on events in their organizations.

  TAC Member Comments:

  - *Appreciative of moving forward with Volt/VAR. Extremely important.*

- *Good to take a fresh, open look and to revisit transmission issues – transfer capacity, NASPI, DMRI, storage, etc. Encouraged by what I heard. Lot of synergy happening.*
- *Some interesting evaluations going on with fast solid state controllers for dynamic voltage control at SCE.*
- *Glad to see the cooperation and exchange between utilities and CEC. Good group. Hope to continue under EPIC. Re intellectual property (IP) – would like process to be as open access as possible. Need a collaborative with one well planned and coordinated R&D program.*
- *On storage, it's a hot issue, but need to be thinking about alternatives to batteries, which are expensive.*
- *I like the collaborative process. I hope that EPIC continues or expands on that.*

- **Questions from TAC members**

   Q: What about the 3 advisory committees formed last year?

   A: We are discussing that now. We would like to retain them if at all possible.

Moving Forward: Next Steps

The question was asked: Any thoughts on what we need to cover in the next meeting?

Comments:

It may be wise to wait to have a meeting until EPIC plans reach a level of functionality.

[Response] There will continue to be PIER projects running through March, 2015, regardless of what happens with EPIC.

APPENDIX D

Proceedings of August 2 – 3 Workshops on the Electric Program Investment Charge (EPIC) Program

Introduction

This two-day series of presentations and panels was for the purpose of discussing the first triennial investment plan for the Electric Program Investment Charge (EPIC) Program.

Meeting Notes – Day 1

Commission Chairman Weisenmiller:

- Innovation and energy important to the Governor
- Senator Padilla's look at PIER has provided important lessons learned
- EPIC is a new program, not a continuation of PIER, and should be viewed as a pathway to implementation. Goal of the CEC EPIC plan is to provide pathway into utility programs, or renewable deployment programs
- Adoption date for the plan to be submitted to CPUC is last week in October

- Commissioners Weisenmiller and Peterman are the leads for the EPIC research and renewable programs for CEC, respectively.

Commissioner Peterman:
- Renewables are important; she would like to see how EPIC can help communities

Commissioner McAlister:
- Energy efficiency should be a strength for EPIC in the tradition of PIER.

Commissioner Schwartz & Cem Turhal (CPUC):
- Andrew Schwartz, Procurement Strategies Supervisor, CPUC, pointed out that he and Cem Turhal, Procurement Strategies Analyst, CPUC, were the points of contact for EPIC at CPUC.
- Andrew Schwartz instructed the participants that they were not to raise questions or make comments regarding past issues around the EPIC Program that came from the CPUC process, i.e., D.12-05-037, establishing a framework for the deployment of funds to provide ongoing support for the development and deployment of next generation clean energy technologies.
- AB32 emphasized; decarbonisation required—both of which require technologies.
- Cem gave an overview presentation of the EPIC Program (http://www.energy.ca.gov/research/epic/documents/2012-08-02-03_workshop/presentations/CPUC_EPIC_Introduction.pdf)
- EPIC Program focus is to be on pre-commercial activities; he referred to the "EPIC-Technology Maturation Curve" in slide 3.

The CPUC considered four focus areas:

- **Applied Research:** Activities supporting pre-commercial technologies and approaches that are designed to solve specific problems in the electricity sector.
- **Technology Demonstration and Deployment:** The installation and operation of pre-commercial technologies or strategies at a scale sufficiently large and in conditions sufficiently reflective of anticipated actual operating environments to enable appraisal of the operational and performance characteristics and the financial risks.
- **Market Support:** Incentives to support technologies that are commercially proven but need assistance to achieve economies of scale and be competitive with other more established technologies. (This focus was for the present excluded from EPIC scope.)
- **Market Facilitation:** A range of activities including program tracking, market research, education and outreach, regulatory assistance and streamlining, and workforce development to support clean energy technology and strategy deployment.

Budget: $162M/year

            Administrators: PG&E $15M/year

                                  SDGE $3M/year

	SCE	$12M/year
	CEC	$45M/year
Oversight:	CEC	$12.8M/year
	CPUC	$0.8M/year
	IOU	$3.4M/year

(5% discretion between categories)

- o Three investment periods: 2012-2014, 2015-2017, 2018-2020. The first IP will be short since 2012 will be past by the time it can be funded, hence "shoveling out of the door PDQ" in 2013.
- o Annual reports due 28 February of each year
- o Evaluation by independent team hired by the CPUC in 2016.

CPUC comments continued:
- Cem provided these guiding principles:
  - o Provide electric ratepayer benefits
    - Enhance reliability and safety
    - Reduce costs
    - Advance the "Loading Order"
    - Promote economic development
    - Reduce GHG emissions
    - Support clean transportation
    - Use ratepayer funds efficiently
  - o Proposed funding activities should be "mappable" to the utility value chain
    - Operations/market design
    - Generation
    - Transmission & distribution
    - Demand side management

Weisenmiller: We are here to implement EPIC, not litigate it.

Laurie ten Hope (Deputy Director, Research & Development Division, California Energy Commission):
- CEC and, separately, the IOUs, to determine the content of EPIC plans for submission to the CPUC.

- After the investment plan has been submitted in October following an October Business Meeting endorsement, there will be another cycle of workshops. The plan would be submitted to CPUC Nov 1.
- The DOE, ARB and utilities are part of the CEC coordination loop in order to preclude duplication of effort and to identify and enhance other funding sources.
- Emphasized the need to focus, a euphemism for reduced scope of content.
- Written comments to docket # 12-EPIC-01 by the 10th (well, 17th actually). Email to: dockets@energy.ca.gov.
- The first workshop day was focused on research, the second day on closer to market issues and on energy innovation clusters.

Frank Goodman (SDG&E, for the IOUs):

Frank Goodman, selected to speak for the three California IOUs, explained:
- The IOUs' focus is on increased safety, decreased costs, and increased reliability to ratepayers.
- Guiding principles to include GHG reduction measures.
- Identified two Valleys of Death, from Demo to Commercialization stage (2nd one) and Technology research to proof of concept stage (1st one) that need support.
- Emphasized importance of utility involvement in R&D:
    - Provide technical and end-user direction and skills.
    - Support through valley(s) of death
    - Work and coordinate with CEC applied research efforts; utility must be involved in the whole technology development chain
    - Emphasized the IOU interest in technology demonstration and deployment in: Grid Operations, Distribution, and Deployment mechanisms.
    - Emphasized that the microgrid (referring to SDG&E's Borrego Springs project) was a representative element of a utility system (I think he was saying that microgrids would become components in future grids, but he might have meant that working within a microgrid is representative of working in the larger grid). He also suggested that smart grid reporting value chain and process be used as a reference for EPIC.
    - SDG&E will be working with other R&D programs as well as with EPIC.

Breakout Sessions

The workshop at this point was divided into three breakout sessions to discuss specific aspects of the topics of demand response, energy generation, and grid operations. Each breakout session was chaired by an Energy Commission staff member. The full workshop was later reconvened and the breakout session chairs reported the findings of each session.

Breakout 1 – Demand-side Management
Moderator: Joe O'Hagan, CEC

Smart Communities:
- University campuses would make good demonstration sites. E.g., UCSD.
- Smart communities need demonstrations of integrated solar design (instead of bolt-on's) in order to get commercial financing.
- Multi-family buildings (i.e., blocks of flats) are a challenge for energy storage.
- Work needed on e-vehicle integration (two e-vehicles charging at the same time will trip transformers…)

Distributed generation
- needs to rely more on local (bio)fuel sources, and not on transporting fuels from more than 15 miles away.
- Fires caused by transmission lines are a high cost through litigation.

Environment and public health
- an urgent for good data for use by future projects, including biomass feedstock in the state. Possible topics:
- climate change impacts on infrastructure
- environmental barriers to clean energy development
- sustainable energy supply chain
- electricity generation impacts on public health
- electricity generation impacts on disadvantaged communities.

Market facilitation:
- Performance data clearing house
- Resource assessment and planning
- Permitting and deployment tools
- Innovation clusters
- Workforce development
- One comment suggested an ARPAe style program at a regional level to ensure project quality assurance giving credibility sufficient to unleash private investment.
- Biogas had a strong focus in the discussion and the CEC needs to think about this.
- Consumer behavior and human factors was a common theme.
- The question was raised about the definition of "zero net energy."

Weisenmiller:

- to look at the potential for energy efficiency in existing buildings as highest priority.
- R&D in the past led through standards development; EPIC should do the same to go to the next level of efficiency.

Breakout 2 – Energy Generation
Moderator: Beth Chambers, CEC

Topics that emerged from discussions were:
- Consumer behavior

- Low income considerations

- Alternative metrics for zero energy projects

- Control systems interoperability

- Motivation for building owners

- Efficiency operations

- Biogas renewal and storage

- Streamlining of policies and regulations

- Improved/updated codes and standards

- Accounting for comfort health productivity

- Universities should be looked at for sustainable community demonstrations

- Integrate clean generation with EV charging

- Mentioned fire hazards to the grid, etc.

- Coordinate with CAISO

Weisenmiller:

- Figure out the role for CEC in biomass

- Mentioned the recently released climate change impact and adaptation report as a source of implied research ideas

Breakout 3 – Grid Operations
Moderator: Jamie Patterson, CEC

The grid operations breakout session, like the others, was asked to address these questions:

- What are the major barriers to developing and commercializing clean energy technologies?
- Where should funding emphasis be placed to maximize the deployment of clean energy technologies? (i.e., Where is technology innovation needed? versus Where is support for commercial scale-up the critical need?)
- What specific initiatives are recommended to advance innovative energy technologies that benefit ratepayers?
- Define the ratepayer need for which EPIC investment should be targeted?
- Prioritize initiatives and identify the benefits that should be anticipated and measured such as:
  - Energy and cost savings
  - Grid reliability

- Job creation
- Economic benefits
- Environmental benefits
- Likelihood of return on investment
- Other

The Structure of the Grid Operations, Transmission & Distribution Systems and Electric Vehicles Breakout Session:
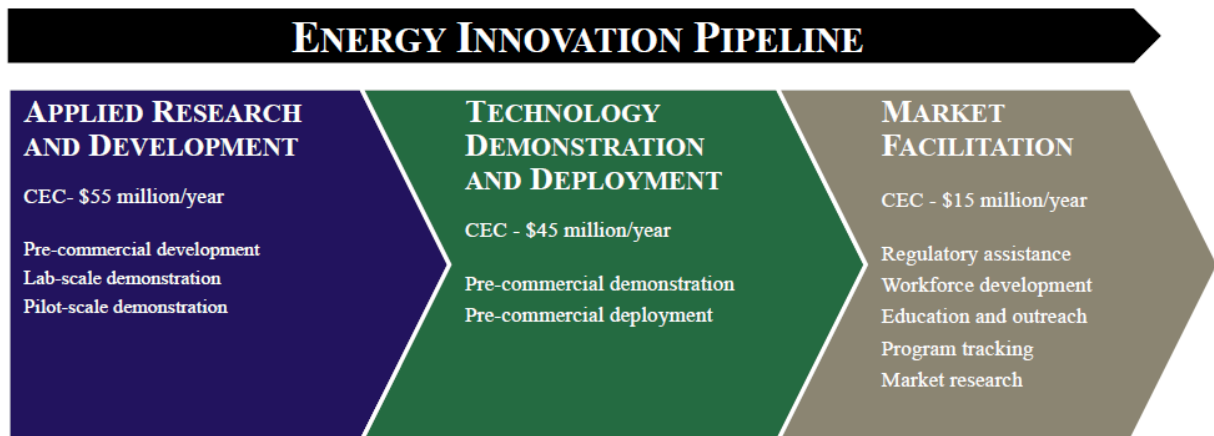- Grid Operations
- Transmission
- Distribution
- EVs
- Other

The Value Propositions Used in Breakout Session:
- Provide IOU electric ratepayer benefits
- Increase cost competitiveness
- Mitigate variable renewable generation & electric vehicle impacts
- Reduce environmental impacts, including climate change effects on the energy system
- Streamline permitting and develop workforce
- Help technologies overcome "valleys of death"
- Complement and leverage other public and private funding sources

Key Policy Drivers Used in Breakout Session
- Renewables Portfolio Standard (RPS)
- Governor Brown's Clean Energy Jobs Plan
    - 12,000 MW of localized renewables
    - 8,000 MW of large scale renewables
    - 6,500 MW of combined heat and power (CHP)
- State Alternative Fuels Plan
    - Displace 376 million gallons of gasoline with electricity.
- The session used the **CPUC Energy Innovation Pipeline**, and asked participants to identify, if possible, which step or steps the recommended research activity or project falls.

ENERGY INNOVATION PIPELINE

APPLIED RESEARCH AND DEVELOPMENT	TECHNOLOGY DEMONSTRATION AND DEPLOYMENT	MARKET FACILITATION
CEC- $55 million/year	CEC - $45 million/year	CEC - $15 million/year
Pre-commercial development Lab-scale demonstration Pilot-scale demonstration	Pre-commercial demonstration Pre-commercial deployment	Regulatory assistance Workforce development Education and outreach Program tracking Market research

Outcome was a list of research initiatives and projects by category listed above:

Grid Operations:
- Metering and telemetry
- Renewables forecasting and other renewable operations tools
  - Visibility behind the meter
  - Real-time monitoring
  - Day-ahead scheduling
- Stochastic and probability forecasting
- Wind boundary layer forecasting
- Fleet flexibility
- Best use of/manage information available from distribution/grid at large
- Aggregations of data streams into system models, for planning to operations
- Synchrophasor application development, e.g., real-time nomograms, state estimators/calculators, system instabilities (e.g., low frequency oscillations)
- Real-time power flow and dynamic control

Distribution:
- CAISO visibility of renewable DG and EVs
  - Load and generation forecasting, especially with "roof-top" PVs
  - Day-ahead weather
- Energy storage – aggregated controls for support of ISO and state grid
- Study – Delivery of ancillary services through distributed resources
- Community and DR Management – integrated control of smart grid at the distribution level
- Synchrophasor applications at the distribution level
- Distribution automation

- Volt/VAR support/control
- Integration of DG, smart inverters and automated DR
- Analytics and simulations

EVs:
- Lower the cost of smart charging infrastructure
- Enable 3rd party services to integrate EV charging and DR through AMI
- Integrate EV charging with night-time wind generation
- Integrate EV charging with solar generation
- Support ancillary services or grid frequency control
- Study cost-effectiveness of 3rd party HANs and aggregators
- EV charger behavior studies for levels 1 and 2
- Information for outreach regarding EV charging
- Certify submeter protocols
- Develop standards for interoperability for EV charging in different utilities

Transmission:

Not reported here.
Other:
- Water heaters for DR
- Price response demand program
- Opportunity to develop standards for interoperability between utilities
- Inventory of DOE research projects.

Closing Comments for 1st Day:

UC Davis person suggested that the CEC should speed up getting research reports published. Weisenmiller replied that CEC could do better, but the researchers need to write better reports – indicating this was the major issue.

Peterman suggested that EPIC plan developers look at the transcripts from the earlier CEC renewable integration workshops for needed research ideas.

Peterman said that the Energy Commission commissioners would look at how well the EPIC plans were integrated.

Power markets were not discussed, but should be part of the discussion of grid operations.

Meeting Notes – Day 2

Panel 1 – Innovation Clusters

The main points of comments made by the panel members are listed below.

Gary Simon: Sacramento Regional Technology Alliance
- Clean Technology Initiative provides training and coaching in business methods, networking opportunities at many levels, and provides visibility to the marketplace. 100 companies in the region, with many successes.

Bill Walden: McClellan AFB
- A renewable testing and validation center for waste and biomass technologies, initially with military energy supply in mind. Can treat 10-1000 tons of waste per day.

Erika Kula: Prescience International
- A Bay Area focus providing comprehensive innovations facilities in clean technology, including venture networks.

Josh Gould: ARPA-E
- Funding energy transformation technologies not replicated in the private sector: high risk-high payoff. Facilitates transfer of technology to the marketplace.

Cameron Gorguinpour: USAF.
- In charge of the military's e-vehicle program, trying to develop a systems approach and sensible deployment. The military has 200,000 non-tactical vehicles. Also vehicles-to-grid usage creates significant savings as well as strategic advantages. LA AFB has a 100% e-vehicle program.

Q&A:

Value of innovation clusters?
- The large commercialization Valley of Death shows a need for incubators and accelerators
- Proof of concept to marketplace is an EPIC success
- Entrepreneurs need help in permitting and regulatory matters – often a major problem for small companies.
- Innovation centers enable someone to plug their technology into an integration system of other technologies.
- Role of pilots important for attracting private funding to get from pilot to commercial success.
- Good technologies often lack a viable business plan to form a company.

- A wide variety of accelerators and innovation programs since one size does not fit all. EPIC could play an important role by coordinating and promoting them to create an assistance ecology for start ups.

Role of EPIC funding for Innovation Centers?
- Connecting businesses with customers is needed: the connection is not good at the moment. A match-making catalogue of facilitators.
- In the Bay Area, the health industry is the biggest customer for clean technologies; the military is another big customer. Not self-evident for many start-ups.
- California is a national and global leader for clean technologies and companies want to move to California, thus it is important that EPIC support this leadership.
- Important for innovative centers to cover regulatory/policy issues as these are as important for commercialization as the technology itself.

Question from CIEE person: Connecting a product, which is often a system itself, to the grid is important, but there is a need to strengthen the interoperability among products in the grid itself. Can innovation centers play a role in system integration into larger systems, i.e., will the system of systems work?

- There is a role for an innovation center to identify problems and find solutions.
- A need for technology that fits into a context is important, and an innovation center can help.
- Recognize the distinction between a gadget commercialization (use "incubator"), or solve a big system problem (system of systems) using centers of excellence.

Laurie ten Hope: How do innovation centers filter good from bad businesses?

- Sequence of filters is applied depending on the business plan. An all-powerful quality control filter is not applied at the beginning.
- The benefit of innovation clusters is over the long term, and EPIC must match expectations to reality.
- ARPA-E sets quite stringent filtering, thus the funding/applicant ratio is quite low.

Panel 2 – Regulatory Assistance & Permit Streamlining

Moderator: Sherrill Neidich

The main points of comments made by the panel members are listed below.

Valerie Winn: PG&E
- A struggle to deal with regulations, but PG&E is proactive with agencies to prevent unnecessary re-inventions of the wheel.

Jennifer Barret: Sonoma County Permit and Resource Management Dept.

- <u>Renewable Energy Combining Zones</u>**:** Look at resources and identify areas for rapid deployment. Would require counties to do upfront "heavy lifting." Often small scale technologies might not be permitted because not in the code. Need to know the interconnections, impact, how they work, need technical assistance. Need to amend codes, no funds available for this. Building, zoning, fire codes. Each jurisdiction is different. EIR becomes key and understanding what is the critical path. More coordination with permitting agencies is key.
- A frustrating lack of progress and too many people are involved in the process.
- Regulators and technology developments lack an understanding of each other's problems.
- Regulatory codes are frequently obsolete
- Getting the sequence of permits right is often a challenge: arcane and counter-intuitive.
- At the (Sonoma) county level there is now a permit-combining zone to streamline things.

Gary Craft: Craft Consulting (solar panels)
- Focus on promoting innovation clusters and removing regulatory barriers. Working together to determine regulatory barriers. CPUC and Rule 21, net metering process. Contra Costa is updating Williamson Act. Looking at permit streamlining issues.
- There are specific solar panel issues resulting from arcane and outdated codes.

Mike Hart: Sierra Energy
- First railroad run on biodiesel. Take trash and turn into fuels through gasification. Working with UC Davis on technology from steel industry. Able to generate syngas for biofuels. Demonstrating in Sacramento. Issue is that most projects require a big central facility bringing in trash from 100 miles around. Goal is one modular system for a 5,000-10,000 person community, and make the community responsible as compared to large waste management company. 5,000 sq. ft. facility, 25,000 gal. of fuel per day that generates slag for use as road base. Controls heavy metals. 10-12 jobs created with each one of these modules. Came out of an innovation cluster center.
- Sees EPIC funding for communities to assist in permit preparation, to be paid back once the project is successful. His business has national recognition.
- Sees lack of small funds for permitting holding back private investment, of which there is much.
- Sees improvement in lessons learned by regulatory agencies to ensure more efficient action in subsequent permit issuance.

Chris Calee: Office of Planning & Research

- Initial moves are in place for the coordination and guidance for permitting and planning. More to come. What information do locals need for upfront deployment of resources?

Vernon Hunt: US Navy
- The Navy has aggressive energy goals, both in the fleet and onshore, but it experiences regulatory challenges. Mr. Hunt mentioned the cumulative impacts of regulations as worthy of analysis, but wondered how to fund it.

Questions to consider:
- The Energy Commission anticipates that cities, counties, and regional governments will seek grant funding. Are there other entities that should be targeted for regulatory assistance funding?
  - *Suggestions: Special districts, e.g., water and sewer districts, school districts, etc., since they have been active in deploying new technologies. Need state-wide, holistic view. Community colleges and others could provide training. Also include construction contractors.*

- What local planning and permitting challenges do clean energy technologies pose now and in the future?
  - *Education is key. Need to work with private sector and business associations. Distributed Generation easier since it is smaller. Issue: codes are old fashioned, need updating. If not in code, cannot do it. OPR and CEC can assist in vetting new technologies. Suggestion: Provide single point of contact (developer funded) Ombudsman, whose role would be to coordinate efforts among agencies. Wave energy is an example of major financial risk from a permit perspective. Most general plans for jurisdictions are more than 10 years old. They need updating to allow renewable energy technologies. Pre-qualified areas save significant funds for developers.*

- How can EPIC investments leverage current efforts rather than duplicate them (e.g. DOE SunShot Initiative and model frameworks from the California County Planning Directors Association and Governor's Office of Planning and Research)?
  - *Need someone to help coordinate grants between OPR / DOE / EPIC. Need to coordinate efforts. One suggestion was setting up funds for communities for planning. Uncertainty in permitting process prevents financing. PG&E said issue is permitting many facilities vs one central facility. Not set up to do this. Demonstration funding is the key. AUGUST 16: Importance of deployment projects.*

- What, if any, local planning activities should EPIC invest in? What, if any, local permitting processes should EPIC invest in? What do these initiatives cost and how long do they take?
  - *Cost of permitting should go down as technology is deployed further. Opportunities to share data across permits, e.g. energy projects, high speed rail, etc. Sonoma trying to create an energy zone for 20 MWs.*

- If meritorious, how should EPIC measure ratepayer benefits for local planning and permitting assistance?
  - *Do the customers get the actual benefit of new technology deployment? Important to create competition.*
  - *PG&E meeting on Aug. 16 & 17 at the PG&E Energy Center, 851 Howard Street, San Francisco. Info:* Valerie.winn@PGE.com
  - *Mike Hart: qualifies for 1603 financing. Looking for innovative technologies at Port of West Sacramento. Share with Mike's facility.*

Comments

- EPIC as a statewide one-stop-shop for permitting/regulatory coordination between agencies – an ombudsman model.
- EPIC might fund training for contractors (and others) on code compliance.
- EPIC should fund only public entities and not private companies.
- For deploying new technologies, the permitting process is too burdensome for any one company.
- EPRI has played a role as an ombudsman for sharing technology and experiences in permitting.
- Award notifications lack coordination and are widely dispersed among too much other information.
- Data needed for wildlife impacts from renewable siting (and urge funding to universities to do this). Getting good data more important than streamlining (in the sense of cutting corners) permitting.

Public Comment

- Need to have mix of short term and long term ROI
- Bring in companies like Dow Chemical and facilitate one-on-one. Dow selects who to work with.
- Focus on developing clusters: 5-10 years. Need to help companies look out in time and understand what the market will look like.

Panel 3 – Workforce Development

Moderator: Sherrill Neidich

Panelists:

Barbara Halsey, Executive Director, California Workforce Association

Kurt Schuparra, Assistant Secretary, California Labor and Workforce Development Agency

David McFeely, Director of Industry Solutions and Grants, SolarTech

Jim Caldwell, Executive Director, Workforce Incubator

Mark Lennon, Deputy Secretary, Department of Veteran Affairs

Blake Konczal (Invited), Fresno Workforce Investment Board

Discussion comments:

- It's a mistake to create a program and then train people without first working closely with employers in order to ensure that jobs will actually be available.
- Small companies have much experience to share, but no time or resources to do so. Larger companies have this capacity, but inherently have a slightly different perspective.
- It would be valuable to have a standardized training program that could be offered regardless of provider.
- There's a need for facilitating movement of military veterans to the civil workforce. The Center for Energy Workforce Development is helping by urging military experience for college credit, and through outreach to women and minorities.
- The use of social networking systems to enable job seekers to get online rather than inline: a virtual center for opportunities, and not an investment in bricks and mortar.
- Would be helpful to aggregate job opportunities at the county level (people generally are averse to moving) at a one-stop-shop job site.
- A UCB study on workforce energy certification is well intentioned but has a danger of unintended consequences by preventing people from entering the workforce. Employers from some sectors prefer in-house training to certified prospective employees.
- There is an issue of the discrepancy between outgoing expertise and incoming expertise.
- There's a preference for modular education rather than a silo-based classroom approach.
- Despite a need for specialized skills, there is a strong need for basic, off-the-shelf skills, such as JAVA programming, AUTOCAD, and financial skills.
- How do you measure the benefit of EPIC funds in support of workforce training?

- *Local economic development (for which standard measures can be applied)*
- *Return on investment through business re-investment*

Questions to consider:

- Does the clean energy sector shape employee training programs? What partnerships exist between training programs and employers to promote job placement, apprenticeships, and externships?
  - *Reaching out to academic institutes to provide technical expertise. Connecting with high school teachers to be able to guide students to career fields.*
  - *Industry involvement and having apprenticeships. Industry involved in resume review and mock interviews. Tours and job shadowing. Opportunities to engage with professionals.*
  - *Problem is with new emerging companies, who do not have the bandwidth for these activities. David McFeely working closely with industry to build these relationships.*
  - *Need broad alliance of stakeholders, look for clusters, i.e. common approaches, need standard credentials (not matter what institute).*
  - *Efforts to translate military personnel skills into private sector utility jobs. Military could be a huge source (42% unemployment). Key is connecting military needs to private sector needs.*

- Significant investments are being made to develop a clean energy workforce. Should EPIC workforce development investments build upon these efforts? If so, how?
  - *Collective impact is the key, need to align investment strategies.*
  - *How to get credit for previous experience.*
  - *Methodologies to project out demand. Develop tools to take out to management to explain the future scenario from a workforce. Tier 1-6 skill sets, need specialization.*
  - *Much funded by stimulus funding. Many of those funds are now gone.*
  - *Many courses and programs were developed with stimulus dollars. Issue is they do not have faculty, therefore courses not mainstream. Need for faculty that can maintain courses.*
  - *Need to look at full spectra of jobs needed: (1) Professional development, (2) cultivate stimulus investments. Major challenge is keeping momentum going that has been generated. Need public / private partnership.*

- Should EPIC fund the collection, storage and dissemination of a clean energy workforce information center? Would a clean energy workforce center connect the workforce to the employer?

- o *Focus on job training as compared to the green economy. Key is tying into a nationally certified network for certification and training. Source people with information they need. Key is being informed advisor.*

- Distributed PV and wind have industry recognized certifications (i.e., NABCEP). What technologies would benefit from similar certification programs?
  - o *Energy Efficiency is one area where certification is needed. Certification for power engineers would be good. Keep in mind you sometimes need to connect licenses, e.g., have PE license as well as solar certification.*
  - o *Employees provided feedback to workforce incubator for a certificate program at CSU. Employees wanted specific capabilities that were recognized by industry. 1 yr certificate program with 4 classes. Other option is "badges" or mini-certification. Take one class and get certified, more attractive for hiring.*

- How should EPIC measure ratepayer benefits for workforce development?
  - o *Metric showing progress towards AB 32 goals. Job placement, consumer spending, local economic development. Time element is important, i.e., speed of adoption.*
  - o *California workforce (UCB) and development standards recommend case studies and RFPs to develop this further. Focus should be tackling strategic problems, e.g., lack of specific skills.*
  - o *Cross-cutting approach needed, integrated skill sets. Cannot deliver with traditional in class. Modular, "badge" approach. Can supplement existing skill sets going forward. Must work hand in hand with utility supply chain.*
  - o *Need for people who could do financial calculations, know AutoCAD. An example of re-positioning and skill sets and creating applicability.*
  - o *Need to be better about getting students through community colleges.*