Handout for
The Emerging Technologies for the Integration of Renewables Workshop
July 31, 2008, Hearing Room A
California Energy Commission

Purpose:

This emerging technology workshop is designed to address the wide range of emerging technologies that have the potential of increasing the amount of grid-connected renewables that California can reach by the year 2020. Given the limited time of this one-day workshop, the Energy Commission staff prepared this handout with information to complement the workshop. The purpose of this handout is to provide workshop attendees and interested parties additional information to encourage more comments and recommendations from the attendees and other interested parties.

Please provide any comments or additions to the information in this handout so that information can be used in the preparation of the Emerging Technology input to the 2008 and 2009 Integrated Energy Policy Report (IEPR). There is information at the end of this handout addressing how to submit comments. All comments are due by 5 p.m. on Friday, August 8, 2008.

1. The Role of New Technology in Integrating Renewable Generation and Electric Transmission to Meet California Renewable Energy Goals

Introduction

Because most new renewable power plants will be located in areas rich in renewable resources but remote from California electricity customers, electric transmission will be crucial for transporting the renewable electricity to load centers, and thus for meeting the state's renewable energy goals. Consequently, each new renewable power plant must be successfully integrated with the transmission system. To fulfill this mission, transmission must achieve three broad objectives: (1) provide physical access for each new power plant, (2) increase its power carrying capacity to handle the additional electric power flows, and (3) reliably accommodate any unique renewable generator behaviors.

It is reasonable to assume that modest penetrations of renewable generation, say, 20%, can be successfully integrated into the grid by traditional system investments, such as building new lines and conventional generation for increased capacity and to maintain reliability. However, as the penetration of renewables grows to perhaps 33% and beyond, and more renewable power plants and transmission infrastructure are added to the system, its complexity will grow along with operational difficulties. It also will likely become increasingly difficult to meet the environmental and economic criteria for siting new infrastructure in a timely manner, further reducing the effectiveness of the "build" approach. As an alternative, new technologies can be deployed in the transmission system to endow it with improved or new capabilities that, at a minimum, will make renewable integration easier and less costly, and ultimately at higher renewable penetration levels, will probably be required to achieve California's renewable energy goals.

Improved and New Capabilities
Each improved or new capability, and its enabling new or emerging technologies, is generally described below in the context of addressing the challenges facing the achievement of each of the three broad transmission objectives for successful renewable integration.

Access to Transmission System
For most new renewable power plants, access to the transmission system can be directly translated into acquiring new right of way (ROW), and building new transmission lines between the power plant and an interconnect point on the transmission grid.

The siting process for new transmission project is highly complex and difficult, involves many different stakeholders, and takes many years, typically10 to 12 years for a major line. While there are a number of state and national policy changes being pursued to shorten this time, concern remains that it will take longer to build the new transmission extension to a renewable power plant than it will to build the power plant.

Two major impediments to timely new ROW approvals are cost/benefit allocation economic debates, and siting challenges, exemplified by, "not in my backyard." A couple of improved capabilities the transmission community could use to accelerate new transmission projects are:

Access Siting Capability #1: To facilitate environmental and societal deliberations, and enhance acceptability of new transmission lines.
Some enabling new technologies: Hardware technologies that reduce the physical footprint or visual impact, such as underground and compact high current lines; public process techniques that facilitate environmental/societal issue definition and resolution, and stakeholder interactions.

Access Cost/Benefit Capability #2: To enhance clarity of project costs, and economic and societal benefits for new transmission lines
Some enabling new technologies: Techniques, methodologies and models that would bring science to bear on enhanced understanding and validity of economic and societal costs and benefits, their allocation among stakeholders, of new transmission line projects.

Increased Transmission Capacity

Any transmission line has physical limits on the amount of power that can be transmitted. Which limit is the dominant factor constraining the capacity of a given line at a given time depends on the conditions of that particular line and the broader wide-area transmission grid.

Because the technological sophistication of current situation monitoring capability is not particularly accurate or precise, conservative static operating limits have been set often far below the physical limits as an engineered safety factor, which is in effect a derating of the capacity of a line typically by 20 to 50%, or more.

There are two fundamental classes of limits, thermal and stability.

> Thermal Limits: The maximum power a particular line can ever handle is its thermal limit. The primary source of heat comes from the interaction between the electrical resistance of the line material and the electric current flowing through it. Above this limit, a line may excessively sag, creating a safety hazard or an outage, or be physically damaged by excessive temperature.
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> Stability Limits: Poor voltage support, and dynamic and transient instabilities can result in even substantially lower capacity limits below the thermal limits in some situations. It is not unusual for a major interconnection path to be operationally limited by instabilities to half its rated static thermal limit. This effect imposes severe limits on the amount of renewable power which can be imported into California, and into major load centers within the state.

There are emerging technologies that could in principle provide the capabilities to reduce the margins of operating limits required for safety, and even raise the physical limits, thereby adding substantial "new" capacity without building new transmission lines. The capabilities would prove vital to meeting renewable energy goals if building all of the new transmission capacity needed falls short, especially likely in dense urban load centers, and might be preferred as a cheaper way to get greater transmission capacity.

New Capacity Thermal Capability #1: To raise static and physical thermal limits

> *Some enabling new technologies:* New conductor materials with a higher thermal capacity, direct current (DC) transmission, or possibly superconducting cable could result in significant transmission capacity expansion, and dynamic (real time) "thermal" rating monitoring to relax static limit margins could produce incremental capability increases, all in the same or smaller environmental footprint.

New Capacity Voltage Stability Capability #2: To relax, or eliminate need for, voltage stability constraints.

Some enabling new technologies: New monitoring, evaluation and predictive analytic and modeling tools, e.g., optimized real-time nomograms, could improve situation awareness and permit smaller, better defined, constraint margins. New hardware, such as devices using advanced power electronics or energy storage, deployed locally, could provide voltage stability support.

New Capacity Transient Stability Capability #3: To relax, or eliminate the need for, transient stability limits.

Some enabling new technologies: Transient stability is the ability of the transmission grid to regain its equilibrium in the event of a transient disturbance, such as a line fault or generator trip. Time frames are typically milliseconds to seconds. Predictive off-line techniques, real time monitoring and analysis techniques could alert operators and automated systems, and new or improved methods or power electronic equipment could control for instabilities.

New Capacity Dynamic Stability Capability #4: To relax, or eliminate the need for, dynamic stability limits.

Some enabling new technologies: Dynamic stability is the ability of the transmission grid to regain its equilibrium over time frames of 1 minute to as much as 30 minutes. Problematic instabilities can manifest in a number of different behaviors, with low frequency oscillations being perhaps the most egregious in the Western grid as a reason for capacity deratings. Low-frequency oscillations, which cause power to surge back and forth through wide-areas of the grid, typically have a period of a few seconds and can build over periods of minutes to hours. They have been identified as the initiating event of some costly major multi-state blackouts, such as the widespread blackout in the western United States and Canada in 1996. The root causes of these dynamic instabilities are not all well known and more research is needed. Wide-area real-time monitoring, detection, alarming, analysis and visualization operator tools could be developed to operate the transmission system with smaller dynamic margins. damp oscillations. In conjunction with certain control technologies, perhaps energy storage, the tools might be used to mitigate dynamic instability threats, such as to damp oscillations.

Accommodation of Renewable Energy Characteristics

From a transmission operational dynamics perspective, some renewable energy plants such as geothermal, biomass and perhaps solar thermal with enough thermal storage will benignly operate similar to traditional base-load thermal power generators. Wind and some solar renewable generation, however, are intermittent, and exhibit power plant behaviors unfamiliar to grid operators, and for which the grid was not designed.

Solar power characteristically ramps up in the morning and down in the evening with no night time output, but with a seasonable-variable power profile. Additionally, it has short term variations due to cloud cover. Solar photovoltaic generators use solid state invertors that exhibit little or no operating inertia so characteristic of conventional thermal generators with their large rotating mass, and therefore will react much more quickly to transients. Little is known about the effects of large penetrations of these low-inertia generators on the transmission system.

Wind power tends to be higher at night and is subject to short term variability from changes in wind. The dynamic behavior of wind generators is different from typical thermal generators, and there are significant differences between different types of wind turbines designs.

The Energy Commission Intermittency Analysis Project has projected that meeting the 33% goal by 2020 will result in power production capacity in excess of total demand requirements. Existing conventional plants would need to be closed or operated at lower capacity factors, potentially reducing the availability of system support generation. This situation might be compounded if coastal thermal plants using once through cooling must be shutdown.

Finally, in order to stimulate the private development of renewable power plants, utility contracts generally include the guaranteed acceptance of power generated, whether or not it is needed or is the most economical available.

There are emerging technologies that could provide new transmission capabilities to accommodate the special operating needs of renewable generators, and some of their system effects.

New Accommodation Ramping Capability #1: To reliably respond to rapid up and down power ramping.

Some enabling new technologies: Current ramping techniques include the ability to dispatch fast acting generators. These are typically gas fired, so increased use of current techniques will tend to dilute the beneficial effects of renewable resources, and have future electricity cost consequences. Equipment capable of delivering or absorbing power, such as energy storage, wind and solar forecasting techniques that project ramping needs, and perhaps some load management approaches might compensate or mitigate ramping requirements.

New Accommodation Power Market Capability #2: To enable intermittent renewables to participate in power markets on equal basis.

Some enabling new technologies: To maximize their economic return, renewable power plant developers need to sell power in the established power markets, both short term and long term. This requires a high level of generation predictability over short and longer-term time periods, or the ability to dispatch. Wind and solar forecasting techniques, market prediction techniques, and control equipment, such as storage, to control when power can be dispatched, should increase the market value of intermittent renewables.

New Accommodation Dynamic Behavior Capability #3: To operate the grid in response to renewable power plant dynamic behaviors.

Some enabling new technologies: The primary concerns around dynamic behavior are associated with the potential decrease of total system inertia leading to increased instabilities and the dynamic response of large wind farms. New generator modeling, analysis or forecasting tools related to these behaviors, or control equipment to mitigate the impacts of these dynamic behaviors are some technology candidates.

New Accommodation Excess Total Power Capability #4: To reliably take excess capacity.

Some enabling new technologies: The existence of excess total capacity requires that some existing system power plants be underutilized or closed. These will likely be older, less efficient plants, many that are located closer to load centers. This may create additional grid stability issues as power plants, on average, become located further from load centers. Planning tools, studies, and techniques could evaluate and mitigate both the economic and technical impact of plant closures, and tools and equipment, such as energy storage, could compensate for loss of grid support from these plants.

New Accommodation Minimum Load Capability #5: To economically and reliably take renewable power during times of minimum load.

Some enabling new technologies: If, as expected, wind power becomes the largest single source of renewable energy power, the minimum load problem is expected to become significant. Wind power tends to peak and night when loads are lightest. In combination with other sources of "must take" energy, such as nuclear power and power contracts, there are expected to be periods when total "must take" power exceeds demand. To avoid economic penalties, consumption could be increased during those periods. Planning and forecasting tools, and equipment for increasing or control load could be developed to provide this capability.

Major Technology Platforms

There are a wide range of many new technologies that will be needed, some alone, but many as integrated components of a system or platform, to provide the transmission system with the improved or new capabilities described above. There are too many to even list here. However, there are some major technology platforms or systems that could have a substantial roll in enabling a large number of these capabilities and determining their effectiveness. The first three of these platforms are elements of a smart grid because they provide intelligence and the ability to act to fulfill the intent of that intelligence.

Real-Time Monitoring and Control

The role of this smart grid technology platform is to provide real-time wide-area situation awareness, state forecasting, operator decision support, and automated response. It is essential to many of the capabilities for increasing capacity and accommodating renewable plant characteristic behaviors.

Many technologies potentially make up this platform, but its core is synchrophasor measurement and monitoring, and several related applications for disturbance detection, diagnosis, compliance monitoring, model benchmarking and situational awareness. It is critically important for renewables integration, because, in addition to enhancing grid reliability, it also offers the promise to significantly reduce the capacity derating of key transmission pathways.

Phasor measurement units (PMUs) are an established monitoring technology that, when widely deployed throughout the power system, provides the grid operator with unprecedented real-time information of grid status, and detection and diagnosis of events over a wide-area. Collecting satellite time-stamped data at speeds between 60 and 120 times a second, PMUs, placed optimally in the transmission grid, can provide the operator an "over the horizon" real-time, early-warning view of grid conditions that might represent a threat to the reliable, economical and secure operation of the California transmission system, and take mitigation actions.

With successful R&D, this platform promises to help detect and mitigate low frequency oscillations and, through improved operating tools, free up significant underutilized transmission capacity for importing renewable power into the state and into major urban areas. It also could provide the basis for intelligent protection systems to better maintain reliability under the uncertainty of intermittent renewable generation.

While the real-time monitoring and control platform provides the intelligence for the capabilities to rapidly detect a wide variety of operating issues and determine what actions to take, without enhanced power flow control capability the menu of corrective actions is extremely limited, thereby limiting the promise of the smart grid concept.

Power Flow Control

The present capability of the grid to control power flow is very limited, because power flows take the path of least resistance. However, for the first time since the first power grid was built, technologies are emerging that should enable the operator or automated systems to control power flow. As the level of renewable generation grows, power flow control capabilities become increasingly important for maintaining reliability, increasing capacity, and improving market efficiencies, such congestion management. There are two aspects of power flow control of most interest: spatial and temporal.

A host of new technologies, largely possible because of advances in power electronics, offer the means to control **where** power flows via switching and variable impedance control. The largest class of these technologies is called flexible AC transmission system devices (FACTS), but there are others based on AC/DC conversions. System protection is another application for power flow control. As the capacity for power in the system increases to handle more renewable generation, the demands on the protection system also increase. Today, fault currents are threatening to overwhelm existing protection systems. New protection devices, called fault current controllers are developed to protect property and lives.

There is also much value to renewable integration to be able to control **when** power flows, and the candidate technology is energy storage in its many forms. Energy storage can be deployed to give renewable generation dispatch attributes, such as capacity firming, which would greatly increase the economic value of its power. Storage can also be used to provide a variety of other benefits for renewable integration: ancillary services, fast ramping, voltage support, stability, and congestion mitigation.

The effectiveness of capabilities to use data for intelligence for grid operations and planning depends on the quality of analysis techniques.

Advanced Analytics

As the complexity and uncertainties of transmission system operations and planning have increased, and will continue to increase with growing penetration of renewable generation, the traditional deterministic planning and analytics will be replaced with statistical and probabilistic analysis and forecasting. Advanced mathematical and computational techniques will play an ever growing role in improving the capabilities for operating and planning the power grid, from critical disruption forecasting, to long term congestion management planning, to extreme event analysis, evaluation, planning, mitigation and containment. Many of these new techniques will likely be migrated and adapted from other industries and governmental sciences, such as health or military.

Some new capabilities will require new technologies made possible through new materials.

Advanced Materials

An emerging cable technology using high-temperature, low sag conductor materials could be used to possibly double the capacity of a ROW using existing towers. It uses core material having temperature attributes similar to ceramics and flexibility similar to ductile metals. Further into the future, wires made of high-temperature superconducting (HTSC) material could increase the current density by many times, and are expected to find their first uses in niche applications such as substation get-aways located in dense urban areas. HTSC is already being deployed in experimental fault current controllers. While widespread use of HTSC lines is likely decades out, it has the potential to radically change the transmission paradigm. The other promising area for new material development is in very high power solid state electronics for power flow controllers and convertors.

Conclusion

There are a number of new emerging technologies that promise improved or new capabilities for the transmission system that at a minimum will make renewable integration easier and less costly. At some point with increasing penetration levels, the use of new technologies will likely be required in order to meet renewable energy goals, as conventional technologies prove to be inadequate to meet the challenges. It is recommended that R&D be consistently conducted on a selected portfolio of transmission technologies to accelerate the adoption of emerging technologies, and to advance the state of the science of less developed technologies to be ready when needed. Also note that, while some device R&D is needed, a significant proportion of R&D resources should also be directed to system and analytical developments for the quickest and greatest value for renewable generation deployment.

COMMENT: Please provide you comments, corrections and/or additions to the information in section 1 above:

2. Grid-Connected, Distributed Renewable Resources That Do Not Currently Contribute to RPS

Background

In California, much attention has been paid to the renewable energy capacity and generation utilities are using to meet their obligations under the renewable portfolio standard (RPS). The RPS calls for in-state generation from eligible technologies or fuels purchased or delivered to investor-owned utilities (IOUs), electric service providers or community choice aggregation. There are also additional resources owned by or delivered to publicly-owned utilities (POUs), which are not currently counted toward the state RPS. This will likely be captured by the POUs for compliance with their own RPS mandates going forward.

RPS eligibility guidelines dictate that generation from net-metered systems or facilities that receive incentives from certain rate-payer funded programs cannot be counted toward the state RPS. An exception is granted through Public Utilities Code 399.20 for systems participating in certain standard tariffs. Most customer-sited renewable resources are not eligible for the RPS as they have been funded through rate-payer funded programs such as the Self-Generation Incentive Program (SGIP), Emerging Renewables Program (ERP) or the California Solar Initiative (CSI), and/or participate in net-metering programs. Looking forward, state policies to encourage customer-sited renewable capacity and mandates for new zero energy homes and buildings will encourage the development of more renewable energy systems on the distribution grid. The magnitude of this distributed generation capacity and potential to contribute to the RPS has not been analyzed.

Key Observations[1]

Almost all of the distributed generation renewable resources in the IOU service areas are rooftop PV, biogas-powered DG[2] or small wind.
Over 350 MW of renewable generation has received incentives through SGIP, ERP and CSI since 1998. Solar PV accounts for nearly 90% of this installed capacity.

Generation from these distributed, non-RPS eligible renewable resources is limited, given the intermittency of solar- and wind-powered generations. Expected generation output from the distributed, non-RPS eligible renewable resources within IOU territories is approximately **800 GWh**[3].

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[1] All number are preliminary in this draft and may be revised

[2] Fuel cells, gas turbines, internal combustion engines and microturbines powered by digester gas, landfill gas and other unspecified renewable methane

[3] Based on capacity factor of 18% for solar PV, 30% for wind and 90% for all others

The targets set for CSI alone (3,000 MW ≈ 4,700 GWh by 2016) significantly exceed current totals for distributed, non-RPS eligible renewable resources in IOU territory (350 MW/800 GWh).

COMMENT: Please provide you comments, corrections and/or additions to the information in section 2 above. Of specific interest is your comments on how to better account for the increasing amount of renewable resources that are being installed below the transmission level (residential PV, C&I level PV and wind, others.

3. The Role of electric Energy Storage to Increase the Penetration of Renewable Resources in California

During the workshop, several speakers addressed the current state of energy storage and some potential applications that support the use of renewables in California. Please provide your comments and recommendations on the following areas:

a. How much grid connected electric energy storage do you feel should be provided by 2020 to support the 33% Renewable Portfolio Standard (RPS)?

b. What energy storage technologies do you feel are emerging and have the potential to be commercial in time to help California meet the 2020 RPS Goals?

c. What energy storage technologies do you feel are have the [potential to become commercial and can be applied at the grid areas below in time to help California meet the 2020 RPS goal?

   a. Transmission connected?
   b. Distribution connected?
   c. End customer connected?

d. Is there a defined amount of storage you feel should be fielded as new renewable resources are fielded (such as 10% storage for each 1MW of renewables, etc.). Is this number different depending on the type of renewable technology (solar, PV, wind, etc)?

e. Are there actions California should take to increase the number of commercial energy storage alternatives available by 2020? If so, what actions do you recommend?

Written Comments

Written comments on the handout and workshop topics must be submitted by 5 p.m. on Friday, August 8, 2008. Please include the docket number **08-IEP-1B** and indicate **"*2008 IEPR Update* – Emerging Technologies for the Integration of Renewables"** in the subject line or first paragraph of your comments.

The Energy Commission encourages comments by e-mail. Please include your name or organization in the name of the file. Those submitting comments by electronic mail should provide them in either Microsoft Word format or as a Portable Document File (PDF) to docket@energy.state.ca.us. **One paper copy** must also be sent to the Energy Commission's Docket Unit at the address shown below.

Parties may also submit comments in hard copy. Please hand-deliver or mail an original plus 10 paper copies to:

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