Reliability Challenges White Paper

Introduction

In June, WECC introduced its new Integrated Reliability Assurance Model, which outlines the process through which WECC will identify, analyze, and address the top reliability challenges facing the Western Interconnection. As a first step to operationalizing this model, WECC held a Technical Session in September where the WECC Board of Directors, members, and other stakeholders engaged in a discussion about key Reliability Challenges. Using this discussion as a foundation, WECC staff drafted this Reliability Challenges Whitepaper to provide a high-level background on these challenges. WECC is now seeking feedback from stakeholders on the challenges covered in this Whitepaper in order to inform the decision making regarding top priority challenges for the next three to five years.

Specifically, WECC is seeking feedback from stakeholders in three areas:

- General feedback on the inclusion or exclusion of challenges;
- Feedback on actions WECC could and should be taking to address the challenges; and
- Information on other current or planned work regarding the challenges.

To provide feedback on this white paper or reliability challenges in general, please submit your comments by October 31, 2014 to reliabilitychallenge@wecc.biz.

WECC’s Integrated Reliability Assurance Model

The Integrated Reliability Assurance Model represents WECC’s approach to identifying, analyzing and addressing the top reliability challenges facing the Western Interconnection. WECC is taking an integrated approach to Registered Entity oversight, Reliability Planning, Performance Analysis and Stakeholder Outreach. Through its unique perspective as the Reliability Assurer for the Western Interconnection, and by leveraging its independence, expertise and analytical capabilities, WECC will partner with stakeholders to address key reliability challenges facing the West.
This document divides the reliability challenges into six categories. A brief description of each challenge is provided below to guide the reader. More detailed background information can be found in each of the challenge sections.

### Resource and Load Challenges

**Changing Resource Mix** – The composition and location of generation capacity in the West’s Resource Portfolio is a major driver of the electric industry. The West leads the continent in development and integration of renewable resources, reductions in conventional thermal generation, and a significant shift to gas; trends we anticipate continuing.

**Retirement of Conventional Generation** – The Bulk-Power System in the West has traditionally been reliant on generation from “conventional” resources; primarily hydro, nuclear, coal and gas. These resources provide energy and essential reliability services.

**Natural Gas-Electric Interdependencies** – The Western Interconnection’s reliance on natural gas generation continues to grow and will do so into the foreseeable future. The coordination between the gas and electric industries will be more critical than it has ever been.

**Changing Load Composition** – Energy consumption patterns and types of demand (together load composition) change relatively slowly. Future shifts in policy, technology, and other drivers could change load composition and load shape in the Western Interconnection at a faster rate and higher magnitude than in the past.

**Impacts of Climate Changes** – Climates are constantly changing at both the global and more granular levels. The political topic of “Climate Change” aside, the effects of changes to climatic conditions have the potential to impact the Western Interconnection in a number of ways, for example drought and extreme weather.

### Variable Generation Challenges

**Integration of Variable Generation** – Variable generation is reliant on fuel sources—wind and sun—that cannot be stored and are intermittently available. This results in increased uncertainty and variability on the system.

**Balancing Variability** – The intermittency of variable generation requires balancing by the system, which requires operational flexibility.

**Distributed Generation** – Distributed generation (DG) is connected directly to the electric distribution network, making it difficult, if not impossible, for Bulk-Power System operators to see and control. The penetration of DG, specifically solar photovoltaic (PV), is increasing at a rapid pace.
Operational Challenges

**Situational Awareness** – Reliability requires the ability to see and comprehend what is happening on the system. Situational Awareness is accomplished via near-term modeling and real-time monitoring of the system.

**Equipment Failure** – AC substation equipment failure was the second leading cause (behind weather/lightning) of automatic transmission outages in the Western Interconnection over the last five years. Unlike weather and lightning, equipment failure can be mitigated.

**Protection System Reliability** – Protection systems, such as Remedial Action Schemes (RAS) and relays, are designed to minimize equipment damage and prevent cascading outages. As more complex protection systems are added, there is potential for interactions or misoperation of protection system relays.

**Operational Practices** – Reliable operation of the Western Interconnection is dependent upon appropriate and consistent operational practices. The large number and wide diversity of operational entities in the West make consistency and broad adoption of best practices a challenge.

Security Challenges

**Cybersecurity** – The digital age has enabled increased efficiency and improved awareness as the system becomes increasingly integrated. This integration also provides expanded opportunity and access for cyber threats that can disrupt information communication and the physical workings of power system elements.

**Physical Security** – The range of physical threats to system elements, usually substations, has expanded from occasional acts of vandalism or minor theft to include coordinated attacks bent on destruction. Physical attacks can result in instability, uncontrolled separation, or cascading failures.

**High-Impact Low-Frequency Events** – Events such as coordinated physical or cyber-attack, pandemic, geomagnetic disturbance, or large-scale disasters are rare, but have the potential to cause wide-spread impacts to the system.

Policy and Regulatory Challenges

**Impacts of State Policy and Regulation** – Policy and regulation are drivers of the electricity industry, but electricity reliability is not always a consideration in policy and regulatory decisions.

**EPA 111(d) Clean Power Plan** – The EPA’s proposed plan has the potential to significantly impact the Western Interconnection. Compliance with the plan is the responsibility of the states, though the issues span the West.

**Functional Model** – Inconsistencies between the NERC Functional Model, Glossary, Rule of Procedure and Reliability Standards create gaps in Registered Function coverage.

Human Performance Challenges

**Workforce** – The imminent loss of critical skills and knowledge as a large part of the workforce retires, cognitive overload of System Operators, and compliance with a large volume of reliability standards are pervasive issues that require coordinated industry efforts to address.
**WECC’s Role**

WECC does not order, recommend or approve plans for generation additions or retirements. Nor does WECC own, operate, or fund any generation. WECC’s role is to assure the reliable operation of the Bulk-Power System.

**Current WECC Work:**

» Conducts system stability studies of high variable generation penetration.

» Runs production model studies of futures with more than expected renewable resources.

» Studies twenty-year capital expansion cases designed to investigate how changes in policies and economics could drive future resources mixes.

**Opportunities for WECC to Add Value:**

» Conduct more robust reliability assessment of various futures involving high renewable scenarios.

» Evaluate different operating practices including how and where reserves are held.

» Study integration issues on an subhourly basis.

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**Issue**

The resource mix refers to the composition of installed electric generation capacity that makes up the Resource Portfolio. The resource mix is a central driver of the electricity industry. In the West, generation is owned and operated by a range of entities such as vertically integrated utilities, merchant generators and customer cooperatives. Generation additions, dispatch and operations are not centrally coordinated in the Western Interconnection, and the unique characteristics of each generation type dictate how the resources are dispatched and operated, both individually and as part of the larger system.

**Background**

The resource mix in the West is evolving. Hydro, coal and natural gas make up the majority of the West’s resource portfolio and natural gas generation accounts for the largest portion of that majority. The portion of coal, nuclear and hydro capacity in the resource mix continues to shrink, yet these resources continue to provide large amounts of energy. Wind and solar generation capacity has increased every year for the last five years. In 2013, more than twice the amount of solar generation was added than in 2012, a trend that has occurred each of the last five years.

**Challenges**

**Considering a Wide Range of Drivers**

Each of the economic, policy and social drivers of the changing resource mix present a unique challenge. Examples of these drivers include the following:

» Retirement and replacement of conventional resources (e.g., coal, hydro, nuclear) and low natural gas prices drive increased reliance on natural gas generation.

» Local, state and federal environmental regulations drive resource dispatch and investment decisions, spur increases in renewable resources, and cause reductions in coal generation.

» State policies and utility engagement drive energy efficiency programs that affect demand.
CHANGING RESOURCE MIX

» Consumer choice drives increases in distributed generation.
» Technology advances decrease upfront capital investment costs for new generation technology.

Ensuring Resource Adequacy
Maintaining resource adequacy will be an ongoing challenge as the resource mix in the Western Interconnection changes. Current projections indicate that reserve margins will be adequate for the next seven-to-ten years. Changes outside the assumptions used in resource adequacy evaluations could present challenges.

Replacing Retired Capacity
Large base-load generators like coal- and nuclear-fired generators provide essential reliability services, such as frequency response, system inertia, and voltage control. As these generators are retired, they may be replaced by generation with less or no ability to provide these services. This is the primary challenge associated with replacing retired generation capacity. These and other challenges associated with the retirement of generation capacity are discussed in greater detail in a separate section.

Integrating Variable Generation
The integration of variable generation resources presents a number of operational and planning challenges, including planning for flexibility in the future resource mix, understanding the implications of drivers of variable generation, managing the uncertainty associated with wind and solar resources, and balancing the intermittency of these resources across the system. The challenges associated with integration of variable generation are discussed in greater detail in a separate section.

Managing Distributed Generation
The penetration of distributed generation resources is increasing, and all indications are that this will continue into the foreseeable future. Distributed generation resources have the same characteristics as their Bulk-Power System counterparts, with one important difference: BPS operators have no direct visibility or control over Distributed Generation resources. This key factor presents a challenge as the amount of DG grows.

Coordinating the Natural Gas and Electricity Industries
As our reliance on natural gas increases, issues surrounding the interface between the gas and electricity industries may intensify. The electricity industry is not the primary customer of the natural gas industry, which is designed around supplying gas to residential and commercial customers. This may present scheduling and supply challenges as we continue to supply firm electricity service that is sometimes fueled by non-firm gas supply. In addition, normal stability analyses do not specifically evaluate the potential impacts to electric reliability of major gas contingencies.

Accounting for System Composition
Resources location is an important consideration in planning the resource mix. Coal generation plants are often located near coal fuel supplies (mine-mouth coal), requiring long transmission lines to move the power they produce to load. Hydro generation must be located at the resource location. Wind and solar generation must also be placed at their fuel source, which may require additional long-distance transmission. The location of natural gas generation, is more flexible but may depend upon gas pipeline location.
Issue
The Bulk-Power System (BPS) in the West has long been reliant on “conventional” resources, most significantly, hydro, nuclear, and thermal resources such as coal and gas. Power generation using these resources provides both energy output and essential reliability services, e.g., frequency response, system inertia, and voltage control. As conventional generation is retired, the energy and services it provides must be replaced. In some cases, the replacement generation can provide the same services as the retired generation, e.g., natural gas generation that replaces coal generation can provide the same essential reliability services. In other cases, the replacement generation cannot supply the same services as the retired generation, as may be the case when certain types of solar generation replace a conventional generation resource.

Background
Over the last decade, the portion of the West’s Resource Portfolio made up by conventional generation resources has decreased from approximately 96 percent in 2003 to 87 percent in 2013. This includes a 25 percent increase in gas generation resources. This trend is expected to continue as few new hydro and nuclear resources are added and coal resources are retired. Each type of conventional generation resource, and the resources available to replace them, presents unique considerations and challenges.

Challenges
Planning for Hydro Limitations
While hydro capacity has decreased only marginally (3 percent) in the last decade, the role of hydro generation in the future resource portfolio must be carefully considered. The current political and regulatory climate makes large additions of hydro capacity unlikely in the near future. In addition, climatic changes, policies and regulations governing the use of water for plant cooling, environmental rules, and increasing tension between states over water matters are factors that affect the availability and use of hydro resources. These factors must be considered as the role of hydro generation is evaluated in planning and operational contexts.

WECC’s Role
WECC does not examine or make recommendations concerning plant retirements. WECC uses information from industry on potential or planned plant retirements in its resource adequacy work and input from stakeholders on plant retirement assumptions for modeling work.

Current WECC Work:
» WECC’s annual Power Supply Assessment examines the near- and long-term resource adequacy of the Western Interconnection, including planned generation retirements.
» WECC studies the transmission planning implications of various coal retirement scenarios on a bi-annual basis.
» WECC is studying the potential impacts of the EPA’s Clean Power Plan.

Opportunities for WECC to Add Value:
» Perform additional planning and operational studies to evaluate the impact of coal retirements on reliability.
» Establish performance metrics for essential reliability services to ensure that they are provided.
» Participate in the NERC Essential Reliability Services Task Force.
Re-Evaluating the Role of Nuclear

In 2013, the retirement of the San Onofre Nuclear Generating Station (SONGS) reduced the installed capacity of nuclear generation by nearly 2,300 MW. Nuclear generation now makes up approximately 3 percent of the West’s resource portfolio. In the Western Interconnection, given the current political and social climate and extensive regulatory and financial processes involved, it is not likely that new nuclear generation will be built in the near future. Federal public policy may impact this outlook. For example, in its proposed Clean Power Rule (EPA Rule 111(d)), the Environmental Protection Agency urges states to consider, or reconsider, nuclear as an option for reducing carbon emissions from the power sector.

Maintaining Essential Reliability Services

Large conventional resources provide essential reliability services such as frequency response, system inertia, and voltage control. Provision of these services must be accounted for when conventional generation is replaced by forms of generation that have limited or no ability to provide these services, e.g., wind and solar. This presents both operational and planning challenges.

Accounting for Retired Coal Generation

The retirement of coal generation in the Western Interconnection is driven by policy, economics and environmental considerations. Approximately 15 percent (38,745 MW) of the installed capacity in the Western Interconnection Resource Portfolio is coal-fired generation. In 2013, 848 MW of coal-fired capacity was retired. Between 2015 and 2024, 5,800 MW of coal generation is anticipated to be retired or converted to another fuel type. These expected retirements are captured in resource adequacy planning and planning reserve margins appear adequate for the next 7–10 years. However, if the rate of coal-fired generation capacity retirements accelerates, new resources will be required to replace the retired generation.
**Issue**

Natural gas-fired generation has grown substantially in the Western Interconnection over the last two decades. With continued growth in variable generation and planned coal retirements, the Western Interconnection’s reliance on natural gas-fired generation is expected to increase. This presents challenges regarding the coordination of the gas and electric industries, the adequacy of gas infrastructure, and the reliability impacts of natural gas supply disruptions.

**Background**

In 2013, there was approximately 95,000 MW of natural gas-fired capacity, accounting for approximately 40 percent of installed capacity.

**Challenges**

*Considering the Gas-Electric Interface*

While there is generally a good understanding of the relationship between the electricity and natural gas industries, the potential reliability impacts of the interaction between the two industries is less understood. Issues such as the interruptible nature of gas supply, scheduling timelines, and operational differences between the two industries could present reliability challenges.

*Understanding Supply Issues*

Bulk-Power System (BPS) planners have not traditionally analyzed fuel supply dynamics. However, with so much additional gas-fired generation in the mix adequacy of the BPS becomes largely a function of gas supply and pipeline capacity and reliability. There are a number of factors that make gas supply a potential Reliability challenge, including the growing dependence on natural gas-fired generation; unique nature of gas pipeline delivery; and problems caused by weather, equipment failure, and/or generators not performing to schedule. Specific challenges include:

» Communication of pipeline operational restrictions and other critical gas supply information to Balancing Authorities (BA), Reliability Coordinators (RC), and Power Plant Gas Coordinators (PPGCs).

» Changes to the BPS to accommodate potential fluctuations in pipeline pressure caused by increased use by natural gas-fired generators and increased penetration of variable generation.

**WECC’s Role**

WECC monitors the reliability of the electricity industry but does not monitor or regulate the gas industry.

**Current WECC Work:**

» WECC has sponsored various meetings to discuss the issues related to FERC Order No. 587-V and to maintain awareness of FERC actions related to natural gas scheduling changes.

» The Market Interface Committee at WECC regularly includes presentations and updates on natural gas-electric coordination issues.

» The Transmission Expansion Planning Policy Committee (TEPPC) studies often analyze the impact that a particular future scenario may have on the gas fleet.

**Opportunities for WECC to Add Value:**

» Facilitate cooperation between the Bulk Electric System and the natural gas pipeline/supply system to address reliability issues and to foster coordination with natural gas producers, distributors and pipelines.

» Study potential reliability impacts of gas supply interruptions.
— ELECTRIC INTERDEPENDENCIES

» Identifying the most severe BPS contingencies that could be caused by gas pipeline or pipeline-related equipment failures.

» Assessment of preparedness and emergency response plans.

Reconciling Differences in Scheduling Practices
Differences between natural gas scheduling and electricity scheduling affect the daily operations of the power system. Similar to the difference between energy and transmission capacity in the electricity industry, there is a distinct difference between purchasing natural-gas supply and securing natural gas delivery capacity. This creates the potential for situations where electric companies purchase non-firm natural gas delivery to supply firm electric generation.

The purchase and delivery of natural gas requires more time than electricity because unlike electricity, which is produced and consumed in real-time, natural gas is a physical commodity that requires time to process and deliver. Natural gas pipelines operate with less flexibility in their schedules than real-time operations may desire so as not to over or under “pack” the natural gas pipelines. Consequently, generators must plan further ahead and are not able to make as many real-time changes in operation.

Planning for and Operating during Severe Weather Events
Extreme temperature events can impact natural gas supply and delivery. During the 2013 Polar Vortex event, natural gas availability presented a major challenge in the Eastern Interconnection. Weather events can also affect natural gas plant controls. In 2011, severe cold weather in Texas caused plant controls at some plants to freeze, rendering the plants unavailable though gas supply was unaffected.
**Issue**

Load composition refers to the combination of energy consumption patterns (i.e., peaks) and types of demand (i.e., residential or commercial). Both consumption patterns and types of demand are changing. Historical load composition has been slow and fairly predictable, resulting in minimal impact to the reliable operation of the system. Future changes to load composition could present operational and planning challenges.

**Background**

Historically, changes to demand patterns were the result of manufacturing and commercial customers modifying their demand patterns by shifting more demand to the cheaper “off-peak” hours. Within the last few years, residential demand changes have affected load composition. For example, residential use of air conditioning has increased, energy efficiency has increased, and there have been technological advances in residential electronics and appliances.

**Challenges**

**Planning For and Operating To Changes in Demand**

While changes in load may not present drastic challenges to reliability and may actually help reliability, there will be challenges associated with planning and operating for the changes in load composition. Below are examples of types of load composition changes that could present challenges.

- **Mechanisms for reducing demand** – Temporary reductions in demand through demand-control tools may present operational challenges in incorporating these tools into operations. Demand-Side Management/Demand Response is an example of this type of mechanism. This is a growing area of exploration as a way to not only manage demand but also address issues with frequency response. From a planning perspective, Demand-Side Management (DSM) programs must be sophisticated and large enough to provide adequate and responsive demand reduction. These programs are often voluntary and require negotiation and careful management.

- **Mechanisms for removing load** – Permanent reduction in load, while a reliability benefit, presents long-term planning challenges. Energy Efficiency programs are an example of this kind of mechanism.

**WECC’s Role**

WECC gathers information and conducts historical and forward-looking analyses on demand. WECC does not promulgate rules or policies that affect demand or directly control demand in any way.

**Current WECC Work:**

WECC is:

- Examining changes in demand patterns to correlate the changes to reliable operation of the electric grid.
- Analyzing “on-peak” to “off-peak” shifts in demand to evaluate potential impacts to reliability.
- Studying the potential operational benefits of electric “plug-in” vehicles.
- Studying the impacts of energy efficiency.
- Conducting high energy-efficiency and high demand-response studies in transmission expansion planning work.
- Undertaking a “flexibility” assessment designed to analyze the reliability impacts of drastic “net load” swings caused by a large penetration of rooftop solar and other types of renewable generation.

**Opportunities for WECC to Add Value:**

- Work with reliability entities to implement new technologies while maintaining system reliability.
- Monitor the change in demand patterns to understand impacts to reliable operation of the grid, as well as any actions being taken to prepare for future changes.
» High penetration of new types of demand – New technologies and commodities may cause changes to load composition. For example, rapid and high penetration of plug-in vehicles has the potential to change consumption patterns. Peak demand could increase as people return home in the evening and charge their vehicles. The severity of these changes depends upon how rapid and to what degree this technology is implemented.

Understanding the Drivers of Load Composition Changes
There are a number of drivers to changes in load composition, some discussed in other sections of this document. While we have a good understanding of some drivers, others require additional evaluation. For example, the effects of climatic changes in the West could change load patterns. Warmer weather in the Northwest may shift the peak demand toward the summer, rather than the winter. Another example is distributed generation (DG), which could pose the largest imminent change to load. While DG is a resource issue, DG is a load reduction mechanism and a large influx of these resources could cause an inverted load shape similar to the California “duck chart.”
Issue
Climatic change is a process that manifests through variations in the prevailing weather conditions over a long period of time, measured from decades to millions of years. The effects of climatic change can be more tangible, sometimes discrete events that can be measured, tracked and, in some cases, planned for. For example, drought, an effect of the desertification process, is a condition we can measure and to some extent plan for.

Background
The Western Interconnection covers a number of interdependent regional climates. Changes to these climates will affect the Interconnection in various ways. The challenge facing the Interconnection is to identify effects of climatic change that may impact reliability and then develop plans to mitigate or adapt to those impacts. This process is complicated because the Western Interconnection covers such a large geographic area.

Challenges
The challenges associated with climatic changes affect the Western Interconnection on varying time scales. Near-term effects present operational challenges while long-term changes present planning challenges. The response to these challenges—in the form of new policies, regulations, and practices—can also present challenges.

Managing the Operational Impacts
Some effects of climatic change have near-term impacts. The following are examples of climate changes effects that may impact system operations.

» Temperature – Changes in temperature include changes to average and extreme temperatures. Increases in extreme temperature events could alter peak load patterns and magnitude. These events can be acute (e.g., hottest or coldest day of the year) or more extended (e.g., hottest summer on record).

» Extreme weather events – Extreme weather events, such as storms, can increase as climates change. The impacts of extreme weather can be concentrated or drawn out over time. Storms can damage physical infrastructure or create conditions that impede the restoration of power, e.g., flooding. In contrast, increases in lightning over many years may result

WECC’s Role
WECC distinguishes the issue of changing climate conditions from the political topic of climate change. WECC focuses on the effects of climatic changes and how they may impact the reliability of the Western Interconnection. WECC is not involved in the climate change debate, which includes discussions, studies, policymaking, etc., on both the effects and causes of global climate change.

Current WECC Work:
» WECC considers Renewable Portfolio Standards compliance in some of its future study work.
» WECC analyzes drought scenarios and hydro sensitivities as part of its long-term transmission expansion planning work.

Opportunities for WECC to Add Value:
» Develop scenarios that consider the impacts of a changing climate and prolonged drought.
» Investigate the relationship between the water and energy sectors (i.e. water-energy nexus) and identify reliability risks.
in momentary outages on the transmission system—in 2013, the largest cause of automatic transmission outages was lightning. The secondary effects of extreme weather (such as flooding, fallen trees, and wildfires) also present challenges.

» Wildfires – While not a weather event, wildfires are often caused or perpetuated by weather. Wildfires pose a direct physical threat to infrastructure. Smoke, heat, and flames from wildfires can interrupt transmission service. Each year, generation plants and other staffed facilities are evacuated due to wildfire.

Planning for Impacts to Resource Adequacy
Climatic change effects may impact future resource adequacy, presenting planning challenges.

» Precipitation – Changes in precipitation include increases and decreases in the amount of precipitation as well as timing shifts in the precipitation cycle. These can affect snow pack, river flow, and water availability for plant cooling. For example, over the next several decades, the Pacific Northwest may experience more precipitation that falls later in the spring and in the form of rain. This could impact the availability of hydro generation that is relied on by not only the Northwest but by all regions in the Western Interconnection.

» Temperature – Changes to average temperatures that occur over time present planning challenges. These types of changes have the potential to permanently alter load patterns.

Coping with the Immediate and Long-Term Effects of Drought
Drought is the manifestation of a long-term precipitation change and, in the Western United States, usually temperature increases. Droughts pose a challenge to a system that is heavily reliant on water as both a fuel and cooling mechanism for thermal power plants. In addition, water is a highly contested commodity for other major industries, meaning that reliability priorities pertaining to water may have to compete with other social and economic priorities including agricultural, sanitation, and health priorities.

A complicating consideration is that droughts often include spans of years with higher-than-normal precipitation, which can effectively lull the industry into a feeling of false security. For example, California, which is now in its third year of an extreme dry spell, has experienced an oscillation between wet and dry spells lasting three-to-seven years for the last 150 years. The dry spells are referred to as droughts and during these periods, planning for reduced water availability is a higher priority than when the state is experiencing a wet spell and water is plentiful.

Responding to Policies Addressing Climate Change
Policies spurred by climate change affect every aspect of the electric grid, from how much demand there is for energy (e.g., increased plug-in vehicle penetration) to generation procurement and resource adequacy (e.g., Renewable Portfolio Standards) to plant operations. The power industry accounts for roughly one-third of greenhouse gas emissions in the United States, presenting a high-priority opportunity for policies addressing climate change. In addition, policies to reduce emissions from other sectors, for example the transportation sector, could affect the power sector.
**Issue**

Variable generation refers to generation resources that rely on fuel sources that cannot be controlled and are intermittently available (i.e., wind and solar generation). Integrating variable generation resources into the system presents operational and planning challenges. Wind and solar generation is operated differently than other types of renewable generation (e.g., geothermal, and traditional thermal or hydro generation). In addition, variations in the availability of fuel for wind and solar resources must be planned for.

**Background**

Over the last decade, variable generation penetration has increased dramatically in the Western Interconnection. Most of the increase has been wind capacity; however, the growth rate of solar capacity overtook that of wind in 2012 and 2013. Solar growth is expected to continue as solar technology continues to mature, prices drop, and distributed solar generation penetration increases.

**Challenges**

**Understanding the Drivers**

Many drivers of variable generation are outside the control of the electricity industry and its regulators. State and Federal policies that reflect environmental, economic, and social priorities are major drivers of variable generation. These policies often have unintended consequences that pose system planning challenges. Examples of policy drivers include:

- *Renewable Portfolio Standards (RPS)*
- *Federal and state tax incentives for wind and solar development*
- *Renewable energy credit programs*
- *Federal policies and regulation, such as EPA’s proposed Clean Power Plan*
- *State requirements for accounting for flexibility in utility IRPs*

The retirement of base-load capacity, specifically coal, may drive future increases in variable generation. Replacing base-load generation with variable generation poses a multi-faceted challenge. Wind and generation have lower capacity factors than coal-fired generation, so more wind and solar installed capacity is required to replace the energy output of retired coal-fired plants. More challenging is the variability of the wind and solar resources. The greatest

**WECC’s Role**

WECC’s work on variable generation is focused on identifying potential challenges and impacts to reliability. WECC does not make recommendations on, sanction, permit, or fund variable generation development. WECC may provide input on the potential reliability implications of proposed policies or regulations, but WECC does not promulgate, advocate, or oppose state or federal policies or regulations concerning variable generation.

**Current WECC Work:**

- WECC develops variable generation stability models.
- WECC evaluates the impact of high levels of variable generation on system operations
- WECC participates in industry forums related to variable generation.

**Opportunities for WECC to Add Value:**

- Continue and enhance inclusion of high-variable-generation-penetration scenarios planning and stability analyses.
- Create data for subregional and Interconnection-wide wind and solar integration studies.
challenge may be that wind and solar generation may not be capable of providing essential reliability services, such as firm capacity, that base-load generation like coal provides.

Managing Uncertainty
The uncertainty and uncontrollability of wind and sun pose operational challenges. Over the last decade, analysis of historical meteorological data has provided valuable insight into wind and solar patterns, and aided improvements in forecasting technology and practices; however, no forecast can provide absolute certainty. Sudden large changes in wind or sun exposure can result in rapid increases or decreases in instantaneous energy output that must be managed.

Balancing Variability
Balancing the variability of wind and solar generation is an ongoing challenge. The generation fleet must have enough flexibility to balance out not only regular variations in variable generation output but also manage large ramp events. Options for balancing variability are discussed in a separate section of this document.
**Issue**

Balancing loads and resources takes place as a basic function of grid operations. Variability on the grid must be balanced to ensure reliability. There are two primary sources of variability on the grid: consumer loads and variable generation resources. Increased penetration of variable generation will require increased operational flexibility to balance and manage the stability of the system.

**Background**

Variable generation resource availability is constantly changing. In some months of the year and hours of the day, variable generation resources experience steep ramps that occur in the opposite direction of changes in demand. The uncertainty associated with when, and to what extent these changes occur makes balancing the variability of intermittent resources a complex task. Conditions with high variable-generation penetration can stress system operations as changes in supply and demand are balanced. While balancing load variability and balancing variable generation are fundamentally the same – load must be equal to generation – the characteristics of variable generation, and the political and regulatory environment surrounding it, pose unique challenges.

**Challenges**

*Planning for Flexibility*

Flexibility can be achieved through the resource mix (e.g., adding gas generation) and through operational mechanisms (e.g., energy storage, demand response). These options require planning that may require long lead times to implement and each has inherent challenges. For example, increased use of natural gas generation to manage variable generation contributes to a growing dependency on natural gas resources. Natural gas dependency presents its own challenges, discussed in more detail in another section of this document. Energy storage is currently a high-cost option that is not widely used and may not be recoverable in utility rate base. Demand response requires complex programs that rely on volunteered curtailment or reduction of load, and may not be suitable in all areas. In addition, demand response participation may change over time.

**WECC’s Role**

WECC’s work on variable generation is focused on identifying potential challenges and impacts to reliability. WECC studies system flexibility but does not advocate for or promote any specific mechanism to ensure flexibility on the system.

**Current WECC Work:**

- WECC is undertaking a flexibility assessment designed to investigate reliability impacts associated with high penetration of variable generation.
- The WECC Variable Generation Subcommittee completed a BA cooperation and intra-hour scheduling study.
- WECC developed a Market Mechanisms white paper that identified market options in the West.

**Opportunities for WECC to Add Value:**

- Participate in stakeholder development processes for fast-dispatch market developments.
- Study the correlation between ramping and outage rates on conventional generation units.
- Follow and evaluate potential state requirements for including flexibility in utility Integrated Resource Plans.
**Balancing Variability**

*Holding Operating Reserves to Balance Variability*

To balance variable generation, entities often hold special operating or regulating reserves (sometimes called flexibility reserves). Holding reserves can be expensive and can affect system operations. Entities can ramp conventional generation to match changes in wind and solar output, but most thermal generation plants must maintain minimum generation levels and are not designed to operate in this manner. The additional wear and tear on generating units may lead to increased forced outage rates, as well as increased and longer maintenance outages. Redispatching hydro generation is another option, but it can be limited by factors like environmental regulations that control water flow.

*Diversifying Variability*

One way to manage variability is to spread it over larger areas. Managing variability over a larger load base and generation fleet may help mitigate the effects because the larger footprint may be better able to absorb the variability and entities can share flexible resources to address it. For example, recent developments in fast-dispatch markets (e.g., California Independent System Operator Energy Imbalance Market, Northwest Power Pool security-constrained economic dispatch, and Front Range Dispatch Initiative) aims to manage variability across broad areas through market mechanisms. Evaluation and implementation of these mechanisms consumes time and resources and may require a change in traditional attitudes in the Western Interconnection.

*Sharing Variability*

Another way to spread variability is by scheduling variability from one area (e.g., a Balancing Authority) to another. Mechanisms like transfers, and more specifically dynamic transfers, between areas allow variability to be “moved” but come with operational challenges.

*Implementing Scheduling Changes*

FERC Order 764 requires entities to offer 15-minute scheduling, which allows transmission customers to address imbalances within the hour rather than only at the top of the hour. Order 764 also requires the provision of meteorological and forced outage data for variable generation resources to Transmission Providers to help with power production forecasting. Implementing Order 764 requires coordination between entities, and draws on additional time and resources.
WECC’s Role
WECC’s focus is the BPS and it does not oversee the reliability of the distribution level power grid.

Current WECC Work:
» The Modeling and Validation Work Group developed models to allow specific representation of distributed generation as part of the load model.
» The Planning Coordination Committee (PCC) is constructing a base case that accounts for DG.
» WECC Flexibility Assessment analyzing system operational concerns in a future with large penetrations of variable generation.
» WECC analyzes high levels of DG in its transmission planning scenario work.

Opportunities for WECC to Add Value:
» Assess benefits and opportunities for voltage control by DG power inverters.
» Use newly developed models to explicitly represent distributed generation in base cases and perform system analysis.

Issue
Distributed generation (DG) refers to any generation (wind, solar photovoltaic, or other) that is connected directly to the electric distribution network as opposed to the transmission network. Historically, most electricity generation has operated as part of the Bulk-Power System (BPS), and this remains the case. However DG penetration is increasing and all indications are that this will continue into the foreseeable future. As the penetration of DG grows, it could change load composition. In addition, not all DG resources are monitored or controlled in the same way as BPS resources, potentially presenting operational challenges.

Background
The majority of recent DG growth has been in solar photovoltaics (PV). In 2013, California alone reached 2,000 MW of PV distributed generation capacity. Technology advances that improve efficiency and reduce costs, and favorable regulatory environments have contributed to this growth.

Utilities are beginning to understand the potential reliability impacts posed by DG to distribution systems through studies on the interconnection of these resources. However, the potential impacts posed by DG to the BPS are less understood.

Challenges
Managing Variability
Distributed generation resources individually are small and have negligible impact on the BPS. However, when DG resources are aggregated, their potential impact becomes more significant. It is possible that the aggregate effects of a growing number of DG resources could impact the BPS in a more significant way. Because the majority of DG resources are variable generation resources (i.e., wind and solar) large aggregations of these resources present the same challenges as their BPS counterparts.

Improving Visibility of DG Resources
Bulk-Power System operators typically cannot directly view DG resources as they can generators. Visibility of these resources has not historically been an issue because the resources are imbedded in and swamped by loads that are also variable and not visible to the utility. Individually, DG resources have little to no impact on the BPS. However, as the penetration and concentration of these resources grows, the potential for impact to the BPS makes visibility a critical issue.
**Coordinating Control of DG Resources**

Bulk-Power System operators cannot directly control DG resources because many of these resources are consumer-sited resources. For example, unlike turbines in large wind farms that can be somewhat controlled through options like blade feathering, small backyard wind turbines cannot be controlled in a coordinated manner.

**Reconciling Practices and Standards on Response to Faults**

DG resources are connected according to the IEEE 1547 Standard, which requires resources to disconnect from the system under abnormal conditions so that distribution protection systems can operate. Generators on the BPS are not operated in this manner during abnormal system conditions because they are required for low-voltage ride-through. This has the potential to result in the disconnection of large aggregations of distributed generation from the system at times when ride-through is critical.
**Issue**

Situational Awareness refers to the ability to see and comprehend what is happening on the system. There are a number of processes necessary to maintaining Situational Awareness including real-time monitoring, and real-time and near-term contingency analysis studies. The coordination and sharing of data is critical to Situational Awareness because each process relies on various types of data. The lack of adequate situational awareness limits entities’ ability to identify and plan for the next most critical contingency, which, in turn, impacts the reliability of the entire system.

**Background**

The review of the September 8, 2011 Desert Southwest Blackout event showed that portions of the Western Interconnection were not being operated in a secure N-1 state, i.e., they were not capable of surviving the loss of the next single contingency. Operating in a non-secure state limits an entity’s ability to prevent instability, uncontrolled separation, or cascading outages. The events of September 8 exposed a latent weakness related to a lack of appropriate tools and monitoring to enable all entities to manage reliability in real-time. Inadequate real-time situational awareness was cited as one of the two primary weaknesses that led to the September 8 event. Strides have been made since the event to address shortcomings in Situational Awareness in the Western Interconnection; however, challenges remain.

**Challenges**

*Increasing Use of Real-Time Tools*

The challenges associated with a lack of appropriate real-time tools and monitoring capabilities are pervasive and unpredictable. A number of entities do not have real-time tools and cannot ensure the constant monitoring of potential internal or external contingencies that could affect reliable operations. Events such as the August 14, 2003, and September 8, 2011 blackouts exemplify the need for real-time tools. Addressing these concerns pose a challenge to the industry.

**WECC’s Role**

WECC’s role in situational awareness is multifaceted. WECC receives information from entities on system disturbances and compiles that information into reports that are forwarded to NERC. In addition, WECC gathers information and coordinates Interconnection-wide work on operational practices and issues such as Next-Day Studies.

**Current WECC Work:**

» The Next-day Study Task Force is identifying best practices in contingency analysis and developing a common methodology.

» WECC issues an annual Operational Practices Survey to gather information from entities on near-term studies, seasonal studies, and situational awareness and protection.

» WECC’s Data Exchange Work Group developed the a guideline that provides a clear process for the treatment and exchange of system operations data.

» The WECC Energy Management System Work Group developed the Real-time Tools Guideline that provides entities information and best practices related to real-time tools.

**Opportunities for WECC to Add Value:**

» Continue the Operational Practices Survey to identify Best Practices and opportunities for improvement.

» Work with entities to expand external visibility in their models through more complete data sharing.

» Monitor and support efforts to improve the use of real-time tools to ensure the constant monitoring of potential contingencies.

» Facilitate communications among entities and robust sharing of information and data critical to maintaining Situational Awareness.
Situational Awareness

**Coordinating Information and Data Exchange**

Situational Awareness requires various types of data to accurately monitor the system in real-time. Real-time communication and sharing of data among entities is critical for entities to identify potential contingencies and how those contingencies affect the interconnected systems in the Western Interconnection. Gaps in data sharing, while improved in recent years, still pose a challenge that industry must overcome. For example, most entities share next-day and seasonal study information with only neighboring entities and only when it is deemed necessary or when a neighboring entity requests the information. Agreements must be in place to govern the flow of real-time information among entities. While the Universal Non-Disclosure Agreement with the Balancing Authorities (BA) and Transmission Operators (TOP) has helped remedy this issue, ensuring that required data flows between entities will be an ongoing challenge.

**Expanding External Visibility in Entity Transmission Models**

In 2011, it was revealed that many entities do not have visibility into their neighboring systems, so they cannot model those systems. In 2014, some TOPs and BAs do not ensure that generation and transmission outages as well as scheduled interchanges are included in their next-day studies. This leaves these entities unaware of potential contingencies that may affect their systems. In some cases, entities do not obtain sufficient data to monitor significant external facilities in real-time, specifically those that are known to have a direct bearing on the reliability of their system. In other cases, entities do not properly assess the impact of internal contingencies on neighboring entities.

**Improving Consistency and Quality of Next-Day and Seasonal Studies**

The quality and coordination of system studies, specifically next-day and seasonal studies, were a major concern identified in the September 8 event review. Improvements have been made across the industry over the last three years; however, continued improvement and coordination of system studies is an ongoing endeavor. Currently, the periodicity, quality, and sharing of these studies varies widely across entities, though to less degree than three years ago. For example, some entities conduct daily next-day modeling of their system using up-to-date, day-ahead forecasts for system conditions. Other entities use a single snapshot of the system in all of their next-day studies and make adjustments only when necessary.
WECC’s Role
In its annual State of the Interconnection Report, WECC monitors and reports on transmission outages caused by equipment failure. WECC also participates in NERC’s efforts to address equipment failure issues.

Current WECC Work:
» WECC’s Substation Work Group (SSWG) monitors and makes recommendations concerning planning, design, operation, maintenance, and documentation of substations. The SSWG also provides assistance to other groups to enhance understanding and operation of WECC substation equipment and systems.
» WECC is the only Regional Entity that currently has a process in place to collect data on substation equipment failures. WECC's SSWG collects Substation Trouble Reports, which are used to share information with utilities concerning equipment failures and potential problems.
» WECC is an active participant in NERC forums such as the AC Substation Equipment Task Force (ACSETF).

Opportunities for WECC to Add Value:
» Compile information learned from its data gathering efforts into a comprehensive overview of equipment failure issues.

Issue
Equipment failure refers to the malfunction of AC substation equipment, e.g., circuit breakers and transformers. AC substations are complex facilities that operate continuously. Failure of components can result in momentary outages or contribute to longer-term events. The 2013 and 2014 NERC State of Reliability Reports identified AC substation equipment failures as significant contributors to disturbance events, with a positive correlation to increased transmission outage severity.

Background
For the last five years, AC equipment failure was the second largest cause (behind weather/lightning) of automatic transmission outages in the Western Interconnection. Focused efforts have greatly reduced the number of equipment failure-related outages over the last five years, but there is room for additional improvement. Equipment failure related outages tend to last longer than outages resulting from other causes. This is in part because occasionally equipment must be replaced. Longer durations can also be attributed to increased complexity associated with equipment failure-related outages.

Challenges
Reducing Outages Caused by Equipment Failure
Equipment failures occur in any operating system, and understanding when the number of equipment failures becomes cause for concern can be a challenge. Tracking the rate of occurrence aids industry in understanding and identifying potential systemic issues, such as manufacturing flaws or operational practices.

Minimizing the Impact of Equipment Failures
Inherent in AC substation equipment failure is an increased probability that additional BPS elements will also be forced out of service, potentially increasing Transmission Outage Severity. The function and arrangement of substation equipment often increases the number of transmission lines forced out of service when substation equipment fails. By design, substation
Equipment is always located in close proximity to transmission line terminals. Substation equipment failures can be explosive and combustive in nature, often resulting in additional AC Circuits forced out of service due to the impact of debris or conductive combustion products. In addition, faults caused by substation equipment failure can cause protection system misoperations. Large fault currents in the substation ground grid caused by equipment failure can impact relay communications and lead to transmission line protection system misoperations. Multiple protection system misoperations can also be caused by failed instrument transformers.
**Issue**

Remedial Action Schemes (RAS), also known as Special Protection Systems (SPS), are plans designed to minimize equipment damage and prevent cascading outages, uncontrolled loss of generation, and to minimize interruptions of customer electric service. RAS detect abnormal system conditions and (often) take pre-determined or pre-designed actions to prevent those conditions from escalating into major system disturbances. RAS supplement ordinary protection and control devices (fault protection, reclosing, Automatic Voltage Regulators, Power System Stabilizers, governors, Automatic Generation Controls, etc.) to prevent violations of the NERC/WECC Reliability Criteria for Category B and more severe events. RAS have become more widely used in recent years to provide protection for power systems against problems not directly involving specific equipment fault protection. As a result, the potential exists for RAS to interact with and impact one another. This could create a reliability risk to the Interconnection.

**Background**

Economic incentives and other factors have led to increased electric transmission system use, power transfers, and changes in historic usage patterns, both among regions and within individual utilities. New transmission construction has often lagged behind these changes, resulting in lower operating margins. The resulting system-wide problems usually require separate solutions that can be provided by equipment-specific protection schemes, i.e., RAS. Currently, there are 265 RAS in the Western Interconnection, 49 percent of total RAS in North America.

The FERC/NERC Report Arizona, Southern California Outages on September 8, 2011 (Joint Report) identified areas of deficiencies regarding RAS within WECC. The Joint Report noted the lack of studying/modeling and coordinating the effect of protection systems, including RAS, during plausible contingency scenarios. Additionally, the Joint Report noted WECC’s definition of RAS excluded many protection systems that would be included within NERC’s definition of SPS. As a result, the report noted that WECC did not review and assess all NERC-defined SPS in its Region and WECC’s Transmission Operators

**WECC’s Role**

WECC is the Reliability Assurer for the Western Interconnection. In this capacity, it oversees the Reliability Coordinator.

**Current WECC Work:**

» WECC is leading the effort to model SPS and potential impacts on the BPS. The Remedial Action Scheme Reliability Subcommittee (RASRS) reviews the reliability aspects of existing and planned RAS and works to enhance grid performance within the Western Interconnection by providing a uniform review process.

» The Modeling SPS and Relays Ad-hoc Task Force (MSRATF) identifies methods to better model RAS and relays in planning simulations. The MSRATF developed a method and format for implementation in the major simulation programs used by planners to read a common data file defining the RAS schemes.

» WECC is working on implementing the new capabilities in simulation programs.

**Opportunities for WECC to Add Value:**

» Continued participation on NERC standard drafting team for a new RAS standard. There are currently four members from the West on that team.

» Facilitate Interconnection-wide discussions about SPS and RAS in the West.

» Facilitate understanding outside of the Western Interconnection of the role that RAS and SPS play in the West.
did not perform the required review and assessment of all NERC-defined SPS in their areas. Specifically, the lack of WECC’s assessment and review of the S-Line RAS and SONGS Separation Scheme were determined to have had an adverse impact on the reliability of the grid.

**Challenges**

*Evaluating and Managing the Interaction of RAS*

The interaction among RAS poses a challenge. RAS are designed and tested for specific systems or parts of systems, so their operation in protecting those systems is well understood. What is less understood is how RAS interact or impact one another, i.e., situations where the activation of one RAS creates conditions that trigger another RAS to activate. Evaluating the potential interactions, and then managing those interactions that present a risk, will require time and resources.

*Ensuring Proper Relay Settings*

In 2012 and 2013, incorrect settings, relay failures and malfunctions, and communication failures accounted for 76 percent of Protection System misoperations. Incorrect settings alone accounted for 34 percent of all misoperations. WECC and industry continue to focus on these issues in response to the Recommendations in the Joint Report.

*Reducing Relay Misoperations*

Between November 2010 and August 2014, there were 50 reportable events involving RAS in WECC, of which 14 were due to failure or misoperation of the RAS. The number of Protection System misoperations that occurred on elements below 200 kV increased from 126 in 2012 to 151 in 2013. In 2012 and 2013, the under 200-kV voltage class, which makes up the largest portion of the transmission system, had the greatest number of misoperations in proportion to its size. Despite this, evaluation of all relays connected to elements below 200 kV is not mandatory under regional reliability standards.
Problem
The Western Interconnection is vast not only in physical size but also in the number and type of entities that plan and operate the system. Reliable operation of the system depends upon appropriate and consistent operational practices. However, the number and diversity of registered entities in the Western Interconnection makes consistency and broad adoption a challenge.

Background
Each year, WECC surveys entities in the Western Interconnection to identify processes, best practices, and areas of concern associated with specific reliability-related operational practices. Evaluation of the information from the Operational Practices Survey provides a non-compliance look at trends in operational practices across the Interconnection over time.

Challenges

**Evaluating Trends in Operational Practices**
WECC evaluates trends in operational practices through its annual Operational Practices Survey. In general, the Operational Practices Survey covers six categories of operational practices: 1) Near-Term Studies; 2) Seasonal Studies; 3) Situational Awareness; 4) Protection Systems; 5) Angular Separation; and 6) Energy Management Systems. The information gathered through the survey is used to evaluate trends, identify new areas of concern, and develop best or recommended practices. The survey is extensive and requires time and resources on the part of the responding entities, adding to an already high work load. While entities understand the value of the survey, their participation must be balanced among a number of company priorities. Over the three years that the survey has been issued, WECC has seen increasing participation. Continuing this growth and identifying additional ways to gather this trend information will be an ongoing challenge.

**Identifying Best Practices**
In theory, identifying best operational practices is a straightforward undertaking. However, in practice, the diversity of entities in the Western Interconnection makes identification of best operational practices a challenge. Best practices that fit one entity’s particular situation may not be appropriate to another’s. From a compliance perspective, there are Reliability Standards that govern certain operational practices. In some cases, these standards identify only the minimum requirements for entities to meet.

**WECC’s Role**
WECC is a leader in addressing operational practices in the Western Interconnection. WECC coordinates work on operational practices at both the Interconnection-wide and specific practice levels.

**Current WECC Work:**
- Through its annual Operational Practices Survey, WECC identifies processes, best practices, and areas of concern in operational practices.
- The WECC Operating Practices and Event Analysis Subcommittee (OPEAS) reviews Event Reports and identifies areas for improvement.
- The Performance Work Group (PWG) identifies areas of improvement through investigation and analysis of Interconnection control performance.
- The Path Operator Task Force (POTF) investigates challenges related to current path operations and identifies recommendations for improvement.
- The Next-Day Studies Task Force (NDSTF) is developing a guide line on how Next-day Studies should be conducted, as well as the nature of the studies, necessary data input and how the results are shared.

**Opportunities for WECC to Add Value:**
- Promote best practices through a quarterly webinar with entities
- Extend the Operational Practices Survey Performance Reports to the Generator Owners and Operators
- Continue to refine the Operational Practices Survey and increase participation and response quality
Promoting Adoption of Practices across Diverse Entities

There is incredible diversity in the type, size, economic characteristics, and governance of the operating and planning entities across the Western Interconnection. Wide, consistent adoption of operational practices beyond those required by the standards, or in the absence of standards, can be difficult. Limitations like time, resources, technology, and jurisdiction vary across entities.
Issue
Cybersecurity in the power industry refers to the protection of information, communications, and electronic devices (including hardware, software and data). Cyber-attacks on the power system can disrupt information flow and communication, as well as the physical workings of power system elements. While the electric sector has yet to experience a cyber-attack that affects the operations of the North American Grid, WECC agrees that the risk of a large-scale attack is significant and must be addressed.

Background
In 2007, NERC created mandatory reliability standards addressing cybersecurity concerns. Over the past several years, cybersecurity threats have been on the rise in the electricity sector. As entities have become more reliant on automated systems and integrated technology, it has become more important to identify the cybersecurity risks associated with using advanced technologies.

Challenges

Balancing Benefits of Technology with Increased Exposure to Cyber Risks
The Western Interconnection is more integrated now than it has ever been because of computers, digital information, real-time tools, expansive communication systems, etc. While integration of system components has led to efficiencies and better awareness of the system, it has also increased the system’s vulnerability to cyber threats. Prior to recent advances in integrating the system, threats to system security remained isolated because a single access point provided access to a very limited part of the system. Advances in the integration of the system allow much greater access from a single access point. Balancing the need for integration with the risk of increased vulnerability to cyber-attack will pose an ongoing challenge.

Identifying Significant Vulnerabilities on Regional/Interconnection-wide Basis
Historically, WECC (and other regions) have performed compliance monitoring activities with limited tailoring and consideration of the potential risks posed by specific registered entities and interactions between registered entities. Rather, two generic instruments have dictated the scoping and timing of compliance monitoring activities: the NERC Actively Monitored List of Reliability Standards (AML) and the mandatory compliance audit cycles.

Ensuring a Proactive Focus to Compliance
Aspects of a “zero-tolerance” approach may have been acceptable, and perhaps necessary, during the initial era of compliance. However, WECC now faces the challenges of ensuring a proactive focus to address reliability risks

WECC’s Role
In its role as the Regional Entity for the Western Interconnection, WECC monitors and enforces compliance with reliability standards, including Critical Infrastructure Protection (CIP) Standards. WECC also facilitates discussions and information sharing on cybersecurity with stakeholders.

Current WECC Work:
» WECC completed the cybersecurity regional risk identification project and identified several cybersecurity risks that WECC will focus its monitoring efforts on in 2015.
» WECC is conducting a trial Internal Controls Evaluation for an entity for some of the identified cybersecurity risks. The evaluation will help WECC determine the appropriate depth and scope of compliance audit and self-certification for the entity.

Opportunities for WECC to Add Value:
» Continue compliance monitoring of Reliability Standards, including determining the scope of Compliance Audits, Spot Checks, and Self-Certifications.
» Continue enforcement of Reliability Standard violations, including enforcement discretion, penalty determination, and deterrence techniques.
» Conduct registered entity outreach for specific areas of risk.
» Identify and communicate best practices to industry.
within the dynamic nature of the Bulk-Power System (BPS). As part of this next step in the evolution of compliance paradigms WECC aims to develop a risk-informed construct through the Reliability Assurance Initiative (RAI). The comprehensive RAI approach can be viewed as a four-step process that consists of:

» Identification of the significant vulnerabilities common to the BPS on either an Interconnection-wide or regional basis
» Assessment of entity inherent risk
» Evaluation of the internal controls implemented by a registered entity to address these risks
» Compliance monitoring and enforcement decisions based on the results of inherent risk assessment and controls evaluation

Managing Potential Risks
WECC has identified several risk areas that highlight cybersecurity vulnerabilities faced by registered entities in the Western Interconnection. The following are the top seven risks:

1. Event and incident response, continuity of operations: Establishing and maintaining plans, procedures, and technologies to detect, analyze, and respond to cybersecurity events.
2. Threat and vulnerability management: Establishing and maintaining plans, procedures, and technologies to detect, identify, analyze, manage, and respond to cybersecurity threats and vulnerabilities.
3. Risk management: Establishing, operating, and maintaining an enterprise cybersecurity risk management program to identify, analyze and mitigate cybersecurity risk to the organization.
4. Asset and configuration management: Managing an entity’s information technology assets, including both hardware and software.
5. Identity and access management: Creating and managing logical or physical access to an entity’s assets.
6. Workforce management: Establishing and maintaining plans, procedures, technologies and controls to create a culture of cybersecurity and ensure ongoing personnel suitability and competence.
7. Situational awareness: Establishing and maintaining activities and technologies to collect, analyze, alarm, present, and use power system and cybersecurity information, including status and summary information.
WECC's Role
WECC does not own assets and is not the party responsible for securing assets.

Current WECC Work:
» WECC’s Physical Security Work Group addresses issues related to the physical security of the system.
» WECC hosts a CIP Compliance User Group three times a year, where WECC subject matter experts share observations and guidance on industry best practices.
» WECC CIP auditors provide entities feedback during the audit process that identifies potential improvements.

Opportunities for WECC to Add Value:
» Support efforts to bridge the gap between entities and regulators on justifiable costs for security improvements.

Issue
Physical security refers to the protection from physical threat of any critical infrastructure. In practice, this most often means substations. Unlike generation elements that are usually housed within structures, and transmission lines and towers that can be difficult to access, substations are out in the open and have minimal security. Physical security can also apply to fuel sources, such as open reservoirs and fuel delivery, e.g., natural gas pipelines. Physical attacks on system components have the potential to impact the reliable operation of the Bulk-Power System. If these physical attacks are carried out on critical transmission stations or transmission substations, they could result in instability, uncontrolled separation, or cascading failures.

Background
Historically, physical security has largely been a matter of individual companies protecting their assets from occasional damage. This changed with the attack on the Metcalf substation near San Jose, California in April of 2013. The incident thrust physical security into the national spotlight and prompted FERC to direct the creation of new Reliability Standards. While the Metcalf incident did not result in any load loss, it ignited concerns about how breaches in physical security could affect the reliability of the system as a whole.

The Metcalf incident notwithstanding, the majority of physical security incidents are acts of vandalism. Of the 125 physical security-related events reported under Department of Energy Form OE-417 from 2011 to 2013, 74 were acts of vandalism. Thirty-nine events were suspected but not confirmed physical attacks, and nine confirmed physical attacks were reported.

Challenges
Ensuring a Proactive Approach to Physical Security
The quality of the physical security of electrical substations has improved over the years. Historically, individual utilities have, at their discretion, implemented steps to prevent physical damage to their facilities, which mostly was vandalism. Today, critical substations are protected by technology such as high resolution cameras, infrared and motion intrusion detection, and electronic

<table>
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<th>Physical Security Electric Disturbances (DOE Form OE-417)</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>Total</th>
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<td>6</td>
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<td>11</td>
<td>25</td>
<td>74</td>
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<tr>
<td>Suspected Physical Attack</td>
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<td><strong>Total</strong></td>
<td>53</td>
<td>35</td>
<td>37</td>
<td>125</td>
</tr>
</tbody>
</table>
card readers. Many of these measures were put in place in response to the Critical Infrastructure Protection reliability standards, some of which are now retired or have been replaced. The Western Interconnection needs to go beyond the standards and examine other factors like ballistics and coordinated physical attacks to secure substations.

**Implementing the New Physical Security Standards**

There are currently no enforced reliability standards specific to physical security and it is only briefly addressed in the CIP Standards. That will change when the new CIP-014-1 Physical Security Standard goes into effect. The new standard requires owners and operators of facilities to evaluate and implement plans to prevent and mitigate physical threats. Companies will have to alter their perspective from securing their substation from within the fence to outside the fence. For example, vegetation outside the substation should be considered as a point for a coordinated attack and should be looked at to mitigate the possibility. Companies should also be looking at placing boulders or guard rails around substations to continue to ensure that vehicles cannot penetrate the substation perimeter. However, some entities and state regulators see these measures as extreme because the likelihood that this type of attack is too small.

**Securing the Grid Against a Range of Threats**

Physical security presents a multi-faceted challenge because of the wide variance in the location of vulnerable assets, nature of the threats, types of attack, and magnitude of the impacts.

- **Location**: There are thousands of substations in the Western Interconnection. The vast majority of substations are in isolated, often remote locations.
- **Threats**: Physical security threats range from people openly assaulting facilities to sabotage of essential resources such as fuel deliveries. The perpetrators can range from bored youths to highly organized and funded terrorist or foreign criminals.
- **Attacks**: The type of attacks can vary from spray painting to copper theft, to destruction of components through gun fire or bombs.
- **Impacts**: The impacts of an attack can vary. In the case of the Metcalf event, there was no service interruption, but the substation was not fully operational again for 27 days. However, vandalism could destroy components and disrupt service. Concerns have been raised that an outage caused by a coordinated attack could be extraordinarily long because of the lack of transformer inventory and the length of time that it takes to manufacture and deliver a high voltage transformer. Some experts worry that substations farther from cities could face longer attacks because of the increased distance from police or other responders.

**Managing the Costs of Securing the Grid**

Addressing physical security concerns will pose an economic challenge to the industry. Several major utilities have already indicated that they could spend as much as 100-500 million dollars to harden their systems.
Issue

High-impact, low-frequency events refer to events such as coordinated physical or cyber attack, pandemic, geomagnetic disturbance, or large-scale disasters. The probability and extent of the potential impact of these kinds of events is difficult to measure because these events either have never occurred or occur with great infrequency, creating little historical data to measure.

Background

High-impact, low-frequency events pose a unique reliability challenge because the impact and probability of these events is largely unknown. In addition, prioritizing these challenges is difficult because we may be planning for events that may never happen or may have impacts that are less significant than we imagine.

Challenges

Preventing Coordinated Cyber and/or Physical Attack

More than an isolated cyber or physical incident, a coordinated attack on the electric system could result in damage to key systems and components and render part or all of the system inoperable for an extended period of time. Cyber and physical attacks of this nature are among the top priorities at FERC, NERC, the Department of Energy, and the Department of Homeland Security. Measures have been taken to protect sensitive information that could be used to plan these kinds of attacks by classifying some information as Critical Energy Infrastructure Information (CEII).

The challenge associated with coordinated cyber or physical attacks is that information on potential threats is often classified and not available to operators and planners. Because of this, the topic can be somewhat obscure. Ensuring that the best and most appropriate expertise is called on to address these issues is essential to the development of effective standards and other protection measures.

The topics of cyber and physical security are covered in more depth in other sections of this document.

Mitigating the Potential Impacts of Geomagnetic Disturbances

Geomagnetic disturbances, or electromagnetic pulses, can result from solar flares or space weather. The impacts of space weather are complex and depend on numerous factors, but space weather has demonstrated the potential to disrupt the operation of the Bulk-Power System. During a geomagnetic disturbance (GMD) event, geomagnetically-induced current (GIC) flow in transformers may cause half-cycle saturation, which can increase...

WECC’s Role

WECC role with regard to high-impact, low-frequency events is to support work by FERC and NERC and to ensure that entities in the Western Interconnection comply with applicable reliability standards.

Current WECC Work:

» WECC supplies data and analysis to NERC for activities on these issues.
» WECC develops and distributes Interconnection-wide base cases that may provide a framework for analyzing the potential impacts of high-impact, low-frequency events.

Opportunities for WECC to Add Value:

» Work with entities throughout the Interconnection to provide data for a more robust analysis.
» Perform an Interconnection-wide assessment and provide high-level results that would limit the study scope for the entities in WECC.
» Provide a venue for training and exchange of assessment results along with subsequent mitigation.

Issue
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Challenges

Preventing Coordinated Cyber and/or Physical Attack
More than an isolated cyber or physical incident, a coordinated attack on the electric system could result in damage to key systems and components and render part or all of the system inoperable for an extended period of time. Cyber and physical attacks of this nature are among the top priorities at FERC, NERC, the Department of Energy, and the Department of Homeland Security. Measures have been taken to protect sensitive information that could be used to plan these kinds of attacks by classifying some information as Critical Energy Infrastructure Information (CEII).

The challenge associated with coordinated cyber or physical attacks is that information on potential threats is often classified and not available to operators and planners. Because of this, the topic can be somewhat obscure. Ensuring that the best and most appropriate expertise is called on to address these issues is essential to the development of effective standards and other protection measures.

The topics of cyber and physical security are covered in more depth in other sections of this document.

Mitigating the Potential Impacts of Geomagnetic Disturbances
Geomagnetic disturbances, or electromagnetic pulses, can result from solar flares or space weather. The impacts of space weather are complex and depend on numerous factors, but space weather has demonstrated the potential to disrupt the operation of the Bulk-Power System. During a geomagnetic disturbance (GMD) event, geomagnetically-induced current (GIC) flow in transformers may cause half-cycle saturation, which can increase...
absorption of Reactive Power, generate harmonic currents, and cause transformer hot spots. Harmonic currents may cause protection system misoperation leading to the loss of Reactive Power sources. The combination of these effects from GIC can lead to voltage collapse.

On May 16, 2013, FERC issued Order No. 779, directing NERC to develop standards that address risks to reliability caused by GMDs. In response to Order No. 779, NERC has developed TPL-007-1 that requires applicable entities to conduct assessments of the potential impact of benchmark GMD events on their systems. If the assessments identify potential impacts, the standard(s) will require the applicable entity to develop and implement a plan to mitigate the risk.

The main challenge in performing the assessments is the development of adequate datasets. Several pieces of data about the substation are required such as: location, grounding resistance, and transformer connections. This data is difficult to get and coordinate.

**Identifying and Mitigating the Potential Impacts of a Pandemic**

A pandemic refers to an outbreak of a virus or disease with sustained and efficient human-to-human transmission. A pandemic differs from an outbreak of seasonal flu because it does not follow seasonal patterns and affects people indiscriminately. In addition, mortality resulting from pandemics is a direct result of the virus or disease, not of related complications, as is most often the case with seasonal flu. Pandemics can have very high mortality rates.

Pandemics have the potential to have a high impact on the power sector through the temporary or permanent loss of critical personnel. The challenge associated with pandemics is in the variability of severity and duration of these types of events, which makes them difficult to predict and manage.

**Predicting and Mitigating the Impacts of Large-Scale Disasters**

Large-scale disasters in this category include disasters that affect wide areas and multiple sectors, the impacts from which last for an extended period of time. The impacts of these types of disasters on the electric system could range from physical disruption or destruction of infrastructure to loss of critical personnel to loss of critical support from other sectors. Examples of these types of events include major earthquakes in heavily populated areas or across major transmission paths, and large volcanic eruptions on a regional scale. These types of disasters have the potential to destroy infrastructure, cause wide-spread human loss, and create conditions that limit our ability to restore service. As with other high-impact low frequency events, the challenge lies in the inability to predict these events or their impacts.
Issue

Policy and regulation are key drivers of the electricity industry. While policymakers and state regulators do not directly affect or control reliability, their decisions have the potential to impact reliability. For example, state policymakers enact laws that affect utility actions, and state regulatory commissions oversee the electric utilities directly. The impacts of policymaking and regulation are not always readily apparent and often require analysis, evaluation and discussion to discern the potential impacts they could have on reliability.

Background

In 2013, WECC became a 501(c)(4) organization, shifting its mission from a member-driven to a social welfare-driven focus. Prior to this change, state policymakers and regulators were included in WECC’s member classes, but the new organizational focus emphasizes the role of policy and regulation in assuring the reliability of the Western Interconnection.

Challenges

Identifying Policy and Regulatory Drivers

The potential impacts to reliability of policymaking and regulation are pervasive. There is an obvious link between some state policies or regulations and the electricity industry (e.g., state Renewable Portfolio Standards). In many cases, the link is more attenuated (e.g., state economic policies). In any case, identifying how state policies and regulations may impact the electricity industry and electric reliability is an important activity.

Ensuring Policies and Regulations Consider Reliability Concerns

Often, policies that have the potential to impact the electricity industry are made without consideration of the potential impacts to reliability. This is sometimes due to a lack of credible, accurate and timely information about important electric reliability considerations. Robust communication and outreach is critical to providing the information policymakers need to include reliability considerations.

WECC’s Role

WECC does not advocate for or make policies or regulations. WECC may provide input, information, or data on the reliability aspects of some proposed policies, rules, and regulations.

Current WECC Work:

» WECC develops information on reliability issues and shares that information with state policymakers and regulators.

» WECC is analyzing and engaging with stakeholders on the proposed EPA Clean Power Plan.

Opportunities for WECC to Add Value:

» Continue to provide trusted, objective and independent facts, analysis and perspective on near- and long-term reliability challenges facing the Interconnection.

» Partner with policymakers and regulators to ensure that reliability considerations are included in policy decisions.

» Develop a process for sharing information with policymakers and regulators on key reliability considerations for policymaking and regulation.

» Support discussions of multi-state policies, plans, and processes on electricity and energy issues.
Emphasizing the Interconnected Nature of the Western Interconnection

State regulators and policymakers work within state boundaries. While policymakers sometimes cross those boundaries to engage in multistate efforts, a state’s policy decisions are made within the state and are influenced by a number of factors specific to that state. Electricity does not respect state lines, and the power industry is influenced by state and Interconnection-wide factors.
**Issue**

In June 2014, the Environmental Protection Agency (EPA) issued a proposed Clean Power Plan rule (EPA 111(d)). The proposed rule aims to reduce CO₂ emissions from the power sector by reducing emissions from existing electric generation facilities. EPA 111(d), if adopted, has the potential to significantly impact the Western Interconnection and may have implications for reliability.

**Background**

EPA 111(d) aims to reduce CO₂ emissions from existing power generation sources to 30 percent below 2005 levels by 2030. The proposed rule places the onus for compliance on the states, which must develop plans to implement the rule, but provides a high level of flexibility for states to tailor their plans to their specific circumstances. In addition, states may develop individual plans or work together on multi-state or regional plans.

The rule provides state-specific rate-based goals for CO₂ reductions and guidelines for states to follow in developing their compliance plans. The emission goals were developed using four building blocks that represent what the EPA believes to be the four best approaches to reducing emissions from the power sector. These building blocks are critical to both the creation of the rule and the development of state compliance plans.

**EPA 111(d) Compliance Building Blocks**

| Building Block 1: Coal Plant Efficiency | Improve the heat rate of coal-fired power plants by 6 percent to reduce the coal needed per MWh of generation. |
| Building Block 2: Increased Gas Use | Increase utilization of existing natural gas plants up to 70 percent capacity factor. |
| Building Block 3: Renewables & Nuclear | Increase penetration of renewable and nuclear generation, and delay or cancel retirement of nuclear plants. |
| Building Block 4: Energy Efficiency | Increase energy efficiency programs (or targets under existing programs) to reduce energy demand by 1.5 percent per year. |

**Challenges**

**Evaluating the Reliability Impacts**

WECC is uniquely positioned to provide information on the potential impacts on reliability of the proposed rule; however, providing this information presents a challenge. The impacts of the proposed rule will depend on state implementation plans. Knowledge of the contents of the state plans will be critical to WECC’s evaluation of the potential reliability impacts. WECC’s analysis must consider a broad range of potential compliance scenarios, be

**WECC’s Role**

WECC does not own, operate or build transmission or generation; therefore, WECC has no direct compliance obligation under the proposed rule. However, as the Reliability Assurer for the Western Interconnection, WECC does have an interest in the proposed rule’s potential impact on reliability.

**Current WECC Work:**

- In the four months since the release of the proposed Clean Power Plan, WECC has responded by developing a phased plan that addresses states’ need for information and provides initial thinking on how WECC might study the reliability impacts of the proposed rule.
- Participation at NERC on the issue.
- Outreach and interaction with Western states to understand their concerns and needs.

**Opportunities for WECC to Add Value:**

- Combine analysis techniques and tools to address issues related to the implementation of the proposed rule.
- Provide a forum for industry-wide discussions about the proposed rule.
- Investigate the potential interactions and impacts of proposed state compliance plans.
- Provide data that states can use in developing their compliance plans.
provided in a timely manner, and leverage the appropriate aspects of the work WECC does in its role as the reliability assurer for the Western Interconnection.

**Accounting for Flexibility in Implementation**

While states are responsible for implementing the proposed rule, the impacts will be felt industry and interconnection wide. The flexibility provided by the proposed rule may assist states in developing compliance plans, but it could present a reliability challenge. There is a wide range of potential implementation scenarios, each with unique impacts on system planning, operations and stability. Information on these impacts will help states consider the potential reliability impacts of their compliance decisions and develop more consistent and regionally minded compliance plans.
**Issue**

The NERC Reliability Functional Model (Functional Model) serves three purposes:

- Describes the functions that are essential to the reliability of the Bulk Electric System;
- Identifies which entities—functional entities—are responsible for performing each function; and
- Provides the framework for the development and applicability of Reliability Standards.

The Functional Model was designed to be flexible enough to be applied to the many different types of organizational structures across the country. However, in some instances the flexibility of the NERC Functional Model and a lack of consistency between it and existing WECC practices and processes have created the potential for gaps in coverage of functions.

**Background**

The original Functional Model was approved by the NERC Board of Trustees in 2002, prior to the approval of the Compliance Monitoring and Enforcement Program (CMEP). In addition, many of the terms, concepts and roles designated in the original functional model existed prior to the standards development process. This has created some inconsistencies between the Functional Model, the *Glossary of Terms Used in NERC Reliability Standards*, the *Rules of Procedure* (ROP) and reliability standards. Over time, improvements have been made to align the definitions and application of these documents, but issues with gaps persist.

**Challenges**

*Aligning Registration with the Functional Model*

While improvements have been made to the Functional Model, gaps in registration remain. Regional Entities, like WECC, register functional entities for compliance obligations based on the definitions found in the NERC ROP rather than the Functional Model.

**WECC’s Role**

WECC is the Regional Entity for the Western Interconnection with delegated authority from NERC to perform its role in assuring the reliability of the Western Interconnection. In its role WECC performs the following general actions:

- Reliability planning and performance analysis
- Compliance monitoring and enforcement
- Regional reliability standards development

**Current WECC Work:**

- The WECC Planning Coordinator Function Task Force (PCFTF) is investigating and addressing issues related to gaps in Planning Coordinator coverage across the Western Interconnection.
- The WECC Path Operator Task Force (POTF) works to better understand and document various issues related to Path operations. Currently, the POTF is investigating the existing Path operations paradigm, analyzing issues and alternate approaches, and identifying potential solutions.

**Opportunities for WECC to Add Value:**

- Analyze how the Functional Model is implemented from the Interconnection-wide perspective.
- Partner with registered entities to provide education and an independent perspective for identifying compliance and reliability risks.
- Map registered entity-hierarchical relationships and develop a database that identifies responsibilities, coverage and gaps.
**FUNCTIONAL MODEL**

*Addressing Gaps in Planning Coordinator Registration*

Based on recent assessments conducted by WECC, several Planning Coordinator coverage gaps have been identified within the Western Interconnection. These gaps not only create a compliance risk for several registered entities, but can also lead to significant reliability risks for the Interconnection where certain planning functions may not occur.

*Evaluating the Role of the Path Operator Function*

The Path Operator Function, although not recognized in the Functional Model, has historically played a vital role in the day-to-day reliable operation of the Western Interconnection. However, recent events, including the September 8, 2011 Desert Southwest Outage, have led several entities to question whether it is appropriate to operate to path limits in real-time operation. There have also been concerns raised about the authority and liability Path Operators assume by not being part of the Functional Model.

*Coordinating Seams Issues between Registered Functions*

With so many types of registered functions and registered entities performing those functions, seams in coverage naturally form. In some cases, these seams are easily managed by the entities and do not pose a risk to reliability. In other cases, the seams issues can pose reliability challenges. The Reliability Coordinator (RC) must coordinate the seams between registered entities because, while they are physically connected, registered entities operate as individual companies.
Human performance challenges encompass a range of issues facing the electricity industry today, including the imminent loss of critical skills and knowledge with the retirement of an aging workforce, cognitive overload of System Operators complicating the task of maintaining reliability, and an apparent shift in operating philosophy toward operating to standards rather than to reliability. These issues are pervasive and require coordinated industry efforts to address.

Background

The electricity industry workforce is shrinking, and with it critical skills and knowledge. In 2006, when the first of the Baby Boomers became eligible for retirements, they made up 44 percent of the American workforce. As Baby Boomers retire, they are not being replaced by young workers at a rate that will sustain the industry into the future. While there has been a decrease in the number of energy-related jobs over the last five years, it does not make up for the workforce deficit the industry is facing. In addition, while the number of jobs has decreased, the work has not, and employees are being asked to take on more responsibility and work than those who are preparing to retire.

Challenges

Managing the Workforce Retirement Transition

Over the next decade, many utilities will begin to lose a large portion of their workforce to retirement. There is a large age gap in the electricity industry workforce, so replacements for retired workers are not always readily available. Companies face challenges with attracting new talent and offering competitive compensation.

Addressing the Reduction in Knowledge Capital

The issues related to utility workforce retirement are more profound than with personnel turnover because it represents a loss of critical institutional knowledge. Compounding the matter is that there is no substitute for on-the-job experience. New workers rely on the expertise and knowledge of prior generations of workers to learn how to operate the complex system. This knowledge base embodies the art of the organization, not just the information that is explicitly documented in manuals, maps, procedures, and databases. This institutional knowledge also includes the organizational culture and attitudes that have shaped the reliability of the system to date. As the aging workforce leaves and is replaced by younger workers, utilities face a potential fracturing of the motivational belief system that once bound the workforce to common goals.

WECC’s Role

While WECC does offer ongoing operational training courses, WECC does not regulate the workforce or provide workforce resources such as recruitment.

Current WECC Work:

» The WECC Operations Training Subcommittee and the WECC System Operator Training Program continue to work together on addressing training needs and ways to re-skill the Bulk-Power System operators.

» WECC offers internships to students with an interest in the electricity industry.

» WECC training is designed to maximize learning by using existing schemas so as to not overload working memory. This can help with concerns about cognitive overload.

Opportunities for WECC to Add Value:

» Collaborate with technical colleges to develop power plant and operations programs.

» Work with NERC to define core knowledge requirements to help eliminate the difficulty in moving from one utility to another.

» Evaluate the impacts of the aging workforce on reliability.

» Bring awareness to the topic of cognitive overload.

» Enhance its coverage of standards training in System Operator Training sessions to help operators become more knowledgeable about standards.
**Managing Cognitive Overload**

Cognitive overload is a growing issue as System Operators are required to take on increasing responsibilities and perform a growing number of tasks. This overload is caused in part by the shortage of workers to fill vacant positions, requiring existing employees to take on more work to cover for the shortfall. Cognitive overload can also be attributed to changes in how the system is operated. As the operation of the system continues to change and new issues arise, the burden on System Operators will increase. Examples of changes that could increase the burden on System Operators include intra-hour scheduling of resources, new markets, and physical security standards. The overload facing System Operators may affect existing operators and may complicate the recruitment of new ones.

Ongoing training programs are essential for the new workforce when it no longer has the senior operators to rely on. Institutional knowledge can be captured by interviewing, recording and then building training programs to share that knowledge. However, loss of the aging workforce can be turned into a positive trend as the innovation of the younger workforce is encouraged and revealed.

**Shifting to a Reliability-Focused Culture**

In the years since the reliability standards became mandatory, there has been an apparent shift in industry’s operating philosophy toward operating to standards rather than to reliability. In many cases, the pressure to remain compliant with the standards eclipses the need to focus on being reliable.