SECTOR BLACK SKY GUIDEBOOK 1.0

ABSTRACT
The Electric Sector Black Sky Guidebook reflects collective input from numerous Electric Subsector operational and administrative managers and power industry technical personnel, as a recommended framework for planning resilience investments, restoration planning and cross-sector coordination needed for long duration, multi-region power outages. This peer-reviewed document is designed as a resource for the electric subsector, addressing critical Black Sky resilience needs for Preparation/Mitigation, Response, Restoration and Recovery measures.

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V1.0 02/11/2019
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Role of the EPRO Electric Sector Black Sky Guidebook

This Guidebook is designed to continuously engage Subsector members to provide an evolving framework for recommended guidelines to manage risks of long duration, multi-region power outages associated with emerging “Black Sky” hazards.

This Guidebook will be consistently updated and reviewed using the EPRO ELECTRIC SUB-SECTOR steering committee process through consultation with subsector professionals and managers. It represents the consolidated recommendations of these subsector managers and professionals for the unique challenges posed by wide area, long duration outages. The Guidebook provides guidelines to help individual entities strengthen their own resilience measures, develop focused operational plans and assess external support needed to address these severe hazard scenarios.

Sector Background

The Electric Sector is responsible for the design, construction, and operation of the electric grid, which is one of the world’s largest, most complex machines. In the US alone, there are approximately 7,700 power plants and 300,000 miles of transmission and distribution lines. The components of the grid are supported by a very large infrastructure that supplies and delivers fuel, chemicals, and water by rail, barge, truck, and pipeline. Tens of thousands of highly skilled workers plan, operate, and maintain the grid. Complex computer systems provide monitoring and control of electrical and mechanical systems.

Ownership of the grid is fragmented. There are numerous utilities that may be privately owned, owned by their customers, or owned by local, state, and federal governments. Those entities own the transmission and distribution facilities and are responsible for their maintenance and operation. In some cases, transmission operation responsibility is assigned to a Regional Transmission Organization (RTO) or Independent System Operator (ISO), e.g. PJM, MISO, California ISO, etc. Generation ownership can be by utilities, generation and transmission coops (G&Ts), municipal utilities, or independent power producers (IPPs). Distribution facilities are generally owned by the local utility, coop, or municipal utility.

As ownership of the grid is fragmented, so is regulation. Regulation of the grid is done by a combination of state public service commissions and the Federal Energy Regulatory Commission (FERC). FERC regulates the transmission system and the states regulate the distribution system. The owners and users of the Bulk Electric System (BES) (generally defined as 100 KV or higher) are subject to mandatory and enforceable reliability standards promulgated by the North American Electric Reliability Corporation (NERC) and approved by FERC. The NERC standards cover a range of activities including planning, operations, emergency operations, restoration, and cyber security. Generation is unregulated for the most part.

The transmission system is monitored by Reliability Coordinators, who have a wide area view that covers multiple transmission owners. Reliability Coordinators have the ultimate responsibility for system reliability and have authority to direct actions to be taken by transmission owners and generation owners to preserve system integrity and reliability. Generation is controlled by individual utilities or independent power producers. Where available, generators can participate in regional wholesale power markets, where they respond to dispatch signals from the market operator and get
compensated by the market operator. However, even in those situations, the generation owners are required to comply with the directions of the Reliability Coordinator. Delivery of power and energy to the ultimate retail customer is by distribution providers who deliver power to the ultimate retail customer. These providers may purchase power on the wholesale market, or they may be part of a vertically integrated utility.

The North American electric grid is very robust. The grid is planned and constructed to survive the loss of multiple components without cascading, wide area outages. The grid is operated to a so-called “N-1” criterion, meaning that any single element of the grid (transmission or generation) can go out of service without compromising the reliability of the system. In order to ensure that reliability is preserved, transmission system operators have sophisticated control systems that can simulate outages of any element to ensure that the N-1 criterion is maintained. Most major area outages are the result of severe weather, such as a hurricane or an ice storm, damaging the low voltage distribution system in a relatively localized area. These weather events, even if very severe, rarely result in power outages that last more than a few days. Even the load lost during the 2003 Northeast Blackout, which was a cascading outage that impacted generating stations and higher voltage transmission facilities over multiple states and Canada, was substantially restored within 24 hours.

Resilience planning for “gray sky” events is a particular strength for the Electric Sector. System operators receive training in emergency response and restoration procedures and these procedures are practiced in drills and simulations. NERC routinely audits the performance of the Reliability Coordinators and transmission owners to verify their performance in accordance with the NERC standards. Where deviations are identified, those entities can be subject to substantial fines as part of the FERC/NERC enforcement process.
Sector Black Sky Environment

Black Sky events are expected to have a high impact on the electric grid, creating outages that could last for days, weeks, or longer, depending on the severity of the event. Existing utility preparedness procedures generally presume that the system is undamaged, or that damage is confined to a local area. Black Sky events are very likely to be accompanied by damage to multiple system elements and that damage will be distributed across the grid in a large area. In that scenario, a long, tedious process of damage assessment will be required in order to effectively start the restoration process. Once started, the process will move painstakingly across the grid with continual redirection caused by encounters with damaged elements.

Adding to the difficulties of executing the restoration process, other necessary infrastructures may be out of service and unavailable to restoration personnel. Examples of infrastructures deficiencies that will impact restoration include:

Communications

- Normal communications may be severely interrupted after a Black Sky event. Equipment may be damaged, back up diesel generation for cell and other communications sites may be inadequate. Without some form of communications, system operators have no situational awareness or ability to control facilities during a Black Sky black start

- Natural Gas Delivery
  - No onsite storage
  - Some electrically-driven gas pipeline compressors
  - Pipeline SCADA and communications
  - Pipeline tariffs (FERC regulated) not aligned with Black Sky conditions

- Fuel Storage for emergency generation
  - Most emergency generation has inadequate onsite fuel supply for extensive Black Sky recovery

- Dual Fuel Generator Fuel Supply
  - Most dual fuel generators have inadequate fuel supplies for extensive Black Sky recovery
Sector Black Sky Strategic Mission Statement

Following a Black Sky event with its wide area of impact, long duration power outages, and disrupted environments associated with Black Sky hazards, the most critical goals for societal health and continuity will be systematic, timely and well-prioritized power grid restoration, while simultaneously enabling the largest possible numbers of people to “shelter in place” during the multi-week or longer restoration period.

While many tasks must go forward to enable these two goals, among the most critical will be properly focused resilience investment and planning by the Electric Subsector, along with the corresponding investment and plans by partner sectors, required to support the Electric Subsector’s measures.

**Electric Subsector Black Sky Mission:** Develop and implement focused resilience investment and operational plans required to allow for timely, well-prioritized power restoration following a Black Sky event, along with definition and coordination of requisite support from partner sectors.

Strategic Mission Priorities Matrix

A Black Sky event has the potential to shut down the entire grid in a multistate region, and there will be no electrical service except from emergency generators located at a customer’s site. Depending on the amount of damage to black start generators and key transmission and substation facilities, it may be several days or longer before initial service is restored to preplanned, critical load. The black start process will be initiated—the goal of which is to create small, balanced islands of load and generation that can lead to the further restoration of additional islands leading up to the restoration of transmission and larger generators.

As the black start process proceeds, secure enclaves of generation, transmission, and load will be established. However, the reliability of these enclaves may be poor due to the unstable nature of the small portion of the grid that is online. The secure enclaves will be expanded as fuel secure units and possibly nuclear generation is brought online, along with an equal amount of load. There will be a preplanned prioritization of loads to be served, and rotating blackouts may be an important part of the transmission operator’s tool box. When the secure enclaves are interconnected to nearby enclaves, and then ultimately to the entire grid, near-normal operations can resume. At that time, the grid will be relatively stable and as much load as is available to be served will be connected to the grid. Reliability for the load served at this stage of recovery should be similar to pre-event reliability.
Black Sky Decisions Overview

The first priority of the Electric Sector after a Black Sky event will be implementing the Black Sky black start plans. To implement the plans, decisions will be required about which generation to start, which transmission cranking paths to energize, where personnel should be dispatched to inspect and repair equipment, and what communications systems can be relied on to provide situational awareness and control.

The Transmission Operator’s Black Sky black start plans should have black start generation and cranking path transmission facilities identified, as well as initial critical loads. However, after a Black Sky event, some equipment expected to survive to implement the plan will be damaged or otherwise non-available, while some non-hardened equipment may be available. The Transmission Operator must decide how to implement the plan, and whether to modify the black start plan based on an assessment of the availability of generation and transmission.

To the extent natural gas transportation infrastructure may be available to serve generation, gas fired generation may be included in the Black Sky black start process.

The Black Sky event may have damaged communications. The Transmission Operator must determine what communications system(s) are available, whether SCADA is reliable, and how to communicate with equipment and personnel in the field or at generation stations.

The Transmission Operator should identify key locations that require communication with the control center about equipment status, and then dispatch personnel to those locations. The Transmission Operator should also identify key equipment that must be inspected before operation, and repaired, if necessary.

The initial Electric Sector decisions will be: what communications systems to utilize, what generation to start, what transmission to energize, and what critical loads should be served.
Situational awareness is key to the successful operation of the electric grid. Transmission Operators cannot guess about the status of generation, transmission facilities, and load without endangering personnel, potentially damaging equipment, and risking unstable operation. Situational awareness means that the Transmission Operator has sound information on the state of key grid parameters, (e.g., voltage and frequency measurements over a wide area) and knows the state of all bulk electric system elements (e.g., transformers, breakers, switches). The Transmission Operator must know if a generating unit is synchronized to the grid and its approximate electrical output. Transmission system circuit breaker status and approximate system load levels are required for reliability and for matching generation levels with load levels. Under normal circumstances, energy management systems (EMS) or Supervisory Control and Data Acquisition (SCADA) equipment provides the situational awareness picture in the Transmission Operator’s control room. Automatic generation control (AGC) from the control center often regulates the generation. After a Black Sky event, communications channels for EMS or SCADA may be impacted, and key information may only be provided verbally to the control center from field personnel. Some Transmission Operators drill this procedure to ensure they can retain adequate control of their portion of the grid\(^1\).

Natural gas fired generation is a significant portion of the generation in the US. Gas fired generators are less complex than coal fired units and lend themselves to faster inspection, repair, and operation than a coal fired unit. However, unlike a coal plant, there is no onsite storage of fuel available. Knowledge of the availability of natural gas transportation infrastructure allows the Transmission Operator to understand the availability of generation within its footprint.

Communications between generation stations and field personnel are necessary for control and operation of the grid. If supervisory control is available and reliable, these functions can be performed by the Energy Management System in the control room. If supervisory control is not available, verbal communications and manual data presentations can substitute.

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The ability to expand and interconnect secure enclaves is dependent on the availability of generation, transmission, and load serving equipment. Communications on the status of equipment allow the Transmission Operation to plan expansion of the enclaves.

The Transmission Operator has the ability to build the secure enclave, and interconnect enclaves within the Operator’s area. However, the Transmission Operator may not have the visibility of other parts of the grid to allow interconnection with neighboring utilities or systems. The Transmission Operator must have communication with the region’s Reliability Coordinator to safely and efficiently build the grid. As a minimum, verbal communications must be established between the Operator and the Coordinator to permit interconnections of enclaves with the grid without threatening system reliability.

### Priority Information Requirements Matrix

<table>
<thead>
<tr>
<th>Information</th>
<th>Source</th>
<th>Priority</th>
<th>Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial status of electric grid transmission, generation, distribution</td>
<td>EMS, SCADA, verbal communications from the field</td>
<td>High</td>
<td>High – must have confidence in information in order to initiate black start restoration plans</td>
</tr>
<tr>
<td>Status of critical natural gas delivery infrastructure</td>
<td>Verbal and/or electronic communications with natural gas transportation sources</td>
<td>High</td>
<td>High - Must have confidence in fuel delivery capability in order to restart and operate critical gas fired generation</td>
</tr>
<tr>
<td>Instructions on operation of generation and substation equipment</td>
<td>SCADA, EMS, verbal communications with field personnel and generation stations</td>
<td>High</td>
<td>High – Breaker status and operation, load information, and generation levels critical to black start</td>
</tr>
<tr>
<td>Time to repair and return to service non-functional equipment</td>
<td>Verbal communications with field and generation personnel</td>
<td>High</td>
<td>High – Information required to implement secure enclave growth and expansion</td>
</tr>
<tr>
<td>Status of regional grid and instructions from Reliability Coordinator</td>
<td>Verbal or electronic with Reliability Coordinator</td>
<td>High</td>
<td>High – Information required to interconnect secure enclaves with neighboring systems</td>
</tr>
</tbody>
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Sector Initial Actions

The initial actions of the Electric Sector after a Black Sky event will be focused on implementing Black Sky black start plans. These plans are similar to the NERC required black start plans, except that the generation and transmission cranking paths will be composed of facilities that have been hardened, and can be expected to be functional. The initial objective will be to energize secure enclaves of generation, transmission, and critical loads. Critical loads include water and wastewater treatment facilities, natural gas delivery infrastructure, and nuclear power plant switchyards. The second step will be to incorporate additional fuel secure generation, transmission, and loads into the enclaves. Finally, the enclaves will be interconnected with each other and with neighboring utilities until load serving capability is at a “near normal” level.

Sector Initial Actions Matrix

<table>
<thead>
<tr>
<th>Priority</th>
<th>Initial Action</th>
<th>Desired/Required Outcome</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Situational Awareness – After a Black Sky event, the grid will most likely be</td>
<td>Determine what parts of the grid are intact, and what is out of service. Determine the extent that Black Sky black start equipment is damaged. Establish black start sequence. Direct repair personnel to damaged equipment.</td>
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<tr>
<td></td>
<td>de-energized. Before any component of the electric grid can be reenergized, the</td>
<td></td>
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<tr>
<td></td>
<td>Transmission Operator must know the status of equipment (primary and</td>
<td></td>
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<tr>
<td></td>
<td>protective relaying) related to the section of the grid that is part of the</td>
<td></td>
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<tr>
<td></td>
<td>black start plan. Are breakers open or closed? Are black start generators</td>
<td></td>
</tr>
<tr>
<td></td>
<td>available and capable to restart or out of commission? Are critical loads able</td>
<td></td>
</tr>
<tr>
<td></td>
<td>to accept electric service? Is protective relaying equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>damaged or in alarm along the black start path?</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Communications – After a Black Sky event, communications may be completely</td>
<td>As a minimum, verbal communications established with generation stations and field personnel. Additionally, electronic communications via SCADA established to black start and nuclear generation, and substations that are parts of the cranking paths, greatly enhance the Transmission Operator’s ability to black start.</td>
</tr>
<tr>
<td></td>
<td>interrupted. Communications are critical to providing situational awareness to</td>
<td></td>
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<tr>
<td></td>
<td>the Transmission Operator. Communications are also vital for initiating the</td>
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<tr>
<td></td>
<td>black start sequence. SCADA must be tested for operability and functionality.</td>
<td></td>
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<tr>
<td></td>
<td>Voice communication via cell phone, radio and emergency systems must be tested.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Energize black start generation, cranking path transmission, and pick up</td>
<td>Initial generation is placed on line, a backbone transmission system is energized, and service begins to initial, critical loads.</td>
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<tr>
<td></td>
<td>critical loads within secure enclaves.</td>
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Internal Sector Resilience Investment Priorities

Black Sky planning will typically include hardware investments and expanded operational planning to enable these systems to operate in degraded equipment, communications, and fuel delivery modes.

Secure Enclave Resilience Measures

Black Start and Tier1/Other important Generators

Black start, and fuel-secure, Tier 1 generation should have a high priority for hardening against Black Sky threats. These generation units should be protected to allow for a safe shutdown – without damage – in the event of a Black Sky event, and a rapid restart (or, if not running at the time of the event, an assured, rapid start.) Hardening should extend to onsite emergency generation, critical control equipment, station batteries, emergency lubricating oil pumps, and other equipment critical to the startup of the generation.
Cranking Path Transmission

Cranking path transmission should have at least one level of relay protection that is either hardened against a Black Sky event or is impervious to its effects, such as electromechanical relays. The substation facilities associated with the cranking path transmission should also receive sufficient hardening to permit the energization and operation of power transmission.

Control Centers

Control centers should be hardened to the extent needed to provide the vital situational awareness the system operators require for the restart and control of the electric grid. This would include EMP hardening of communications systems, computer systems, and power supply to the facility. Some United States utilities are taking the approach of fully integrated Black Sky hardening of the entire facility. Control centers should develop methods of maintaining situational awareness through voice communications and manual updating of screens, or even the use of paper charts, if there is loss of SCADA communications.

Critical Facilities

Power utilities should harden Secure Enclave facilities used to serve previously identified facilities critical to the operation of the electric generation and to the grid. Critical facilities may also include lifeline services such as water and waste water facilities.

Fuel Supply Infrastructure

Power utilities should make resilience investments to harden their facilities that service the fuel supply infrastructure. The movement away from coal-fired generation with its substantial on-site fuel storage places more reliance on other types of generation with little local onsite storage. Power supply to gas pipeline compressor stations and to other critical gas infrastructure will facilitate the supply of natural gas to electric generation facilities. Power supply to diesel fuel storage and distribution assets will ensure that diesel fuel flow can be maintained in the supply chain for continued delivery to emergency generators, dual fuel generators, and other critical fuel consumers. Even though the majority of gas pipeline pumping stations are currently self-powered, there is a move toward powering compressors with electricity. Even self-powered pumping stations are controlled with electronic equipment that may be vulnerable.

Nuclear Power Plants

Nuclear power plants consume diesel fuel for emergency generators to operate safety systems in the plant when there is a loss of offsite power to the plant switchyard. This use of diesel fuel comes at a time when normal resupply is likely to become disrupted, and there will be increased demand for diesel fuel from other priority users. Utilities should make resilience investments in the increased onsite storage of diesel fuel at the nuclear plant site, above and beyond that required by current regulation, wherever possible. Secondly, power utilities should make investments in the protection of transmission facilities connecting fuel secure “sister units” to the nuclear power plant in order to provide offsite power, and in some cases, allow nuclear
Secure Fuel Supplies

Dual Fuel Storage Increases

Supplies of the secondary fuel for dual fuel generating stations should be enhanced to ideally provide approximately 30 days of run time on the secondary fuel. Because of the nature of a Black Sky event, it is likely that the supply of the primary fuel will be disrupted for an extended period of time and the ability to resupply the secondary fuel may also be disrupted. Therefore, extended secondary fuel stocks, even if not at a 30-day level, are necessary to allow operation of the unit until normal fuel delivery is available for the generation fleet. Storage of larger quantities of liquid fuels will also require monitoring and treatment to avoid contamination.

Co-locate Black Start Plants with Fuel Infrastructure

As noted above, a Black Sky event is likely to interrupt the normal resupply of fuel to generation stations. Fuel supply for black start plants should become a siting consideration, just as the availability of transmission service is a consideration. When practical, future black start gas fired generators should be strategically sited near major pre-existing fuel storage facilities, natural gas storage, and oil and liquefied natural gas (LNG) terminals.

Increased Natural Gas Storage Adjacent to Black Start Plant

As a hedge against Black Sky outage effects on gas gathering and long-distance gas transmission, measures could be taken to further increase gas storage capacity of underground facilities that are located near major power plants and other critical users.

Increased Liquefied Natural Gas (LNG) Storage

Where underground construction is not geologically practical, construction of LNG facilities – if/where they can be cost effective – should be considered as an alternative means to support fuel resilience for power generation.

Emergency Generator Fuel Storage

Many critical facilities have onsite emergency generators, however fuel storage for these generators is typically sized for short duration emergencies. This onsite storage should be increased to at least seven days of normal use, to allow time for system-wide emergency generator refueling during a Black Sky event.

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2 EPRO Black Sky Protection Initiative: http://eiscouncil.org/Protection/ItemDetails/60
Chemicals

Generation facilities require consumables other than fuel to operate reliably. For example, chemicals are required for the control of boiler water quality, and hydrogen is required to cool generators. Consideration should be given to increasing the onsite supply of essential chemicals.

Operational Resilience Measures

Black Sky Restoration Plans

Plans should expand existing plans to include Black Sky-induced extended outages.

Every region in the United States maintains black start plans, procedures, capabilities, equipment testing and exercises that must comply with the North American Electric Reliability Corporation (NERC) Reliability Standard EOP-005-2, “System Restoration from Blackstart Resources,” and other regulatory mandates. Planning should be extended and modules should be added to these black start plans that address Black Sky hazards.

Trained Workforce

Black Sky hazards are expected to cause significant hardware damage distributed over very large regions, and restoration will typically require far more engineering support staff than under ordinary conditions. Cyber or EMP damage to electronic equipment may be difficult to detect without skilled testing, placing greater demands on support staff.

Given the number of power companies that would be affected, sharing corporate staff between companies will likely be insufficient to address this shortfall.

Maintaining a large, skilled workforce is costly and difficult. Power utilities should make investments in the training and cross training within their organization of technical personnel in the skills necessary to address the damage that could occur during a Black Sky event. Enhanced training may be required to ensure technicians have the skill sets necessary to maintain both electronic and electro mechanical relay systems, if electro mechanical relays are retained as part of transmission system hardening. Basic emergency training could enable skilled personnel to utilize less skilled assistance to enhance their effectiveness. Emergency operations plans using minimum system protection requirements rather than fully redundant systems could lessen the demand for skilled technicians and engineers. The Certified Power Recovery Engineering Teams Initiative addresses this scenario by utilizing engineering personnel normally working with companies or government agencies outside the power industry as an emergency resource.3

Strategically Located, Generous Spares

Black Sky events are likely to cause extensive damage to utility facilities. An EMP event, for example, has the potential to cause the failure of electronic devices such as system protection relays and control devices. These devices are not readily available on short notice in large quantities. A resilience measure to mitigate against damage is storing a generous quantity of spares in strategic locations.

3 Certified Power Recovery Engineering Team Project: http://eiscouncil.org/Protection/ItemDetails/63
Investments in spare components that are essential to Black Sky recovery should be made by the power industry. Spare components sensitive to EMP exposure such as transmission protective devices (relays), electronic test equipment, generator control and protection components, communications components, and hand-held devices should be protected, where appropriate, in EMP secure enclosures and should be staged near the expected need.4

Emergency Communications and Training

A Black Sky event will have an adverse impact on communications systems. The electric power industry should invest in sufficiently hardened communications that will allow communications between control centers and generation stations, field personnel, reliability coordinators, and state and federal officials handling the emergency. Utility personnel should be trained in the use of these communication systems, and utilities should conduct regular drills and exercises.5

Planning for use of an appropriate emergency communication system for internal and external communication and data and use of a synergistic emergency situational awareness and decision support tools, will be essential to accommodate both internal operational plans and coordination with external sectors. As an example, utilities may review and utilize, as a basis for these plans, the planned Emergency Communication (BSX) System architecture, recently developed for this purpose.6 This architecture will have clear lines of authority on how the capabilities will be used and shared among the many entities that will depend upon them.

Expanded Maintenance and Testing

Emergency generation and dual fuel units will be critical to Black Sky black start success. Regular maintenance and testing of these types of generation equipment should become normal practice to continuously ensure successful execution of the role that generation will play in black start procedures.

Emergency generators should be periodically operated at full load to ensure that equipment will be able to perform their functions. Not all generator owners are rigorous with testing.

Dual fuel units should be started and operated – at full load – on their secondary fuel on a periodic basis to ensure that equipment operates correctly and plant operators remain familiar with secondary fuel operating techniques. Fuel stored for long periods of time requires maintenance and treatment.

Strong procedures should be in place to avoid unauthorized modifications to Black Sky hardening that could reduce its effectiveness. For example, unauthorized penetrations of shielded enclosures, reduction of access controls, and bypassing of cybersecurity protocols should be avoided.

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4 See comments by David K. Owens, Executive Vice President, Business Operations, EEI at Electric Infrastructure Security Summit V http://eiscouncil.org/Summit/Archive/35
5 Ibid
6 EIS Council, Emergency Communications (BSX) Project: http://eiscouncil.org/Protection/ItemDetails/62
The Electric Subsector will be able to meet its mission requirement only if it has assured support from other sectors, to supply those services and resources that lie outside its normal capabilities. Defining the sector’s required external support – and coordination with the appropriate sectors – is a crucial part of development of the Black Sky Protocol.

**Protected Enclave Hardening**

The Secure Enclave is the basic building block for recovery from a Black Sky event. The Secure Enclave is a subset of the electric grid capable of operating without external power from the grid, and because it accomplishes the goal of recovery of the electric grid while avoiding the necessity of hardening the entire grid, is a cost-effective method of providing grid resilience.

Power utilities should work with regulators to encourage the hardening of the generation, transmission, and distribution facilities within the Secure Enclaves, and to adopt design standards that incorporate facility hardening techniques in new facilities. Regulators should provide the power industry with cost recovery for these resilience measures.

**Dual Fuel Generation**

**Increased Secondary Fuel Storage**

Even the widest possible distribution of fuel-switching capabilities will be of little resilience value when gas flows are interrupted unless generating stations have the secondary fuel they need to operate. On-site storage of secondary fuel offers the greatest value for resilience in Black Sky events.
The power industry should work with zoning boards, environmental regulators and other officials and stakeholders in power resilience to include resilience considerations in assessing specific fuel storage construction proposals. When practical, future gas generators might be strategically sited near major pre-existing fuel storage facilities and terminals. In addition, regulatory measures to assure maintenance of adequate storage levels of secondary fuels for critical dual fuel generators should be made a priority.

Emergency Waivers – Regulatory, Environmental, and Supply Chain Considerations

The power industry should work with State Public Utility Commissions and federal agencies (including the Environmental Protection Agency, FERC/NERC, DOE and others) to consider emergency waiver authorities and triggers for secondary fuel use, to allow more effective resilience planning and investment. Relief by FERC from market and reliability regulations may be appropriate. At the federal level, existing authorities to be examined and potentially utilized in this assessment should include those provided for in the Stafford Act. At the state level, relief from regulations related to trucking of diesel fuel should be examined.

Cost Recovery for Dual Fuel Storage/Operations

Market rules and regulations should allow for cost recovery for dual fuel generators.

Partly due to the cost of seeking emission permits and installing necessary pollution control equipment, new dual fuel generators and their fuel systems are more expensive to procure than their gas-only counterparts and are more expensive to operate and maintain. The power industry should partner with regulators and other stakeholders in power resilience to examine how financial inducements might be created to encourage the construction of dual-fuel generators. Market rules and other regulations should explicitly provide for the cost recovery of dual fuel storage construction and inventory carrying costs.

Incentivize Fuel Switching Capability

Power utilities should work with regulators and with generation markets to create special incentives to provide fuel-switching capabilities for generators that support black start operations.

In January 2016, the “FERC-NERC-Regional Entity Joint Review of Restoration and Recovery Plans” recommended that studies be made of possible strategies for replacing lost coal-fired black start resources, and of factors to be included in replacing them (including geographical diversity and fuel switching capabilities). As those studies go

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7 See comments by David K. Owens, Executive Vice President, Business Operations, EEI at Electric Infrastructure Security Summit V http://eiscouncil.org/Summit/Archive/35
forward, they should develop targeted incentives and cost recovery mechanisms for dual fuel generators serving as black start resources.  

Gas Supply During Black Start Restoration

Emergency Waivers – Avoid Curtailment of Service to Generators

Regulatory “Curtailment Policies” provide for curtailing gas deliveries to industrial customers, including power grid generators, to prioritize delivery to residential customers when a power outage or other factors reduce pipeline gas flows. During a severe, long duration power outage, this prevents power grid generating stations from producing electricity, resulting in less electricity to those very same residential customers, and also possible shutdowns of electric gas pipeline compressors that would further reduce gas flows, causing a “vicious cycle” that quickly becomes a serious societal problem.

Power utilities should coordinate with regulatory authorities to authorize emergency waivers to avert curtailments to power generators during Black Sky events. Many state governors already have the authority to declare an energy emergency when they determine that the health, safety, or welfare of their citizens is imminently threatened by gas supply shortages. These emergency authorities should be revised to provide that when an especially severe event occurs, including those that would fall into the category of Black Sky events, governors can temporarily revise state curtailment policies and state environmental rules in order to make preservation of gas service to power generators a top priority.

Firm Gas Delivery Contract Cost Recovery

Market rules and regulatory mechanisms should allow for the recovery of the additional costs of firm versus interruptible gas delivery contracts.

Many state utility regulators who approve regulated utility cost recovery are sensitive to the additional cost that accompanies firm pipeline transportation. However, such firm contracts can greatly reduce the likelihood of gas curtailments in Black Sky hazards. Generation companies should work with regulators to develop options to provide for the additional funding firm contracts require.

Information sharing with Pipeline Industry

Restoration and recovery operations in a Black Sky hazard scenario will be complex, and information sharing will be vital to allow lifeline infrastructure utilities to pool their resources, address critical issues and optimize restoration. Regulators and lawmakers should address the challenges associated with anti-trust laws that have a negative effect on such information sharing between companies, especially in the fuel industry.

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As one effective approach, regulators can create temporary solutions that can be enacted during large-scale outages and disasters

**Support for Emergency Generator Fuel Delivery**

Normal supply chain arrangements may fail during Black Sky recovery and the ability to obtain diesel fuel for emergency generators may be curtailed. This would be especially critical for nuclear power plants and for other key facilities.

The power industry should become engaged in the formation of the National Emergency Power Commission (NEPC). One objective of the NEPC Initiative is to support Black Sky restoration planning through emergency diesel fuel distribution.\(^9\)

**Support for Chemical Deliveries**

Normal supply chain arrangements for important chemicals required for electric generation operation during a Black Sky recovery may fail, limiting the ability of generation to operate.

The power industry should become engaged in the formation of the National Emergency Utility Consumables Commission (NEUCC), which has an objective of developing the capability nationwide of supplying critical chemicals to the water and energy sectors.\(^10\)

**Water Supply for Generation Station Use**

A number of generating stations utilize purified waste water or public water supplies for cooling tower makeup, or other plant uses. The power industry should identify those water / waste water systems that are critical to generation station operation and ensure that those loads: 1) are included as part of the critical loads to be served by the electric utility’s protected enclaves; and, 2) the water / waste water systems understand and support the role they play in maintaining the availability of critical electrical generation.

**NGO Requirements**

Critical Personnel and Family Support: Utilities will need to supplement their own critical personnel and family support activities, to assure their labor force will be available. Mass care NGOs can play a crucial role in this area, and will require such information from electric utilities to enable them to plan and train to provide such support.\(^11\)

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\(^9\) The National Emergency Power Commission Initiative: http://eiscouncil.org/Protection/ItemDetails/64  
\(^10\) The National Emergency Utility Consumables Commission Initiative: http://eiscouncil.org/Protection/ItemDetails/65  
\(^11\) See comments by David K. Owens, Executive Vice President, Business Operations, EEI at Electric Infrastructure Security Summit V http://eiscouncil.org/Summit/Archive/35
### External and Cross Sector Requirements Matrix

<table>
<thead>
<tr>
<th>Requirement Area</th>
<th>Priority</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial – Regulatory</td>
<td>High</td>
<td>Regulatory agencies should approve the cost recovery of Black Sky resilience measures, such as system hardening, increased onsite storage of dual fuels, increased levels of spare parts</td>
</tr>
<tr>
<td>Financial – Regulatory and Markets</td>
<td>High</td>
<td>Regulatory agencies and generation markets should provide financial relief for operation and maintenance of dual fuel units that are identified as Black Sky black start units</td>
</tr>
<tr>
<td>Operations – Natural Gas Delivery Priority</td>
<td>High</td>
<td>Regulatory and tariff requirements that limit the supply of natural gas to Black Sky black start generation units should be examined and modified as to how they are applied to Black Sky events.</td>
</tr>
<tr>
<td>Financial – Fuel and Regulatory</td>
<td>Medium</td>
<td>Market mechanisms should be developed to allow the recovery of firm gas transportation costs for generation units identified as Black Sky black start units.</td>
</tr>
<tr>
<td>Communications (Physical)</td>
<td>High</td>
<td>Communications providers should examine the resilience of their systems that support the Electric Sector. The Electric Sector typically relies on multiple sources for communications. This would include the internet, cell phones, public telephone, and in some cases, satellite. The Electric Sector also has internally provided communications such as fiber, radio, and microwave.</td>
</tr>
<tr>
<td>Chemicals – Supply Chain</td>
<td>Medium</td>
<td>Generators rely on certain chemicals, in addition to food, for operation. Those entities that are part of this supply chain should have secure communications with the utility, and plans for delivery of critical supplies after a Black Sky event.</td>
</tr>
<tr>
<td>Water - Operations</td>
<td>Medium</td>
<td>Some generating stations rely of treated wastewater for cooling. These wastewater systems should make resilience investments in order to serve critical generation.</td>
</tr>
<tr>
<td>NGO</td>
<td>Medium</td>
<td>Mass care NGOs can play a role in providing support to utility critical workers and their families.</td>
</tr>
</tbody>
</table>

### Sector Specialized Resource Requirements: Overview

The Electric Sector requires a number of key resources to successfully restore service after a Black Sky event.

A significant component of the required resources for the Electric Sector revolve around fuel: for black start generating units, dual fuel generating units, emergency generation, sister units for nuclear plants\(^\text{12}\),

\(^{12}\) EPRO Black Sky/Black Start Protection Initiative (BPSI), www.eiscouncil.org
and natural gas delivery. It is highly likely that normal supply chains will be disrupted as a result of a Black Sky event. Therefore, the most effective method for the supply of liquid fuels will be enhanced on-site storage. Units that are components of a Black Sky black start plan should have sufficient fuel to enable operation through the expected restoration time period. Emergency generators at critical locations should also have enhanced on-site fuel storage. Regardless of the availability of on-site storage, the utility should pre-plan with its fuel supply chain to ensure that there are reliable communications between the utility and the suppliers in place. Local law enforcement should be aware of the need to give priority to fuel deliveries. Natural gas is a critical fuel for most utilities. Natural gas fired units are generally simpler to operate, and more likely to be part of the Black Sky black start recovery plan. Resilient communications between the natural gas delivery system serving critical plants should be in place. Pre-planned priorities for service should be established with the gas pipeline operator. Electrical service to pipelines serving electric generation should be incorporated into the utility’s plans as a critical load.

Resources also revolve around spare equipment. Much of the equipment supporting the electric grid is potentially sensitive to EMP. System protection devices, generation control systems, communication systems, maintenance equipment and SCADA all contain electronic components that are often connected to metallic conductors that could convey voltage surges from an EMP event. The supply chain for delivery of spare parts will likely be disrupted in a Black Sky event. Therefore, generous supplies of spare parts stored in a protected environment are a resiliency requirement. Pre-event planning should have identified the facilities critical to the Black Sky black start process. Non-critical facilities could be a source of spare parts. The parts that are removed could be replaced later in the restoration process when normal supply chain processes are restored.

Chemicals are also a key resource. Like water systems, generating stations have a number of chemicals that are critical to operation. Pollution control devices often cannot be bypassed and require chemicals to remain in operation. Power plant steam boilers require chemicals to maintain water purity in order to avoid tube failure. Generators require hydrogen for cooling. Due to anticipated interruptions of the existing supply change as a result of a Black Sky event, consideration should be given to increased onsite supplies of chemicals at generation units that are key to Black Sky recovery.

Human resources are also key to the Electric Sector. The internal staffing for the normal maintenance of system protection, control, and communications equipment will be inadequate to support the necessary testing and repair of sensitive electronic equipment in a Black Sky environment. A source of trained technical personnel will be essential to expedite recovery, but likely will not be available from nearby utilities due to the wide scope of a Black Sky event. A utility should consider basic technician training for a wide range of its employees, who could then support the normal maintenance staff after a Black Sky event. The EPRO Certified Power Recovery Engineering Team (CPR) Project concept is a potential source of trained technicians from neighboring industry. Partially trained technicians can work under the supervision of the utility’s technicians, increasing the span of the existing workforce.

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13 Certified Power Recover (CPR) Engineering Team Project, www.eiscouncil.org
Sector Commodity Specific List Matrix

<table>
<thead>
<tr>
<th>Phase</th>
<th>Commodity</th>
<th>Estimated Quantity</th>
<th>Potential Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>I, II, III</td>
<td>Diesel Fuel</td>
<td>TBD</td>
<td>On site storage for emergency generation and dual fuel generating units, supply chain</td>
</tr>
<tr>
<td>I, II, III</td>
<td>Spare parts and equipment</td>
<td>TBD</td>
<td>Generous sparing policy by utility, supply chain, relocation from non-critical facilities</td>
</tr>
<tr>
<td>II, III</td>
<td>Natural Gas</td>
<td>TBD</td>
<td>Natural gas pipeline delivery system</td>
</tr>
<tr>
<td>II, III</td>
<td>Chemicals for generation stations</td>
<td>TBD</td>
<td>Increased onsite storage for black start and secure fuel generating units, supply chain</td>
</tr>
<tr>
<td>II, III</td>
<td>High tech manpower to supplement existing personnel, capable of testing and repairing communications, control, and protection equipment</td>
<td>TBD</td>
<td>EPRO /Certified Power Recover (CPR) Engineering Team Project(^4) utilizing trained resources from neighboring industry</td>
</tr>
</tbody>
</table>

Sector Black Sky Communications Overview

The ability to communicate after a Black Sky event is critical to the Electric Sector. Without a two-way exchange of data, and the ability to direct the operation of system equipment, the Transmission Operator will be greatly hampered in its ability to control and operate the grid. Voice communications can supplement SCADA data exchange, if there has been planning and training to simulate loss of communications. Data is required to provide the control center with situational awareness, and the ability to talk with field personnel in order to control equipment is essential in the event of the loss of SCADA.

\(^4\) Certified Power Recover (CPR) Engineering Team Project, www.eiscouncil.org
There are numerous best practices that can be adopted by the Electric Sector to provide resilience for the existing system, incorporate resilience measures into new construction, and to plan and train for Black Sky events.

NERC standards require Transmission Operators and operators of black start generators to have, test, and drill black start plans and procedures. These Transmission Operators should incorporate a Black Sky module into their black start plans. These Black Sky modules should recognize the more severe conditions that will exist in the aftermath of a Black Sky event than occur during a normal “gray sky” event or a cascading outage caused by equipment failure. Black start drills should incorporate total loss of communications or other Black Sky impacts such as damaged equipment.

Installation of Black Sky resilience measures in new construction is easier, and less costly than retrofitting existing facilities. Utilities and generators should consider modifying design practices to incorporate resilience measures in new construction. These measures could include the use of fiber cable rather than metallic cable for control and communications. Incorporation of six wall shielding in new control houses and control centers, limiting points of entry into protected space, utilization of metallic doors with RF shielding, and waveguide protection of ventilation and fluid penetrations are other examples of design enhancements for new construction.
Sector Best Practices Matrix (On-going)

<table>
<thead>
<tr>
<th>Area of Operations</th>
<th>Recommendation</th>
<th>Expected Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Enhance current black start procedures to include a Black Sky element</td>
<td>Many current black start plans do not assume damaged equipment, loss of fuel infrastructure, and complete loss of communications</td>
</tr>
<tr>
<td>Planning</td>
<td>Perform regular drills for Black Sky, black start events</td>
<td>Black Sky events are more severe than normal black starts. Damaged equipment and degraded communications should be incorporated into drills</td>
</tr>
<tr>
<td>Design</td>
<td>Incorporate resilience measures into design practices and specifications for new facilities and equipment</td>
<td>More cost effective to include resilience in new construction than retrofitting</td>
</tr>
<tr>
<td>Planning</td>
<td>Identify generation, transmission, and substation facilities that are critical to Black Sky black start</td>
<td>Provide direction on where to apply resilience measures</td>
</tr>
<tr>
<td>Fuel</td>
<td>Dual fuel units that are part of the Black Sky Black Start plans should have significant onsite storage of the secondary fuel</td>
<td>Provide for the extended operation of dual fuel units to ensure the ability to start up secure fuel units.</td>
</tr>
<tr>
<td>Fuel</td>
<td>Work with the natural gas transmission provider to understand the gas transportation network facilities that are critical to delivery of gas to generating units. Ensure those facilities are resilient to a black sky event.</td>
<td>Ensure the ability to deliver natural gas to critical generating units after a Black Sky event</td>
</tr>
</tbody>
</table>

Sector Black Sky Resilience Investments Considerations Overview

There are a number of actions and investments the Electric Sector should take to improve electric grid resilience against a Black Sky Event.

The normal staffing levels of technicians and engineers at an electric utility are designed to maintain a system under normal conditions. During a gray sky event, such as an ice storm or a hurricane, assistance is usually provided by technicians on loan by utilities outside of the storm area. A Black Sky event will be widespread enough that outside assistance may not be available. In the event of a coordinated cyber-attack, outside utilities may be reluctant to provide assistance because of the possibility they will soon be attacked. The EPRO Certified Power Recovery Engineering Team Project is a method of increasing the availability of trained technicians that could work under the supervision of existing staff.
A Black Sky event, depending on the type, may damage communications systems. The EPRO BSX communications project is developing the architecture for a communications system that would withstand an EMP burst or cyberattack and satisfy the Electric Sector’s need for emergency communications that would provide situational awareness and command and control after a Black Sky event.

Resilience Investments Matrix

<table>
<thead>
<tr>
<th>Initiative Title</th>
<th>Initiative Description/Cost</th>
<th>Expect Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certified Power Recovery Engineering Team Project</td>
<td>Developing a certified, supplemental high-tech manpower surge capability for lifeline utilities and their partners by drawing from aerospace, high-tech companies.</td>
<td>Adequate skilled manpower to test and repair damaged communications, protection, and control equipment</td>
</tr>
<tr>
<td>Emergency Communications BSX</td>
<td>Develop a resilient communication system that will provide voice, and possibly some data, transmission in the event of failure of telephone, SCADA, internet, and cell phone communications</td>
<td>Provide the minimally acceptable ability to maintain post-Black Sky event situational awareness and control</td>
</tr>
</tbody>
</table>

Sector Black Sky Regulatory Issues Overview

There are several areas of regulatory oversight of the Electric Sector that hinder resilience investment, impede training and preparation for a Black Sky event, or have the potential to slow down Black Sky recovery efforts.

The EPRO concept of secure enclaves provides for only the most critical facilities receiving resilience investments. By limiting the facilities to be hardened, the cost of resilience is reduced compared to the cost of hardening an entire electric grid. However, resilience still has an associated cost, and a regulatory method must be developed to assist the utility industry and regulatory bodies in determining a just and reasonable, cost effective level of investment. The utility must be assured that the cost of retrofitting existing critical facilities will be recovered, or it cannot make the investment. The incremental cost of incorporating resilience measures in new construction likewise must be recovered. Utilities and state and Federal regulators should come to an agreement on what is just and reasonable.

Dual fuel units require a considerable amount of onsite storage in order to be prepared for a Black Sky event. There are fixed costs associated with this inventory, as well as maintenance costs required to maintain fuel quality. Dual fuel units should be periodically operated on the secondary fuel to ensure that they will successfully operate in an emergency. Because the secondary fuel is generally more
expensive than the primary fuel, the fuel cost differential will require recovery. If the dual fuel generation is part of a marketplace, the generators and the market operator should work to develop market mechanisms to incentivize the dual fuel capability.

Environmental regulations may limit the period of time that a liquid-fueled generating unit can operate because of air quality. This may limit the amount of time that emergency generators can be operated for testing purposes. Both dual fuel units and emergency generators should be operated routinely to ensure they are capable of performing their functions. The utility industry and state and federal regulators should work collectively to ensure environmental regulations do not inhibit the maintenance of Black Sky capability for select generators.

During the restoration of the grid following a Black Sky event, it seems intuitive that the need for electrical power and lifeline facilities would override any regulation of any type. Anecdotally, it appears that this viewpoint is not universally held. There are numerous regulations that address power system operations (NERC Standards), air quality (EPA), natural gas service priorities, trucking, and other issues that could affect Black Sky restoration. Industry, government, and regulators should review regulations and explicitly remove impediments to a Black Sky recovery.

**Sector Regulatory Issues Matrix**

<table>
<thead>
<tr>
<th>Area of Operations</th>
<th>Issue</th>
<th>Recommended Solution/Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finance</td>
<td>Black Sky resilience measures have costs associated with design standards, construction, maintenance, and increased levels of spare parts. Electric utilities require assurance that reasonable expenditures may be recovered.</td>
<td>State public service commissions and Federal regulators should develop a methodology for evaluating the reasonableness of Black Sky resilience investments and provide for cost recovery in rates, or through other mechanisms.</td>
</tr>
<tr>
<td>Fuel</td>
<td>Black Sky black start dual fuel units require a substantial amount of onsite storage of the secondary fuel. There are financial barriers for onsite storage of secondary fuels related to the cost and maintenance of the fuel.</td>
<td>Generation markets should develop features that would financially incentivize dual fuel generators to maintain onsite storage for Black Sky recovery. These markets should also provide compensation to the generators when they operate in dual fuel mode for testing to prevent financial harm from out of market dispatch.</td>
</tr>
<tr>
<td>Fuel, Operations</td>
<td>Environmental regulations limit the time duration for burning liquid fuels for dual fuel units. Removal of regulatory barriers for routine testing of dual fuel units on secondary fuels would provide assurance that the units will be capable of operating</td>
<td>Air quality regulations should be amended so that generating units designated as Black Sky-related dual fuel units are provided sufficient regulatory relief to allow periodic operations for testing purposes.</td>
</tr>
</tbody>
</table>
after a Black Sky event. Diesel fueled emergency generators may also have time limits based on air quality rules that may limit the amount of routine operation for testing and maintenance.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Emergency diesel generators for critical facilities should be provided sufficient regulatory relief to allow periodic operations for testing purposes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>Much of US generation is fired by natural gas. Current tariffs and regulations may provide a higher priority of service after a disturbance to other types of gas transportation customers than units that would participate in a Black Sky black restart.</td>
</tr>
<tr>
<td>Fuel</td>
<td>Market rules and natural gas transportation tariffs should be amended to provide priority delivery service after a Black Sky event to generating units designated as critical to Black Sky recovery.</td>
</tr>
<tr>
<td>Fuel</td>
<td>Many gas-fired combustion turbine generating units rely on non-firm gas delivery service because of the cost of firm gas transportation, and the lack of assurance that the generator will recover these costs.</td>
</tr>
<tr>
<td>Fuel</td>
<td>Market rules and regulatory policies should be modified to provide for the cost recovery of firm gas delivery service for generating units identified in Black Sky black start restoration plans.</td>
</tr>
<tr>
<td>Supply Chain</td>
<td>Trucking regulations that impact the size of a load or the length of time drivers may work could impede delivery of critical resources after a Black Sky event. Large equipment such as transformers may need immediate movement. Critical diesel fuel will likely be transported to the Black Sky area from a distance.</td>
</tr>
<tr>
<td>Supply Chain</td>
<td>State and federal regulatory agencies should put in place automatic exemptions to selected regulations that inhibit recovery from a Black Sky event.</td>
</tr>
</tbody>
</table>

**Sector Black Sky EMP Protection Overview**

The essential elements of the electric grid are generation, transmission/distribution, substations, communications, and energy management control centers. All of these elements must be in place to restart the grid after a Black Sky event, and to restore the grid to near pre-disturbance conditions. All of these elements are subject to damage during a Black Sky event.

Generating stations are complex electro-mechanical systems. The individual units are protected by and controlled by systems containing digital devices that are sensitive to EMP threats. There is not a large body of work on the vulnerabilities of power plant electronics, but there is much similarity with substations and control centers with respect to digital devices. EMP protection techniques should be considered for generating stations.

Transmission and distribution lines connect black start generators to fuel secure generators and to critical loads. In general, the lines are not severely impacted by EMP radiation. Lower voltage lines may be susceptible to flashover, which can be corrected by application of lightning arrestors similar to systems use to protect against lightning. The greatest risk to these lines is during severe terrestrial weather, such as ice storms or hurricanes. As events in Puerto Rico have demonstrated, severe weather has the possibility of breaking poles, and causing conductors to fail. An earthquake would have the same
effects. Resilience investments in the form of more stringent design standards enabling the lines to withstand higher winds and heavier ice loads, and aggressive right of way maintenance to keep vegetation away from the lines, would improve Black Sky performance.

Substations are nodes in the transmission system that protect lines, and step voltages down to distribution levels. They contain large numbers of EMP sensitive electronic protective, control, and communication devices. EMP shielding techniques should be applied to critical substations, and design standards for new construction should incorporate EMP shielding.

Communication systems are vulnerable to EMP. Typical EMP shielding techniques are the appropriate remediation. Some communications, such as cell phone towers, use emergency generators on site to supply power in a grid outage. These generators can run out of fuel or otherwise fail, shutting down the cell tower. Increased onsite supplies of fuel for the emergency generators will help remediate this condition.

Control centers utilize a computer system infrastructure and a communications network to maintain situational awareness of the grid, and to control generation and transmission switching equipment. These centers are vulnerable to EMP/IEMI effects. Many utilities are incorporating HEMP and IEMI remediation when building new control centers.

### Sector EMP Protection Matrix

<table>
<thead>
<tr>
<th>Element</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>Generating units have control systems that are susceptible to EMP/IEMI damage</td>
</tr>
<tr>
<td>Transmission - Distribution</td>
<td>Transmission and distribution lines are not severely threatened by EMP/IEMI, but are exposed to damage from physical assault, severe terrestrial weather, and earthquakes. Most load is served from the distribution system.</td>
</tr>
<tr>
<td>Substation</td>
<td>Substations are protected and controlled by electronic devices sensitive to EMP and IEMI. They are also exposed to equipment damage from physical assault, severe terrestrial weather, and earthquakes</td>
</tr>
<tr>
<td>Communications</td>
<td>Communications systems are exposed to damage from the effects of EMP/IEMI. Cell phone towers that lose emergency backup power due to lack of fuel for emergency generators are subject to failure in extended outages.</td>
</tr>
<tr>
<td>Control Centers</td>
<td>Control centers utilize SCADA systems and extensive IT structures to maintain situational awareness and control of the electric grid. These tools are subject to damage from EMP/IEMI and are threatened by cyber attack.</td>
</tr>
</tbody>
</table>

### Sector Black Sky Specialized Skill Training Requirements: Overview

Numerous skills are required to build Black Sky resilience into an electric system. System planners, design and construction engineers and personnel, maintenance and operations personnel all contribute
to determining and implementing cost effective resilience measures. The response, restoration, and recovery from a Black Sky event falls heavily on the shoulders of those who have command and control of the system, and those who inspect and repair the equipment that may be damaged by the event.

The transmission operator is the position with the ability to recognize the impact the event has on the electric grid. This position determines the actions to be taken to respond to the event and to guide the system’s recovery to near normal conditions. Transmission operators are highly skilled, and have years of training and experience before they are positioned to manage the system. In addition to extensive, ongoing training, transmission operators are NERC Certified.

An EMP or IEMI Black Sky event is most likely to damage sensitive electronic equipment, such as relays, control equipment, and communications equipment. The technicians who manage the inspection and repair of this equipment are key to response and restoration. All of this electronic equipment must be inspected before being placed back into service. If damaged, it must be repaired or replaced. Technicians have significant amounts of training.

Severe terrestrial weather such as a hurricane or an earthquake, or physical assault, is more likely to damage equipment, especially transmission structures. For these Black Sky events, physical damage must be repaired, and the key responders would be transmission/distribution line workers and substation technicians. These personnel are skilled workers, with significant training. The jobs are hazardous, with work around energized equipment and transmission lines, and dealing with heavy equipment and components.

### Sector Specialized Skill Training Requirements Matrix

<table>
<thead>
<tr>
<th>Phase</th>
<th>Position/Skill</th>
<th>Training/Certification Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2, 3</td>
<td>Relay/Instrument Technician</td>
<td>Substantial training in setup, inspection, and maintenance of relays, control, and communications equipment</td>
</tr>
<tr>
<td>1, 2, 3</td>
<td>Transmission System Operator/Dispatcher</td>
<td>Substantial training and experience required. Training is ongoing and wide ranging. NERC Certification is required</td>
</tr>
<tr>
<td>1,2,3</td>
<td>Line workers and Substation Technicians</td>
<td>Substantial training and experience required. Training is ongoing.</td>
</tr>
</tbody>
</table>