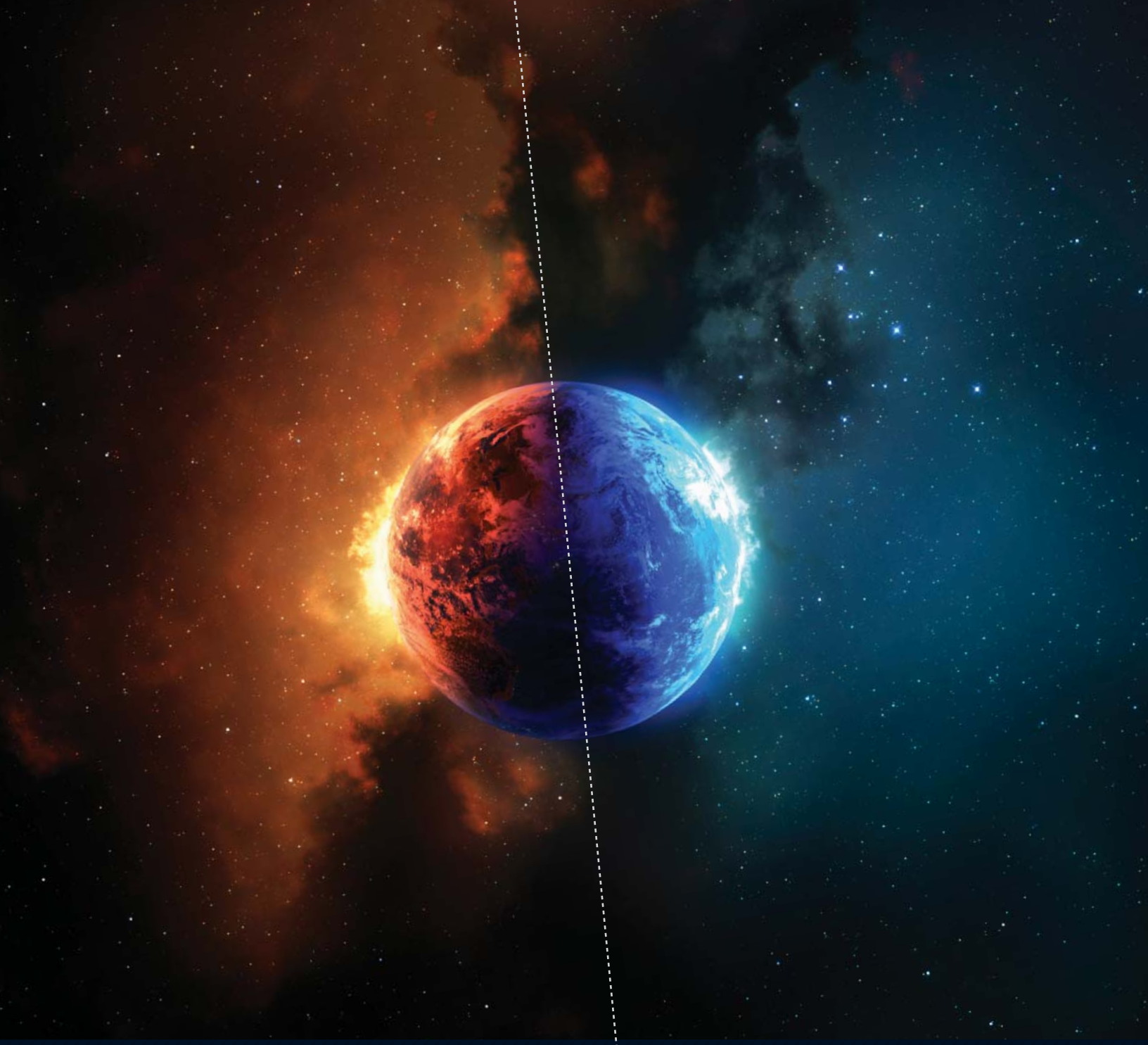


Black Sky Black Start **Protection Initiative™**

BSPI™

Black Sky\Black Start Protection Initiative™

BLACK SKY/ BLACK START PROTECTION INITIATIVE™

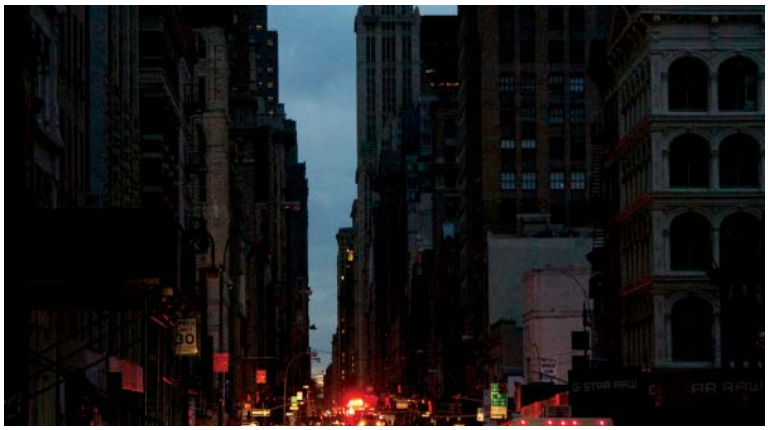
In the United States and other developed nations, the life-supporting resources once provided by and for local communities are now delivered by lifeline infrastructures powered by national power grids: organic, national and continent-scale infrastructures. The result has been unprecedented access to electricity, water and wastewater service, food, fuel, communications, health care, transportation and all the other life-critical and societally essential commodities and services.

Ubiquitous, instantaneous electricity service is the bedrock on which modern nations are founded. Its' continuity is essential to societal health, national security and, fundamentally, our survival.

The power grid is often referred to as "the world's largest machine." And like any well designed machine, the grid has a "restart" capability: the Black Start system, designed to ensure that when major outages occur they are quickly recoverable.

As electric utilities and their partners begin to address uniquely severe, wide area and long duration "Black Sky" outages, it is crucial that the Black Start system is enhanced to meet this new challenge.

BACKGROUND



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Ensuring that most or all of the Black Start System remains fully operational is a fundamental prerequisite for national recovery from Black Sky Hazards.

Measures focused on power grid protection may be divided into three categories, addressing three different hazard scenarios.

1 | "BLUE SKY" SCENARIO

Electric generation, transmission and distribution networks are designed to provide for uninterrupted access to electricity under normal conditions, including a full range of "normal" weather environments.

2 | "GREY SKY" SCENARIO

Severe weather (e.g., Superstorm Sandy) and other stressing hazards can cause occasional serious interruptions in electric service, typically when local or regional damage to power lines and other distribution hardware causes a shutdown to prevent more serious damage to the system. In such instances, restart of generation facilities generally uses power coming in from outside the affected area.

Black Start: In severe examples of such "gray sky days," external power may be unavailable or impractical, and power companies then use "black start" procedures to restart a grid segment without assistance from external power.

Outages in such scenarios result from preplanned shutdowns designed to prevent damage of major hardware elements. Power can usually be restored -- at least to the most vital facilities -- within hours.

3 | "BLACK SKY" SCENARIO

This class of very severe hazards is now receiving increasing attention. Natural events such as severe regional earthquakes or extreme terrestrial or solar weather, or malicious hazards such as extensive cyber or EMP attacks or coordinated physical assault could cause very large multi-region or potentially continent-scale outages, with widely distributed damage to major equipment. Power companies and government agencies are considering a range of resilience measures and restoration support plans to address such uniquely severe events.

All Black Sky scenarios share a common attribute: Outages would span very large regions, and utilities could require weeks or potentially months to restore power to even the highest priority customers. Planning for cost effective resilience measures for these hazards and, at least as important, for the planning, training and real time cross sector coordination that will be their essential complement, is the focus of the Electric Grid Protection (EPRO®) Resource Family and related initiatives.

SECURING THE BLACK START SYSTEM

However, essential to any such preparations is the security and protection of the "Black Start" system, grid elements designed to "bootstrap" or restart the electric grid without relying on external power.

Ensuring that most or all of this system remains fully operational is a fundamental prerequisite for national recovery from Black Sky Hazards.

THE BLACK SKY/BLACK START **PROTECTION INITIATIVE** (BSPI™)

ASSURED, ADAPTABLE BLACK SKY RESILIENCE FOR THE BLACK START SYSTEM

Robust, Decisive Restoration

The Black Start System – black start power generation plants along with the generating stations on their associated "cranking paths" – will be the backbone for power restoration in any major grid outage.

In very severe outages, this Black Start backbone will itself be subject to unique challenges – both for protection from direct damage by the Black Sky hazard, and for protection from an indirect and potentially even more dangerous risk: failure of the system's fuel supply.

The security and continuity of this system in such environments is, therefore, an essential first step for overall power restoration, mandating development and implementation of new, layered protection strategies that could become the foundation for robust, decisive restoration from Black Sky Hazards.

> Assuring sustained fuel supplies to power generating stations is key to any Black Sky Hazard recovery strategy. For the Black Start system, it is an essential prerequisite.

Introduction

A recent FERC-NERC review[1] has confirmed that, under stressing "Gray Sky" conditions, the power industry's Black Start system provides a solid foundation for grid restoration. Power utilities have identified Black Start generation units, cranking paths and critical load, with personnel trained in restoration procedures. Power can usually be restored to vital facilities within hours, and restoration timelines also fall within the limited lifetimes of backup batteries and emergency generator fuel supply.

However, "Black Sky" hazards represent a substantial departure from Gray Sky events. Power outages like Superstorm Sandy, while challenging, have not been characterized by a general communications breakdown or widely distributed damage to power grid hardware and SCADA control systems. Blackouts in such severe scenarios will not be quickly recoverable. Power outage durations would be unprecedented, and the resulting disruption of civil communications, transportation, water and other lifeline infrastructures would make conventional Black Start restoration procedures unworkable.

Building on the foundation of today's Gray Sky-based Black Start system, the Black Sky / Black Start Protection Initiative (BSPI) examines limited, cost effective upgrades to expand the system's capability to include extended duration outages. As an additional element of this analysis, approaches to address the unique emergency power needs of nuclear power stations are also examined, including the potential to utilize these plants as key recovery assets, rather than liabilities.

[1] "Report on the FERC-NERC-Regional Entity Joint Review of Restoration and Recovery Plans, January 2016"

1 | SECURE FUEL SUPPLIES

The Need

Assuring sustained fuel supplies to power generating stations across affected grid regions is key to any Black Sky Hazard recovery strategy, cutting across all aspects of the effort. For the Black Start system, it is an essential prerequisite.

Without secure, hardened fuel supplies for Black Start System generating plants, power restoration cannot begin.

New initiatives like the National Emergency Power Commission (NEPC) will explore approaches to coordinate monitoring, repair, maintenance and emergency generator refueling of the pumping and compression stations that keep oil and gas flowing in interstate pipelines. But given the realities of operation in the highly disrupted environments characteristic of very severe hazards, flow in many pipelines may degrade or shut down, and be slow to restart with even partial service. Secure, hardened, direct access to fuel is essential for as many Black Start System plants as possible.

Indeed, since assuring such access is unlikely to be possible for all black start plants, a two-tier architecture should become an important goal for utilities and their partners: 1st Tier Black Start System plants would be selected for feasibility of secure fuel-access (adequate for at least 30 days), as well as critical load. As discussed below, given their vital role in restoration, they should also be a focus for specific Black Sky Hazard protection, as core assets with "Secure Enclave" ranking, as recommended in EPRO Handbook I.

Implementation

By carefully selecting Black Start System stations (black start and associated cranking path generation plants) for 1st Tier ranking, the complexity of assuring long-duration fuel security can be minimized.

Generating plants using natural gas typically have minimal "built-in" fuel reserves, depending on real time gas delivery from interstate pipelines which could fail or be substantially interrupted

in Black Sky scenarios. Other plants, however, lend themselves naturally to fuel security, with substantial built-in reserves.

- **Hydroelectric generating stations**

  These generating plants represent an important resource for a 1st Tier Black Start system. Though not located in all regions, where available, the "fuel" used by these plants will have undiminished availability during very severe hazard scenarios. By combining the efficiencies of a "built-in" fuel supply with environmentally friendly generation and rapid restart, hydroelectric generating stations also represent a resource that will have continuing availability for many years to come.

As coal plants are decommissioned, their role as 1ST Tier Black Start System units should be taken by gas turbine plants with large fuel stocks.

- **Fossil Fuel-fired generating stations**

  - **Coal-fired generating plants**

    Coal plants typically maintain a minimum of a 30 day fuel supply on-site, and these minimum reserve levels could, potentially, be increased. They also have, today, wide geographic distribution.

    These factors together make coal-fired generating stations a good complement to the more limited-distribution hydroelectric plants. Configured as black start-associated "cranking path" generation stations (to address their long startup and restart timelines), these units could become important assets for a 1st Tier Black Start System.

    Unlike hydroelectric plants however, maintaining coal-fired plants in compliance with environmental standards is expensive, and although they represent the largest single category of generating plant operating today, their market share, over time, is dwindling.

  - **Gas turbine generating plants**

    Often used for load-balancing, gas turbine generating plants do not have the geographic distribution limits of hydroelectric plants, and startup time is rapid, generally requiring only minutes to achieve full load. Unlike coal plants, meeting environmental standards is not typically a serious economic concern for these facilities.

    While gas turbine generators can burn gasoline, diesel fuel or natural gas, meeting the suggested 30 day minimum requirement for secure, direct access to large fuel stocks for 1st Tier Black Start System ranking would typically mandate use of diesel or gasoline (though natural gas plants with a secure, adequate, dedicated fuel supply could also be an option).

    The cost for onsite storage of these quantities is comparatively high, relative to other fuel choices. However, where coal-fired plants cannot economically meet steadily increasing environmental regulations, phasing out coal-fired electric generation will continue to be a high societal priority. As coal plants are decommissioned, their role as 1st Tier Black

Start System units should be taken by gas turbine plants with large fuel stocks, in regions where hydroelectric power is not available.

▪ Nuclear Power Plants – Black Start Liability... or Asset

Chief among critical facilities at risk without external power are nuclear power plants. These power plants require substantial levels of "outside power" to cool the reactor core and the spent rod cooling pools. In current planning, in the event of a power outage, while the nuclear reactor would shut down, the power needed for these cooling requirements would be supplied using the plant's own emergency diesel generators, and its own diesel fuel stocks.

From Liability …

However, diesel fuel supplies at such plants are limited, with nuclear facilities maintaining supplies adequate for one week[2], a duration far shorter than likely best-case Black Sky hazard recovery times. The quantities of diesel fuel required, given the tens of megawatts such plants require for cooling, are substantial. Supplying and resupplying fuel at these quantities, according to current planning, would require a steady flow of many diesel trucks daily.

In a disrupted Black Sky environment, the logistics of organizing, supplying and maintaining a refueling fleet to meet critical safety needs at many nuclear power plants would be a major undertaking. And if achieved, it would dramatically reduce the nation's ability to meet vital lifeline infrastructure needs.

… To Asset

Nuclear power plants typically have on the order of a full year of "fuel" in their reactor cores. If adequate, secure outside power could be provided, these plants could continue to operate through a black sky scenario. Rather than a critical liability, functioning as a heavy drain on national restoration and emergency response capabilities, they would become a vital asset, part of the Black Sky System backbone which utilities could use to restore power across the grid.

In an extended duration, multi-region power outage 1st Tier Black Start hydroelectric generating stations and fossil fuel plants (if they do not shut down) could continue to function independently. Continued operation of nuclear power plants in a wide area power

[2] ANSI /ANS-59.51-1997, American National Standard Fuel Oil Systems for Safety-Related Emergency Diesel Generators

outage would require pre-planned "coupling:" associating designated nuclear plants with one or more 1st Tier "sister" generating stations with their own secure fuel supplies, prioritized to provide adequate outside power to allow the nuclear plant to continue in normal or near-normal operation.

With appropriate planning, nuclear power plants could become powerful, even indispensable Black Start System 1st Tier generation assets.

Nuclear plants have limited load-following capabilities, although this constraint is expected to ease over time, as a result of efforts such as EPRI's Nuclear Plant Flexible Power Operations Program.[3] In the near term, use of nuclear power plants as part of the cranking path associated with the Black Start system in very severe outages will require additional operational planning. For example, restart of a nuclear power plant would typically be delayed until there is adequate load in the relevant, islanded portion of the grid to roughly match the nuclear plant's generation. For stable operation, "sister" generating stations should have load-following characteristics compatible with restoration plans for the relevant islanded portion of the grid.

By building plans for such relationships among power plants into Black Sky restoration plans, nuclear power plants could become powerful, even indispensable Black Start System 1st Tier generation assets.

Once implemented, this plan would use a combination of hydroelectric plants, fuel-secure fossil fuel plants and nuclear plants to develop an architecture of 1st Tier Black Start System assets -- assets that could become a robust national backbone for decisive restoration from Black Sky Hazards.

With secure, long term access to fuel, these generating plants could become the foundation for power restoration and recovery operations, providing continued power while other power plants, interstate fuel pipelines and related systems gradually come back online.

This combination of resilient hydroelectric plants, fossil fuel plants and nuclear plants could become a fuel-secure national backbone for robust, decisive restoration from Black Sky Hazards.

[3] EPRI Program on Technology Innovation: Approach to Transition Nuclear Power Plants to Flexible Power Operations. Product 3002002612

2 | PLANNING A 1st TIER BLACK START SYSTEM "SECURE ENCLAVE"

Functioning in this fashion, however, implies one additional requirement: operation of the 1st Tier Black Start System with sufficient Black Sky Hazard protection to allow either uninterrupted or only temporarily interrupted operation, due to the direct impact of the Black Sky hazard.

The "Secure Enclave" strategy calls for hardening, not an entire grid region, but carefully selected black start (and associated cranking path) generation and transmission assets, so they either remain operational or can be quickly restored. Deployment of such protection could be highly selective to ensure cost effective implementation, potentially limited to the 1st Tier Black Start System.

EPRO I, the first volume of the EPRO Handbook Series, proposed such a strategy – defining Secure Enclaves for the Black Start system, using EMP protection as a case in point. Extending this strategy to the 1st Tier Black Start System defined above would prioritize hardening designated hydroelectric plants, fuel-secure fossil fuel plants and nuclear plants against the full set of black sky hazards.

As a starting point, nuclear power plants could be used as a key to defining generating plants to be considered first priority for such protection. Each nuclear plant would be "coupled" with one or more hydroelectric or fuel-secure fossil fuel "sister" Black Start System generating stations, to provide continuing, secure power, with sufficient power regulating capability to allow the nuclear plant to function within safe operating limits.

By combining this approach with carefully expanded sparing and key personnel retention measures, and working with the electric industry's partners on critical cross-sector requirements, the nation's nuclear fleet in severe Black Sky outages will become, not a liability, but a powerful and potentially decisive restoration asset, with a full year's worth of "fuel" on site and available.

IN SUM: The 1st Tier Black Start System, with its fuel secure, Black Sky Hazard-protected power plants, could become the backbone for power restoration and national recovery in severe, extended power outages.

BSPI™, a special project of EIS Council, addresses severe Black Sky Hazards (The Black Sky Protection Initiative™) and associated approaches for protection of the Black Start system (The Black Start Protection Initiative™).