

## **Information Paper**

### **DoD and Industry Black Start Exercises**

#### ***Overview***

The term “black start”, for either DoD or industry, refers to the ability to start an electrical system from a state of complete shutdown: where no generation assets are running and the high voltage transmission and lower voltage distribution lines are de-energized. There have been no complete black start events on the bulk transmission grids in the continental U.S., as the closest event was in Puerto Rico after the island lost power in 2017 from hurricanes (area-wide blackouts have occurred where restoration was necessary, and are described later in this paper). However, the DoD has conducted five black start exercises at military installations, the largest of which was at Fort Bragg, North Carolina.

While the electric industry has not conducted a similar black start exercise where large amounts of customer load are deliberately taken off-line, it has conducted tabletop exercises, simulations, and drills for many years to enable black start capabilities. The tabletop exercises, simulations, and drills help ensure the readiness of the electric industry and its personnel to energize substations, generation, and the associated infrastructure to ensure regional outage restoration on the bulk transmission system. During its table-top exercises, simulations, and drills the electric industry looks to ensure continuity of critical loads identified in their restoration plans and operations, such as: life, health, and safety operations; national security operations; communications operations; and, economic operations.

In regards to simulations, large utilities train their staffs annually in operations simulators that incorporate supervisory control and data acquisition (SCADA) systems mirroring their electric grid control center. The simulation is revised annually for training purposes, and provides a near, real-time black start training environment. The electric industry, much like the DoD, has similar objectives to ensure energy resilience within its service territories.

The DoD over the last few years planned and executed black start exercises on its military installations. The five completed black start exercises are the first of their kind conducted in the U.S. The DoD implements black start exercises by similar methods to electric industry tabletop exercises and drills. It disconnects from the commercial electric grid (transmission system) and de-energizes its distribution lines to ensure continuity of critical loads and missions. Upon disconnection from the commercial electric grid, DoD black starts the installation electric grid, portions of it, or individual buildings, as well as reconnects to the external power supply. This black start process is essential to ensure continuity of critical loads and the readiness of critical mission operations and personnel on military installations. The military installation community (public works and civil engineering community) operates like a utility provider, ensuring the safety and security of its customers and tenants on military installations.

Given its execution of black start exercises, the DoD can help inform national energy resilience strategies through its lessons learned. It can transition capabilities to the electric industry to help improve national energy resilience priorities. This partnership could provide more realistic training for personnel and help improve the understanding of interdependent infrastructure on the commercial electric grid.

#### ***Comparison of DoD and Industry Black Start Processes and Procedures***

The following provides a more detailed comparison of the electric industry’s black start procedures versus DoD executed black start exercises, and compares the two approaches.

## **Information Paper**

### **DoD and Industry Black Start Exercises**

#### ***Industry Background***

There have not been planned black start exercises of a widespread region to test the electric industry's black start capabilities. This is due to safety requirements for restarting the power grid from a complete outage and the length of time critical operations, such as life, health, and safety operations, would be without power. As an example, in order to conduct a black start exercise in New York City, it would require an outage of at least sixteen hours in length. The duration of a black start exercise is regionally dependent, where switching operations, safety precautions, infrastructure and equipment, and system configuration (e.g., overhead versus underground lines) would need to be considered during planning stages. There were instances on the commercial electric grid where large portions of the transmission grid lost power (1977 NYC blackout, 2003 Northeast blackout, 2011 Southwest blackout, 2012 Derecho outages, as well as others), but those did not require system-wide black starts. Instead, wider interconnections still with power were used to synchronize and gradually energize the bulk transmission system for the region that had lost power.

Electric industry stakeholders are required to test their black start capable assets in an isolated manner to receive a North American Electric Reliability Corporation (NERC) certification. The ability to re-start its generation, transmission, and distribution systems in a simulated fashion is required for the certification.

The bulk U.S. electric grid is comprised of large generation assets that provide power through high voltage transmission lines and substations. These interconnected systems on the electric grid deliver power to load connections at distribution substations. The systems on the U.S. electric grid are synchronized and balanced so that power does not unnecessarily flow over large distances. In order to provide power from higher voltage transmission systems to lower voltage distribution systems, substations are used to distribute power to cities, towns, industrial, and rural customers. On the U.S. electric grid, there is a NERC requirement to maintain a sufficient generation reserve to ensure a failure of the largest generation plant in a region would not result in a system collapse. A concern, depending on system configuration, would be that immediate increase of power flows can trigger automatic protective relays and failure of infrastructure or equipment<sup>1</sup>.

During a loss of power, the electric industry would need to have sufficient generation to energize large portions of its high voltage transmission system within an impacted region. Depending on the scope of the black start event, the electric industry may need to synchronize other generation assets in other regions to ensure continuity of critical mission operations and loads. A large scale black start event would be complicated by prioritizing distribution system loss of power and the challenge of attempting to energize tens to hundreds of miles of high voltage power lines to a critical substation, feeder, or load, depending on the needs of a customer. The electric industry, like the DoD, prepares for loss of power to its transmission system and attempts to recover power by black start capable generation assets. The key difference is that the electric industry operates bulk power equipment requiring high voltage transmission of power<sup>2</sup> to sustain critical mission operations. The objective of the electric industry during a black start event is still very much energy resilience.

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<sup>1</sup> Overloads result in equipment failure vice tripping, unless operators shut down lines via SCADA protection. This concern is based on distance relaying with low current settings and simultaneous voltage decline, which can be resolved with current differential protection schemes.

<sup>2</sup> It should be noted the electric industry also operates medium and low voltage distribution systems. This point is to distinguish between the electric industry capabilities to operate high voltage and large power plants, where DoD capabilities align to low voltage, distributed systems.

## **Information Paper**

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#### ***DoD Background***

As described in the National Defense Strategy (NDS), the velocity and variety of global threats continues to evolve, and we must anticipate attacks and mitigate risks to our critical defense, government, and economic infrastructure. The homeland is no longer a sanctuary, and maintaining energy resilience is critical to the Department's readiness. Black start exercises are critical to ensure the energy resilience of DoD installations and the grid that supports them.

The DoD must be able to continue its mission against asymmetric threats from its adversaries. Unlike the electric industry, the DoD does have the benefit of establishing enclaves to conduct black start exercises. Some of DoD's exercises are large-scale ( $> 100$  MW of peak load) and can help inform a national energy resilience strategy. Benefits of black start exercises include: they help influence behavior and culture changes, draw out interdependencies between infrastructure and critical mission operations, and provide senior leaders information and data to make risk informed decisions.

Vulnerabilities found during black start exercises on military installation could also help inform or remediate potential risks to the commercial grid if a black start event occurs. For example, if the bulk power grid fails, it is anticipated that a black start event could have similar impacts to housing, hospitals, schools, large commercial entities with food stored, gas stations, traffic lights, water and waste-water pumping stations. Therefore, for a safe and effective black start exercise, mission-critical and supporting infrastructure must be considered, along with their interdependencies. Military installations consider these important interdependencies and tradeoffs when conducting black start exercises.

To ensure continuity of critical NDS missions and support black start exercises, the DoD pursues energy resilience to ensure the readiness of military installations. In 2016, the DoD published DoDI 4170.11 requiring annual full scale testing or black start exercises; in 2017, the DoD published implementing procedures for DoDI 4170.11 requirements in its operation, maintenance, testing, and exercising procedures; and, in 2020, the DoD published targeted black start exercise frameworks. Further, the DoD funded and executed black start exercises across five of its military installations. These exercises serve as real-world examples of how to implement black start exercise requirements. In each of the exercises, military installations disconnected from the commercial electric grid and transmission system. The black start exercises were conducted for multiple hours to assess the ability of military installations to start generation assets and continue critical military operations, understand vulnerabilities and remediate risks, and reconnect to the commercial electric grid once complete.

The DoD, like the electric industry, prepares for loss of power to the transmission system and attempts to recover power by black start capable generation assets. The key difference is that the DoD operates distributed energy assets that require low voltage distribution of power to sustain critical mission operations. The distribution of power for DoD occurs within its fence-line at the substation, feeder, or building level. It is critical to realize that the objective of the DoD, along with the electric industry, during a black start event is energy resilience.