PNNL-29118

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Electric Grid Blackstart: Trends, Challenges, and Opportunities

PNNL Technical Report
October 2020

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U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

Acknowledgements

DOE-CESER Program Manager

- John Ostrich

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Overview

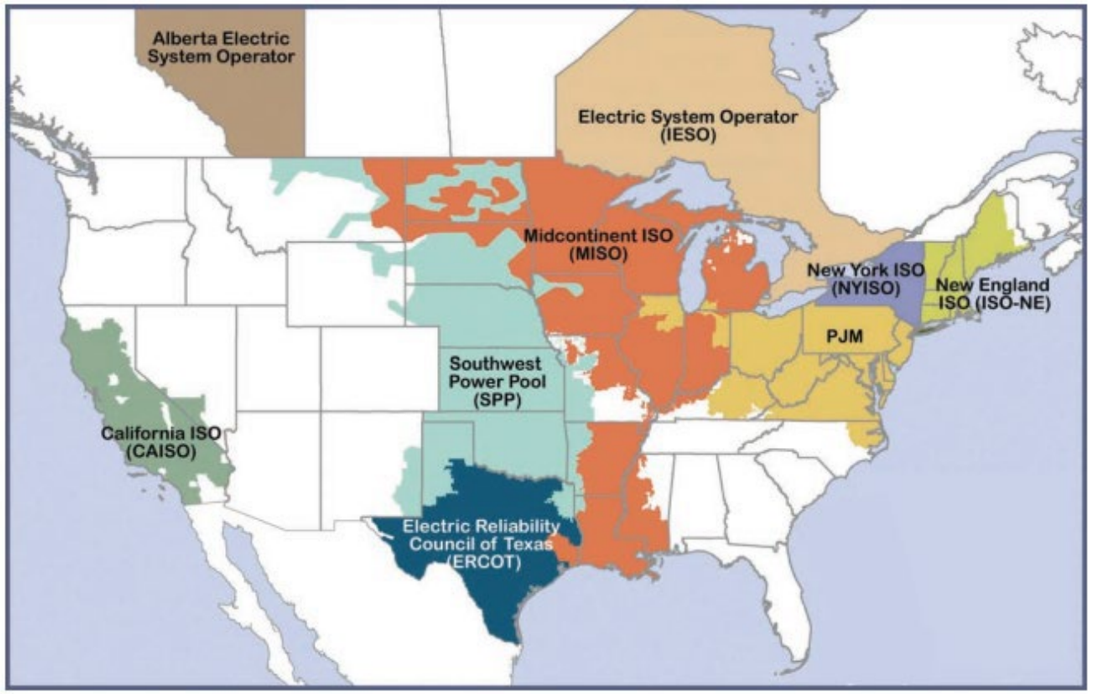
- The purpose of this technical report was to examine methods of system recovery from major outages
- If the blackout results in a complete power outage within the interconnection (which is extremely rare), a “blackstart” of the power system is required
  - Otherwise, the restoration process is greatly facilitated by connecting transmission to the un-outaged portions of the grid
- The blackstart process includes consideration of power generation that is able to start without access to offsite power
  - And includes transmission pathways between those sources of power and additional generation facilities
  - All while maintaining balance between generation and critical load
- Blackstart plans are carefully reviewed and regularly drilled
  - But need to be flexible based on real-time conditions and the nature of the damage
- This report provides a summary of the state-of-the-art and the potential shift in operational methodologies due to technological advances

Blackstart Practices and Considerations

- Blackstart resources requirements
- Suitability of various generation sources
  - Hydropower
  - Simple and combined cycle gas units
  - Coal
  - Diesel
  - Nuclear
  - Wind
  - Photovoltaic
  - Storage
- Transmission requirements
  - Cranking paths
  - Frequency and voltage control

Functional Entity Roles and Responsibilities

- NERC Standard EOP-005-3: System Restoration from Blackstart Resources
- NERC Standard EOP-006-3: System Restoration Coordination
- Reliability through markets (blackstart as a service)



RTO and ISO service areas in the United States and Canada

Blackstart Restoration Strategies and Approach

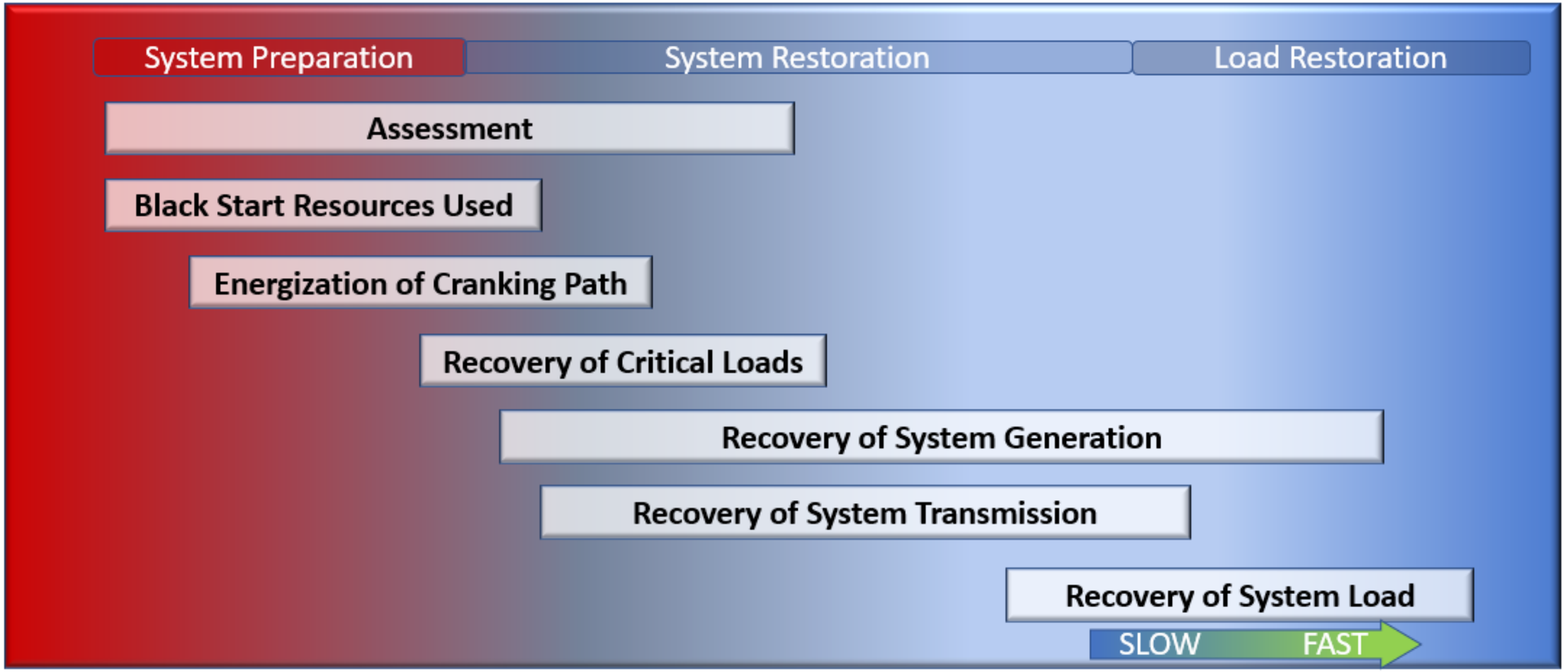
Restoration strategy:

- Analyze
- Stabilize
- Restore
- Return to normal operation

Restoration priorities:

- Energize transmission facilities (e.g., cranking paths)
- Provide offsite power to nuclear power plants
- Provide start-up power to generation stations that can aid in system restoration
- Restore loads that are critical for substations to support infrastructure
- Return system to normal operations
  - When the choice of the next load to be restored is not driven by the need to control frequency or voltage

Blackstart Restoration Phases



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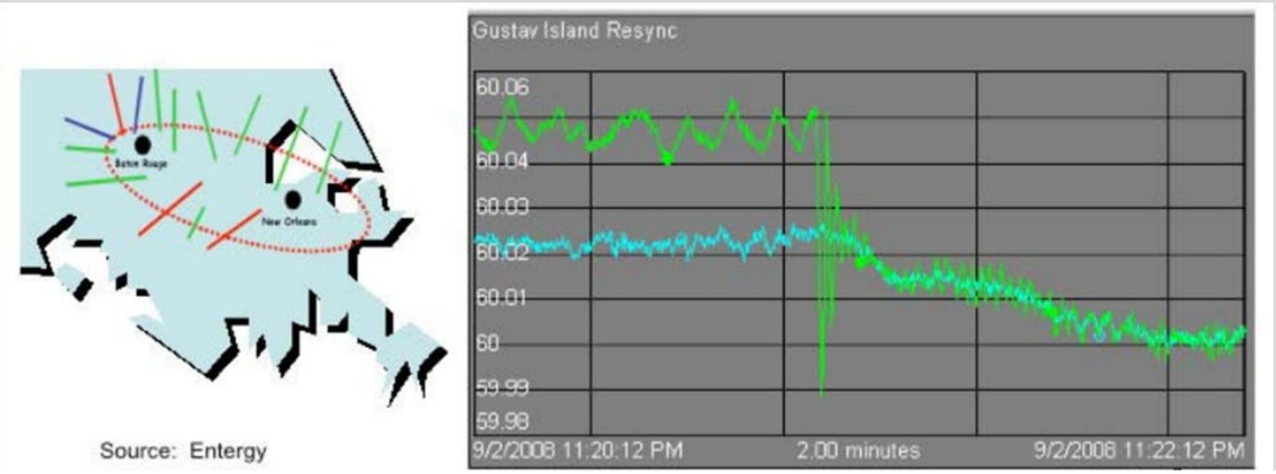
Opportunities and Challenges

- Changes in grid generation portfolio
  - Renewable generation currently provides ~20% of the total power demand in the US and is expected to dramatically increase in the next few decades
  - The variability of renewable generation requires associated power plants that can provide balancing reserves
    - ✓ The largest source of this is natural gas
  - Retirements of coal and nuclear power plants have little effect on blackstart capability, as these units are typically not blackstart capable
- Energy storage
  - With renewable generation, it is possible that the time of the day that the maximum power produced does not directly coincide with the largest power consumption
    - ✓ Storage can help bridge that gap
  - Energy storage, given the proper power electronics, has the potential to become a black-start resource

Opportunities and Challenges (cont.)

- Advanced monitoring and metering (synchrophasors)
  - Time-synchronized measurements are made possible with the introduction of synchrophasor technology
  - The analysis that can be performed may include:
    - ✓ Islanding detection – indicate when a portion of the grid may have become disconnected from the rest of the system
    - ✓ Analyze cause and resulting system conditions – if the events that led to the event are known, it gives a much clearer path for recovery
    - ✓ Assess post event system health



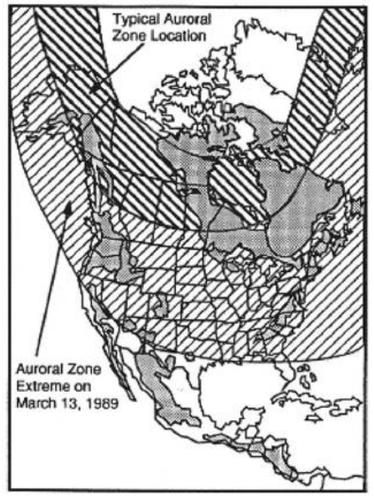
Entergy system islanding during Hurricane Gustav in Louisiana (2008)

Opportunities and Challenges (cont.)

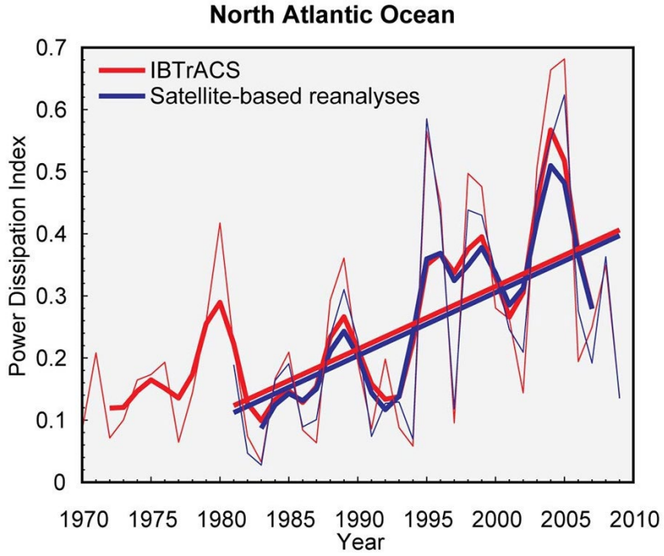
- Advanced distribution management systems (ADMS)
  - Allow for distributed resources to energize the local area, resulting in a kind of "microgrid"
  - Can recover the distribution system much faster in an intelligent way
- Transactive controls
  - Enabling a "market" for consumer resources for more active management of load and other distributed energy resources during the recovery phase
    - ✓ "Curtail" load during the recovery where certain loads in the home would not be recovered immediately (e.g. water heaters)
    - ✓ Enable electric cars to act as a battery storage device
    - ✓ Utilization of DER as "blackstart resources"

Emerging Threats

- Cybersecurity
  - As the lines of operational technology (OT) and information technology (IT) become crossed and blurred (especially at the distribution level), there is a cyber-exposure of previously isolated industrial control systems
- Climate Change
  - There has been a marked increase of both magnitude and occurrences of hurricanes in the north Atlantic ocean over the past 40 years
- Geomagnetic Disturbances (GMD)
  - And Electromagnetic Pulse (EMP) threats



GMD event on March 13, 1989 impacting the Quebec power grid



Observed trends in hurricane intensity

Unconventional Blackstart Methods

- Battery used for station service in order to start up a natural gas plant
  - Demonstrated in California
- The High voltage direct current (HVDC) voltage source converter (VSC)
  - Can provide real and reactive power separately
  - VSC is inherently configured for blackstart
    - ✓ This has been recently demonstrated in the Baltic States

Recommendations

- Increase Resiliency
  - Identify critical power system components to determine optimal locations where hardening of components could improve system reliability and blackstart
- Improve system modeling
  - Determine how system models can be improved to perform more extensive studies of blackstart capability and system restoration plans
- Perform more extensive studies
  - Perform additional studies to determine best approaches to system restoration given more complex scenarios (e.g., use of DER to increase system resiliency and aid in restoration)
- Coordinate emergency response with natural gas industry
  - Identify interdependencies that can impact blackstart capability, conduct joint studies, and establish processes to communicate information and coordinate during major events

Recommendations (cont.)

- Enhance training activities
  - Consider how electric industry training activities can be improved upon to provide a deeper knowledge of how power system operating characteristics are changing and how those changes may impact blackstart capability and system restoration
- Perform outreach
  - Consider establishing programs to work with other parties that own or operate generation, transmission or distribution facilities that could be involved with system restoration activities
- Capture and share industry best practices
  - Curating, enhancing, and disseminating best practices to key North American stakeholders

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Thank you