

Critical Infrastructure Protection and Recovery

A Common Recovery Model for Grid Systems in Blackout Scenarios

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■ ABSTRACT

Twenty five years' experience observing and developing disaster and crisis recovery plans within the electric utility industry provided the impetus and knowledge to develop a software-based single system strategic recovery algorithm for electric utilities utilizing systems engineering techniques. The threat of system failure resulting from solar flares (security management), electromagnetic pulse (EMP) (Savage, Gilbert, and Radasky 2010) or industrial control system (ICS) cyber interruption (Weiss) on the electrical utility system can cascade up from the distribution system and/or cascade down from the high voltage transmission system (Watson et al. 2015). Systemic electrical system failure, regardless of the type of catastrophic event, causes the same socio-economic disasters within the region of electrical failure. This paper will address the concept of single system recovery techniques utilizing existing recovery methodologies, titled the Common Recovery Model, as an approach to hedge against, and or recover from, the potential of cascading failure of the electrical transmission and distribution system. The premise for the need of a Common Recovery Model is that one or all three of the threats are imminent, thus the necessity of electric utilities to develop a Common Recovery Model prior to the actual outage event.

ELECTRIC UTILITY SYSTEM RELIABILITY AND RISK ASSESSMENT

Existing Regulations

Regulations in 2015 require electric utilities to report the quality of outage restoration through collection of yearly reliability indices. The data collected from each electrical outage during a calendar year reveals the speed at which an electric utility restores electricity to the rate payers by totaling the total minutes of outage per customer throughout the year. The reliability indices provide utilities with a measure to compare the reliability of each utility to one another within the same geographic region. The reliability indices encourage the use of automated devices to reduce the number of customers out of service faster than restoration through manual operations. The speed of restoration using automated devices prevents some of the electrical interruption from being classified as sustained outage, 5 minutes or greater by IEEE standard 1366-2012 (IEEE Std. 1366-2012), which aggregate into the total number of electrical outage for a given event. The sum of events in a given calendar year defines the metrics of reliability.

Autonomous intelligently controlled devices improve the speed at which an

electric utility can restore outage to affected customers to reduce time of outage to customers and improve reliability matrices. However, the automated devices can also be the proverbial "Achilles heel" to the electric utility due to the impact created by the three threats. Regulators recognize the potential for wide spread outage and are adding standards to compel electric utility operators to develop defense against the threats (University of Lincoln).

Federal Energy Regulatory Commission (FERC) 2016 approved the geomagnetic disturbances (GMD) reliability standard TPL-007-1 requiring grid operators to assess the vulnerability of their transmission system to GMD and prove their system meets certain performance requirements. The commission said: "While we recognize that scientific and operational research regarding GMD is ongoing, we believe that the potential threat to the Bulk Electric System warrants commission action at this time, including efforts to conduct critical GMD research (FERC 15)."

Sandia National Labs published a report for the US Department of Energy (DOE) defining how to make the energy sector and electric grid resilient (Watson et al. 2015). Indeed, defining methods to

make the grid more resilient to attacks causing blackouts is a necessary endeavor (EEI). Resilience models, electrical load shedding, and switching algorithms define methodologies to make the grid risk averse and/or minimize the significance of the outage. In addition, the IEEE (Arab, Khodael, Khator, and Han 2016) for post disaster grid recovery details and defines the economics of recovering from blackouts by computational methods.

WHAT METHODS OR TECHNOLOGIES SHOULD WE EMPLOY AS AN APPROACH TO RECOVER FROM SYSTEM-WIDE BLACKOUT?

All electric utilities employ the same technologies for operating and distributing electricity to consumers. Electrical transmission lines interconnect through electrical switching devices that operate via software based systems vulnerable to the three threats. The map below provides an overview of the US bulk transmission system.

Recovery from regional or widespread system failure requires the same manual and technological approach to isolated outages. Regional or widespread blackout will require a planned system engineering approach and methodology for manual

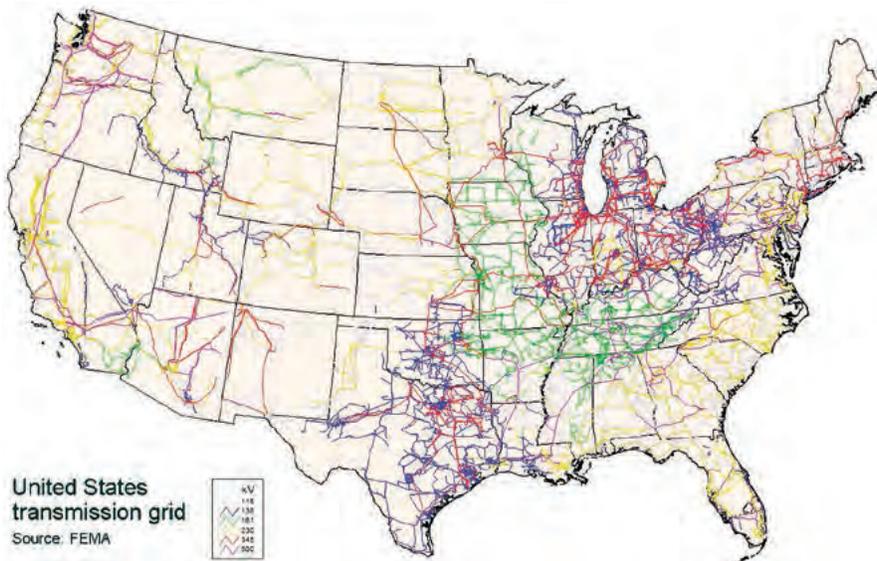


Figure 1. Map of United States of America Electricity Grid – National Energy Grids – Library Network Institute http://www.grid.org/globalenergy/library/national_energy_grid/united-states-of-america/americanationalelectricitygrid.html source: <https://commons.wikimedia.org/wiki/File:UnitedStatesPowerGrid.org>

restoration of the electrical system. Therefore, collecting strategies and data from existing electrical utility system recovery techniques will provide the information and opportunity to coalesce existing strategic approaches into a Common Recovery Model methodology.

The system above provides an overview of a basic electrical system. The depiction removes the complexity of the overall system to identify the primary elements within the distribution system that would be affected by the three threats. Publications from the National Academy of Sciences (Carlowicz and Lopez 2002) provide insight regarding the intensity of EMP and solar flares resulting in the impact and loss

of functionality of the various automated control devices. Blackouts from one of the three threats would create the inability for utility operators to control the distribution system causing loss of service to other areas of critical infrastructure.

The President of the United States issued an Executive Order – Coordinating Efforts to Prepare the Nation for Space Weather Events. The Executive Order Section 4 part (d) “The Secretary of Energy shall facilitate the protection and restoration of the reliability of the electric power grid during a presidentially declared grid security emergency associated with a geomagnetic disturbance pursuant to 16U.S.C 824o-1 (Ex.: 13744 issued October 13, 2016).”

COMMON RECOVERY MODEL

The application of systems engineering techniques to understand the event, develop strategies of threat detection and strategies for recovery, define the “critical path,” or Common Recovery Model utilizing existing or similar recovery techniques to reduce and or prevent catastrophic loss will delay or prevent socio-economic chaos. Engineers can use model-based systems engineering (MBSE) to define the following elements within an electric utilities system by priority of need for the public welfare.

Table 1. Basic table listing priorities to use in MBSE to develop a Common Recovery Model

Priority	Critical Infrastructure Cluster		
		Lat	Long
1	Substation		
2	Hospital		
3	Food Water		
4	Security		
5	Shelter		

Identify clusters of critical infrastructure (CI): electrical substations (1), hospital, (2) food and water (3), emergency and security (4), shelter (5). The assignment of priorities can vary and or increase based upon emergency operators and responders’ development of priorities. The list of CI can increase and change based upon the clusters of CI in an area relative to the population. Table 1 is a basic list to provide the concept and methodology using MBSE to define the Common Recovery Model for each utility.

Power System Overview

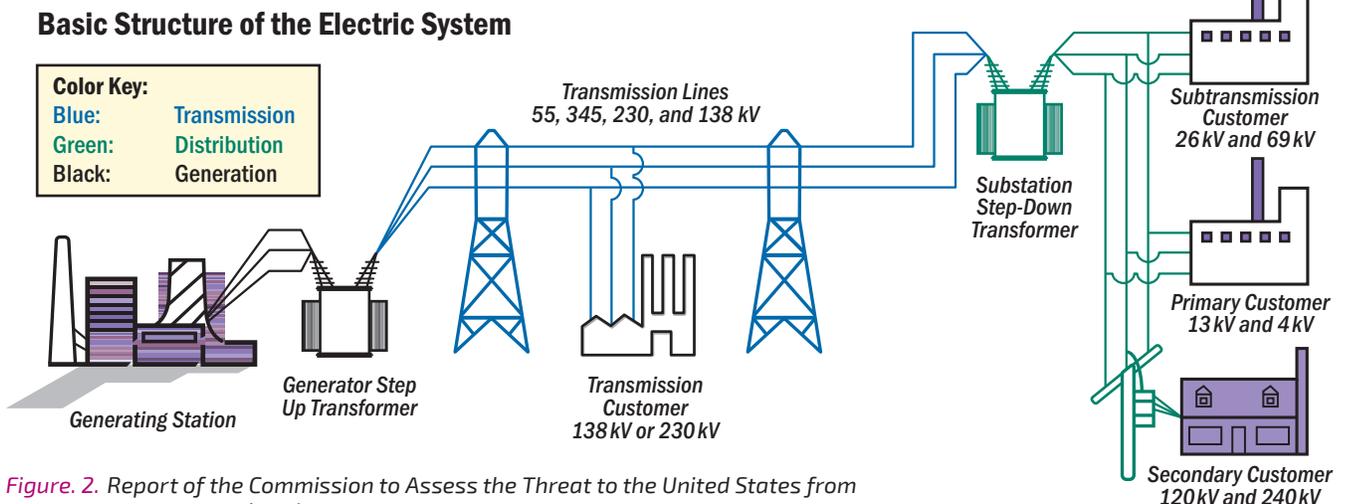


Figure 2. Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack

Utilizing the table above to develop a Common Recovery Model using MBSE techniques and architecture will provide a model to recovery from regional or wide-spread electrical outage.

Systems engineering tools will develop a Common Recovery Model to identify the critical path to electrical recovery based upon the priority given to each CI that is in proximity to the electrical system that can provide recovery to the largest number of critically grouped priorities. All electric utilities require the same systems engineering approach, hence the title Common Recovery Model, to recover, regardless of the number of CI served and the number of electrical facilities in the system. Electric utilities can develop Common Recovery Models utilizing tools, techniques, and architecture within various MBSE software products.

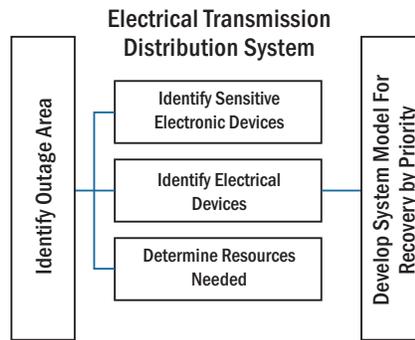


Figure 3. Basic Concept to develop a Common Recovery Model

CONCLUSION

Electric utility operators, industry experts, various government agencies, and

most recently President Obama have issued reports, publications, and executive orders providing recommendations and orders to defend or make the “grid” more resilient. The threat is imminent, thus we require a method to recover from regional or wide spread electrical outage.

All electric utilities have autonomous electrical systems to decrease the duration of electrical outage for consumers. The autonomous devices provide the fastest response to minor electrical outage, however, the devices are also more susceptible to one of the three threats. Therefore, all electric utilities can utilize a common method for recovery, the Common Recovery Model. ■

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