

Overcoming Fragmentation: Building US Grid Resiliency to Promote National Security

A Monograph

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2018

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.					
1. REPORT DATE (DD-MM-YYYY) 24-05-2018		2. REPORT TYPE Master's Thesis		3. DATES COVERED (From - To) JUN 2017 – MAY 2018	
4. TITLE AND SUBTITLE Overcoming Fragmentation: Building US Grid Resiliency to Promote National Security				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Mr. Steven D. Piccirillo, USA US Department of Agriculture				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) US Army Command and General Staff College ATTN: ATZL-SWD-GD Fort Leavenworth, KS 66027-2301				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Advanced Military Studies Program				10. SPONSOR/MONITOR'S ACRONYM(S) CGSC	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release; Distribution Unlimited					
13. SUPPLEMENTARY NOTES Critical Infrastructure Public Policy, Energy Policy, Electrical Infrastructure, Electromagnetic Pulse (EMP), Space Weather Events, Geomagnetic Disturbance (GMD), Homeland Security, National Defense, US Department of Agriculture Policy, Rural America					
14. ABSTRACT The US power system is a conglomeration of technology assets purposed to generate and transport electricity over great distance. This monograph discusses the human origin, design, and purpose of the US power system. A diverse population of private entities and government organizations owns these assets. Continued collaboration among US power system stakeholders and US government agencies promotes progressive regulatory standards. Collaboration is needed to facilitate the hardening of the US power system to mitigate risk if a high impact, low probability event were to occur (i.e. Electromagnetic Pulse). Policy changes, directed from Presidential Executive Orders and the legislation of Legislative Branch of the US government, are necessary to direct federal agency assets to secure the US power system.					
15. SUBJECT TERMS Army Armor, Large Scale Combat Operations, AirLand Battle, Full Spectrum Operations, Unified Land Operations					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT (U)	18. NUMBER OF PAGES 40	19a. NAME OF RESPONSIBLE PERSON Mr. Steven D. Piccirillo
a. REPORT (U)	b. ABSTRACT (U)	c. THIS PAGE (U)			19b. TELEPHONE NUMBER (include area code) 609.932.5531

Monograph Approval Page

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Monograph Title: Overcoming Fragmentation: Building US Grid Resiliency to Promote National Security

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Abstract

Overcoming Fragmentation: Building US Grid Resiliency to Promote National Security, by Mr. Steven D. Piccirillo, US Department of Agriculture, 40 pages.

The US power system is a conglomeration of technology assets purposed to generate and transport electricity over great distance. This monograph discusses the human origin, design, and purpose of the US power system. A diverse population of private entities and government organizations owns these assets. Continued collaboration among US power system stakeholders and US government agencies promotes progressive regulatory standards. Collaboration is needed to facilitate the hardening of the US power system to mitigate risk if a high impact, low probability event were to occur (i.e. Electromagnetic Pulse). Policy changes, directed from Presidential Executive Orders and the legislation of Legislative Branch of the US government, are necessary to direct federal agency assets to secure the US power system.

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Acknowledgements

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Acronyms

AC	Alternating Current
CBO	Congressional Budget Office
CFR	Code of Federal Regulations
CME	Coronal Mass Ejection
CPP	Clean Power Plan
DC	Direct Current
DHS	Department of Homeland Security
DOE	Department of Energy
EO	Executive Order
EIA	Energy Information Administration
EMP	Electromagnetic Pulse
EPA	Energy Policy Act
FPA	Federal Power Act
FERC	Federal Energy Regulatory Commission
GMD	Geomagnetic Disturbance
HEMP	High Attitude Electromagnetic Pulse
HSC	Homeland Security Council
HSPD	Homeland Security Policy Directive
IOU	Independently Owned Utility
NASA	National aeronautics and Space Administration
NERC	National Reliability Energy Corporation
NDS	National Defense Strategy
NOAA	National Oceanic and Atmospheric Administration
NSC	National Security Council
NSS	National Security Strategy

NSPM	National Security Presidential Memorandum
OMB	Office of Management and Budget
OPM	Office of Personnel Management
PUHCA	Public Utilities Holding Company Act
PURPA	Public Utilities Regulatory Policy Act
PDD	Presidential Decision Direction
PPD	Presidential Policy Directive
PPS	Power Protection System
RD	Rural Development
REA	Rural Electrification Act
RUS	Rural Utilities Service
SASC	Senate Armed Services Committee
SCHSGA	Senate Committee on Homeland Security and Governmental Affairs
SCADA	Supervisory Control and Data Acquisition
SLTT	State, Local, Tribal, and Territorial Entities
SSCI	Senate Select Committee on Intelligence
USC	United State Code
USDA	United States Department of Agriculture

Introduction

I have heard repeated warnings from every public official involved with intelligence and national security that an attack on our critical infrastructure is not [only] possible – it is likely. How many shots across our bow, how many warning shots do we have to endure? Sony, the [Office of Personnel Management], insurance companies, and now the nightmare scenario of an electric grid attack. I do not want to be here on a darkening winter afternoon and see the lights going off across America – the power to hospitals, the power to our transportation system, the power that makes our lives what [they are] today. This is not an abstract threat; we know from Ukraine that the capability exists to do exactly this and take down the grid. We must act expeditiously and directly to counteract that threat. If we do not do so, we are failing our responsibility to the people of America, to our constituents, and to the United States. So I urge rapid consideration of this bill.

—Senator Angus King, (Independent-Maine), addressing the US Senate 7 June 2016

This monograph presents four problems threatening the security of energy and electrical infrastructure, herein referred to as the US power system, within the United States of America.¹ A combination of human interests exist that influence an overarching national energy strategy, future and current public laws, energy infrastructure standards, and the funding of new energy critical infrastructure. First, the US population is unfamiliar with the technical aspects of the US power system. Second, new federal energy policy conflicts with existing federal agency policies. Third, current electrical infrastructure standards fail to mandate new and existing electrical infrastructure that is resilient to manmade attacks or Mother Nature. By exception, few portions of the US power system mitigate risks associated with a high impact, low probability incident. Forth, a federal funding mechanism is not universally available to all owners and operators of the US power system. Public law exists which tasks some federal agencies with approving federal

¹ This monograph references multiple author's research that describes the infrastructure components supplying electricity to the United States. Each of these authors described the energy infrastructure in a different terminology for purposes specific to the theme of their work. The terminology includes US power system, the US power grid, electrical infrastructure, critical energy and electrical infrastructure. These phrases may sound very similar but have vastly different definitions. The all-encompassing phrase which best encapsulates the electron from generation to the metered end consumer is US power system. The US power system, an all-encompassing phrase, comprises all of the power plants generating electricity, together with the transmission and distribution lines and systems, which bring power to end-use customers. The US power system also connects the many publicly and privately owned electric utility and other wholesale power companies in different states and regions of the United States.

loans for energy infrastructure. Unfortunately, those entities, which qualify for such attractive grants or debt service financing, can take advantage of such funding through policies contingent on metrics like population density or poverty level. These problems expose the US power system to a worst-case scenario event defined as a high impact, low probability incident. A high impact, low probability incident is a catch-all phrase describing a rare event, a man-made threat, or one occurring in nature, which could disrupt, disable, or render portions of the US power system functionally inoperable for an extended period.²

Why should the architects of US Government national energy strategy and the diverse assortment of power system stakeholders design a strategy mandating infrastructure resilience for a high impact, low probability event?³ The Carrington Event of 1859 is famous for qualifying as the most extreme space weather event recorded. The 28 August – 2 September 1859 space weather event produced record measurements in four characteristics of geomagnetic storming tracking: sudden ionospheric disturbance, solar wind, geomagnetic storm, and aurora.⁴ Now, what if the same high impact, low probability incident occurred in today's technologically dependent society reliant on the US power system?

² This monograph lists several types of high impact, low probability events. They include terms such as space weather event, solar flare, coronal mass ejection (CME), electromagnetic pulse (EMP), and geomagnetic disturbances (GMD).

³ “[Presidential Policy Directive 21] PPD21 [defines resilience as] the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions... Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents.” The White House: Office of the Press Secretary, Presidential Policy Directive 21, “Critical Infrastructure Security and Resilience,” *Presidential Policy Directive*, no. 21. (February 21, 2013): 6.; The White House, *Economic Benefits of Increasing Electric Grid Resilience to Weather Outages*, August 2013, Executive Office of the President (Washington, DC), 12. Resilience is not just about lessening the likelihood that power system outages will occur. It is also about limiting the scope and impact of outages when they do occur, restoring power rapidly afterwards, and learning from these experiences to better deal with events in the future. This includes hardening, advanced capabilities, and recovery/reconstitution. Although most attention is placed on best practices for hardening, resilience strategies must also consider options to improve grid flexibility and control. Resilience includes reconstitution and general readiness such as pole maintenance, vegetation management, use of mobile transformers and substations, and participation in mutual assistance groups.

⁴ Lloyd's of London and Atmospheric and Environment Research, *Solar Storm Risk to the North American Electric Grid* (London, UK: Lloyd's of London, 2013), 6, accessed January 15, 2017, <https://www.lloyds.com/~media/lloyds/reports/emerging-risk-reports/solar-storm-risk-to-the-north-american-electric-grid.pdf>.

In 2013, Lloyd's of London, a global insurance marketplace, and Atmospheric and Environmental Research Inc., a global environmental research firm, published a case studying illustrating the financial risks to the US power system if a space weather event comparable to the 1859 Carrington event were to occur today. The case study described several sobering facts by forecasting an outage scenario affecting the US Atlantic corridor. First, a Carrington-like event only impacts the United States every 150 years. Second, US citizens are more reliant on electrical infrastructure in 2018 and the risk of a catastrophic power outage constitutes a greater threat to homeland security. The US power system continues to expand in terms of physical assets and financial investment in its physical expansion. Third, proportionate to US population density, the highest risk to the US homeland is along the US Atlantic corridor between Washington, DC, and New York City. Research modeling accounted for risk factors, which included magnetic latitude, distance to the coast, ground conductivity, and transmission grid properties. Forth, the population of the aforementioned geographic region at risk for another Carrington-like event is between 20 and 40 million people; furthermore, the duration of outage time is approximated between sixteen days and one to two years.⁵ The total economic cost from a prolonged power outage based on the case study outage scenario assumptions would represent \$.6-2.6 billion dollars with the variance in value representative of the duration of the electrical infrastructure outage.⁶ The total economic costs accounted for energy providers who are unable to generate revenue, the costs associated with repairing disrupted electrical service, and the lost opportunities to stimulate economic growth due to energy consumers' inability to operate without electricity. A Carrington-like event similar to scale of the 1859 space weather event would significantly disrupt all aspects of

⁵ Lloyd's of London and Atmospheric and Environment Research, *Solar Storm Risk to the North American Electric Grid*, 4.

⁶ Ibid., 4, Appendix A. The US monetary value is in 2013 US dollar value. The authors of the case study calculated estimated economic costs of the outage scenario by calculating the percentage of residential, commercial, and industrial customers without power by state and using the average amount of electricity consumed by every segment in each state, per hour. The US Department of Energy (DOE) Energy Information Administration (EIA) provided the data for this study.

civilized US society, which is more dependent upon electrical infrastructure as compared to 159 years ago.

Lloyds and Atmospheric and Environmental Research, Inc. funded the case study to emphasize the significant risk exposure that the US electrical infrastructure imposes on the global insurance industry.⁷ The function of the insurance industry is to recognize risk and to provide a service to mitigate the exposure of those risks to their policyholders. Lloyd's rationalized that a US electrical grid collapse would prevent insurance providers from performing their core business functions, such as issuing claims to their customers. The global insurance's recognition that the potential disruption of electrical infrastructure represents a risk to the global insurance industry is commendable. The apparent inability of the US Government to understand the problem and take action is frightening. These problems, if unresolved, pose threats to national security, economic stability, safety of citizens, and reduce the extent of US global influence upon allies and adversaries.

This monograph does not intend to evaluate the problems associated with the US power system. Rather, it analyzes the human origins of these problems. The consequences of these problems expose US national security to unacceptable risks. While these problems are complex in singular form, they are interrelated, which adds another level of complexity to the calculation of aggregate risk. Hesitancy to invest in infrastructure to mitigate risk by the US government and the US power system stakeholders is due to several factors. It is the desire of US power system shareholders to maximize profits and minimize costs relative to their business model. Unfortunately, the pressure to maximize revenue and reduce operational costs conflicts with a national energy strategy that includes a resilient US power system. These profit-informed decisions impede the development of corrective actions necessary to mitigate risk associated with a high impact, low probability incident. In comparison, the profit-driven aversion to funding

⁷ Ibid., 15.

modern infrastructure resilient to malicious attack parallels with the problems of supplying electricity in rural America preceding New Deal Rural Electrification Administration (REA).⁸

Debating Risk

[This is] the challenge we have with the electric grid... [It is] designed for efficiency. The problem [with] efficiency is [that] it leads to fragility [because efficiency-modeled electric grid design uses redundant processes predictable for anyone wishing to disrupt its operation].

—The Honorable Newt Gingrich, *Former Speaker of the US House of Representatives*, speaking to the US Senate Committee on Energy and Natural Resources 4 May 2017

The morning of 4 May 2017 was a pristine spring day in Washington, DC, perfect for strolling on the National Mall rather than the stuffy confinement of room 366 of the Dirksen Senate Office Building. On this particular day, Dirksen 366 would play host to the United States Senate Committee on Energy and Natural Resources and a topic of serious national importance, a potential electromagnetic pulse (EMP) incident.⁹ This EMP threat is significant to the national security community and US power system stakeholders.¹⁰ The gravity of the topic commanded

⁸ “[Presidential Executive Order 7037, issued by President Franklin Delano Roosevelt on 11 May 1935, created the Rural Electrification Administration. On 20 May 1936, as directed by Executive Order 7037, Session 2 of the 74th US Congress enacted the Rural Electrification Act of 1936, as amended, authorizing and empowering the REA Administrator, known today as the US Department of Agriculture (USDA) Rural Utilities Service (RUS) Administrator,] to make loans in the several States and Territories of the United States for rural electrification and the furnishing of electric energy to persons in rural areas who are not receiving [electrification] service... [The REA Administrator is also authorized] to make, or cause to be made, studies, investigations; and reports concerning the condition and progress of the electrification of rural areas in the several States and Territories; and to publish and disseminate information with respect thereto.” Franklin Delano Roosevelt, Executive Order 7037, “Establishing the Rural Electrification Administration,” Public Resolution no. 11 (May 11, 1935):1-2; Rural Electrification Act of 1936, Public Law 74-605, 74th Congress, 2d sess. (May 20, 1936): 1363.

⁹ “*Jurisdiction*,” Senate Energy and Natural Resource Committee, accessed December 1, 2017, <https://www.energy.senate.gov/public/index.cfm/jurisdiction>. The jurisdiction of the Full Senate Energy and Natural Resource Committee includes oversight and legislative responsibilities for national energy policy. National energy policy encompasses international energy affairs and emergency preparedness; nuclear waste policy; privatization of federal assets; territorial policy including changes in status and issues affecting Antarctica; Native Hawaiian matters; and ad hoc issues. The full committee consists of four subcommittees. They are the Subcommittee on Energy; Subcommittee on National Parks; Subcommittee on Public Lands, Forests, and Mining; and the Subcommittee on Water and Power.

¹⁰ US Library of Congress, *Congressional Research Service Report on High Altitude Electromagnetic Pulse (HEMP) and High Power Microwave (HPM) Devices: Threat Assessments*

the duration of the hearing. A standing room only audience, consisting of the media, academics, civil servants, Congressional staffers, uniformed representatives of the military, and curious private US citizens, had massed inside Dirksen 366 to witness the hearing. This audience, anticipating several hours of lively discussion about EMP doomsday scenarios, would hear testimony from an extraordinary list of witnesses.¹¹

The committee chairperson, Senator Lisa Murkowski (Republican-Alaska), set the tone of the hearing by openly welcoming the discussion of an EMP threat during her opening statement. In her remarks, the senate committee intended to formulate policy options to protect, or harden, nonmilitary energy infrastructure and provide for system restoration in the event of an EMP attack. During her opening statement, Senator Murkowski also mentioned three reasons to develop policy to reduce the threat of an EMP attack upon US energy infrastructure.¹² First, US policymakers must be mindful of the threat posed by nations such as North Korea and non-state actors. Available information from the intelligence community suggested that these nations might possess or be close to possessing capabilities to use a missile as a delivery vehicle for a high-altitude EMP attack (HEMP).¹³ Second, the nation is more reliant on electricity for

(Washington, DC: Government Printing Office, 2008), Summary, 5. An EMP is a weapon and threat to national security. Is an instantaneous, intense energy field that can overload or disrupt at a distance. Electrical systems and high technology microcircuits, sensitive to power surges, are potential targets of an EMP attack. An EMP creates pulse by two methods. The first method, referred to as high-altitude EMP (HEMP), produces a large-scale EMP effect generated by a single nuclear explosion detonated high in the atmosphere. The second method produces a smaller-scale EMP effect and is generated using non-nuclear devices with powerful batteries or reactive chemicals. This method is a High Power Microwave (HPM).

¹¹ US Senate, *Hearing*. The witness list tasked with providing EMP testimony to the Senate Energy and Natural Resource Committee was exemplary and included Henry F. Cooper, PhD., former US ambassador; the Honorable Newt Gingrich, former Speaker of the US House of Representatives; the Honorable Cheryl LaFleur, the Chairman of the Federal Energy Regulatory Commission (FERC); Ms. Caitlin Durkovich, the former Assistant Secretary of Department of Homeland Security (DHS) for Infrastructure Protection within the National Programs and Protection Directorate; Mr. Robin Manning, vice-president of transmission related research and development for Electric Power Research Institute; and Kevin Wailes, Chief Executive Officer for Lincoln Electric System of Nebraska.

¹² Ibid.

¹³ “[A high altitude Electromagnetic pulse (HEMP)] is produced when a nuclear weapon is detonated high above the Earth’s surface, creating gamma-radiation that interacts with the atmosphere to create an intense electromagnetic energy field that is harmless to people as it radiates outward, but which

communication, transportation, and commerce than at any other time its history. The need to protect the grid outweighs the costs required to harden the grid. In short, the effects of an EMP terrorist incident or a coronal mass ejection (CME) space weather event are indiscriminate to a vulnerable electric grid.¹⁴ Third, owners and operators of energy infrastructure and their regulators must assist government EMP experts in understanding how the electric grid functions in order to develop strategies to prevent failure or degradation of the national power grid.¹⁵ Murkowski emphasized that the electric industry and government must improve upon their collaboration to bolster the nation's ability to respond to EMP and other potential high impact but low probability events.¹⁶ She concluded her opening remarks by publicly questioning if appropriate federal agencies have the authority and resources to counter the above-mentioned threats.¹⁷

can overload computer circuitry with effects similar to, but causing damage much more swiftly than a lightning strike [...] ... A nuclear explosion produces gamma rays, which interact with air molecules in a process called the Compton Effect. Electrons are scattered at high energies, which ionizes the atmosphere, generating a powerful electrical field. This EMP effect is strongest at altitudes above 30,000m, and lasts so briefly that current cannot start flowing through a human body to cause harm to people." US Library of Congress, *Congressional Research Service Report on High Altitude Electromagnetic Pulse (HEMP) and High Power Microwave (HPM) Devices: Threat Assessments* (2008), 5.

¹⁴ "[A coronal mass ejection (CME) occurs when] an eruption within the sun creates an immense cloud of magnetized particles hurled into space which travel over a million miles per hour in state of plasma. The plasma takes up to three days to reach Earth... A CME can jostle Earth's magnetic fields creating currents that drive particles down toward Earth's poles. When these [magnetized particles] react with oxygen and nitrogen, they help create the aurora, also known as the Northern and Southern Lights... [These] magnetic changes can affect a variety of human technologies. High frequency radio waves can be degraded [...] ... [R]adios transmit static and GPS coordinates [can] stray by a few yards... [M]agnetic oscillations can also create electrical currents in utility grids on Earth that can overload electrical systems when power companies are not prepared." "The Difference between Flares and CMEs," NASA, last modified August 7, 2017, accessed March 22, 2018, <https://www.nasa.gov/content/goddard/the-difference-between-flares-and-cmes>.

¹⁵ "[The US national power grid or transmission system] is the interconnected group of power lines and associated equipment for moving electric energy at high voltage between points of supply and points at which it is delivered to other electric systems or transformed to a lower voltage for delivery to customers." "*Electricity 101*," US Department of Energy, accessed March 22, 2018, <https://www.energy.gov/oe/information-center/educational-resources/electricity-101#sys3>.

¹⁶ US Senate, *Hearing*.

¹⁷ Ibid.

The Senate Energy and Natural Resource Committee hearing on 4 May 2017 had a number of significance outcomes. First, the hearing was open to the public. Senate committee hearings pertaining to national security topics rarely are open to the citizens. The discussion of EMP and other national security threats to the US power system usually occur in a closed-door setting where transcripts would not be available to the public due to sensitive nature of the subject matter. Second, several of the Senate audience members came from the Senate Armed Services Committee, the Senate Homeland Security and Governmental Affairs Committee, and the Select Committee on Intelligence. Third, the statements and nature of questions posed by the committee's members offered vital information relevant to the national strategy for US electrical infrastructure.¹⁸

Each of the five distinguished witnesses provided expert testimony summarizing specific cyber, physical, and EMP threats to and weaknesses of the US electrical grid. Two witness testimonies stood out because of their dissimilar perspectives. Former Speaker Newt Gingrich's testimony was focused on cultivating a relationship between the federal regulatory agencies and the stakeholders that own and operate the US power system. He argued that the best way to eliminate the threat was for the energy stakeholders and the federal government to work together to establish a national energy strategy to harden the country's energy infrastructure to eliminate risk of power system failure. The requirement for a critical infrastructure public-private partnership model had been in existence at the federal level for some time. Presidential Policy Directive 21 (PPD21), issued on 12 February 2013 by the Obama Administration, mandated such a public-private partnership to identify risks to all sixteen sectors of critical infrastructure. The Department of Homeland Security (DHS) executes policies meant to protect the country's critical

¹⁸ "Members," Senate Energy and Natural Resource Committee, accessed December 1, 2017, <https://www.energy.senate.gov/public/index.cfm/members>. Senators Jim Risch (R-Idaho) and Angus King (I-Maine) were members of the Senate Select Committee on Intelligence (SSCI). Senators Mike Lee (R-Utah), Mazie Hirono (D-Hawaii), and Angus King (I-Maine) were members of the Senate Armed Services Committee (SASC). Senators Steve Daines (R-Montana) and Rob Portman (R-Ohio) were members of the Senate Committee on Homeland Security and Governmental Affairs (SCHSGA).

infrastructure.¹⁹ The Department of Defense (DOD), DHS, and DOE have their fingers on the pulse of national security threats. From the Clinton Administration to the present, it is required the the Secretaries of Defense, Energy, and Homeland security share critical infrastructure risk assessments with the National Security Council (NSC) and Homeland Security Council (HSC) to direct efforts to mitigate threats to our nation’s critical infrastructure .²⁰ Conversely, the owners and operators recognize that a profit-driven mentality often curbs investment in new infrastructure. The intent of the public-private partnership was to develop a unified national energy strategy, lobby Congress for legislative change in the form of public law, and develop a uniform standard to protect the US power system.

Would it be possible or legal for stakeholders to communicate for the purpose of national security to develop a uniform strategy to protect the US power system? Multiple energy owners and operators discussing the interworking of their electric utility businesses could be perceived as being in violation of antitrust law if the shared dialogue were to constitute some dramatic, across-the-board shift in charging the consumer.²¹ Utility owners who do invest in hardening of their

¹⁹ “[Presidential Policy Directive 21] PPD21 [explicitly states the] federal government shall work with critical infrastructure owners and operators and state, local, tribal, and territorial (SLTT) entities to take proactive steps to manage risk and strengthen the security and resilience of the Nation’s critical infrastructure, considering all hazards that could have a debilitating impact on national security, economic stability, public health and safety, or any combination thereof. [The sixteen critical infrastructure sectors vital to national security were] identified in Homeland Security Policy Directive 7 (HSPD7), issued on 17 December 2003. [HSPD7 was later superseded by PPD21.]” The White House: Office of the Press Secretary, Presidential Policy Directive 21, “Critical Infrastructure Security and Resilience,” *Presidential Policy Directive*, no.21. (February 21, 2013): 3.

²⁰ “[National Security Presidential Memorandum-4 (NSPM-4) was issued on 4 April 2017 to reorganize the structure of the National Security Council, the Homeland Security Council, and affiliated subcommittees. NSPM-4 is the system for] national security policy development and decision-making. It requires the National Security Council and Homeland Security Council to advise the President on matters pertaining to homeland security. Each Council is also responsible for the effective coordination of the security-related activities and functions of the executive departments and agencies.” Donald J. Trump, National Security Presidential Memorandum 4. “Organization of the National Security Council, The Homeland Security Council, and Subcommittees,” *Federal Register* 82, no. 65 (April 6, 2017): 16881-85.

²¹ “[The Robinson–Patman Act of 1936 (or Anti-Price Discrimination Act) is a United States federal law that prohibits anticompetitive practices by producers, specifically price discrimination. The law states it] shall be unlawful for any person engaged in commerce, in the course of such commerce, either directly or indirectly, to discriminate in price between different purchasers of commodities of like grade and quality, where either or any of the purchases involved in such discrimination are in commerce, where

power system assets have to be cognizant of trickle down expenditures. New investment is often passed directly to energy customers in the form of taxes for government owned utilities or rate increases. Electrical utilities are a regulated entity required to report their rates of service charged to regulators.²² Executive Branch policy procedures, like PPD21, pose concern because they may conflict with antitrust law and price regulation policy meant to curtail electric utility owners from engaging in energy price fixing. The Obama Administration issued PPD21 to mandate a public-private partnership policy, but the policy may conflict with public law. Conflicting policies are an example of the problem that thwarts efforts to harden the US Power system.

In contrast to Speaker Gingrich's testimony, Ambassador Cooper harshly criticized the Obama Administration's intelligence community assessment of the nuclear EMP threat as grossly erroneous.²³ He insisted that a military model was best suited to mitigate EMP threats to the US power system. Cooper emphasized that Russia, China, North Korea, and Iran had developed nuclear EMP doctrine for combined arms cyber warfare.²⁴ He elaborated that an EMP attack against the United States would be a preemptive combination of cyber, physical, and radiofrequency attacks to sow disorder and confusion.²⁵ Cooper prescribed a military-minded

such commodities are sold for use, consumption, or resale within the United States or any Territory thereof or the District of Columbia or any insular possession or other place under the jurisdiction of the United States, and where the effect of such discrimination may be substantially to lessen competition or tend to create a monopoly in any line of commerce.]” The Robinson–Patman Act of 1936, Public Law No. 74-692, *US Statutes at large* 49 (1936): 1526, Codified at *US Code* 15 (1936), § 13.

²² “Bulk power entities cost-justification requires not only the approval of utility management, but also of FERC and potentially state public utility commissions which regulate the rates grid owners may charge for electric transmission and distribution service. Regulators are responsible for ensuring that electricity rates are just and reasonable. They must be convinced that any new grid security capital costs and expenses are necessary and prudent before they will allow them to be passed through to ratepayers.” US Library of Congress, *Congressional Research Service Report on Electricity: The Road toward Restructuring* (Washington, DC: Government Printing Office, 2004), Summary.

²³ US Senate, *Hearing*.

²⁴ *Ibid*.

²⁵ *Ibid*.

approach to protect the United States in the event of a manmade attack or space weather event.²⁶ He urged state and regional electrical associations to employ an “islanded” approach in the event of a prolonged blackout, which involved isolating electrical infrastructure and hardening components necessary to generate, transmit, and distribute electricity to consumers. These islanded systems, not physically linked to the US power system, become operational when prolonged power system failure occurs.²⁷ Ambassador Cooper further emphasized the importance of nuclear power generation facility resilience, which would require water-cooling stations to remain operational during a prolonged blackout to prevent a domestic Fukushima-like disaster. Segregated or “islanded” generating and transmission assets would be hardened through faraday cages, surge arrestors, and blocking devices. These islanded assets would restart the nuclear power plants in the event of a cascading power system failure.²⁸

The “islanded” approach does not serve as a perfect solution for mitigating the risk to the US power system. It may serve as an approach for the nonnuclear assets connected to the US power system because the threats of radiation from a nuclear meltdown are a problem of greater complexity. Several different business models represent owners and operators of the US power system, making it difficult for every power system to invest in this model. Few power system owners have made the decision to apply islanded system design because they lack capital to invest, lack approval for such investment, and customer service criteria prevent such a decision.

Many US power system stakeholders lack capital investment for such islanding. Electric cooperatives management structure promotes community ownership and localized investment. It is a standard business practice for a pool of cooperative, consumer-owned distribution utilities to

²⁶ Ibid.

²⁷ Ibid. Islanding is the approach adopted by the Department of Defense during the Cold War to give top priority to protecting strategic systems and their supporting command and control, and communications systems. This DOD tactic was a component of Cold War deterrent policies. Ambassador Cooper elaborated only minimal military infrastructure and essentially no critical civil infrastructure beyond assuring that we could meet Cold War deterrent policy objectives was hardened during the Cold War.

²⁸ Ibid.

invest in a generation facility providing electricity to their consumers. A cooperative business structure keeps the costs of operations and overhead low, much like the business model of an IOU, but not for the same reasons. Cooperatives, for instance, are not structured to maximize profits like an IOU. An IOU retains profits to build equity, invests in new assets, and pays dividends on investor owned stocks. The cooperative model, found throughout rural America, returns excess revenues generated during the fiscal year to its cooperative members after taking into consideration operations and overhead costs.²⁹

The segmented power system comprising of generation, transmission, and distribution assets would need to have a physical connection to a separate power generation source. This separate source of energy generation requires separate hardening for resilience against a high impact, low probability incident. It is the exception, not the standard, for electrical cooperatives to form a partnership to purchase several generation facilities, with some utilized for islanding. Without exception, an investment in an islanded power system represents a significant barrier for US power system stakeholders of limited financial means. This is only one of many funding problems mentioned in the introduction. Simple economics often trumps national security concerns.

Ambassador Cooper's military-inspired island approach has the potential to mitigate risk and provide resiliency for a segment of qualifying US power system stakeholders that possess financial means to execute such an endeavor. A universal approach to harden every component of the US power system by the same means is unrealistic. The US power system exists in a kaleidoscopic environment of multiple owners that serve different end users. The components of the US power system interconnected by physical design t have as its overarching goal the sale of electricity. As stated above, few utilities possess islanded assets. Electrical utilities operating an islanded system would have delayed electrical services resurrection because a black startup relies

²⁹ Marquis W. Childs, *Yesterday Today and Tomorrow: The Farmer Takes Hand* (Washington, DC: National Rural Electric Cooperative Association, 1980), 27-29.

on small-capacity reserve generation assets, not electricity moved via transmission lines, to supply electricity to initiate startup of generation assets.³⁰ Furthermore, the hardening of the US power systems will not occur immediately, but over time. Ambassador Cooper's testimony emphasized that is several high profile assets connected to the US power system. These assets, like nuclear power plants, must have consistent access to electricity to operate water-cooling systems to prevent a meltdown. In addition to nuclear generation assets, hardening must be performed on specific power systems assets that provide electricity to significant portions of the US population, government installations, and the global financial centers located across the United States. The corridor between Washington, DC, and New York City includes a significant population of US citizens, critical federal government resources, and a disproportionate number global business centers.³¹ Disruption or destruction of the US power system assets that service electricity to the northeast corridor would cause irreparable harm to human life, disable significant electric dependent resources necessary to run the federal government, and have negative repercussions for the global economy.

There were several takeaways from the 4 May 2017 hearing. First, US power system design promotes efficiency over resilience and reliability. The combinations of threats and the efficiency approach to grid design have exposed the power system to several vulnerabilities. These vulnerabilities, such as a national security risk because efficiency design standards, executed through redundant operation procedures, are easily observable by anyone willing to disrupt the power grid.³² Second, policymakers and power system stakeholders have not

³⁰ New York Independent System Operator, ed., *NYISO Accounting and Billing Manual* (Rensselaer: NYISO Customer Settlements, 2016), 88-92.

³¹ Lloyd's of London and Atmospheric and Environment Research, *Solar Storm Risk to the North American Electric Grid*, 8, 15.

³² "Reliability Standards impose requirements on the users, owners and operators of the bulk power system to assure that they fulfill their responsibilities in reliable grid operations, consistent with the basic engineering functions and concepts discussed in the primer.... Congress gave FERC authority to certify a non-governmental entity, referred to as the electric reliability organization, to develop and enforce mandatory 'Reliability Standards.'... Congress gave FERC authority to certify a non-governmental entity, referred to as the electric reliability organization, to develop and enforce mandatory 'Reliability

developed a unified approach to mitigate a coordinated EMP event on specific nodal points. The current power system design allows for a cascading US power grid failure if an EMP incident or a space weather event struck the United States. The power system complexity and diversity require greater cooperation between public and private stakeholders. In short, the US Government cannot reduce the risks associated with a catastrophic high impact, low probability event without its corporate and private partners. Third, the allocation of government funds to spur stakeholders to invest in building robustness into the US power system is desperately needed. The witnesses agreed that most stakeholders lacked the means to fund system design standards to harden the US power system. The catalyst for change and investment must come from the executive branch, developing a policy with both a carrot and a stick.

Pushing Narratives and Defining Strategy

I consider that we are living in the most dangerous period of my lifetime for a number of reasons, but the vulnerability of our national electric power grid is among the most important ones. Moreover, I believe we have had clear warning of the nature of this [EMP] threat for years, and are collectively continuing to ignore and/or take ineffective countermeasures to deal with it. Frankly, I have become so concerned about the dysfunctionality of the federal government in dealing with the threat that I am now spending whatever remaining time the Good Lord gives me to work with local and state authorities and private citizens to address the key issues from the bottom up... and I will address one of these important initiatives. If enough of our citizens gain an understanding of the issues and how they [can] be addressed at the local level, then I believe Washington will eventually do its part in addressing this urgent problem.

—Ambassador Henry Cooper providing testimony to the US Senate Committee on Environment and Natural Resources 4 May 2017

Throughout the Senate committee hearing on 4 May 2017, the witnesses spoke of power system *design*. The witnesses scrutinized the US power system design for being the root cause of

Standards.’... In April 2006, NERC filed an application with FERC for certification as the electric reliability organization. NERC also submitted 107 Reliability Standards to FERC for approval. The 107 proposed Reliability Standards were largely the existing voluntary protocols and guidelines repackaged to be the mandatory and enforceable Reliability Standards under the new statute.” US Department of Energy, Federal Energy Regulatory Commission, *Reliability Primer* (Washington, DC: Government Printing Office, 2016), 5-6, 34.

its antifragility.³³ During the dialogue between the committee members and the witnesses, it was difficult to discern who spearheaded power system design. All committee members and witnesses agreed that the ideal power system strategy should focus on resilience and reliability.³⁴ Where did the strategy to design a power system originate? The stakeholders, the branches of federal government, interstate commerce, and national security strategies all influenced power system design. The predictive design of the US power system provides a redundant service with limited faults or system failure to paying customers at all times. However, who had originating powers to prioritize a centralized effort to orchestrate changes in the aggregate US power system?

Progressive power system design strategy originates from a political narrative. Unfortunately, power system design strategy is lost in the process of formulating critical infrastructure policies. Electrical infrastructure threats are not the political narratives delivered to the US population. Critical infrastructure narratives emphasize concerns of aged infrastructure without delving into energy specific problems. Corrective action promotes replacing old with new through funding by both private and public investment. All policy, by design, prioritizes the actions and resources of the US government. The Executive Branch communicates new policy through instruments like executive orders. Executive instruments share the Executive Branch's priorities to all levels of government wherever a relationship exists in terms of government function and applicable resources. These instruments communicate Presidential authority to federal agencies and direct how an agency utilizes its resources.³⁵ The President initiates these

³³ Nassim Nicholas Taleb, *Antifragile: Things that Gain from Disorder* (New York: Random House, 2014), 14-16.

³⁴ US Senate, *Hearing*.

³⁵ "The definitions of these instruments, including the differences between them, are not easily discernible, as the U.S. Constitution does not contain any provision referring to these terms or the manner in which the President may communicate directives to the executive branch. Executive orders and proclamations are directives or actions by the President... [T]hey are founded on the authority of the President derived from the Constitution or statute... [T]hey may have the force and effect of law.... Executive orders and proclamations are written documents denominated as such.... Executive orders generally direct and govern actions [of] government officials and agencies. They usually affect private individuals only indirectly. Proclamations in most instances affect primarily the activities of private

priorities, often introduced during the State of the Union Address and subsequently incorporated into the budget as required by the US Constitution.³⁶ The Presidential State of the Union Address, an executive duty of the President, elevates certain legislature priorities. In short, the President tailors his recommendations to Congress, speaking to Congress on behalf of the people, to identify specific legislative actions for Congress to undertake during the fiscal year. The language of executive orders and the State of the Union also shape domestic and foreign policy. The political narrative is then filtered into the National Security Strategy (NSS), National Defense Strategy (NDS), and interrelated agency strategies. Additionally, the Executive Branch Executive Office of the President, Office of Management and Budget (OMB), releases a preliminary budget to Congress giving further guidance to the legislative branch. The preliminary budget expresses the President's budgetary priorities. Congress then votes on the final budget. In short, Congress can legislate, the President can sign or veto, but neither the Executive nor Legislative Branch can violate the constitution with the Supreme Court of the US being the arbiter of such opinions.

On 4 May 2017, it was evident from expert witness testimony that Congress had not prioritized the EMP threat in an urgent fashion. A way to mitigate risk from a high impact, low probability incident does not exist. Competing national strategies spoke of the importance of hardening the grid in the name of national security, yet the means to accomplish this goal across fragmented stakeholders did not exist. The end state of a hardened grid, underwritten by the federal agencies and public law, does not presently exist. Strategic ends must incorporate ways to

individuals. Since the President has no power or authority over individual citizens and their rights except where he is granted such power and authority by a provision in the Constitution or by statute, the President's proclamations are not legally binding and are at best hortatory unless based on such grants of authority." US Library of Congress, *Congressional Research Service Report: Executive Orders: Issuance, Modification, and Revocation* (Washington, DC: Government Printing Office, 2014), 1.

³⁶ "[The Recommendation Clause of US Constitutions states the President]... shall from time to time give to the Congress Information of the State of the Union, and recommend to their Consideration such Measures as he shall judge necessary and expedient; he may, on extraordinary Occasions, convene both Houses, or either of them, and in Case of Disagreement between them, with Respect to the Time of Adjournment, he may adjourn them to such Time as he shall think proper; he shall receive Ambassadors and other public Ministers; he shall take Care that the Laws be faithfully executed, and shall Commission all the Officers of the United States." US Constitution, art 2. sec. 3.

harden, anticipates threats, and mitigate risk to meet the end state. The US power system has vulnerabilities, which exist in its current design, and policy makers should understand the power system's operational environment when writing and implementing policy.

Current infrastructure narratives communicate the absence of overall understanding, the lack of specific details about risk, and describe critical infrastructure in aggregate without isolating the US power system component. Former Speaker Gingrich contended that the optimal way to move forward with identifying the threats to the US power system was to focus backwards from consequences.³⁷ Life without electricity, due to a terrorist attack or from a space-weather event, would be catastrophic and evoke a range of emotional responses. Identifying consequences may be the only means to stimulate change in order to educate the masses on the true state of US power system vulnerabilities. The worst-case consequences are plausible when looking at the current problems in the US power system that was identified in the introduction.

First, the critical infrastructure narratives that describe US critical infrastructure as aged and in need of replacement are vague. One could use the same argument when articulating a desire to replace a pair of running shoes with a new pair because the soles are worn-out. For both infrastructure and the pair of shoes, there is a desire to replace the aged items with a modern equivalent, with the expectation that the replacement item cost the same amount of money. Replacing infrastructure because the power system is aged does not defend it against vulnerabilities such as cyber threats or EMPs. If citizens identify threats communicated through the narrative, they will likely demand solutions to US power system vulnerabilities. To replace an asset because it is aged, however, fails to identify existing risks and weakness in the structural design. The critical infrastructure narrative promoted by the Obama Administration was not effective because it did not emphasize the consequences of having electricity removed from citizen's lives.

³⁷ US Senate, *Hearing*.

Second, Congress did not prioritize the threat to the US power system in an urgent fashion. Speaker Gingrich and Ambassador Cooper criticized Congress for overlooking the urgent threats to the national electric grid. Speaker Gingrich soberly ended his testimony by highlighting the need to act quickly. A lack of action could trigger an end of civilization scenario.³⁸ Witness testimony to Congress clamoring for legislative action to mitigate risks and vulnerabilities to the power system accomplishes little without guidance, prioritization, and a campaign of education. Prioritizing action to bolster the power system must originate from the executive branch. The President's narrative and preliminary budget directs Congress to focus its attention on a mechanism to protect the power system and a means of funding for hardening its components. The scale and scope of the legislation and accompanied budget enacted by Congress also originates from the guidance of the executive branch.

Third, the elected members of Congress are responsible for enacting a wide scope of legislation. It is a reasonable assumption that a select few members of Congress possess more than a casual knowledge of the operational design of the US power system. The legislation development process may fail because elected officials who lack expert knowledge of electrical infrastructure do not conceptualize the overall risk. Members of the US Senate Energy and Natural Resource Committee are not required to be educated electrical engineers, published scientists, or national defense or homeland security experts. It would be ideal for the nation's elected representatives to have education and operational knowledge for the legislation they pass but it is unrealistic to hold elective officials to such a standard. Nor should they be scrutinized for lacking subject matter expertise for all the legislation they author.

The Senate Energy and Natural Resource Committee consisted of twelve Republicans, nine Democrats, and two independents who caucused with the Democratic Party. The twenty-three members included ten attorneys, two medical doctors, two former state governors, a retired

³⁸ Ibid.

US Army National Guard lieutenant colonel, a former Director of the US Office of Management and Budget, a former US Secretary of Education, a former bank president, a former Presidential Democratic Primary candidate, and a former film and television comedian. Only one Senate Committee member had formal education as a chemical engineer and another member had previously owned a renewable energy generation firm. The average age of the committee's members was fifty-eight years of age and all but one member possessed an advanced degree.³⁹ This group was educated and rich in diverse experience. These elected officials are capable problem solvers tasked with enacting legislation to solve the nation's existential threats; conversely, they may not all be well versed on major aspects of the US power system. These members rely on expert testimony to compensate for what they do not know about the US power system.

The Senate Energy and Natural Resource Committee enjoy the right to compel subject matter experts, by means of invitation or subpoena, to testify. Unfortunately, biases from committee members and witness testimony are always possible. With the exception of a few members on the committee, most members of the Senate Energy and Natural Resource Committee did not possess a granular understanding of the operational design of the US power system. These witnesses, subject matter experts of the US power system environment, could only offer broad guidance to the Senate Committee. These witnesses did not write legislation nor did they sign off on public laws. Ambassador Cooper, a trained electrical engineer and seasoned diplomat, favored a military approach to hardening of US power system assets. His islanded approach, a military operation approach in origin, would harden a limited number of US power system assets. Furthermore, he insisted the proper parties to harden the grid were state and local governments, not an Executive Branch narrative directive.⁴⁰

³⁹ "Members," Senate Energy and Natural Resource Committee, accessed December 1, 2017, <https://www.energy.senate.gov/public/index.cfm/members>.

⁴⁰ US Senate, *Hearing*.

Presidential narratives matter. Executive Branch policy matters. Both filter down to every level of the federal government. Federal government agencies are the vehicles responsible for implementing policy and regulations enacted through legislation. Narratives and executive branch policies also define national strategy. The President's policy preferences, whether from a State of the Union speech or Executive Order, directs Congress to develop new legislation and a budget. Legislation and budgets provide the means for federal agencies to operate to achieve their institutional purposes. Policy dictates how federal agencies utilize resources, in accordance with enacted public law, to achieve their statutory obligations.

The Historical Social Construction of the US Power System

[P]eople shape the form of the electrical system as they incorporate it into everyday life. Electrification mixed cultural, economic, and technical factors; it was a social construction that emerged through the interaction of many different entities[.]... [E]lectrification was not an abstract process but a series of choices... [E]lectrification is the story of increasing technical potentialities embedded in social processes.

—David E. Nye, *Electrifying America*

The US power system, existing in an environment influenced by private enterprise and social mandates, is an instrument of national security. Electricity provided illumination and a sense of security to a young nation growing out of the darkness of its infancy. Today electricity is a regulated industry, composed of different business models, ensuring our national security. Private industry and municipal governments serve our nation's electrical needs, without prejudice, electrifying private industry and public infrastructure. US power system expansion, the regulations ensuring its reliability, and the electric services providers originated by means of a complex historical evolution. Electricity transformed the American way of life and fueled the Industrial Revolution. Electricity made family life easier with appliances and reduced labor costs for businesses, replacing unskilled laborers with electrified machinery managed by fewer skilled engineers. The number of electricity producing entities grew in size, servicing employees of

business and families in surrounding communities, as public demand for electricity and kilowatt consumption increased.⁴¹

Economic motivations underwrote electrical service expansion. Reducing the risk of investment failure drove the earliest expansion of electric infrastructure.⁴² Early expansion of electrification in the United States during the nineteenth century presented plenty of risk for investors. A successful electricity business model required a consistent source of load consuming customers in close proximity to the electrical generation assets. The first investors of electrical generation were textile factories selling excess generated electricity, or load, to the neighboring community. The additional revenue received from servicing the adjacent community with electricity had to recapture the costs of providing electricity. The “side business” was successful if the electric revenues recaptured expended investment electricity. Citizens saw the benefits of electrified streetlights, traction public transportation, and electrified homes.⁴³

Starting in the 1880s, electricity investment proved to be unsustainable because technological innovation altered existing community social constructs. Electricity changed labor, eliminating unskilled positions while automating other jobs. Textile factories and sawmills, potentially the largest employers in town, were doing more with less labor. This caused populations to leave communities for work elsewhere. Local governments shut down public transportation since ridership revenue and taxable populations dwindled. Textile factories, burdened with expensive infrastructure and no means to recuperate costs, operated the generators at less than full capacity. This inefficient means of operation increased overhead costs of

⁴¹ David E. Nye, *Electrifying America: Social Meaning of New Technology, 1880-1940* (New Baskerville: Massachusetts Institute of Technology University Press, 1992), 16-23.

⁴² Paul W. Hirt, *The Wired Northwest: The History of Electric Power, 1870s-1970s* (Lawrence: University Press of Kansas, 2012), 22-30.

⁴³ Nye, *Electrifying America*, 85-97.

production, burdening the consumer with higher cost of goods. Unable to provide a product at a competitive price, these inefficient factories closed.⁴⁴

Early electric generation was inefficient due to high costs and flawed technology design. It was difficult for public utilities to sell excess load because of fragmented interconnections amongst neighboring communities. The private business supplied electricity to consumers with direct current power (DC) systems. DC power systems' limitations prevented the expansion of services over great distances, leaving few options to expand service beyond nearby communities.⁴⁵ Transmission lines were not incorporated into design until large-scale electrical generation projects necessitated the movement of power over great distances.

The first public utilities were naturally islanded generation facilities. It was rare for a public utility to sell off excess load to a neighboring community without cannibalizing its own resources. A population's electric demand necessitated the expansion of the US power system to offset the risk of investment. It was essential for early public utilities to understand a community's load consumption activities to guarantee a return on investment. Public transit, electrified households, and round the clock textile factories were consumers of load at varying capacities throughout each day.⁴⁶ The early model for success required an understanding of community social tendencies to maximize grid efficiency and earn a return on investment.

⁴⁴ Ibid.

⁴⁵ Prior to the acceptance of alternating current (AC) as the means of electricity transmission, it was not advantageous for electric service providers to operate a direct current (DC) power system to move electricity over long distances. DC power system possessed some disadvantages if transmitting electricity over long distances. DC power systems required thicker copper cables to move electricity adding to overhead costs. Without thicker cables prevent power from wasting off because thin cables expel more heat as power transmits over long distances. When this happens, power is lost due to resistance of the wire. Resistance is the friction of the electrons bumping into the atoms from voltage forcing the current to flow in a wire. Transmission of power at high voltage levels and low current eliminates the low of power. This is not a practical to offset power loss in the dc system due to the load operating at dangerously high voltage. Most modern commercial electric power companies generate and distribute alternating current because of the disadvantages related to transmitting and using direct current. Ohms law explains the relationship between voltage, current, and resistance where voltage = current x resistance.

⁴⁶ Hirt, *The Wired Northwest*, 22-30.

Successful nineteenth-century electricity providers balanced load with primitive technology among a finite population in defined geographical regions, while keeping costs low and thus justifying investment.⁴⁷

Local and state governments understood electricity was a catalyst for social change and an agent of government legitimacy. For these reasons, the United States deemed electricity a public utility. Designation as a public utility eliminated conflict in the free market for the benefit of all entities operating within the market.⁴⁸ The expansion of electricity in the early twentieth century led consumers and producers to petition the authoritative jurisdiction of government for assistance. Electricity had advanced as a desired public service, but risk of reduced returns on investment created a situation requiring a market sterile of competition. The desired ends represented an electricity market operating in the best interest of the electricity producer and consumer. The best interests of consumers represented affordable electrical service while producers desired reliable profits. The electricity producer, in search of profits, sacrificed a portion of its freedom to earn designation as a public utility.⁴⁹ A government agreeing to this construct shifted its burden of social responsibility to the for-profit business entity. The monopolization of public utilities also shifted the financial burden into private ownership of public utility arrangements. Nineteenth-century government, wanting to mitigate risk and possessing limited revenue generating means, were wary of capital-intensive projects. Society's desire for electrification influenced government legitimization of electricity monopolies. Governments, and later public commissions, accepted for-profit corporations as monopolies so long they provided a mandated basic standard of service.⁵⁰

⁴⁷ David P. Tuttle, "The Full Cost of Electricity: The History and Evolution of the US Electricity Industry," *The University of Texas at Austin Energy Institute* (July 2016): 2-3.

⁴⁸ Hirt, *The Wired Northwest*. 97.

⁴⁹ Ibid.

⁵⁰ Ibid.

Support for the monopoly designation of electricity producing entities existed for several reasons. First, power systems link producers to consumers. Excluding electrical current, electricity was identical among its suppliers. One brand of electricity was no different from another brand. Second, electrical infrastructure required a significant amount of capital to link the producer to the consumer. Few public governments or private corporations possessed such financial means before the end of the nineteenth-century. Third, it was inefficient and wasteful for multiple electric utilities to operate in the same region and compete for finite customers. Building a power system came with the expectation of a return on investment after a significant capital investment. Economies of scale superseded healthy competition since the private utility investor was bearing all of the risk.⁵¹

Electricity consumption continued to grow in the twentieth century, but investment in electrification remained risky to communities wishing to electrify. Technological advancement, pro-monopoly regulations, and the consolidation of public utilities fueled the expansion of the US power system. Electrical expansion was justified by what best maximized economies of scale. Electric public utility's benchmarks of success included servicing a maximum number of citizens, providing a standard of service without fault, keeping overhead costs low, and balancing load over a twenty-four hour day, for a 365-day cycle. From the perspective of the consumer, public utility growth meant electricity at the cheapest price per kilowatt-hour. For the public utility operator, keeping overhead costs low and guaranteeing a return on investment, without violating regulatory mandates, is what drove growth.

The earliest public utility owners relied on social and cultural determinations to identify where to expand. Electrical infrastructure was capital-intensive, necessitating a steady stream of funding to expand services to communities. Armed with monopoly designations, franchising rights, and exclusive service contracts, public utility owners sought to recruit outside investors to

⁵¹ Nye, *Electrifying America*, 169-175

expand coverage. Public utility owners, seeking to capitalize on society's desire for electricity, expanded through mergers and acquisitions to achieve economies of scale.⁵² Monopolized private ownership of public utilities filled the void where government lacked monetary capital to invest.

Shifting the burden of risk in a capital-intensive enterprise was not the only reason government embraced private ownership of public utilities. Electricity had its origins in private enterprise due to federalism and the limitations of decentralized governance. First, governments granted exclusive franchise rights to private corporations because they functioned over multiple jurisdictions with greater ease. Implementing a centralized public utility proved difficult because jurisdictions connected by terrain were not always socioeconomically homogeneous. Second, technological innovations and standardization normalized the electric industry. During this era of expanded investment, efficiency of turbines increased, means of generation diversified, transmission voltages were standardized, and centrality transmission went further distances to capture new markets eager for electricity.⁵³ Third, private industry designed elaborate marketing campaigns, fueling society's expanding demand for electricity. Forth, private corporations also had greater access to capital from banks and stock exchanges. Lenders viewed public utilities as having little risk and were willing to invest in monopolized public utility markets. Expanded access to financing subsidized elaborate marketing campaigns and technological innovation. Therefore, private corporations served as the catalyst for expanding the US power system.⁵⁴

Support for private ownership of electric public utilities owed itself in part to a collective bias against government public utility ownership. A belief existed that natural monopolies functioned best when owned by private entities. First, public administrations were viewed as corrupt due to political patronage and would not hire the appropriate staff to manage public

⁵² Hirt, *The Wired Northwest*, 35.

⁵³ Ibid., 101.

⁵⁴ Nye, *Electrifying America*, 139-140.

utilities. Consequently, the public believed that staffing was influenced more by political affiliation than professional qualifications. Second, approval for public utility investment of resources was not popular. A desire to keep utility rates low prevented the hiring and retention of qualified professionals and kept physical infrastructure investment at a minimum. Third, any efforts to force private industry out of the utility business were denigrated as examples of creeping socialism.⁵⁵

Elaborate marketing campaigns promoting the benefits of electricity sought to secure public appeal for infrastructure improvements. Westinghouse and General Electric expanded their business models into home appliances and marketed the goods to families, promoting convenient way of living.⁵⁶ The appliance industry, funded directly by the producers of electricity, benefited from increased demand due to the popularity of appliances.⁵⁷

Holding companies managed groups of electrical public utility operating companies. Aside from technology advancement, consolidation occurred because private corporations possessed legal and technical assets to procure charters and exclusive rights to supply electrical utilities.⁵⁸ Public utility consolidation achieved economies of scale through mergers and acquisition of public utilities that possessed the ideal market to consume its load. Holding companies operated at ease over state lines and recruited potential investors by issuing commercial stock in utilities. For both the holding company and the risk adverse investee, this became an attractive opportunity for both groups to achieve economies of scale and achieve wealth. Ultimately, this led to an organizational structure christened as a pyramid structure of management. Holding companies, in constant need of consumers to balance their produced load,

⁵⁵ Ibid., 175-176.

⁵⁶ Ibid., 262-272.

⁵⁷ Ibid.

⁵⁸ Childs, *Yesterday Today and Tomorrow*, 10-11.

sought opportunities to achieve the relationship where load demand and consumption were equal and consistent for twenty-four hours.⁵⁹ These public utility monopolies were attractive for outside investment since monopoly designation eliminated competition and made investment attractive.⁶⁰ The earliest means of public utility expansion included traction and trolley routes.⁶¹ Innovative electrified transportation infrastructure lengthened the distance Americans could live from their place of employment. Electrification provided an affordable, stable source of transportation for the family breadwinner to and from his location of employment. The expansion of alternating current technology spread electricity to communities previously lacking such amenities.⁶²

During the first thirty years of the twentieth century, the number of public utilities plummeted due to consolidation, dissolution, and bankruptcy.⁶³ Conversely, the nation increased its electrical generation capacity and total United States kilowatt-hour consumption increased exponentially. The increased electrical generation capacity occurred from innovative technology that supported America's expanding appetite for electricity.⁶⁴ Public utility holding companies persisted until the Great Depression when they came under heightened scrutiny, requiring regulation for the electric utility industry. Private utilities, as well as holding companies, were unable to act in the best interest of the population they served. Holding companies had implemented accounting practices that inflated overhead costs and rate structuring to deceive consumers and state utility authorities.⁶⁵ The Public Utility Holding Company Act of 1935

⁵⁹ Hirt, *The Wired Northwest*, 41.

⁶⁰ Ibid.

⁶¹ Nye, *Electrifying America*, 92-97.

⁶² Ibid.

⁶³ Childs, *Yesterday Today and Tomorrow*, 10-11.

⁶⁴ Hirt, *The Wired Northwest*, 99-101.

⁶⁵ US Library of Congress, Congressional Research Service Report on Electricity: The Road toward Restructuring (2004), 14-16.

(PUHCA) and the Federal Power Act (FPA) sought to eliminate unfair practices and other abuses by electricity and gas holding companies by requiring federal control and regulation of interstate public utility holding companies.⁶⁶ Prior to PUHCA, electricity holding companies were characterized as having excessive consumer rates, high debt-to-equity ratios, and unreliable service. These regulations curtailed such unethical business practices, facilitating public oversight of public utilities through expanded regulatory commission authority.⁶⁷

PUHCA, the FPA, and most recently the Public Utilities Regulatory Policy Act (PURPA) have had a lasting impact on public utility standards of service and standard of security through reliability standards implementation. Electricity generation and transmission entities cost-justification requires not only the approval of utility management, but also of FERC and potentially state public utility commissions, which regulate the rates that grid owners may charge for electric transmission and distribution. Regulators are responsible for ensuring that electricity rates are just and reasonable. Regulators approve grid security improvements prior to imposing those costs on ratepayers.⁶⁸

The earliest power system engineering models promoted redundancy as a benchmark for a successful power system. The public utility met expectations when lights illuminated the darkness without incident. The customer paid for cost of generation and the service of moving electricity to the final destination. The consumption of electricity met the consumer standard of standard of service. The absence of electricity was burdensome for the nineteenth-century farmer, but not perceived as an existential threat. Incorporation of security system protocols to mitigate the risk of malware hacking was not conceptualized by nineteenth-century power system designers. Space weather events were observed for centuries prior to US electrical dependence

⁶⁶ Ibid.

⁶⁷ Ibid.

⁶⁸ Ibid., 17.

and it was not perceived as a threat to national security in the nineteenth-century. The private investor and the considerations of the consumer were the deciders of the location of US electric facilities and systems. They were the drivers of power system innovation, design standards, and placement of power system assets.⁶⁹ Historically private public utility investment had lasting influence on the US power system expansion, but today the burden of ensuring social responsibility remains firmly on the shoulders of the US government.

The US power system is transitioning from a centrally controlled, predictable system with one-way power flows in distribution to a distributed and dynamic system with bi-directional flows in distribution. Grid technologies need to evolve with the changing supply and end-use technologies landscape. Research, development, demonstration, and deployment associated with technologies that connect to the grid are evolving with the grid. If electricity displaces petroleum and natural gas in transportation and heating applications, respectively, the grid may serve an even more central role in the future energy system.⁷⁰ The US government has accepted the burden of responsibility for safeguarding the US power grid. It has shaped the governance, expansion, and protection of the US power system. Unfortunately, the private sector's focus on profit is in tension with the US government's role of preserving national security through bolstering and safeguarding the US grid. The shifting burden for social responsibility has resulted in several laws and policy implementations. These instruments of federal governance mandate a standard of service and a mandate to protect the US power system.⁷¹

A Standard to Protect

Electricity-focused public policy and federal law directs federal agency resources to protect the US Power System. Federal agency resources provide a means to mitigate the risks and

⁶⁹ Nye, *Electrifying America*, 169-175.

⁷⁰ US Department of Energy, *Quadrennial Energy Review: Transforming the Nation's Electricity System Second Installment* (Washington, DC: Government Printing Office, 2017), 425.

⁷¹ Nye, *Electrifying America*, 140.

vulnerabilities to the US power grid by contemporary adversaries or weather phenomenon. Does the ability to mitigate risk depend upon how polices designate federal agency resources to identify threats and risks to the US power system? The USA Patriot Act of 2001 defined critical infrastructure as “systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters.”⁷² US energy policy seeks to ensure a reliable power system, safe drinking water, and functioning means of communication; furthermore, these expectations of critical infrastructure preserve social norms, economic stability, and the security and comfort of every United States citizen. Shifting social and cultural norms and security threats have influenced the manner in which the grid operates. Fundamental changes in both supply and demand technologies are placing new requirements on the electric power system. Accompanying these changes is an evolution towards digital communications and control systems to improve performance and engage consumers. These trends create new technical requirements for a grid that is more flexible and agile, with the ability to optimize grid operations in near-instant periods.⁷³

Failing to provide US power system stakeholders with new sources of funding, such as federally-backed debt service energy infrastructure upgrades, also invites risk. The National Defense Strategy (NDS) desires an end state where the nation’s electrical infrastructure is resilient to attack due to proactive grid security measures.⁷⁴ These ends are unachievable because the NDS directs federal agencies and civilian stakeholders to perform due diligence to reduce risk, yet most federal agencies lack the financial funding resources to pay for preventative risk

⁷² The USA Patriot Act of 2001, Public law 107-56, US Statutes at Large 115 (2001): 5496-47, codified at *US Code* 42 (2001), § 1016(e) et seq.

⁷³ US Department of Energy, Office of Policy, *Quadrennial Energy Review: Transforming the Nation’s Electricity System Second Installment*, (2017), 416.

⁷⁴ US Department of Defense, *Summary of the 2018 National Defense Strategy of The United States of America: Sharpening the American Military’s Competitive Edge* (Washington, DC: Government Printing Office, 2018), 4,10-11.

reduction efforts. With few exceptions, federal agencies lack funding mechanisms to provide US power system stakeholders with the resources they need to finance required energy infrastructure upgrades.⁷⁵

Each new presidential administration has a national security narrative, which includes the National Security Strategy, the NDS, the DOE national energy strategy, and so forth. The existence of the US National Energy Strategy substantiates the importance of electrical infrastructure. The National Energy Strategy provides a vision for the future state of US electrical infrastructure for a given time. Energy strategy, in this context, is a statement of goals or objectives, which a President sets and pursues. The President, through an act such as an Executive Order, Presidential Proclamation, or Presidential Directive, formalizes priorities and the allotment of federal agency resources.⁷⁶

Since September 11, 2001, the President has issued an Executive Branch Policy to promote national defense and homeland security. Currently known as National Security Presidential Memorandums (NSPMs), under the Trump Administration they serve as a means to protect the US critical infrastructure component of homeland security policy, which is administered by the Office of Homeland Security. The Executive Branch performed a reorganization in the aftermath of the September 11 terrorist attacks. President George W. Bush

⁷⁵ “[The US Department of Agriculture’s Rural Utilities Service (RUS) Electric Program is one of the federal agency that finances electrical infrastructure investment. Housed within the USDA Rural Development (RD) mission area, RUS provides] reliable, affordable electricity [essential for] sustaining the economic well-being and quality of life for all of the nation’s rural residents... The Electric Program provides leadership and capital to maintain, expand, upgrade, and modernize America’s vast rural electric infrastructure... The loans and loan guarantees finance the construction of electric distribution, transmission, and generation facilities... [RUS loans can fund] system improvements required to furnish and improve electric service in rural areas[.]... Loans are made to cooperatives as well as to corporations, states, territories and subdivisions and agencies such as municipalities, people’s utility districts, and nonprofit, limited-dividend, or mutual associations that provide retail electric service needs to rural areas or supply the power needs of distribution borrowers in rural areas.” “*Electric Programs*,” US Department of Agriculture, accessed April 9, 2018, <https://www.rd.usda.gov/programs-services/all-programs/electric-programs>.

⁷⁶ US Library of Congress, *Congressional Research Service Report: Executive Orders: Issuance, Modification, and Revocation* (2014), 1-2.

established the Office of Homeland Security and the Homeland Security Council Executive Office of the President to assist with the planning and coordination of federal efforts to combat terrorism and to maintain the domestic security of the United States with (E.O. 13228 of October 8, 2001). On October 29, 2001, President George W. Bush issued the first in new series policy directives, which focused on homeland security and the preservation of critical infrastructure. Known as Homeland Security Presidential Directives (HSPDs), the initial directive concerned the organization and operation of the Homeland Security Council (HSC). Utilizing a whole of government approach, the HSC was tasked to develop homeland security policy with the representation from government agencies and uniformed military.⁷⁷ Furthermore, the need to define, catalogue, and secure the safety of critical infrastructure, as well as the development of threat mitigation approaches, has been a strategic aim long before the Global War of Terror.⁷⁸

The US power system is complex for many reasons. Not all power systems service the same type of customers. Distance between power generation, transmission, and distribution components, spread over great lengths and dissimilar terrain, require engineering designed specific to the conditions of the physical terrain. Power systems also generate energy by different means, further influencing the engineering design of a power system. Additionally, power systems evolve due to technological innovation, new legislation, and consumer behavior. These constructs have evolved due to innovative energy storage technologies, Presidential policies like

⁷⁷ US Library of Congress, *Congressional Research Service, Presidential Directives: Background and Overview* (Washington, DC: Government Printing Office, 2008), 7-8.

⁷⁸ “In a 1983 report, the Congressional Budget Office (CBO) defined ‘infrastructure’ as facilities with ‘the common characteristics of capital intensiveness and high public investment at all levels of government. They are, moreover, directly critical to activity in the nation’s economy.’ The CBO included highways, public transit systems, wastewater treatment works, water resources, air traffic control, airports, and municipal water supply... In response to the President’s Commission on Critical Infrastructure Protection final report, President Clinton signed Presidential Decision Directive 63 (PDD-63) on May 22, 1998. The Directive’s goal was to establish a national capability within five years to protect critical infrastructure from intentional disruption. According to PDD-63, critical infrastructures were ‘those physical and cyber-based systems essential to the minimum operations of the economy and government.’” US Library of Congress, *Congressional Research Services: Critical Infrastructure and Key Assets: Definition and Identification* (Washington, DC: Government Printing Office, 2004), 1-5.

the Obama Administration Clean Power Plan (CPP), increased renewable energy generation, smart grid technology, behind the meter energy efficient homes, and distributed generation. The stakeholders of the US power system are also unique by business model standards, access to a means of generation, type of customer, or existential threats to service. In short, the operational environment of the US power system is diverse in terms of its stakeholders, shared terrain, and financial resources.

There are some universal assumptions amongst US power system stakeholders. The US power system is interlinked through physical connections, making its performance only as strong as its most vulnerable components. Vulnerabilities exist for two reasons: age of assets and power system design. As demonstrated in the previous sections, national security concerns did not influence the construction, design, and evolution of the nineteenth-century power grid. The US power system's original design was to generate electricity and deliver it to a consumer. Shareholders designed the power systems simply to provide reliable service to paying customers. Paying customers expected reliable service with the exception of service interruptions due to natural disasters, such as tornados and earthquakes.⁷⁹ Reconnecting telegraph service to Wall Street bankers in the 1890s was mandated by contractual agreement between the Consolidated Edison Power Company and the consumers on Wall Street. In short, there was no social responsibility to mitigate threats to the grid. The US power system, from its infancy to the present day, was not constructed to be resilient to national security threats. Cyber and EMP threats did not exist during the electrical infrastructure's nascent development. Today's electrical infrastructure threats emerge overseas by can disrupt the operations of Wolf Creek nuclear power plant in Kansas.⁸⁰

⁷⁹ Ronald Krutz, *Securing SCADA Systems* (Indianapolis: Wiley Publishing, 2006), 5-8.

⁸⁰ Andy Greenberg, "Hack Brief: Hackers Targeted a US Nuclear Power Plant (But Don't Panic Yet)," *Wired.com*, July 6, 2017, last modified July 7, 2017, accessed February 22, 2018, <https://www.wired.com/story/hack-brief-us-nuclear-power-breach/>.

By design, a power system communicates among its assets to move electrical current from sources of generation to the metered customer. A realistic assumption is that faults will occur and service will be disrupted or altered on occasion. A power system possesses communication component which ensures that human and nonhuman assets move the current from point of generation to consumers. Power systems are routinely disrupted by faults making it essential these assets communicate at all times to deviate current when a fault occurs. A power system endures catastrophic failure if it is unable to recognize the exact instance of a fault. The power protection system (PPS) is tasked to recognize the instance of the fault along the power system. A PPS is composed of several assets to identify a fault. Current and voltage transformers “step down” the high voltages and currents of the electrical power system to convenient levels for the relays. Protective relays sense the fault and initiate a trip, or disconnection, and send an order. Circuit breakers open or close the system based on relay and autorecloser commands. Batteries provide power in case of power loss during system operations. Communication channels allow analysis of current and enable remote terminals of a line and to allow power system assets to go offline, preventing further damage to power system assets and equipment. The communication component of a PPS shares this fault to human and nonhuman elements tasked to manage overall operations. Depending on the type of fault, human and non-human elements of the PPS deviate the current to contain the fault. The combined system of human and non-human elements, known as SCADA, ensures proper function of the aggregate power system. Communication components are either in house or positioned through broadband lines.⁸¹

⁸¹ “Introduction to System Protection,” *Idaho Power*, 2012, accessed February 22, 2018, https://www.eiseverywhere.com/file_uploads/aaf42a76a5588f69c7a1348d6f77fe0f_Introduction_to_System_Protection-_Protection_Basics.pdf. SCADA is an acronym for Supervisory Control and Data Acquisition. SCADA describes the computer system that monitors and controls transmission and distribution elements of electrical utilities, SCADA will monitor substations, transformers and other electrical assets. These system assets control geographically dispersed assets that are often scattered over significant distance and diverse terrain.

If a PPS communication component fails without the SCADA system's recognition, an incident could cause an undetected fault, triggering a service disruption or a, partial, or full system failure.⁸² NOAA and NASA satellite technology provides the US government advanced warning of space weather events. Space weather event alerts warn power system stakeholders to initiate contingency plans to minimize damage to the vulnerable electrical infrastructure.⁸³

In theory, an attack targeting a specific terrain's electrical infrastructure would be most disruptive if conducted in two phases. First, an event would need to disrupt a PPS communication component without alerting any human elements of the PPS. After the PPS disruption, an isolated EMP or EMPs deployed by a malicious actor would target specific nodal points along the power system. A coordinated attack on the US power grid along the northeast corridor from DC to the NYC metropolitan region would create significant disruption. The location is ideal because disruption would disable global financial centers with lasting impact on US global influence, reducing the United States' posture as a global leader. This area includes the center of the federal government, sprawling US population centers, and a significant portion of US critical electrical infrastructure. In short, disruption of the grid would hasten immediate social disruption, undermine the functionality of the federal government, and cost significant money to restore grid function.

The threat illustrated in the previous paragraph highlights the limitations of the reliability standard established by NERC and mandated by FERC. Specifically, legacy generation and transmission systems are not mandated under FERC reliability standards.⁸⁴ A regulatory mandate to protect critical electrical infrastructure against GMD space weather events and EMP attacks

⁸² Krutz, *Securing SCADA Systems*, 29-31.

⁸³ "The Difference between Flares and CMEs," NASA, last modified August 7, 2017, accessed March 22, 2018, <https://www.nasa.gov/content/goddard/the-difference-between-flares-and-cmes>.

⁸⁴ US Department of Energy, Federal Energy Regulatory Commission, *Reliability Primer* (2016), 28-32.

does not exist. NERC provided FERC a reliability standard for cyber and physical threats, but no standard currently protects against a high impact, low probability incident like a CME or EMP. The NERC reliability standard has several shortcomings. First, the GMD reliability standard does not exist. Second, PPS success is contingent upon a secure communication component. Securing of communication channels is not required nor regulated by FERC. Third, reliability standards only protect new bulk power systems, which limit a standard of protection to only new generation and transmission assets. Aged generation, transmission, and distribution assets are susceptible to vulnerable and unmitigated risk. Fourth, a federal government financing mechanism does not exist to subsidize the power systems upgrades.⁸⁵

Conclusion

Both Capitalism and democratic governance are complex human institutions reflecting diverse and divided interest and loyalties. [T]he task of crafting successful rules and relationships is enormously challenging... [W]e constantly adapt our institutions as historical conditions and social value change... [R]egulation is a fundamental and necessary condition of a well-functioning complex system. Authorities, duties, and behaviors in a family are regulated, both formally and informally. The same goes for business, schools, clubs, churches, communities, states, nations, and economic systems. Successful capitalism requires regulations.

—Paul W. Hirt, *The Wired Northwest*

Power systems, possessing complex technology, are social in origin and operation. Society yearned for electricity to make life easier and bolster industry goals on profit motivation. Corporations and public utilities made decisions where to expand the flow of electricity. Power system assets, imperfect by human creation, create faults that disrupt service of electricity to consumers. Disruptions occur by man in the form of military or terrorist attacks and from nature in the form of space weather events.

The executive branch prioritizes desired strategic ends once a new President assumes his role as Commander-in-Chief. The President outlines his policy objectives by giving Congress

⁸⁵ Krutz, *Securing SCADA Systems*, 20-22.

guidance, in narrative and in budget form, to act on legislation through the State of the Union Address. These priorities are also transmitted through national strategies (e.g. National Security Strategy) to communicate a vision that describes the desired ends of a particular subject specific to national security. Executive instruments, in the form of an executive or policy directive, communicate those priorities to federal agencies and authors of national strategies.

Electricity has evolved from a commodity of limited access, embracing of its role as a coordinator, to universal availability in less than two hundred years. Electricity generated by means of private investor-owned utility or by municipal utility, provides the same social rewards regardless of origin. The US government is involved with the generation and consumption in many forms. An electrical cooperative funded by an USDA Rural Utilities Service loan services electricity to the rural farmer in Appalachia and the privately owned Texas utility, providing electricity to military assets located at Fort Hood. Furthermore, the debate of public versus private utility ownership still rages today. Regardless of the purveyor of electrical service, enacted legislation has mandated minimum standards of service and power system security. In short, electricity is shared by all, variable in cost and function, and necessary to guarantee national security and the American way of life.

In closing, the future actions of society will determine how the US power system is designed to function. The US government and its citizens, dependent upon electricity, have developed policies and enacted legislation to maximize the benefits of electricity. It is both the responsibility of the Executive and Legislative Branches to safeguard the US power system and recognize core problems found which exist in its design. Progressive energy policy will define the ways federal agencies execute action to mitigate risks to the US power system. This process of policy evolution must stay consistent with social constructs. Humans and technology will continue to evolve. The US power system must move away from an expectation to be repetitive and redundant in operation. It must move to an operational design contingent on resilience and reliability.

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