Testimony of

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"Perspectives on Protecting the Electric Grid from an Electromagnetic Pulse or Geomagnetic Disturbance"

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Good afternoon, Mr. Chairman, Ranking Member Peters and Members of the Committee:

My name is David W. Roop, and I am Director of Electric Transmission Operations and Reliability in Dominion Energy's Power Delivery Group.

Thank you for inviting me to appear today to discuss my company's efforts to protect our electric transmission system from naturally recurring Geomagnetic Disturbances (GMD) and the potential for Electromagnetic Pulse (EMP) events. Our company's efforts to protect our system began decades ago, and our response to the threats posed by GMDs and EMPs is an ongoing process. We have taken many steps to protect our electric infrastructure, and we will continue to modify and improve our system as we gain more knowledge of these threats and effective mitigation strategies.

Before offering our testimony, I would like to provide you with some information about Dominion Energy and the Power Delivery Group.

Dominion Energy is headquartered in Richmond, Virginia, and we provide electricity or natural gas to nearly 7.5 million customers – across 18 states – to energize their homes and businesses. We have about $100 billion in assets to provide electric services -- generation, transmission and distribution – as well as natural gas services -- storage, transmission, distribution and import/export.

On January 1 of this year, we were honored to merge with SCANA Corporation. And with that combination came 2.1 million new electric and natural gas customers in the Carolinas and Georgia…most of them served by SCANA's regulated electric and natural gas utilities in North and South Carolina: SCE&G and PSNC Energy.

We are also a leader in clean energy development, with one of the largest solar fleets in the United States. Our electric generating fleet has reduced its carbon intensity – the average amount of carbon dioxide released for each unit of electricity generated – by 50 percent since 2000, and we are committed to a 60 percent reduction by 2030.

Within Dominion Energy, my organization – the Power Delivery Group – is responsible for the safe and reliable delivery of power to the 2.6 million electric customers served by our regulated utility subsidiary in Virginia and northeastern North Carolina. Our system includes about 6,600 miles of electric transmission lines and approximately 250 transmission substations. In 2018 alone we placed into service more than $900 million in additional transmission assets. We expect to add another $700 million in transmission investments this year.

I have served as Director of Electric Transmission Operations and Reliability in the Power Delivery Group since 2001, and in that capacity I lead our company's efforts to provide resiliency to our electric transmission system. I have a 43-year career with Dominion Energy, and I am a Licensed Professional Engineer in the Commonwealth of Virginia. I am also a member of the National Academy of Engineers and serve on the board of directors of the Virginia Academy of Science, Engineering and Medicine.

In addition, I am the U.S. President of CIGRE, a group of power sector professionals from around the world who address the technical challenges facing this industry. I am a senior member of the Institute of Electrical and Electronics Engineers (IEEE) and serve on advisory committees for the Electric Power Research Institute (EPRI), the North American Transmission Forum, and the Electric Sector Coordinating Council R&D Committee.

I can assure you that all of these organizations – including Dominion Energy – recognize the threats posed by the two types of electromagnetic events – naturally occurring GMDs and potentially the high-amplitude EMPs triggered by hostile actions.

Our company is particularly aware of these dangers due to Dominion Energy's service to a vital section of the Eastern Interconnection. The service area for our regulated electric utility, Dominion Energy Virginia, is in close proximity to the District of Columbia and is itself the home of many vital national security and defense operations, including many federal agencies, the Pentagon and the world's largest naval base.

We are also a major supplier of electricity to data centers in Virginia that move more than half of the world's Internet traffic. We understand we have an important role to play in our nation's security and work closely with our federal and state partners.

An important element of maintaining that secure and reliable transmission network is protecting our system from geomagnetic disturbances. We have taken comprehensive steps – including planning and equipment upgrades – to protect our assets and are proud to be a member of the North American Electric Reliability Corporation (NERC) Standard Drafting Team that last year developed a new set of standards dealing with the GMD phenomenon.

But our protective efforts started long before that. In fact they go back three decades, to 1989.

During a major historical GMD event that year, Dominion Energy's electric transmission system was impacted. Multiple infrastructure elements that allow us to maintain voltage within acceptable limits failed – threatening the secure operating state of the electric grid. Immediately after this event, we began work, in cooperation with EPRI, to protect our infrastructure, making it more resilient, with greater immunity to GMD events. This work strengthened our design specifications for transmission capacitors and associated protection systems. Our infrastructure has successfully handled all subsequent events. (Utilities employ capacitors to support system voltage and these devices are critical during GMD and EMP events.)

Given that capacitor banks have a useful service life of approximately 20 years, we made a deliberate transition to the strengthened design. The improvements were components of planned capital upgrade programs. Through this incremental approach, financial impacts were held to a minimum. The protection scheme we deployed was disseminated throughout the electric industry by the IEEE Standards organization and other industry forums. The IEEE has developed several documents that now guide the industry including: IEEE 1036 – *Guide for Application of Shunt Power Capacitors,* IEEE C62.22 G-3, Appendix G, *Arrester energy requirement for shunt capacitor applications,* and IEEE 1531, *Guide for the Application and Specifications of Harmonic Filters.*

Our efforts to protect another vital system component – transformers – from geomagnetic disturbances also began more than a decade and a half ago. GMD can damage large power transformers by causing them to overheat. Dominion Energy worked with Virginia Tech, the University of Tennessee (Knoxville), and our key transformer suppliers to evaluate our existing fleet of in-service power transformers along with new units under construction in our supply chain. This analysis indicated that incremental design changes could improve thermal margins beyond our already generous design margin. Since 2004, we have been replacing the critical units that are approaching end of life with these upgraded designs to ensure their survivability. Our work in this area has also been shared with the industry through the IEEE standards committees, IEEE C57.163 – *IEEE Guide for Establishing Power Transformer Capability while under Geomagnetic Disturbances*.

Additionally, we have been working with NERC, as a member of the GIC Task Force/Standard Drafting team, and also with the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, and NASA to improve our real-time situational awareness by deploying sensors across our system. We have also teamed with these government partners to develop, deploy, refine and provide feedback on a broad array of computer modeling capabilities. This research is on-going but is showing significant promise with improved computer models to better define the actions that our system operators should take during a GMD event to prevent a major outage. More research is

also scheduled in 2020 to better define our models for transformers subjected to this extreme condition. The research will include testing in-service units at one of our 500kV substations. This would be the first testing of its kind in the U.S., and we are eager to obtain, study, and broadly share the results.

Now let me turn to our efforts and approach relating to EMP. Unlike GMD, EMP is not a recurring event. Their impact is therefore difficult to quantify when attempting to justify spending on mitigation efforts.

These events are not deterministic but more random or stochastic in nature, like terrorist attacks. With that in mind, we have worked with PJM and Oak Ridge National Laboratory to develop a probabilistic methodology to allow us to analyze the spectrum of potential impacts of "N-k" events on the electric grid. ("N-k" is a term of art within our industry used to describe analysis of a large event made up of smaller, multiple events simultaneously challenging the electric grid.)

This novel methodology immediately showed value. The model identified previously unknown vulnerabilities to our system. Legacy planning methodology was simply not capable of identifying the vulnerabilities present in this new normal. Since its development and validation, Dominion Energy has employed the new probabilistic planning approach and has shared it with the industry. It has now been widely adopted. (NERC has discussed this methodology as part of its *September 2018 Reliability Guidelines: Methods for Establishing IROLs*.)

While this probabilistic analysis was being developed, we also began an extensive international research initiative to identify leading practices for addressing EMP system vulnerabilities. We immediately began modifying our substation design standards to improve the resiliency of our designs for withstanding these events. Again, we accomplished this incrementally, by incorporating the improvements into our schedule of capital projects. This approach minimized costs. It also provided collateral benefits for protection against more routine system challenges -- such as lightning, transients, and

switching surges, to name a few. Additionally, we standardized an all-metal control enclosure with limited penetrations. These metal enclosures ensure that EMP-radiated waves would be significantly attenuated. We also partnered with utilities across the U.S. to fund EPRI research to provide more specific guidance on other design aspects that would require incremental changes. This research will help us make sure that we are prudently investing in improvements, and ensure the solutions found and implemented do no harm to our equipment and everyday operation of our electric grids.

EPRI's body of work has been extremely valuable in providing data that will inform our future designs. The research has demonstrated the type of damage we could expect from EMP events, and it has improved our ability to specify equipment with greater ability to withstand an electromagnetic pulse. The EPRI work was a critical step in providing us with the technical basis for prudent expenditures. However, their efforts would not have succeeded without significant support from our federal partners such as the Department of Homeland Security, the Department of Defense, and the Department of Energy.

Given the concerns over security, including EMP, Dominion Energy spent 3½ years designing and constructing a 113,000-square foot facility that cannot be compared to anything else in the energy industry. This new System Operation Center (SOC), which opened its doors in August 2017, is hardened against natural and man-made threats. The center includes a MIL-Spec EMP space for critical operations and employs the latest technologies and practices in physical and cyber security, telecommunications, redundancy, and efficiency.

I believe our record of responding to these threats is impressive. I wish I could tell you that we now have all the answers, but unfortunately, we do not. Additional testing and research is still needed to address the impact of EMP on controls and protective equipment. Further work is needed to ensure we have the communications needed during and after an EMP event to restore service. The industry is also still searching for a cost effective means to shield existing control enclosures.

Despite everything we are doing for EMP protection, we still cannot guarantee that all equipment would remain undamaged. To address this gap, we have purchased spare equipment (including emergency spare relays and EHV transformers) and mobile emergency equipment. We have also entered into equipment sharing agreements like STEP through EEI and RESTORE (a broader equipment sharing agreement with multiple utilities). In addition, we have collaborated with the Department of Energy and Oak Ridge National Laboratory on the Strategic Transformer Reserve analysis as part of the FAST Act. This has helped us to develop a minimal transmission grid recovery methodology.

Additionally, we realize that we are part of a larger, interconnected system. For decades, the strength of our systems has depended on neighbors helping neighbors. We continue to share what we are learning through industry trade associations and professional organizations. In addition, we are working with select utilities to directly share our best practices with them. This sharing will help us quickly improve our understanding and deployment of resiliency measures.

Late in 2018, Dominion Energy began an effort to broaden our focus as an industry on the EMP impacts on generation facilities. We began this process by working with the DOD Defense Threat Reduction Agency, members of DHS, DOE and the Electric Infrastructure Security Council. In addition, our technical staff is working to understand the impacts of renewable energy on our blackstart plans. This analysis will help us determine the measures needed to ensure our vital blackstart resources are available to respond to all events - especially EMP.

Dominion Energy is committed to addressing these issues. We have greatly improved our system's ability to handle these events. We are not finished in this endeavor and will continue our prudent investments, as our research identifies needs for improvement.

I want to again thank this Committee for allowing me to speak and express our appreciation for the invaluable support we have been given by our various federal partners in these areas.