Modernizing the Power Grid and Understanding Potential Impacts from Solar Weather

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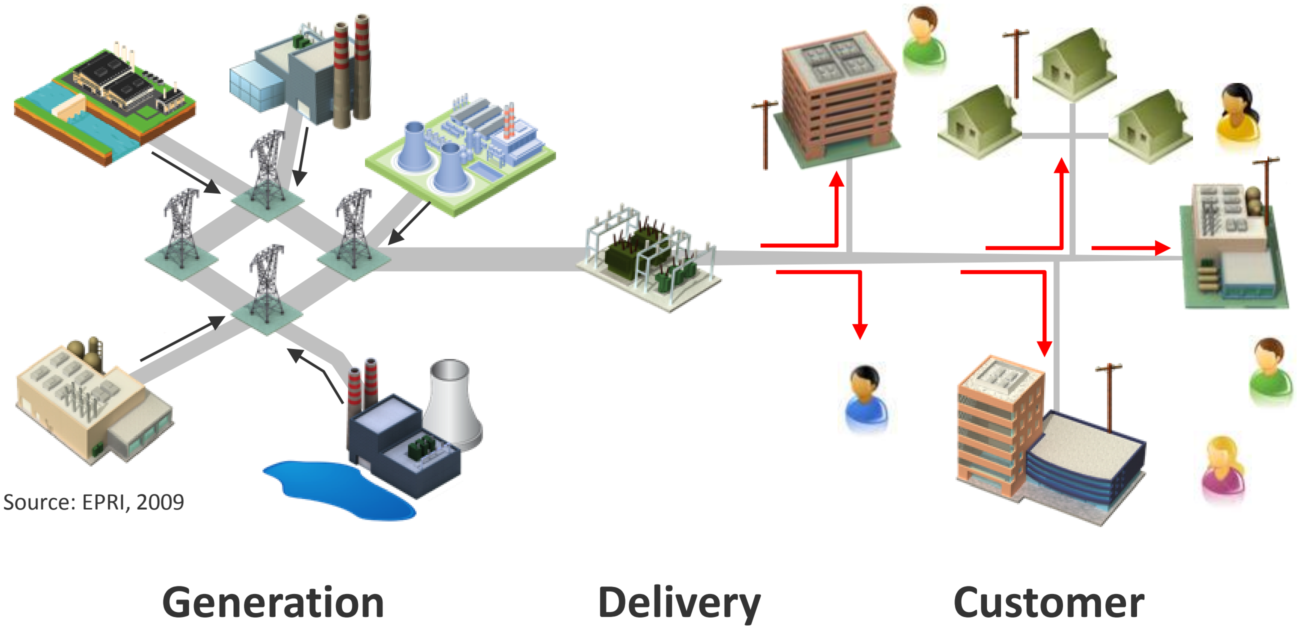
2019 Space Weather Workshop

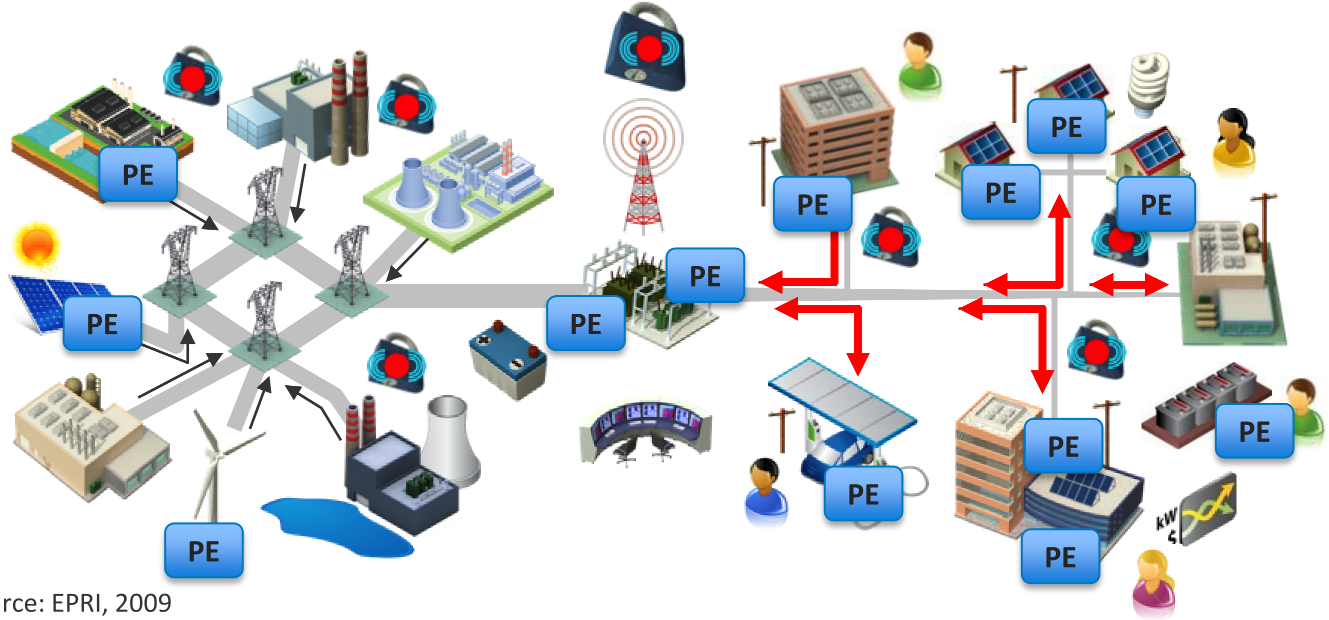
The Grid of the Past



Source: EPRI, 2009

- One-way Power Flow to Customers
- Based on large-scale synchronous generators
- Lots of iron, copper, and aluminum
- Central controls
- Dispatchable generation follows demand
- Passive Customer

The Grid of the Future



Source: EPRI, 2009

Generation Delivery Prosumer

- Two-way Power Flow to and from Customers
- More power electronics
- More communications, data, and information
- Need for cybersecurity and interoperability
- Variable generation is weather dependent

PE **Power Electronics** – Wind, Solar, EV, VSD, Lighting, HVDC, Volt/var controllers

Grid Modernization Vision

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

The future grid provides a critical platform for U.S. prosperity, competitiveness, and innovation in a global clean energy economy. It must deliver ***reliable, affordable,*** *and* ***clean electricity*** *to consumers where they want it, when they want it, how they want it.*

Enhance the Security of the Nation

- Extreme weather
- Cyber threats
- Physical attacks
- Natural disasters
- Fuel and supply diversity
- Aging infrastructure

Sustain Economic Growth and Innovation

- New energy products and services
- Efficient markets
- Reduce barriers for new technologies
- Clean energy jobs

Achieve Public Policy Objectives

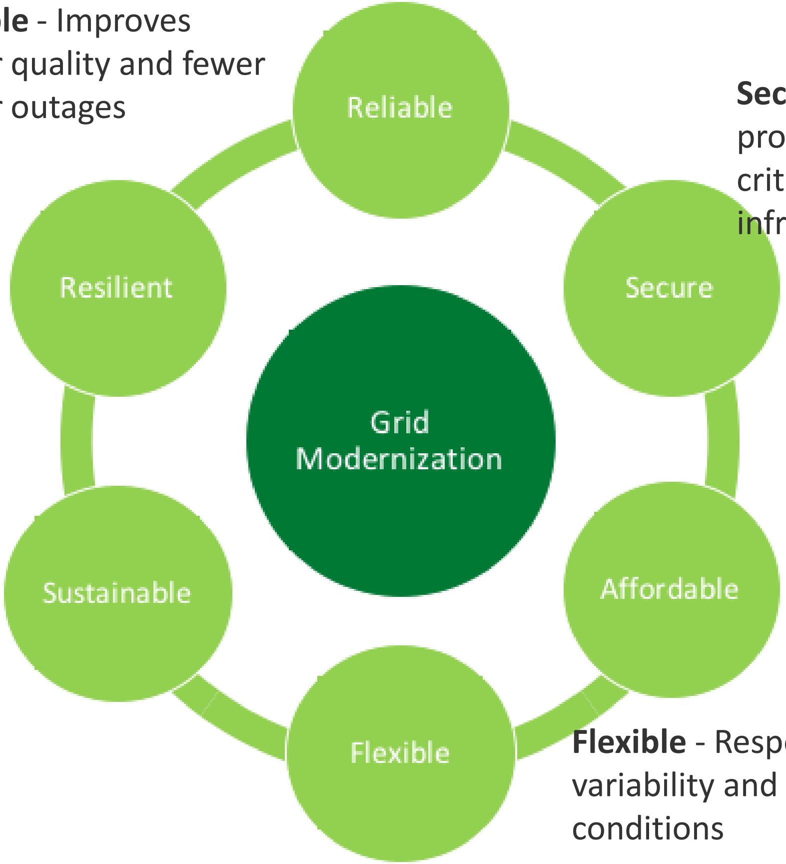
- 80% clean electricity by 2035
- State RPS and EEPS mandates
- Access to reliable, affordable electricity
- Climate adaptation and resilience

Key Future Grid Attributes

Reliable - Improves power quality and fewer power outages

Secure - Increases protection to our critical infrastructure

Resilient - Quick recovery from any situation or power outage



Affordable - Maintains reasonable costs to consumers.

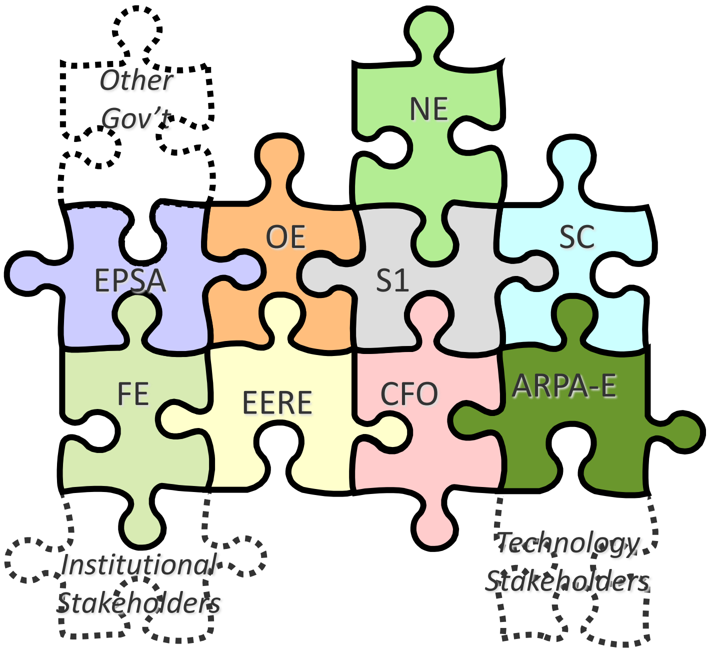
Sustainable - Facilitates broader deployment of clean generation and efficient end use technologies

Flexible - Responds to the variability and uncertainty of conditions

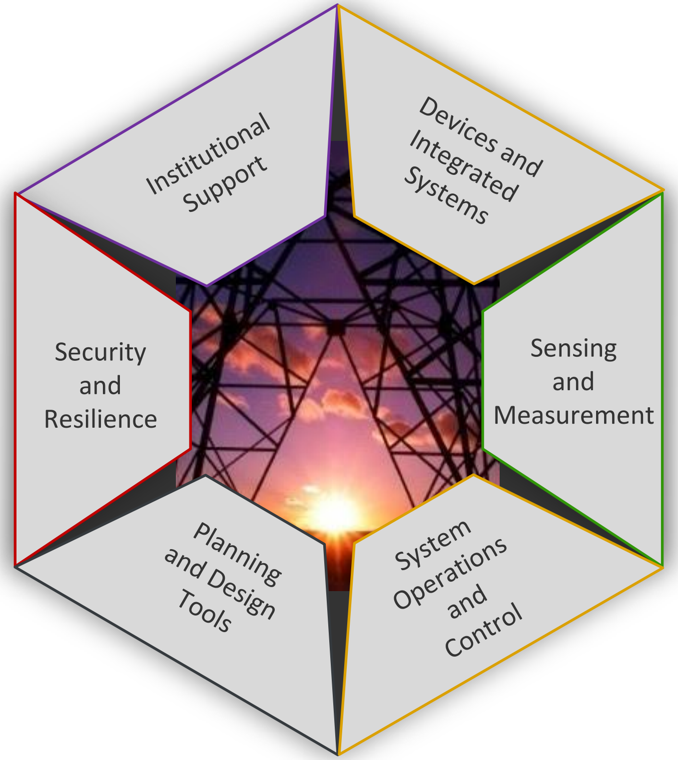
DOE Grid Modernization Initiative

An aggressive five-year grid modernization strategy that includes

- Alignment of the existing base activities among DOE Offices
- An integrated Multi-Year Program Plan (MYPP)
- New activities to fill major gaps in existing base
- Development of a laboratory consortium with core scientific abilities and regional outreach



GMLC - Foundational R&D Activities



Devices and Integrated Systems

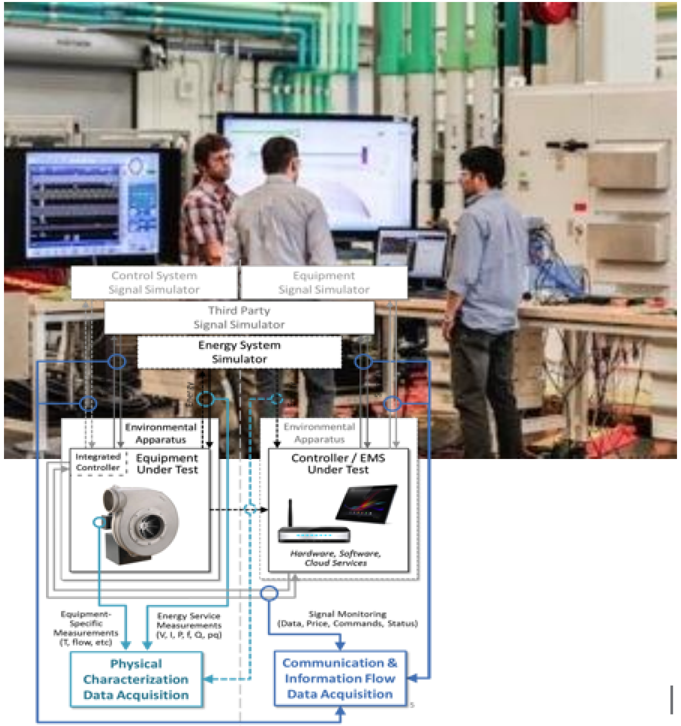
Characterization and testing of energy technologies for providing grid services to improve system affordability, reliability and sustainability

Expected Outcomes

- Develop new grid interface devices to increase ability to provide grid services and utilization
- Coordinate and support the development of interconnection and interoperability test procedures for provision of grid services
- Validate secure and reliability grid operation with high levels of variable generation at multiple scales

Federal Role

- Common approach across labs and industry test-beds for effective validation of emerging technologies
- Develop common interoperability and interconnection standards and test procedures for industry / vendor community



Sensing and Measurement

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Sensor development and deployment strategies to provide complete grid system visibility for resilience and prediction

Expected Outcomes

- Advance and integrate novel, low-cost sensors to provide system visibility
- Incorporate new data streams (e.g. weather
- Develop real-time data management and data exchange frameworks that enable analytics to improve prediction and reduce uncertainty
- Develop next-generation sensors that are accurate through disturbances to enable closed-loop controls and improved syste resilience

Federal Role

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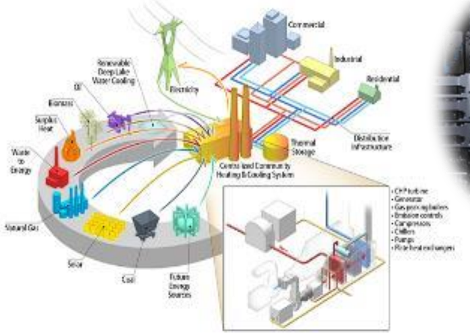


System Operations and Control

Advanced real-time control technologies to enhance the reliability and asset utilization of transmission and distribution systems

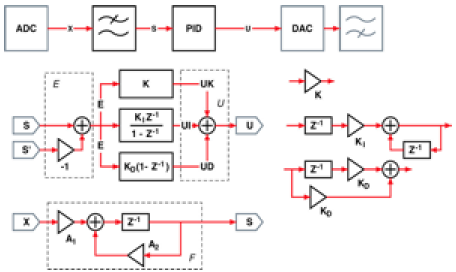
Expected Outcomes

- Deliver an architecture, algorithms, and control frameworks for a clean, resilient and secure grid
- Advanced operations software platform for predictive operations & real-time adaptive control
- New power flow control device hardware and concepts
- Advance fundamental knowledge for new control paradigms

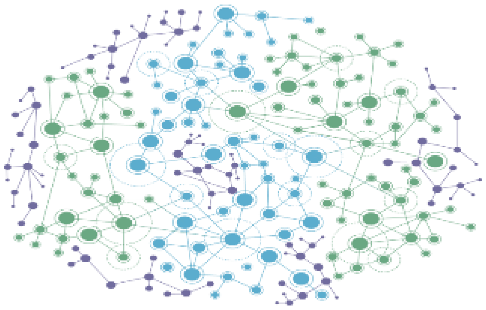
Federal Role

- Convening authority to shape vision of advanced grid architecture
- Advance fundamental knowledge for new control paradigms for emerging grid to support industry transformation
- Deliver computational science, materials science & mathematics from National Laboratories to develop integrated faster-than-real-time software platforms and power electronics control schemes

***Conventional** controls*



***Distributed** controls*



Planning and Design Tools

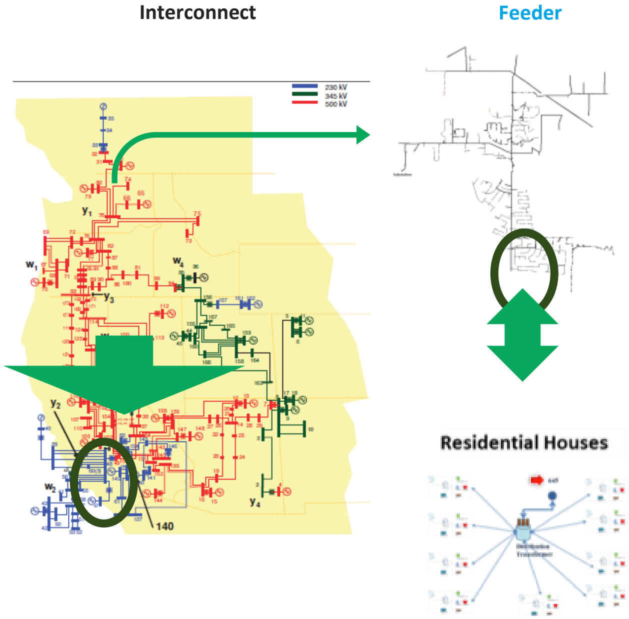
Drive next generation of tools to accurately perform cost-benefit trade-offs and improve reliability of design for deployment new smart grid and renewables

Expected Outcomes

- Incorporate uncertainty and system dynamics into planning tools to accurately capture effects of renewable generation
- Computational tools, methods and libraries that enable 1000x improvements in performance for analysis and design
- Couple grid transmission, distribution, and communications models to understand cross-domain effects

Federal Role

- Apply National Lab advanced computing expertise and capabilities to develop new tools for stakeholder utilization



Security and Resilience

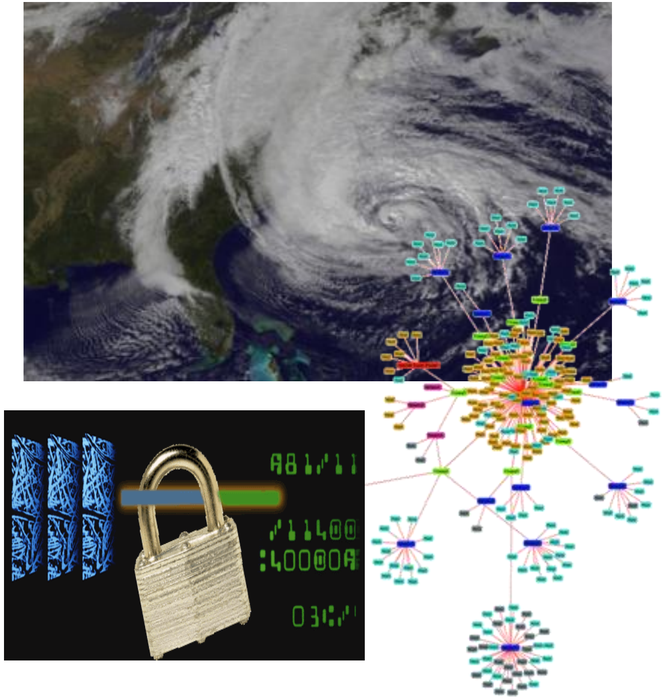
Providing a pathway to comprehensive multi-scale security and resilience for the nation's power grid

Expected Outcomes

- Holistic grid security and resilience, from devices to micro-grids to systems
- Inherent security designed into components and systems, not security as an afterthought
- Security and resilience addressed throughout system lifecycle and covering the spectrum of legacy and emerging technologies

Federal Role

- Lead and establish security and resilience research programs to develop technology solutions and best practice guidance
- Improve adoption of security and resiliency practices, and provide technology-neutral guidance
- Inform stakeholders of emerging threats and help address threats appropriate for government response



Institutional Support

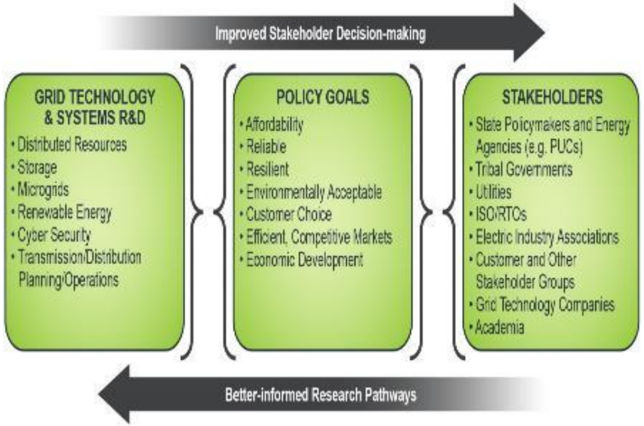
Enable regulators and utility/grid operators to make more informed decisions and reduce risks on key issues that influence the future of the electric grid/power sector

Expected Outcomes

- Accelerated state & federal policy innovation due to enhanced State and Regional technical assistance
- States adopt changes to their regulatory model that better align utility interests with grid modernization and/or clean energy policy goals
- Methods for valuation of DER technologies and services are defined and clearly understood by stakeholders to enable informed decisions on grid investments and operations

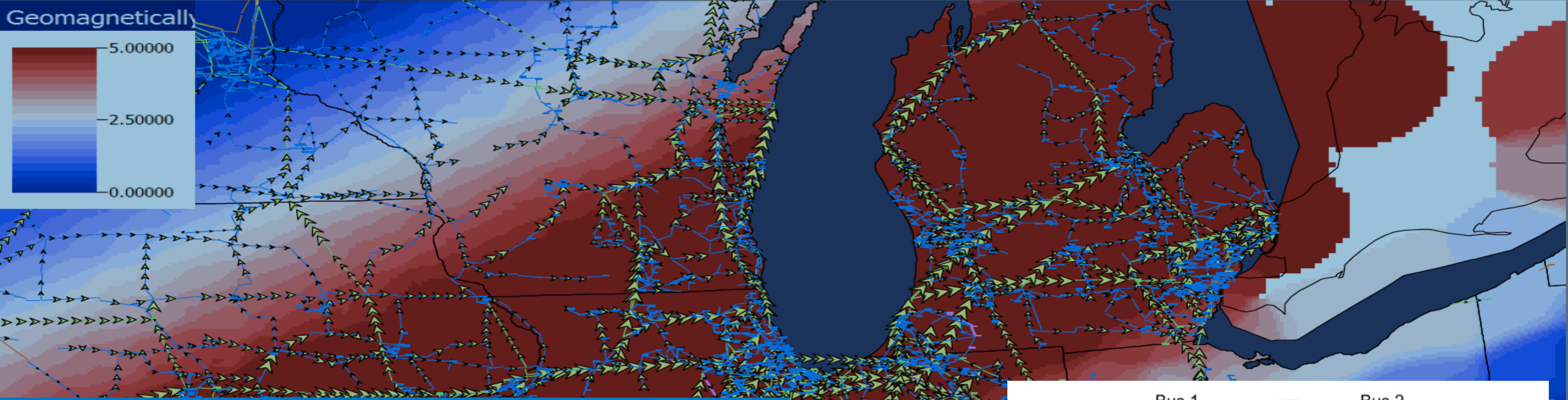
Federal Role

- Provide independent, unbiased technical assistance (e.g., information and analysis tools) that address key grid-related policy, regulatory, and market issues
- Create an over-arching stream of grid-related "institutional" analysis, workshops, and dialogues to raise awareness of the need for grid modernization

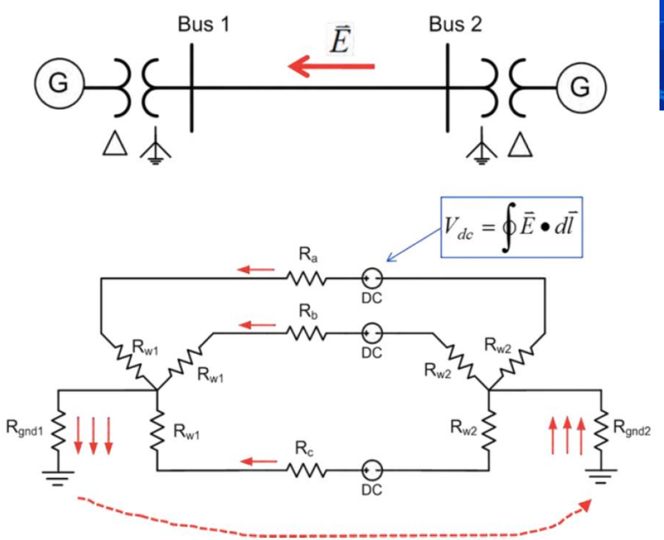


Solar Weather

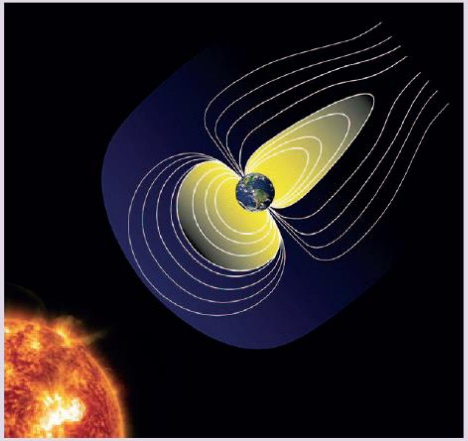
Solar Weather especially coronal mass ejections can significantly impact the power grid



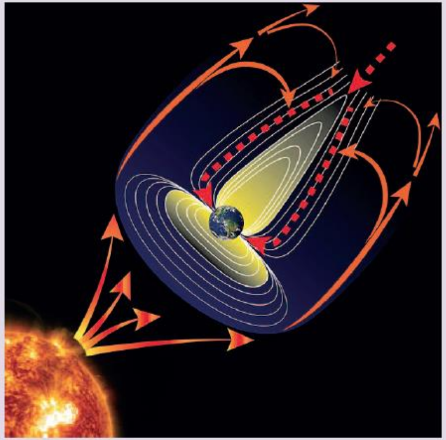
Geomagnetic Disturbances



- Space weather can impact the operations of electrical power systems since it can cause electro-magnetic reactions in the electrical grid and its components.
- Geomagnetic disturbances (GMD) occur when particles discharged from the sun during solar storms interact with the earth's magnetic field. Power systems are vulnerable to geospatial variation in dc voltage caused by GMD.
- Geomagnetically induced currents (GIC) flow through circuits formed by the earth, a grounded transformer, a high-voltage transmission line, and a grounded transformer at the other end of the transmission line. The impact of the GICs on the operation of the power grid is primarily due to the half-cycle saturation they cause in the transformers and large-scale blackout due to voltage collapse.



(a)



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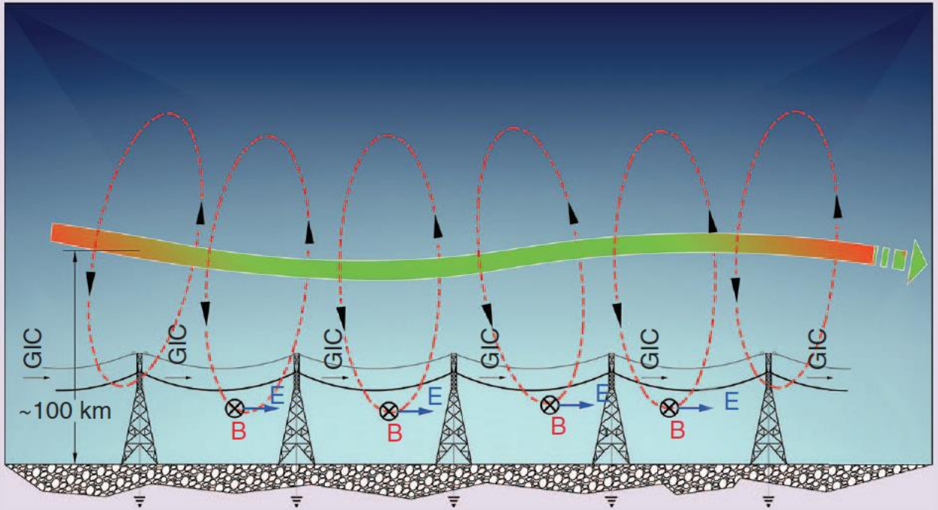


(c)

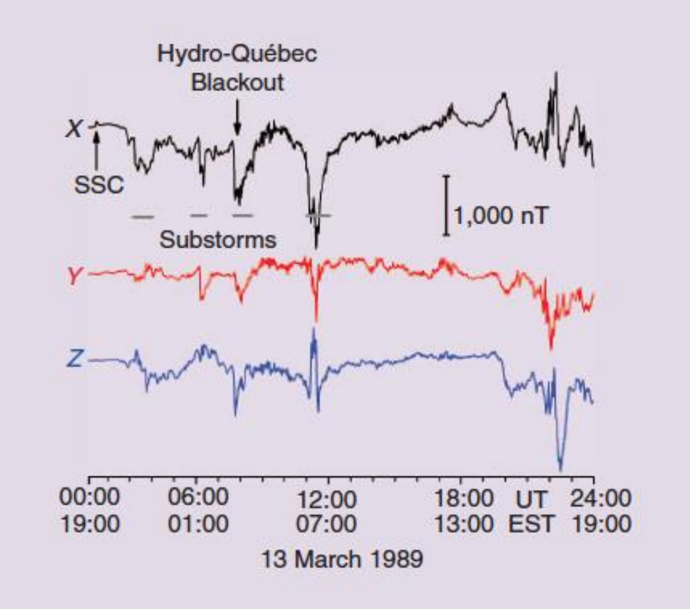
Source: A Colorful Blackout, S. Guillon, P. Toner, L. Gibson, and D. Boteler, IEEE Power and Energy Magazine, Nov/Dec 2016

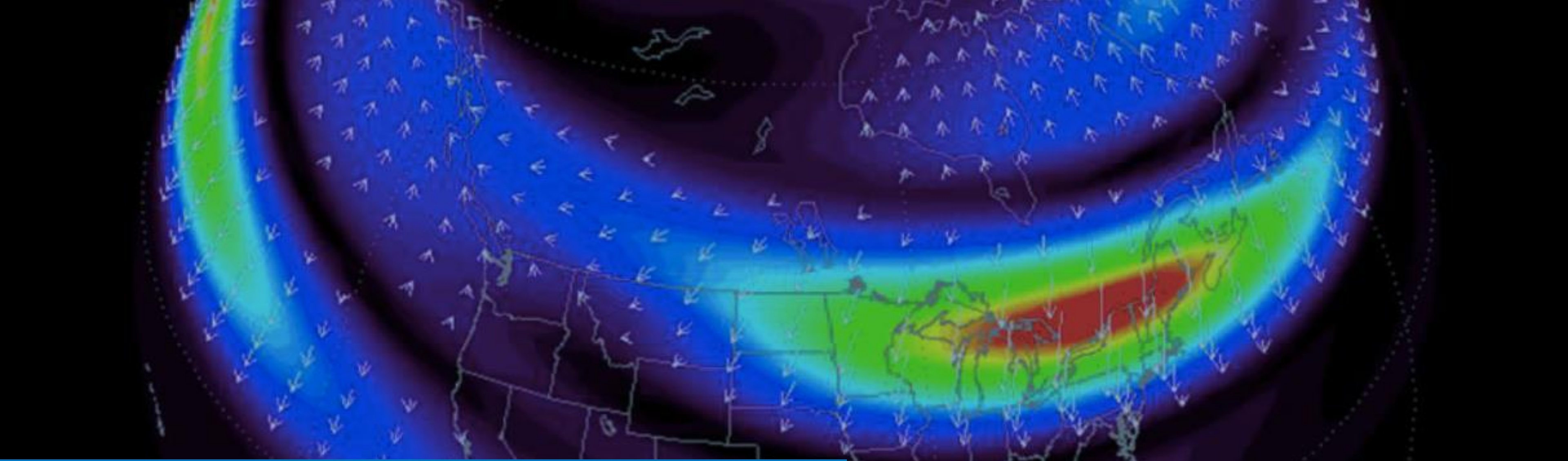
GMD – March 1989

a) Earth's Normal Magetosphere

b) Earth's substorm Magetosphere

c) The geomagnetically induced current in transmission lines



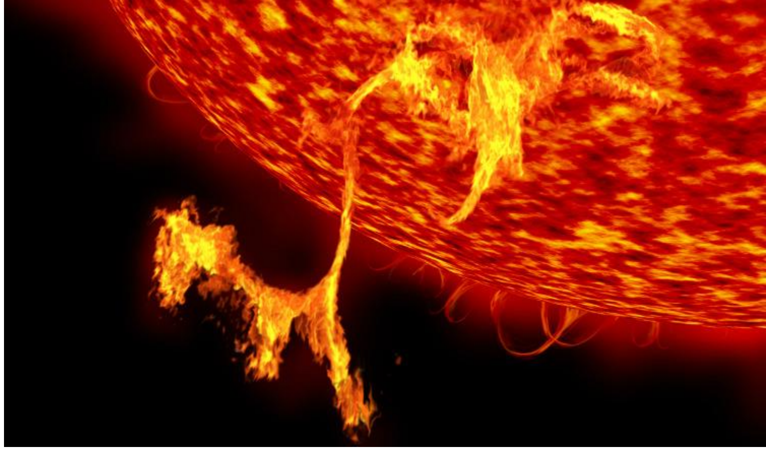


Past GMD Events

- 1859 and 1921 – Very large storms prior to large-scale transmission systems
- March 1989 – Quebec – Caused large-scale Blackout taking 9 hours to restore
- May 1998 – Maine, July 2000 – Oregon, October 2003 – Oregon – smaller storms that did not cause issues
- July 2012 – Near miss – likely to have been the largest GMD in the last 150 years

FERC Orders are in place for Operations Standards and Planning for GMD

Reference Material



DOE Grid Modernization Initiative
https://www.energy.gov/grid-modernization-initiative

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