Power Electronics Systems for the Electric Grid

Ensuring the flexibility, reliability, and resilience of the future grid

U.S. DEPARTMENT OF ENERGY | Electricity Delivery & Energy Reliability

Power Electronics Factsheet

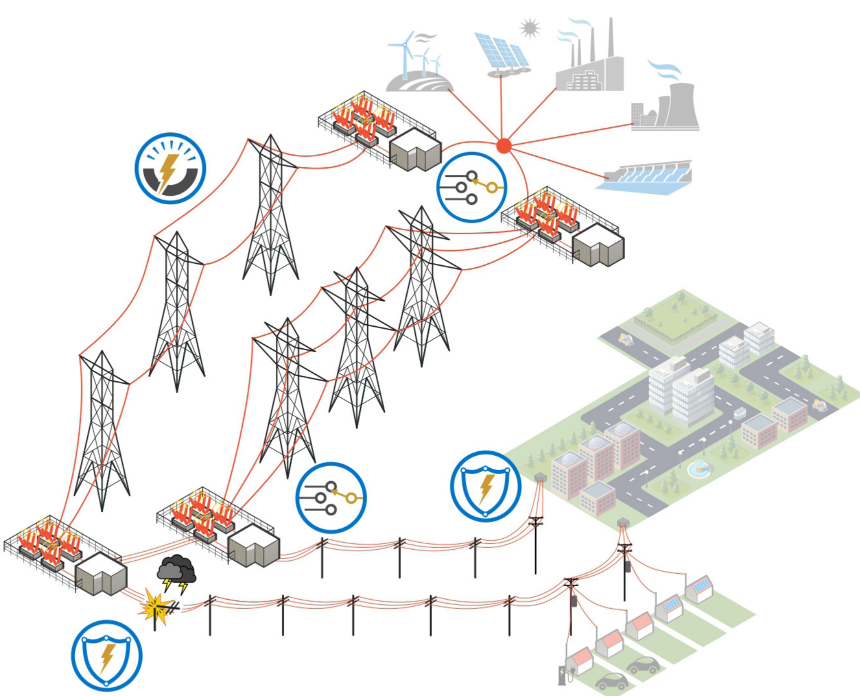
Profound changes affecting the electric power sector offer an unprecedented opportunity to transform the grid. Increasing needs for flexibility, reliability, and resilience in the transmission and distribution (T&D) system require technologies and techniques not conceived of when much of the current infrastructure was deployed. During this period of transition, the deployment of new technologies will play a critical role in shaping the future grid.

Today's electric grid equipment has very limited ability to control, absorb, or reroute power. These critical capabilities can be provided by power electronics systems.

Power electronics systems are one of the key solutions to modernize the electric grid. These advanced technologies—including solid-state transformers, fault current limiters, high-voltage direct current, and power flow controllers—can reduce T&D losses, optimize power delivery, protect critical assets, and enhance resilience. Despite these advantages, large-scale deployment of power electronics systems remains limited because of high costs and insufficient performance levels and technological maturity.

Electric Grid Benefits

- About 6% of the U.S. electricity generated annually is lost in T&D.[1] This is the equivalent of powering all of California for one year!
- Over the last decade, congestion charges ranged from $1 to $2B annually in PJM, one of the largest regional transmission organizations.[2]
- Weather-related outages are estimated to cost the U.S. $25 to $70B annually; in 2012, Superstorm Sandy was estimated to cost $52B.[3]
- ***If power electronics systems could alleviate just 1% of these inefficiencies or costs, it could result in $500M - $1B/year in benefits.*** [4]



Reduce Losses: high voltage direct current systems act as an express lane for delivering electricity. These systems carry large amounts of power over long distances more efficiently, including clean electricity produced at wind and solar facilities that are located far from major load centers.

Optimize Delivery: power flow control systems act as routers to smartly direct where electricity goes. These systems relieve grid congestion, deferring expensive investments, and can reroute power to serve critical loads during an outage.

Protect Assets: fault current limiter systems act as surge protectors for the electric grid. These systems absorb excess power caused by lightning strikes or abnormal events that can damage expensive assets, minimizing the risk of failure, and accelerating power restoration to homes and businesses.

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[1] U.S. Energy Information Administration (EIA). "Frequently Asked Questions." Last updated May 7. Accessed October 29, 2014.

[2] Market Monitoring Analytics, LLC. "2012 Quarterly State of the Market Report for PJM: January through March".

[3] Congressional Research Service. "Weather-Related Power Outages and Electric System Resiliency" August 28, 2012.

[4] Office of Electricity Delivery and Energy Reliability estimate based on conservative assumption of T&D losses, weather related outages, and congestion charges. (2015)

DOE Role

Semiconductor switches provide the core functionality of today's power electronics systems and can comprise 50% of the cost. Silicon-based power electronics systems will be increasingly challenged to cost-effectively meet the new capabilities and growing performance demands of future grid applications, limiting deployment. Next-generation power electronics systems based on advanced materials, such as wide bandgap semiconductors, allow for new designs and capabilities that can dramatically shift the cost-performance curves.

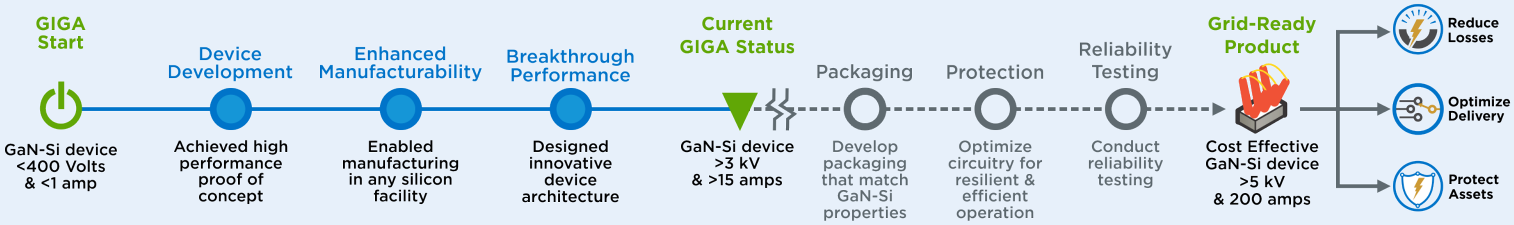
> Next-generation systems require significant cost reductions and improved performance

The U.S. Department of Energy's (DOE) Office of Electricity Delivery and Energy Reliability (OE) spearheads efforts to develop and deploy next-generation power electronics systems for the future grid. OE power electronics research and development focuses on the unique challenges of the grid (high power, high reliability, and high consequence) and leverages other efforts across the DOE to help bridge the gap between discovery and commercialization.

GIGA is Laying the Foundation for Low-Cost, High-Performance Systems

Gallium nitride (GaN), a wide bandgap semiconductor that can operate at higher temperatures and voltages than silicon, is better suited to the demands of the grid. OE's Gallium Nitride Initiative for Grid Applications (GIGA) combines GaN's enhanced material properties with the low-cost, high-volume manufacturability of silicon (Si), to support advanced power electronics systems. GIGA builds on commercial GaN-Si developments (which employ lower power levels) by leveraging effective public-private collaborations to achieve significant milestones. These milestones include:

- Demonstrated GaN-Si is a viable technology for high power applications (>1.2 kV)
- Catalyzed a low-cost domestic supply of high-quality 200 mm GaN-Si wafers
- Developed world record GaN-Si diodes and transistors (>3 kV and >15 A)
- 75+ publications in various technical journals and magazines



GIGA Partners

Massachusetts Institute of Technology | MIT Lincoln Laboratory | IQE | Oak Ridge National Laboratory | Sandia National Laboratories | MACOM Partners from RF to Light

To realize opportunities for improving the T&D system, OE is pursuing a portfolio of activities to address the challenges of next-generation power electronics systems including:

- **Modeling, simulation, and testing** to improve the understanding of device designs and system performance
- **Applied materials research and innovation** to improve fundamental properties and capabilities needed for grid applications
- **Systems engineering, design, and development** to improve reliability, manufacturability, and costs
- **Market and power system impact analysis** to assess deployment opportunities and evaluate societal benefits

OE is looking to engage in public-private partnerships to build on program successes, deliver grid-ready products, and demonstrate advanced applications.

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