

Challenges in Integrating Renewable Sources into the Electric Power Grid: A Power Electronics Perspective

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Topics

- Overview of renewable energy
- Motivation of grid integration
- Functional role of power electronics
- The challenges
- Summary

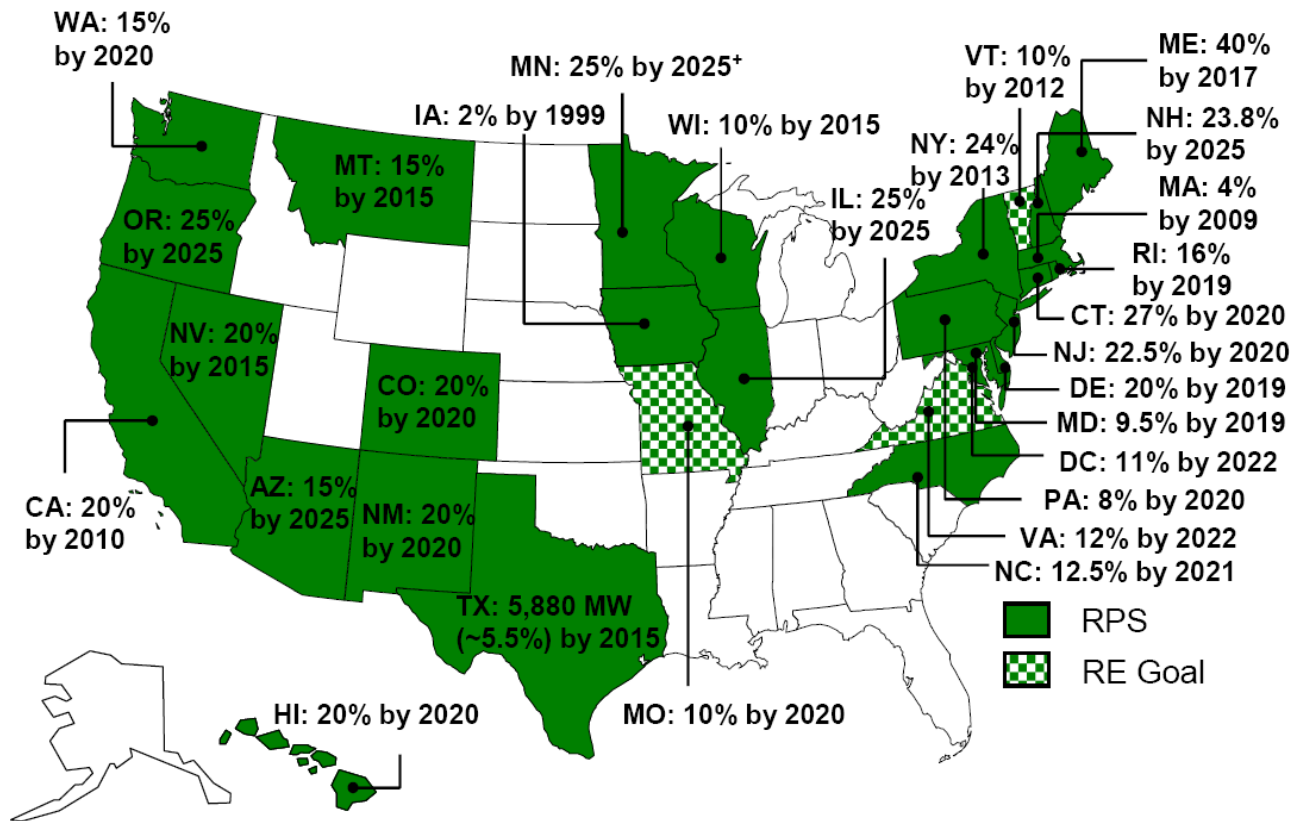
Renewable vs. Sustainable Energy

- Renewable energy
 - is regenerative or virtually inexhaustible.
Focused on supply side.
- Sustainable energy
 - can be replenished at a rate higher than consumption and the waste stream can be naturally absorbed at a rate higher than injection. Focused on supply and use sides.

Renewable Energy Sources

- Renewable energy sources include
 - Solar
 - Wind
 - Biomass
 - Hydro
 - Geothermal
 - Tidal
- Wind and solar enjoy very fast growth rate

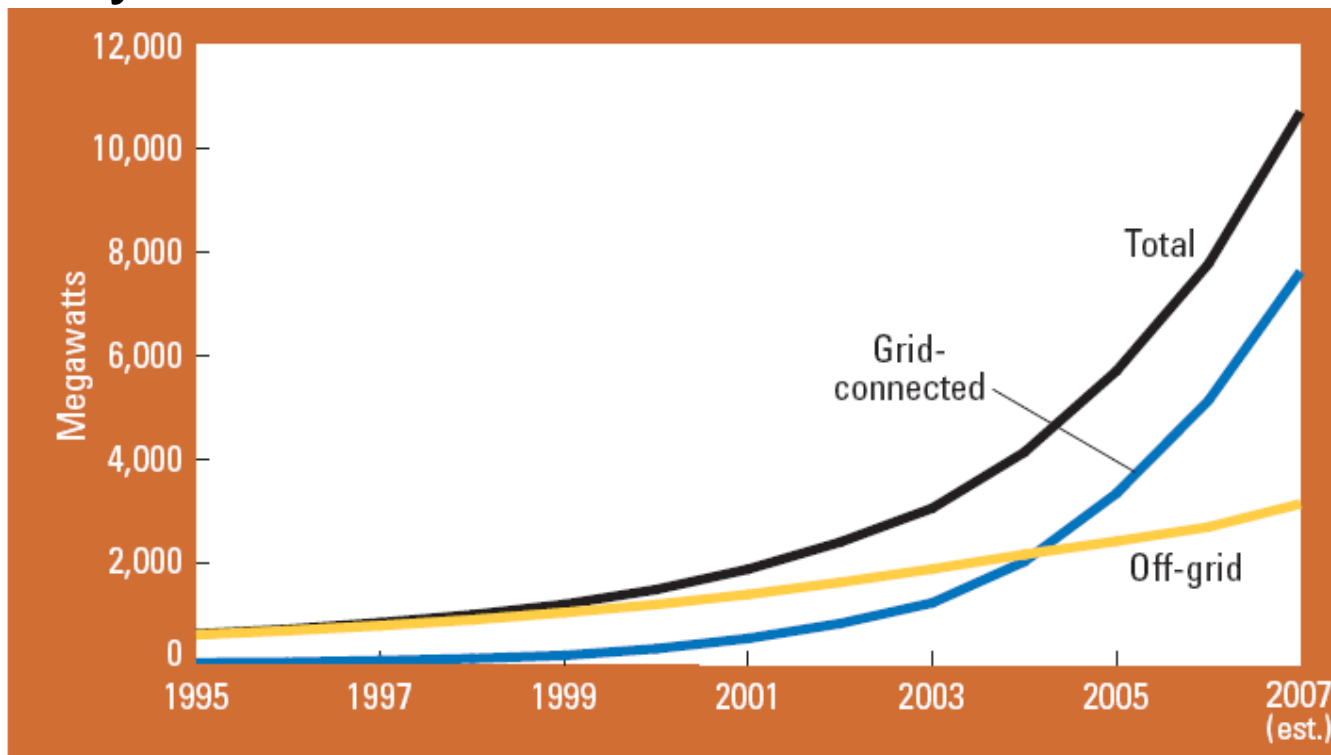
Renewable Portfolio Standards



Source: K.S. Cory and B.G. Swezey, "Renewable Portfolio Standards in the States: Balancing Goals and Implementation Strategies," NREL/TP-670-41409, 2007.

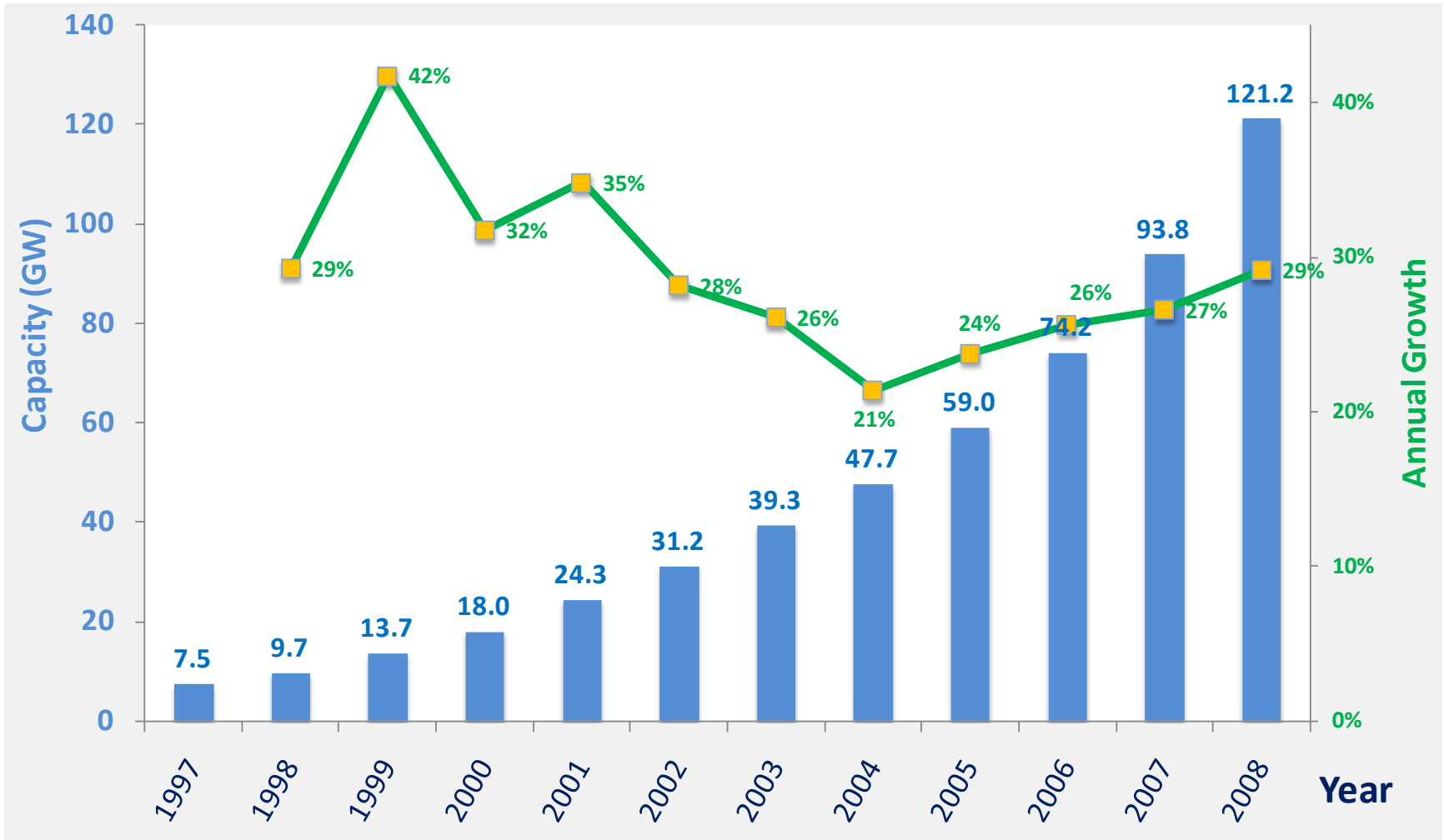
World PV Installation

- Accumulated PV installed capacity reached 10.5 GW by the end of 2007.



Source: *Renewables 2007 Global Status Report*, www.ren21.net.

Wind Installations Worldwide

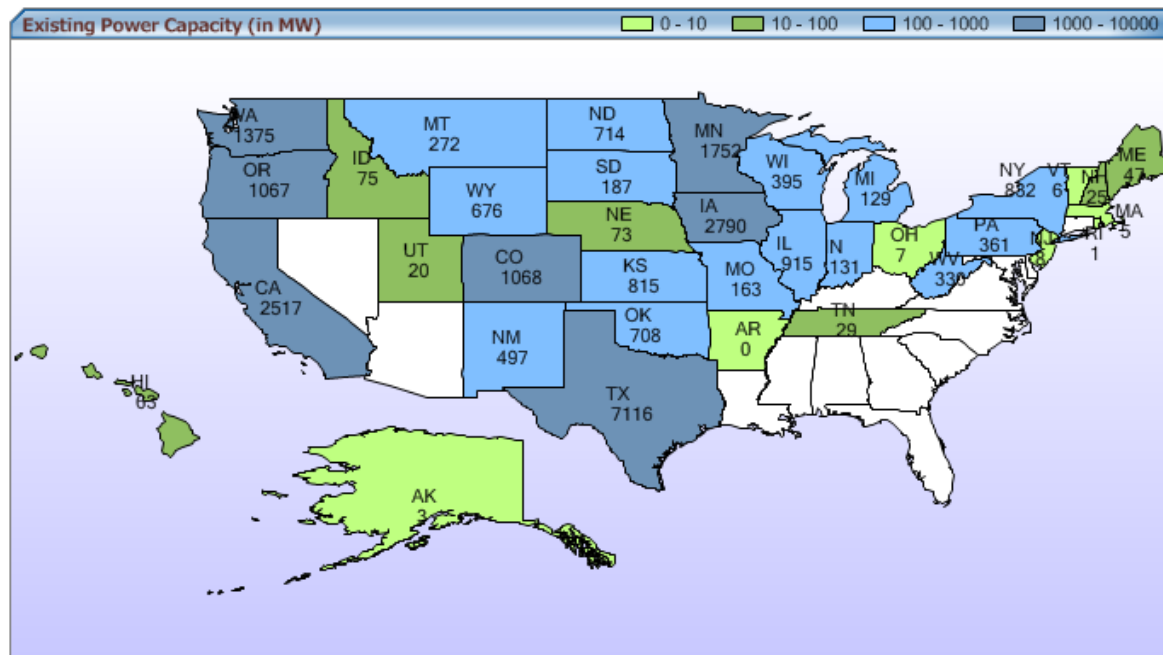


Data from "World Wind Energy Report 2008"

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Wind Power Capacity in U.S.

- Installed wind capacity in U.S. reached 25 GW by the end of 2008.



Source: American Wind Energy Association

Renewable Energy Conversion

- Converted to electricity
 - and delivered using the power system infrastructure
 - or consumed locally
- Converted to fuel
 - and delivered through conventional infrastructure

Why Grid Integration

- Necessity
 - Geographic locations of sources may not match the locations of load centers (particularly true for wind resources)
- For performance / economics
 - Integration provides ways to manage resource output variability
 - Economically advantageous
 - Regulation

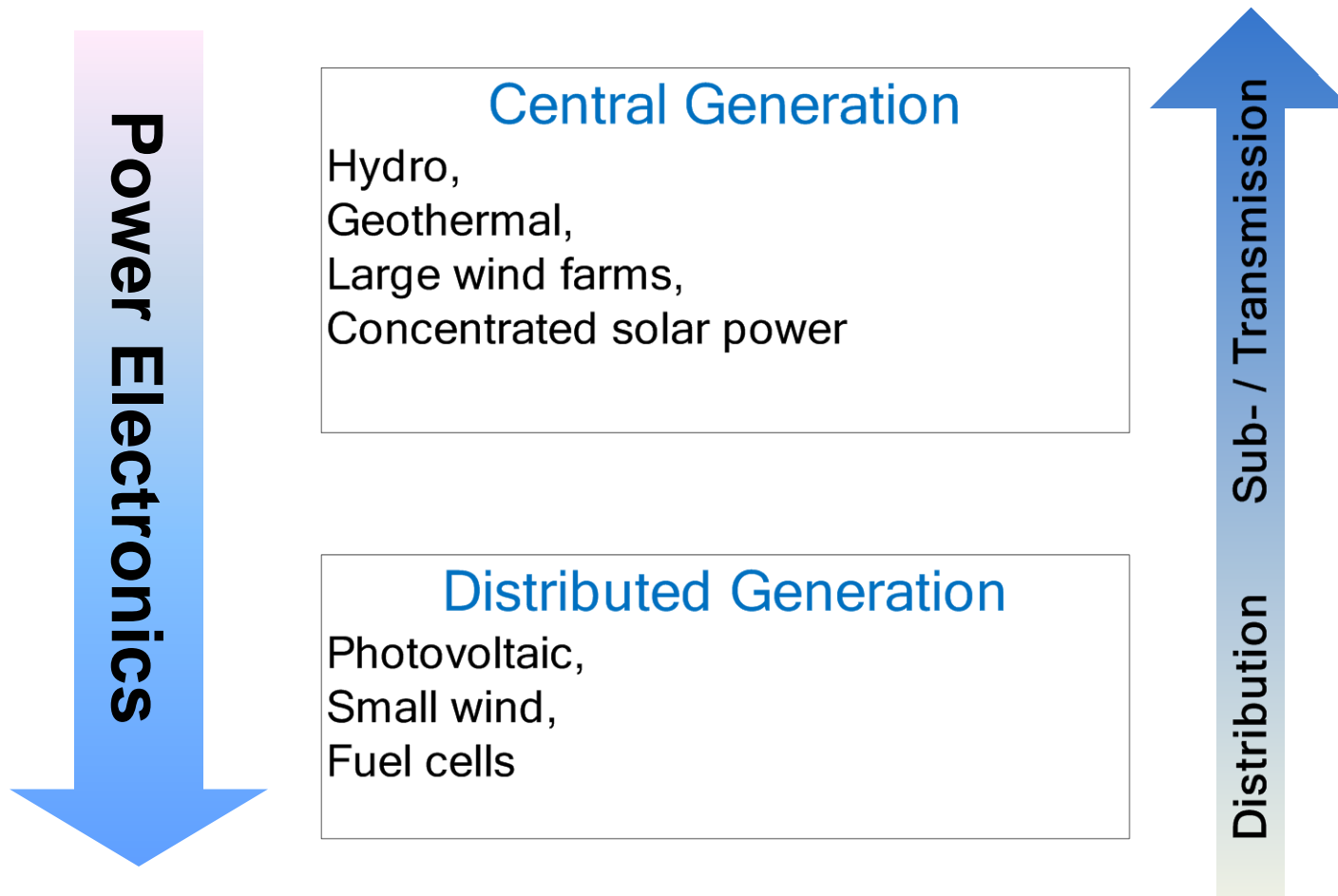
Integration Involves

- Technical aspects
 - Physical layer
 - Information layer
- Market and economics
- Policy and regulation
- ...

Power Electronics for Electric Power Applications

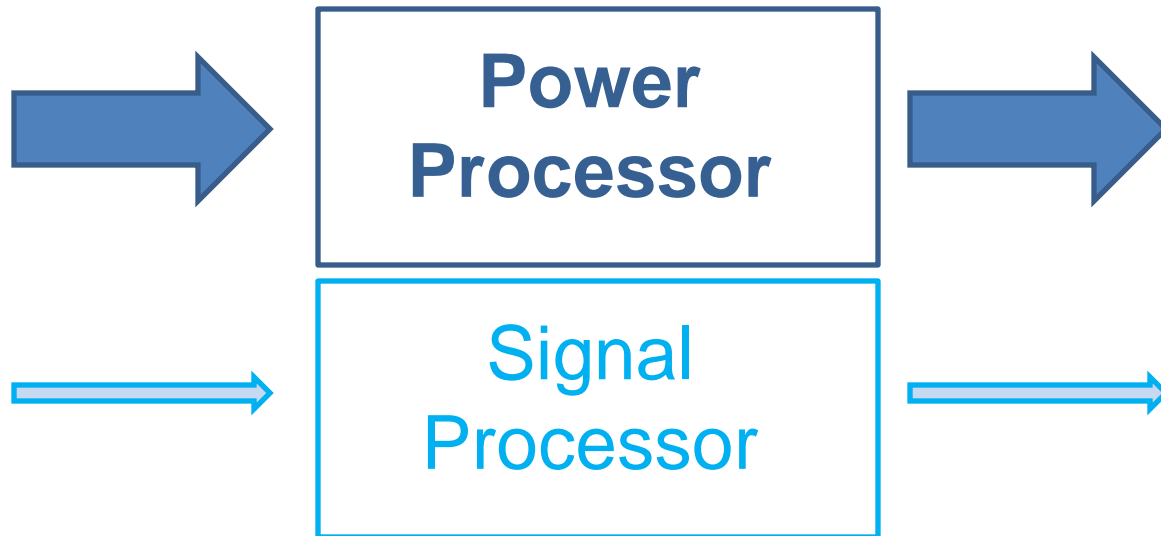


Interconnection Levels



Power Electronics

- Electronics for processing power rather than just for processing signal information.
- Power flows and signal flows co-exist in a power electronics system.

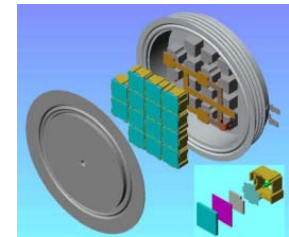
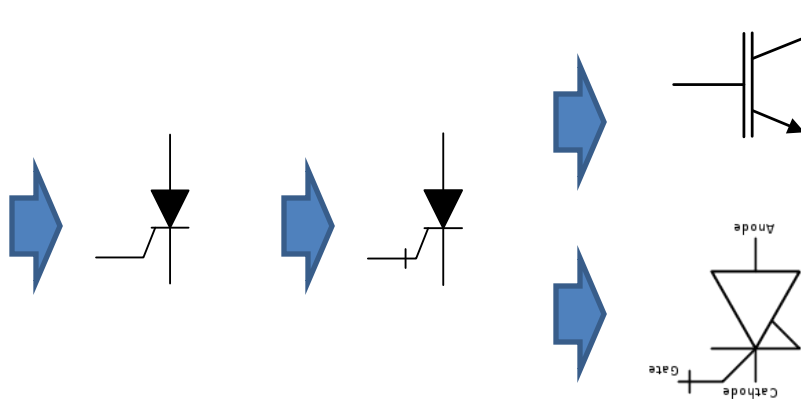


Application of Power Electronics is Evolving

- Power devices drive the power flow path



Mercury Arc Valve



Press pack IGBT



IGBT

- Signal processors drive the information flow path

State of the Art in High Power Conversion

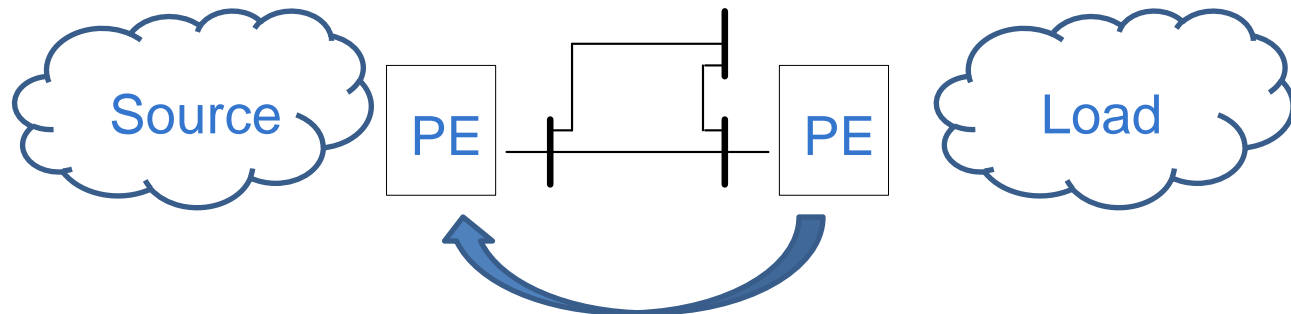
- In electric drives, power throughput of matured single power converter has reached 10 MW.
- These high power converters switch at approximate frequency of 1 kHz.
- They operate at medium voltage 3.3 – 6.9 kV.
- Modular scaling up to 30-100 MW which covers majority of renewable interface.

Role of Power Electronics in Integrating Renewable Energy Sources



Functional Role Change

- Power electronics has been traditionally used to interface the power system with loads (such as motors).
- Power electronics will be broadly used to interface sources and with the power system.



Higher PE Penetration

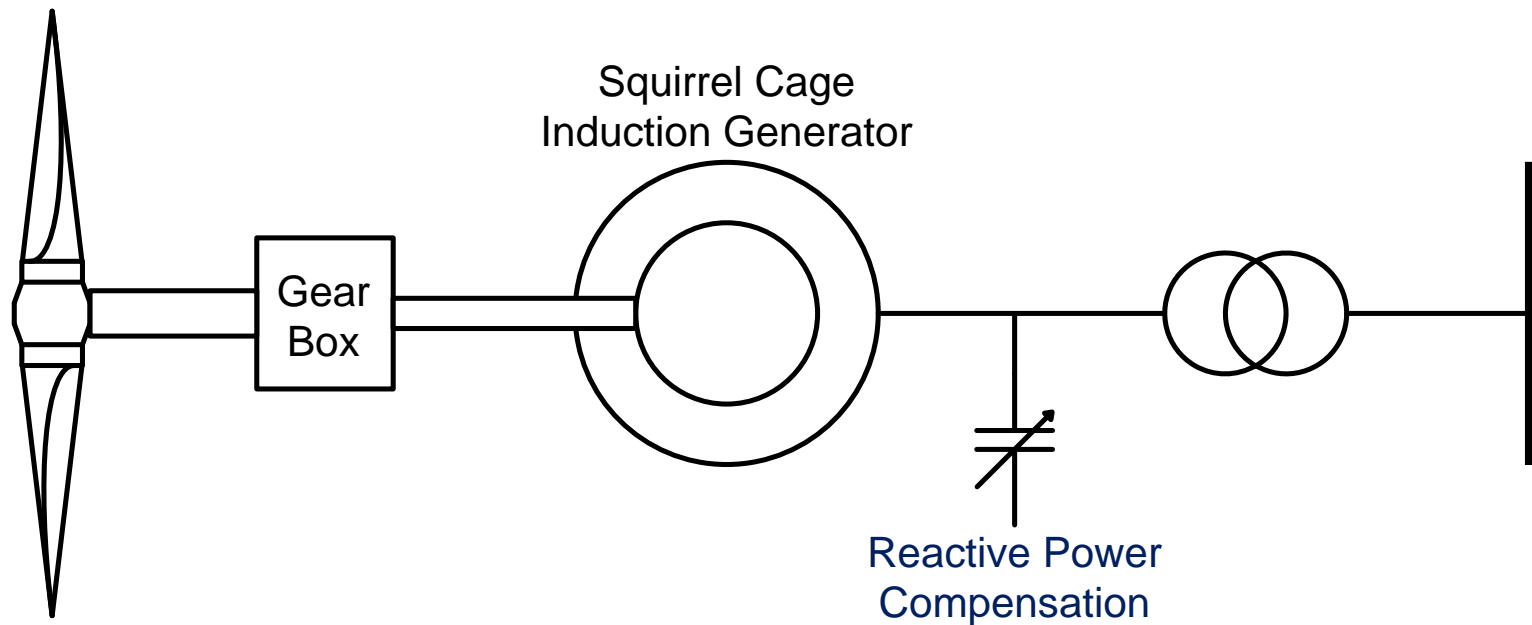
- Higher penetration of power electronics can be expected as use of renewables grows. Power electronics will be used for:
 - Grid interface
 - Energy storage
 - Power flow management



Power Electronics

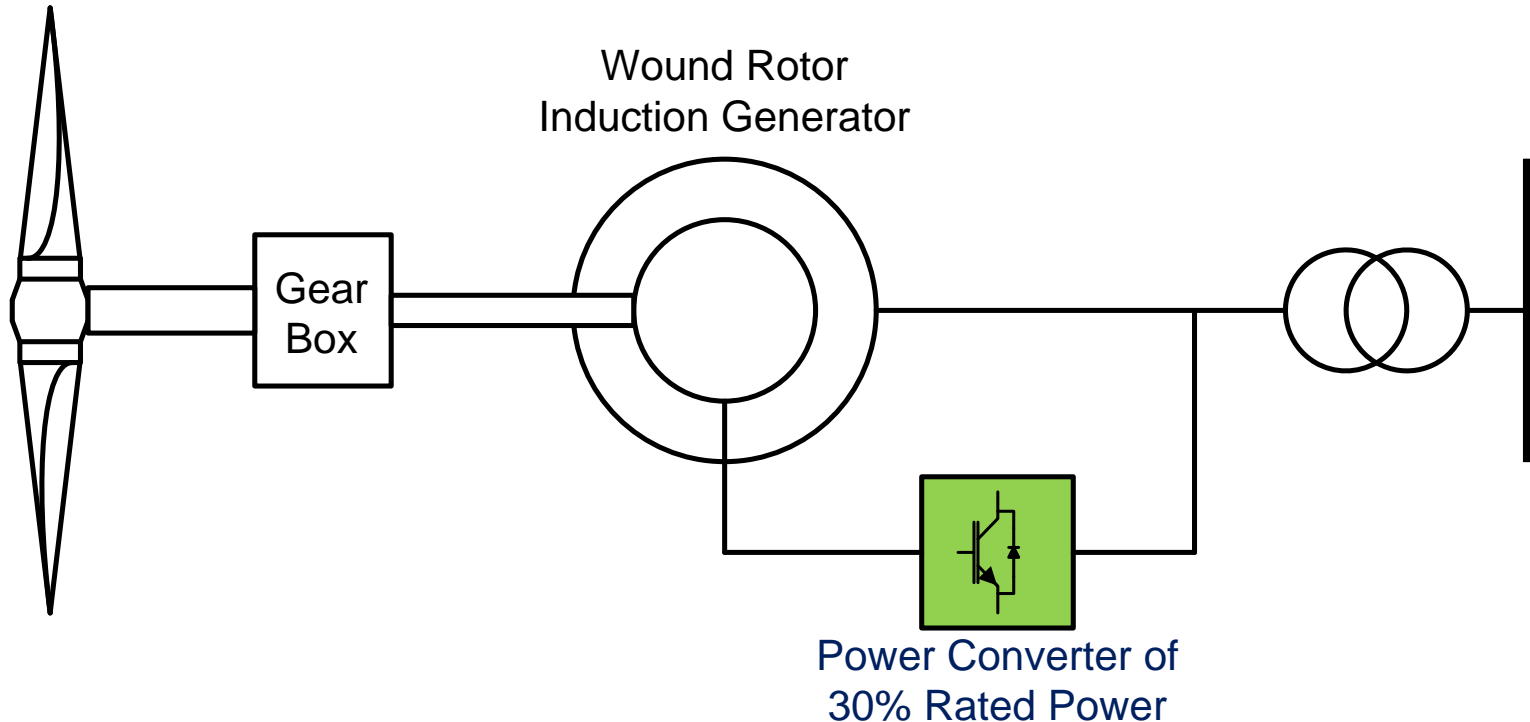
Wind Generation System - Yesterday

- In “Danish concept” wind generation systems, no power electronics is utilized.



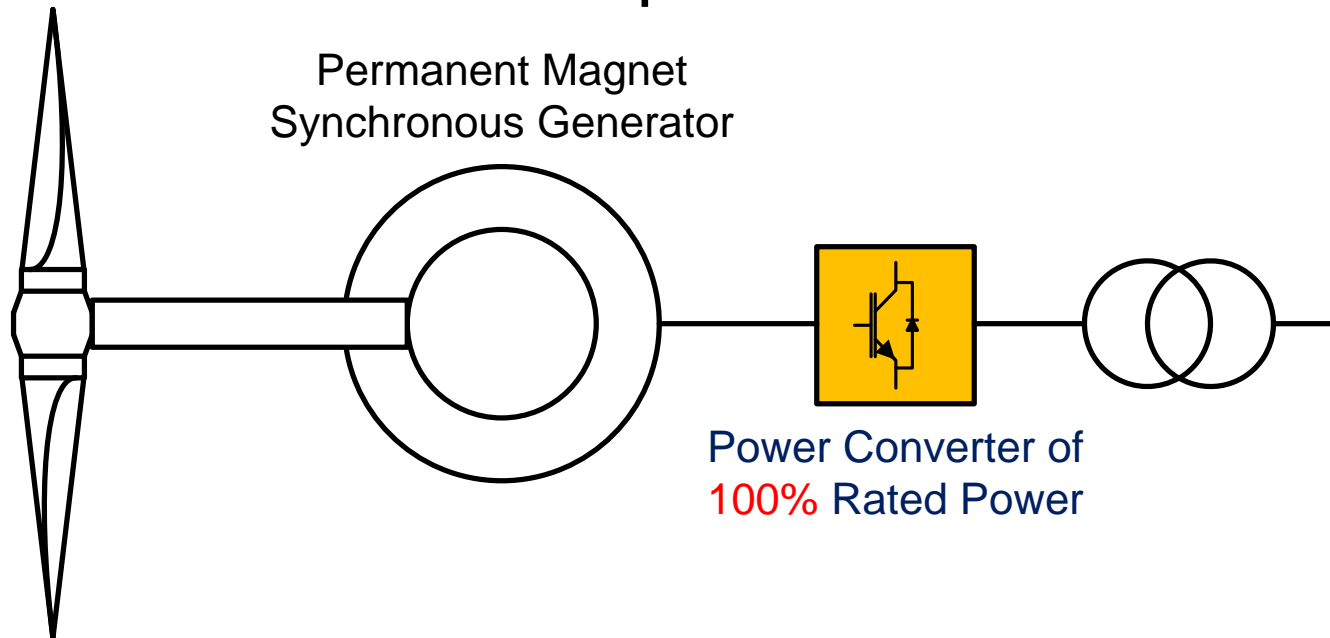
Wind Generation System - Today

- In wind generation systems equipped with DFIG, power converter handles about 30% power flow.



Wind Generation System - Tomorrow

- In the expected large wind generation systems (> 5 MW) that utilize PM generators, power converter handles full power.



Energy Storage

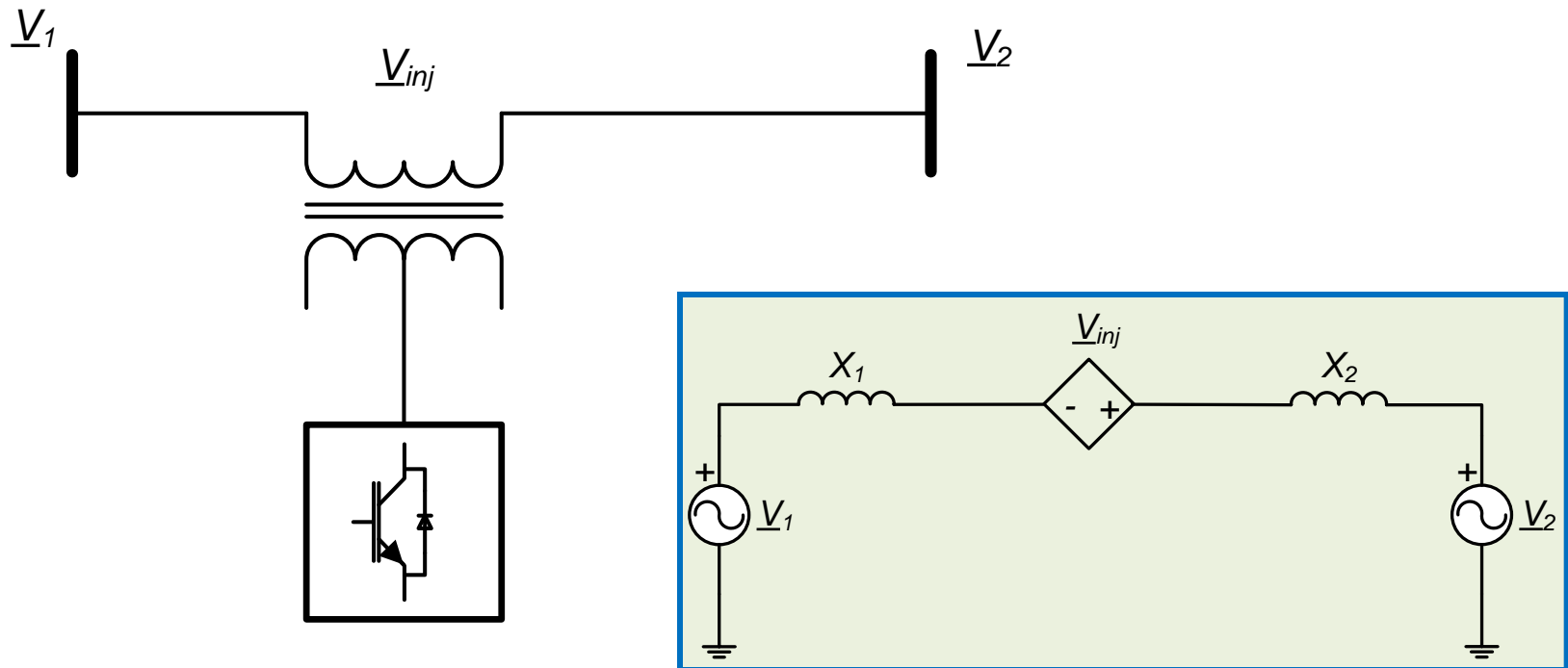
- Energy storage is one of the options to deal with variability of renewable sources.
 - Pumped hydro
 - Compressed air
 - Supercapacitor
 - Flywheel
 - PHEV
- Majority of the energy storage technologies involve power electronics

FACTS Devices and Integration

- FACTS devices will become more important at transmission level because of increased power flow traffic resulting from variability of renewable sources.
- Even at distribution levels, power flow control will become necessary as the radial distribution system is shifted to a meshed system.

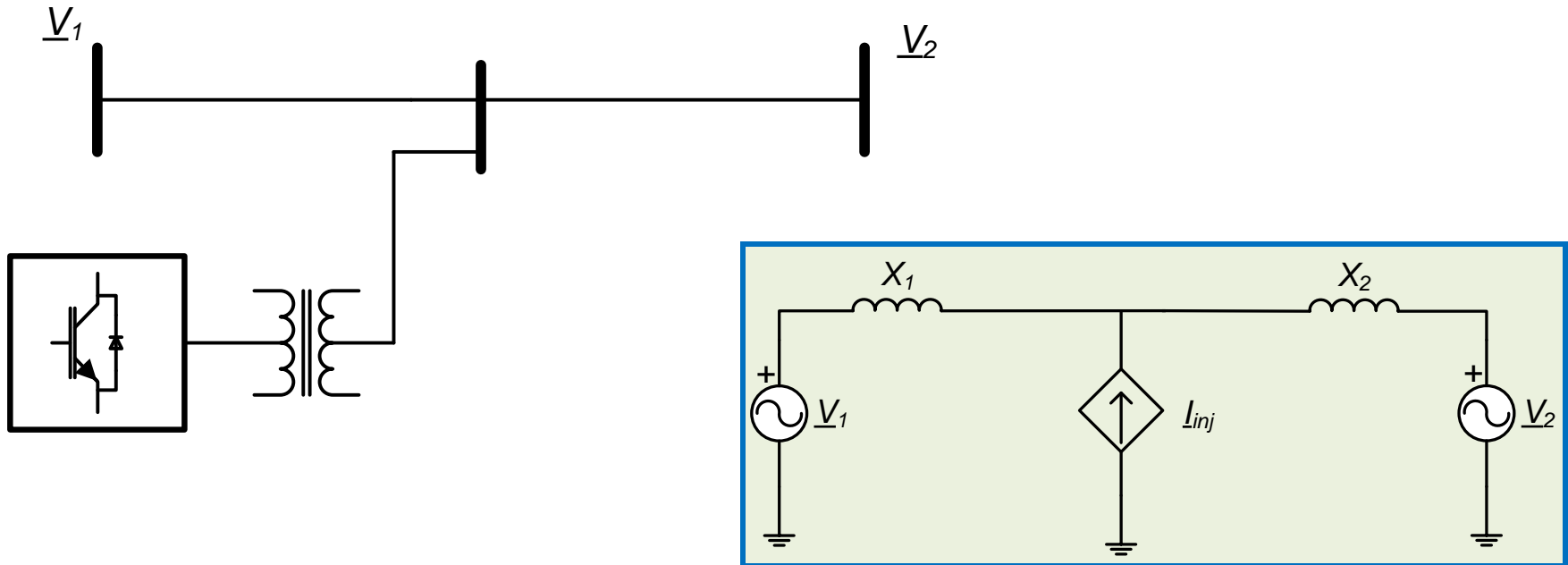
Series FACTS Device

- Power flow controller



Shunt FACTS Device

- Reactive power compensation



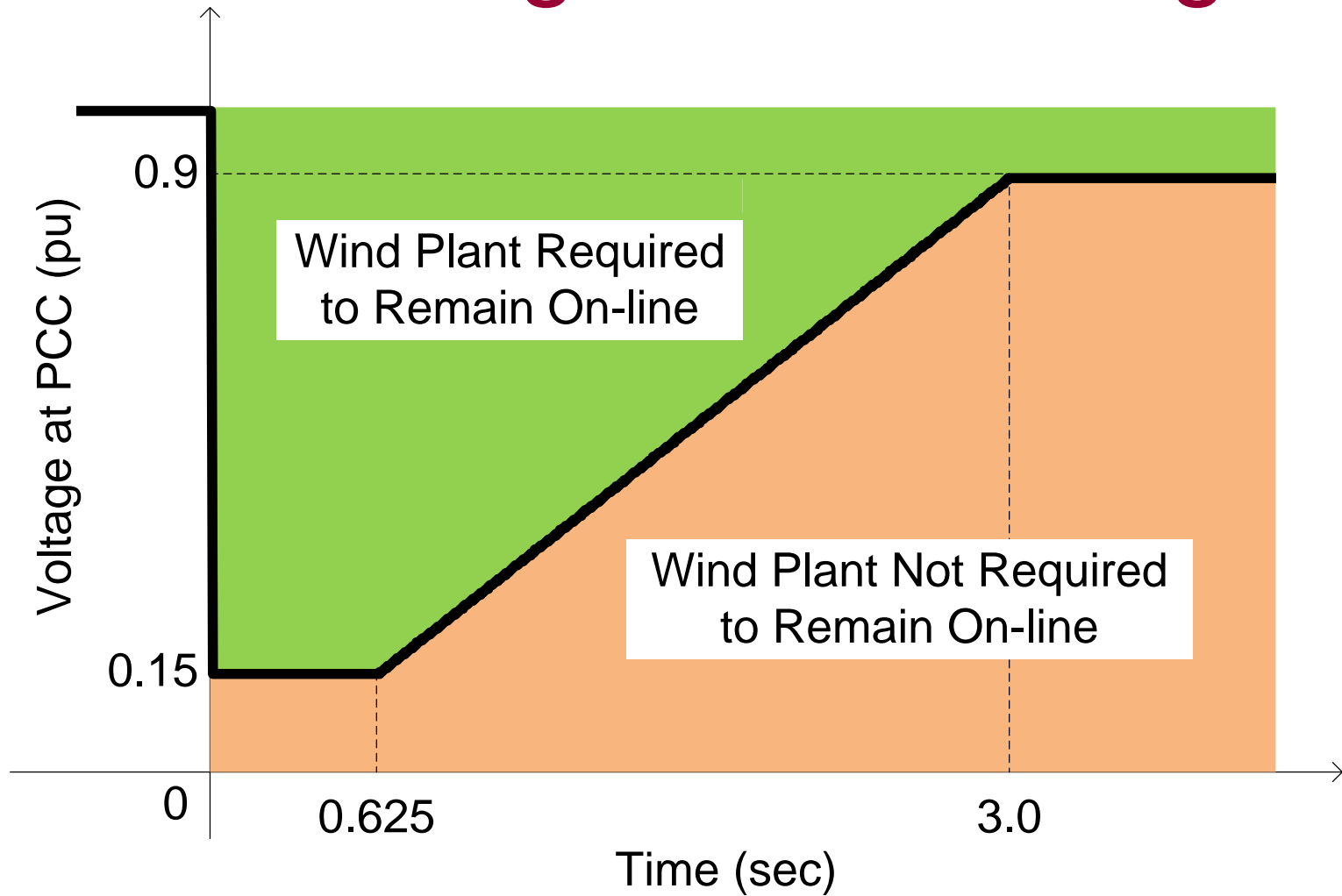
Adding Value with Power Electronics

- Voltage support by reactive power generated by power electronics
- Ramp up and down quickly
- Improve power quality
- Control of a large number of sources centrally
- Low voltage ride-through

Evolution of Standards

- Larger grid support requirement is expected from renewable sources as reach higher penetration levels.
- One of the evolution examples is the low voltage ride through for wind power generation systems.

Low Voltage Ride Through



Communications and Control

- Power electronics needs augmented communication capability to use smart grid features.
- Control in microgrids will rely heavily on power electronics.

Technical Challenges

- New design perspective from downstream to upstream in power flow chain
- Interactions among much larger number of distributed resources with power electronic converters
- Integrated design in high power areas
- Standardized design to improve interoperability

Non-Technical Challenges

- Assessing the economic value of power electronics solutions
 - Cost reduction challenging today due to non-standardized designs
 - Inclusion of lifecycle operating costs
 - Quantification of indirect benefits such as GHG reduction
- Less operational experience as compared to conventional power generation sources

Myths That Need to be Dispelled!

- System “polluter” – harmonics?
- Complex failure modes?

Summary

- Integration challenges must be addressed given anticipated growth penetration of renewable sources.
- Renewable energy integration will be enabled by power electronics.
- The new operating regime and design space present challenges for the needed use of power electronics.