QUANTA TECHNOLOGY

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High-power Electronics and Transmission Systems

An efficient and reliable transfer of electrical energy over long distances and across different parts of the electrical grid.

Reducing congestion and expanding opportunities for trade: value of transmission correlated with energy prices.

Reliable and resilient:

- Redundancy, outage N-k (k=0, 1, …)
- Flexibility during abnormal conditions.

Diverse energy resources: conventional, renewables, storage.

Generation to major load centers.

Power Transmission System Needs

High-power Electronics

HVDC systems:

- **Point-to-point:** mercury-arc → thyristor → turn-off devices, IGBT, IGCT
  - Efficient long-distance transmission, different frequencies, grid interconnection B2B
- **Multi-terminal super grids:** lack of current zero-crossing → HVDC circuit breaker → turn-off devices
- **Renewable integration:** offshore wind farms.

Reactive power and FACTS:

- **Voltage control, sags and swells, flicker, harmonics**
- **Power flow control:** controllable impedance, TCSC, UPFC
- **Stability enhancement:** increased transmission capacity for a short time, SSR damping.

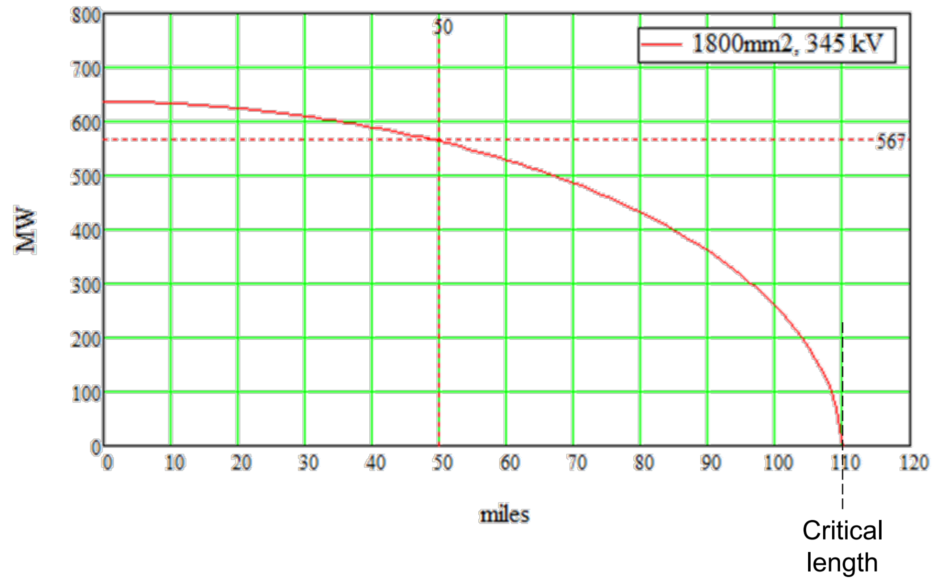
High-power electronics have been a flexibility enabler in transmission systems.

HVDC Cable Applications

- **Integration of OSW to the onshore grid.**
  - AC cables charging current reduces its capacity. DC cable has no critical length.

- **Overhead transmission with a river crossing.**
- **Scarce ROW and permitting.**
- **Eliminate resilience challenges including fire hazards.**

- **MI and lately XPLE for VSC applications.**
  - 100s km long and over 1.6 km depth (submarine).



OSW Application: HVDC Benefits vs. AC Transmission

Efficiency over long distance

HVDC is more effective at minimizing energy losses due to resistance. This means a greater proportion of the electricity generated offshore reaches its destination onshore.

Reduced energy losses

In AC transmission, energy losses occur due to the skin effect and dielectric losses. HVDC transmission does not suffer from these issues to the same extent.

Better voltage stability

HVDC systems are better at maintaining voltage stability over long distances and under varying load conditions. AC systems can experience voltage drops and instability when transmitting power over extended submarine cable lengths, which can affect the reliability of the grid.

Environmental impacts

Lower energy losses in HVDC transmission result in less wasted energy. This is particularly important for OSW, where maximizing the amount of electricity delivered to shore is crucial for economic and environmental reasons. Reduced losses also mean less heat generation, which can be important in sensitive marine environments.

Grid integration

HVDC systems offer precise control over power flow. This control is vital when managing variable power generation from offshore renewables. It enables operators to adjust the amount of electricity transmitted to match supply and demand, enhancing grid stability.

Reduced electromagnetic interference

HVDC generates less electromagnetic interference compared to AC transmission. In underwater environments, this is crucial because excessive interference can disrupt communication systems and potentially harm marine life.

Interconnection of islands

HVDC is often used to connect islands with mainland grids. This enhances the reliability of the island's power supply and supports the integration of renewable energy sources, which are often abundant on islands.

Scalability

HVDC systems are highly scalable. As offshore renewable energy installations grow and power demands increase, HVDC technology can easily accommodate higher power levels without significant losses or grid instability.

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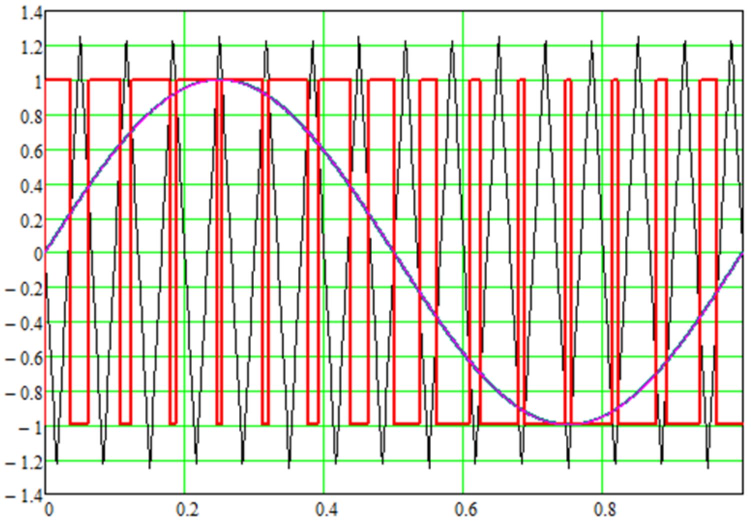

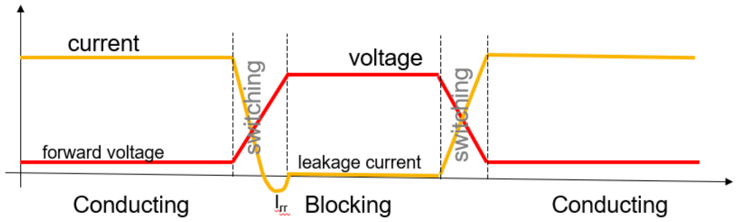

Application to transmission is mainly focused on inverter technology:

- Thyristor-based converters, no turn-off capability – one degree of freedom
- Turn-off-based converters – two degrees of freedom
- Two-level, three-level: neutral-point clamped, flying capacitor
  - ANPC: 150 kV, 330 MW
- Pulse-width modulation, high-frequency switching, losses
- Modular multi-level converter: # of modules → # of levels.

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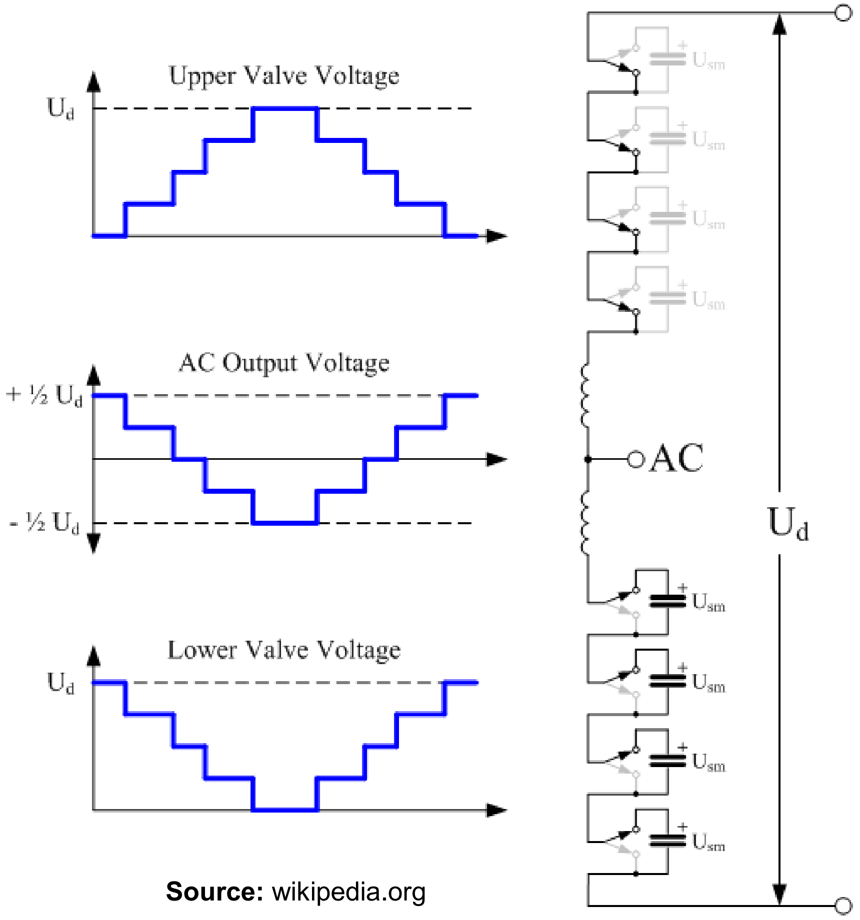
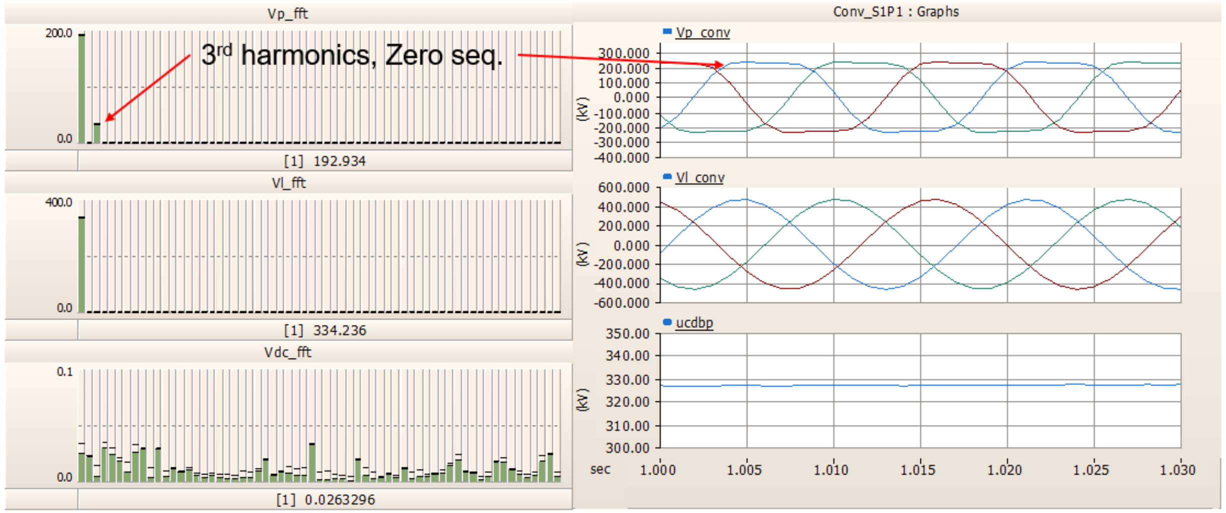


Source: wikipedia.org

Multiple Modular Converter (MMC) technology has become mature and prevalent.

- Standardized module, lower cost.
- Lower losses and Harmonics → no filter.

N=232, 233-level voltage



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FERC's rules and orders:

- **841:** Storage participation, **845:** Interconnection reform, **827:** Reactive power of non-synchronous generation, **901:** Industry gaps on IBR, **2222:** DER participation
- Market participation, interconnection process, grid stability, innovation and flexibility

NERC's standards:

- **PRC-024:** Protective relay settings, **PRC-029:** IBR ride-through,
  MOD-026 and **-027**: Model validation, **FAC-002:** Facility interconnection regulatory impacts

Studies:

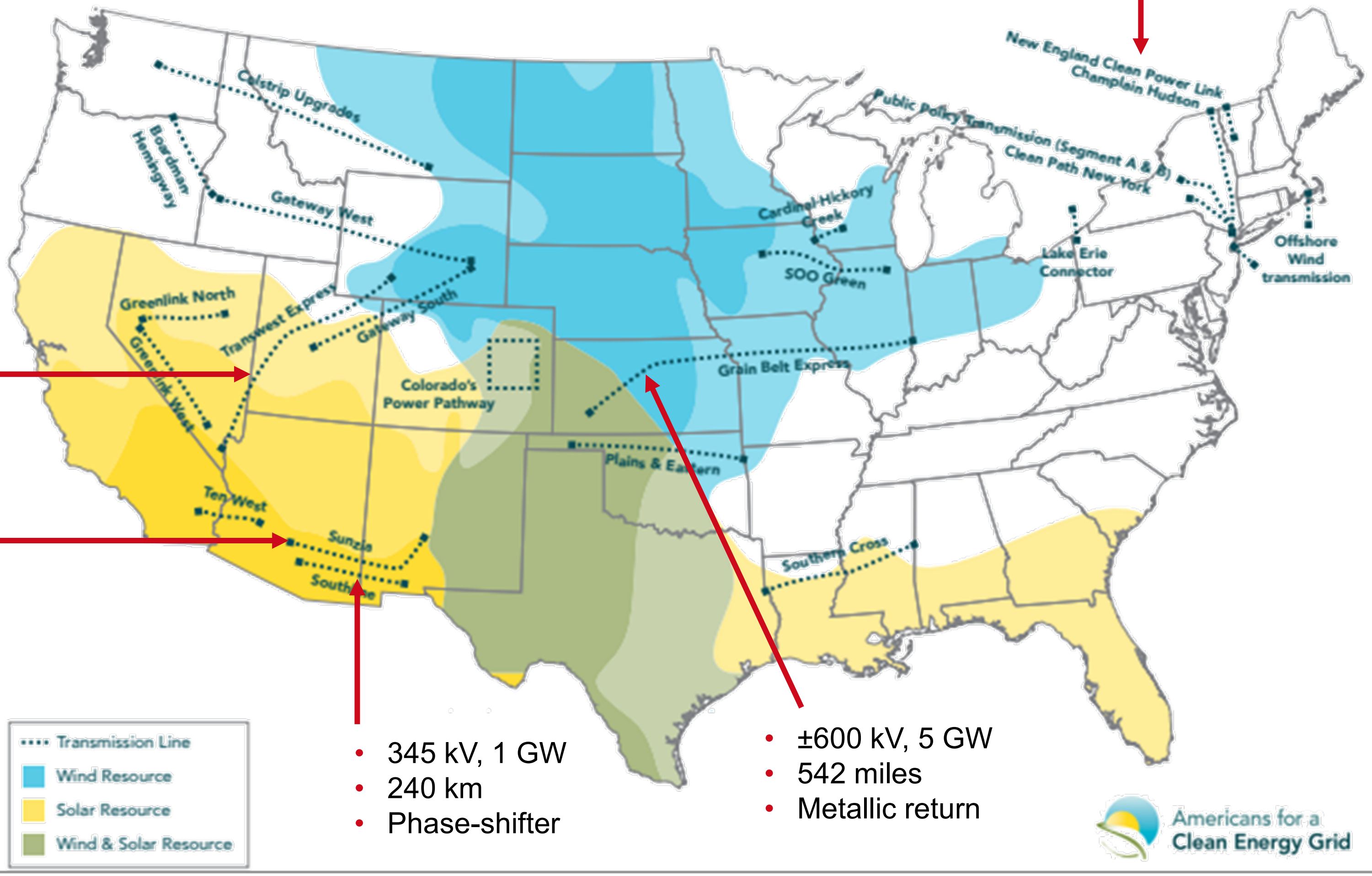
- Large number of IBRs, EMT, and real-time modeling challenges
- Standardization: Average converter modelling and standard hardware control

Proposed Transmission Projects (Under Construction)

- ±320 kV, 3 GW
- 145 miles + cable
- Ground electrode

- ±600 kV, 3 GW
- 405 miles
- Ground electrode

- ± 525 kV, 3 GW
- 513 miles
- Metallic return

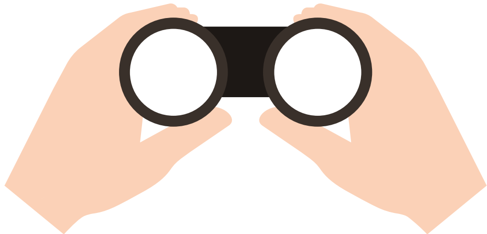


- 345 kV, 1 GW
- 240 km
- Phase-shifter

- ±600 kV, 5 GW
- 542 miles
- Metallic return

Proposed Projects

Region	Project name	Miles	kV	AC/DC	Cost $B
New England	NE Clean Power Link	150	320	DC	$1.60
New York	Clean Path New York	265	320	DC	$1.50
	Champlain Hudson	330	300	DC	$2.20
	Public Policy Transmission	100	345	AC	$1.23
PJM	Lake Erie Connector	73	320	DC	$1.00
ERCOT	Southern Cross	400	500	DC	$1.40
MISO	SOO Green	350	525	DC	$2.50
	Cardinal - Hickory Creek	100	345	AC	$0.52
SPP	Grain Belt Express	780	600	DC	$2.30
	Plains and Eastern Oklahoma	400	600	DC	$1.20
West	Transwest Express	730	600	DC	$3.00
	Colorado’s Power Pathway	560	345	AC	$1.70
	Greenlink North Nevada	235	525	AC	$0.81
	Greenlink West Nevada	351	525	AC	$1.61
	Gateway South	400	500	AC	$1.90
	Gateway West	1,000	500	AC	$2.88
	Boardman to Hemingway	300	500	AC	$1.20
	Ten West	114	500	AC	$0.30
	Sunzia	515	500	AC, DC	$1.50
	Southline	240	345	AC	$0.80
	Colstrip upgrades	500	500	AC	$0.23
Offshore	Multiple projects	30	300	DC	$1.90
	Total	7,923			



11 of 21 projects are HVDC.

Over 2/3 of investment is HVDC.

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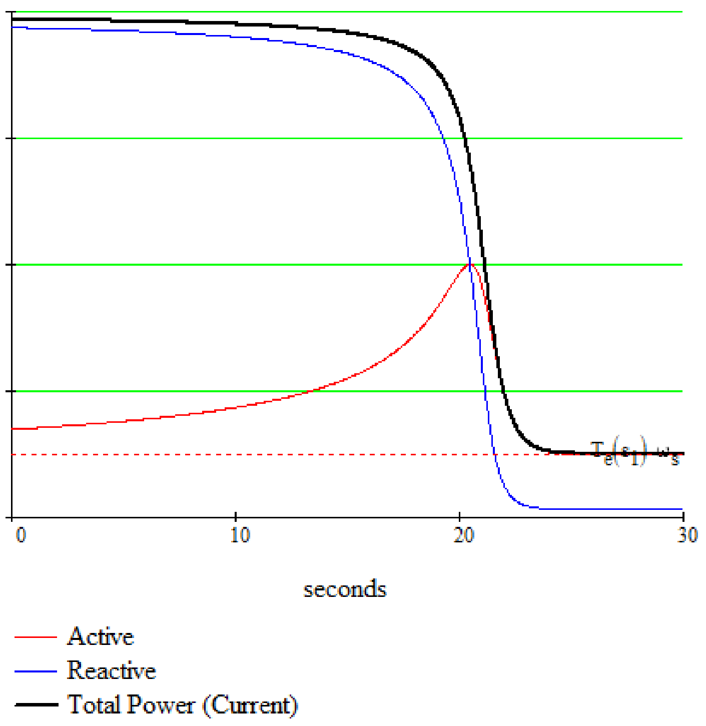

Load changes:

- **VFDs provides sizeable reactive power relief during transients**
- **New loads:** inaccurate load forecasts, electrification, data centers
  - AC units, rectifiers

Inverter operation:

- **Grid-following inverter:** Needs a grid, issues at weak system – low SCR
  - Power-regulated current source
- **Grid-forming inverter:** Voltage and frequency control, island operation
  - Droop control
  - Black start (cold start, transformer energization)
  - Fault current

Conclusion

Converter technology

- Lower cost, more efficient
- New switching devices
- High-frequency transformers, size, and weight reduction

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Increased flexibility

- Improves dynamic performance and stability
- Increases resilience: corrective, restoration, adaptive

+

Multi-terminal HVDC

- Power electronic-based circuit breakers
- HVDC supergrid

Thank You for Your Time.
Accelerate Successful Outcomes for Your Projects.

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