ECE 529
Utility Applications of Power Electronics

Session 34
**HVDC Power Transmission**

- No distance limitation for stability
- No distance limit for underground/sea cables
- Controlled power flow
- High power transfer, fewer lines,
  - Narrower ROW
  - Lower losses
- Potentially a firewall against cascading outages

**Basic Concepts with HVDC**

- Overhead Lines
  - Bulk Power Transfer Over Long Distances
  - Possibly Connecting Asynchronous Systems
- Underwater or Underground Cables
  - Distance Limits Underwater Cables
  - Longer Distances Where Overhead Lines Infeasible
- Back-to-back interconnections
  - Asynchronous systems — same or different frequency
Asynchronous Interconnections

- Economic
  - Firm transactions
  - Shared reserves
  - Increase diversity
  - Economy energy trade

- Reliability
  - Emergency power support
  - Mutual assistance
  - Isolate disturbances
  - 'Fire-wall' against cascading outages
  - Reserve sharing

The HVDC Classic (LCC) Converter Station

- Converter station
- Smoothing reactor
- DC filter
- Control system
- Telecommunication

Enhance Performance

Converter valve

Quadri-value

- 4 bridges
Fast Control Available

- Control Power Flow on DC Link (point to point)
  - Control DC Voltage
  - Control DC Current
- Damp AC Power Systems Oscillations
- VSC HVDC Converters Can Directly Control AC Side Voltage or Reactive Power
- LCC HVDC converters can to an extent

LCC HVDC Transmission

- Common Applications
  - Long-distance, bulk-power transmission
  - Sea and land cable transmission
  - Asynchronous interconnections
  - Power flow control
  - Congestion relief

- Ratings
  - Power range up to 4000 MW at ± 500 kV
  - Power range up to 4800 MW at ± 600 kV
  - Voltage range increasing to ± 800 kV with Power range up to 6400 MW

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Generator Outlet Transmission

- More power on fewer lines
- Improved stability
- Lower installed cost
- Reduced losses
- Double circuit (bipolar line)
- Reduced ROW
- One line vs. two

Interconnections

- Firm capacity
- Bypass congestion
- Avoid loop flow
- No limit due to parallel paths
- Interconnect diverse regions

- Time zone diversity
- Seasonal diversity
**Comparison of Transmission to Rail Transport of Coal**

- 3000 MW power plant
- Coal haul distance 900 miles
- Fuel – sub-bituminous coal 8500 BTU/lb
- Plant heat rate – 8500 BTU/kWh, 85% load factor
- 3 unit trains per day (100, 100 ton cars/train)
- Annual hauling cost $560 M at $50 per ton
  - $186 per kW-yr
  - $25 per MWh
  - 20 million gallons of diesel fuel per year @ 500 net ton miles per gallon
- Subject to escalation, congestion
- Cannot deliver energy from renewable resources

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**HVDC Operating Configurations and Modes**
Modular Back-to-Back CCC
Asynchronous Tie

HVDC Transmission

VSC HVDC Station

Strong or Weak Systems
Dynamic Voltage Control
Underground Transmission
Up to ±150kV, 550MW
Up to ±300kV, 1100MW

IEE 529
Lecture 33
**Topology Options**

- Simplest three-phase VSC topology to build
- Consist of six IGBTs with six anti-parallel diodes.
- Produce two voltage levels
- Use PWM switching technique to control dc voltage and ac phase voltage.

**Multilevel Converters**

- Additional IGBTs/diodes
- Plus damp diodes
- Produce three voltage levels (or more)
- Use PWM switching technique
- Less harmonics’ amplitudes
- More efficient than a Two-Level Bridge VSC
- Less device stress
- More complex and expensive than a Two-Level Bridge VSC
Modular Multilevel Converter

- Preferred VSC topology in new orders
- Consist of 100s of single phase VSC modules in series that switch in and out to control voltage magnitude and phase

What is LCC HVDC?

- Line commutated converter
- Bridge connected converter
  » Originally mercury arc valves, later thyristors
  » Inductive filter on dc side – current stiff
- Reverse direction of power flow by reversing voltage polarity

6-pulse bridge