ECE 529
Utility Applications of Power Electronics
Session 42
Interconnections

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

LCC Operating Configurations and Modes

HVDC Transmission  14  Spring 2023
The HVDC Classic Converter Station

The CCC* Converter Station
*C Capacitively-commutated converter station

HVDC Transmission
Old Two Level VSC HVDC Station

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

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.
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

HVDC Classic Control

$\alpha$ - for rectifier (AC-DC power)
$\geq 15-20^\circ$
$\eta \approx 10-12\%$ - depends on AC side L
and somewhat $I_{dc}$ and $V_{dc}$
\[ V_{dc} = k |V_{ac}| \cdot \cos \alpha \]

\[ \alpha = 0 \quad V_{dc} = k |V_{ac}| \]

\[ \alpha = 90^\circ \quad V_{dc} = 0 \]

\[ \alpha = 180^\circ = V_{dc} = -k |V_{ac}| \]

not possible in practice \[ 90 \leq \alpha \leq 180 \]

\[ V_{dc} \text{ is negative} \]
Commutation Process

- Commutation Failure

AC characteristic current harmonics at $f_n = 12n +/- 1$
- Shunt filters: band pass, high pass, double-tuned
- Typical ac filter performance criteria: THD<1.5%, TIF < 45
- DC side voltage harmonics: $f_n=12n$
- Typically, 35% of station rating in installed ac filters
- Harmonic magnitudes diminish with increasing harmonic number

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LCC Reactive power characteristics

- Operates at lagging power factor
- Both rectifier and inverter operation
- Due to phase control
- Typically reactive power demand = 55% of station real power rating at full load
- $Q_{\text{comp}}$: typically 35% of station rating: ac filters plus shunt banks
- Shunt reactors sometimes used at light load to absorb excess from filters

HVDC Transmission

Short Circuit Ratio

- Commutation performance
- Voltage stability
- Dynamic performance
- Dynamic overvoltage
- Low order harmonic resonance,
- Rule of thumb – $ESCR > 2$ for LCC
- $ESCR = (S_{br} + S_{a} + S_{dc} + Q)/P_{dc}$

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