ECE 529
Utility Applications of Power Electronics

Session 42
Closed Loop LCC HVDC Controls

Pole 1

\( R_c = 6 \text{ ohm} \)

Station 1

Pole 2

Station 2

\( V_{DC1} \)

\( V_{DC2} \)

\( V_{DCIN1} \)
Inverter Controls

Inverter DC Voltage Regulator

Control off is first 0.015 sec
Vin is charged
Lower Vdc rect to allow ramp down of Idc.

Rect lowers Vdc to regulate current.

Change Vdc at 1.011.

(file Average4.pl4; x-var t) v:VDCRP1  v:VDCIP  v:VDCRP2  v:VDCIN
α increases to lower $I_{dc}$

180

$V_{dc}$ decreases

$\alpha$ increases when $V_{dc}$ decreases

Inc a little when $I_{dc}$ falls

$V_{dc}$ decreases

$V_{dc}$

$V_{dc}$ decreases
DC Faults with LCC

- DC faults
  - One end will not feed the fault
  - Use converter control to reverse voltage polarity
    - Reverses current direction
    - Starves fault
  - Smoothing reactor slows rate of rise of current
- AC faults
  - Load rejection
  - Commutation failure

Multiterminal HVDC Systems

- Multiterminal Connection Options
- Controls
- Mixing LCC and VSC
  » Full bridge MMC
  » DC/DC converters
Multiterminal HVDC (MTDC) Systems

- Multiterminal Connection Options
- Controls
- Mixing LCC and VSC
  - Full bridge MMC
  - DC/DC converters

MTDC Topologies

- Different topology options
  - Series
  - Parallel
  - Mesh (now referred to as DC grid)
- Application influenced by converter topology

LCC
VSC

VSC HVDC and MTDC
Spring 2021
Early Concepts

- Proposed for Early LCC Systems
  - Add taps for load centers
  - Cost
  - Control complexity
  - DC circuit breakers for some topologies

Series MTDC

- Bipo
c
- All converters see same current
- Three terminal system: James Bay Canada → Montreal → Sandy Pond

VSC HVDC and MTDC
Spring 2021
**Series MTDC**

- One converter controls $I_{dc}$
  - Often viewed as converter acting as rectifier
- Other converters each control local voltage
- Power flow reversal is difficult
- Control has potential to be brittle
  - 5 terminal New England Electric-Hydro Quebec
  - Operated now as three terminals
  - Only series MTDC in operation

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**Parallel MTDC System**

- All see more or less same voltage
- Highest MVA rated converter controls $V_{dc}$
- Others control current
Parallel MTDC System with LCC

- Several in operation with LCC
  - One or two with taps
  - Paralleled converter terminals in India
- Again power reversal difficult if use LCC converters
- Potential to convert to mesh or grid
- Mesh or grid better with DC breakers
  - Otherwise shut entire faulted pole or possibly system down for DC fault

VSC HVDC and MTDC

North-East Agra MTDC

VSC HVDC and MTDC
CIGRE B4 Test System

VSC HVDC and MTDC

Circuit Interruption Options

- Lack of DC breakers (at least fast ones)
  - BPA test, metallic earth return breakers
  - IGBTs in line (point to point better)
    - Drawbacks: ratings, losses and they don't truly "open" and "isolate"
- Recent developments HVDC breakers
  - Muterminal HVDC Grids will need DC breakers
  - Possibly as little as 2 ms response needed
  - Driving the development of HVDC breakers
How Fast?

- Concerns about overcurrent ratings on power electronic devices
  - IGBTs
  - Thyristor bypass on MMC modules
- DC voltage stability
  - 2-5 ms preferred
- AC stability
  - Grid codes

Resonance Based Breakers

- Open mechanical circuit breaker
  - Generally SF6 with stronger jets
  - Voltage across arc triggers LC resonance
  - Oscillation grows until zero crossing in breaker
  - MOV to absorb energy from line
- Response time 100-300 ms in older designs
  - Now 5-10 ms