HVdc Transmission World View

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TGS

HVDC market

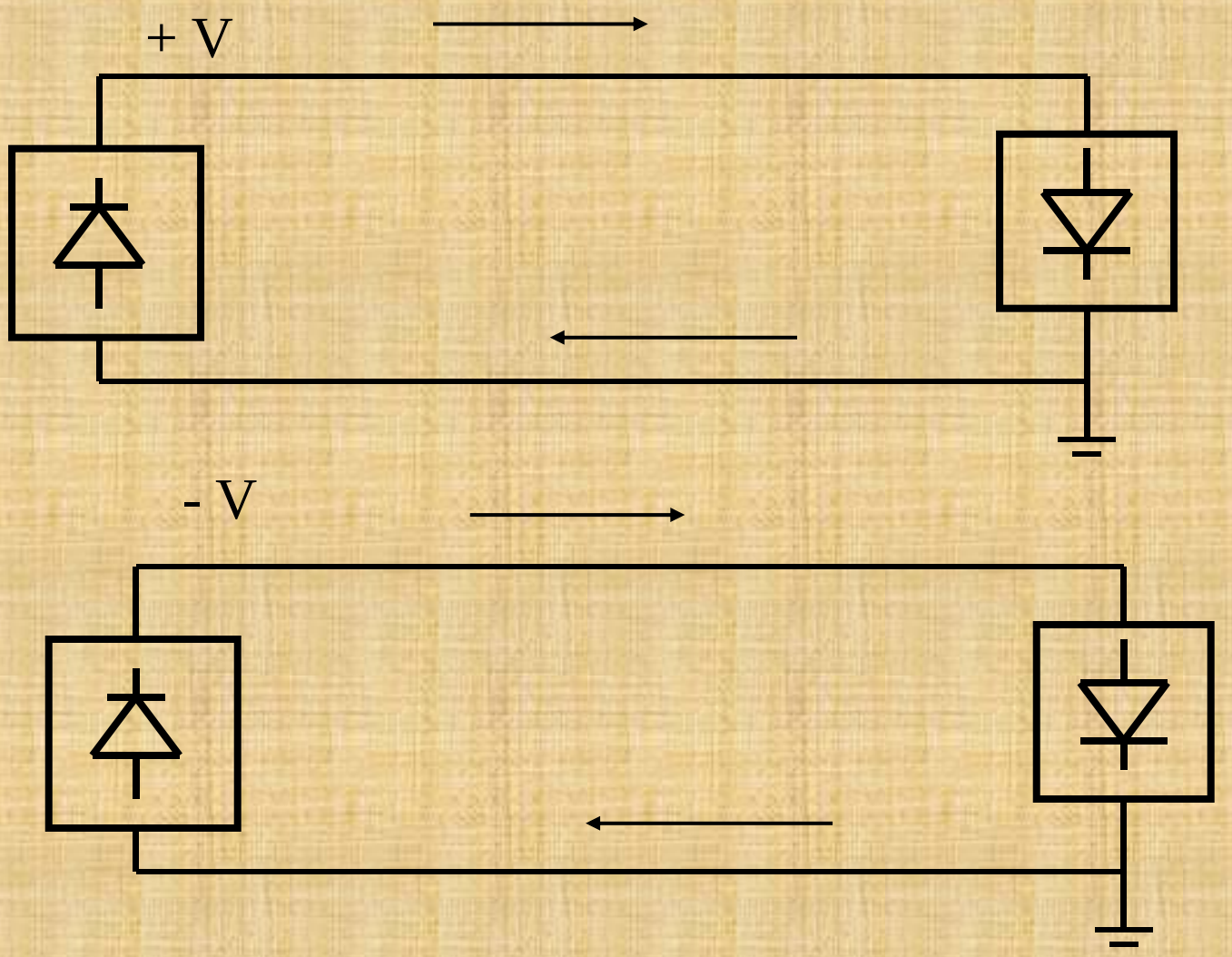
- The Market for HVDC and FACTS are currently buoyant as evident from the many projects around the world. Some of the drivers:
- Growth in energy demand in some markets,
- Need for interconnections for system security and diversity,
- New sources of generation from remote locations
- Integration of renewables such as offshore wind
- Super Grids

HVDC developments

- HVDC LCC links are in operation at +/- 800 kV and ratings of 7000 MW in a single bipole. There are multi-terminal HVDC links at +/- 800 kV and 6000 MW under commissioning.
- Currently there are plans for HVDC single bipoles at +/- 1100 kV and 10,000 MW
- Presently thyristor valves can be designed with 6 inch thyristors capable of up to 5000 A and 8 kV blocking voltage

HVDC developments

- Until 1997 the only HVDC technology available on the market is the Line Commutated Converter (LCC).
- In 1997 the Voltage Source Converter (VSC) was introduced at the rating of 3 MW and 10 kV dc.
- The VSC technology is based on the application of Insulated Gate Bipolar Transistors (IGBT)
- The VSC technology together with the introduction of the XLPE cables for HVDC applications provided an attractive economic solution that was not available before with the LCC technology.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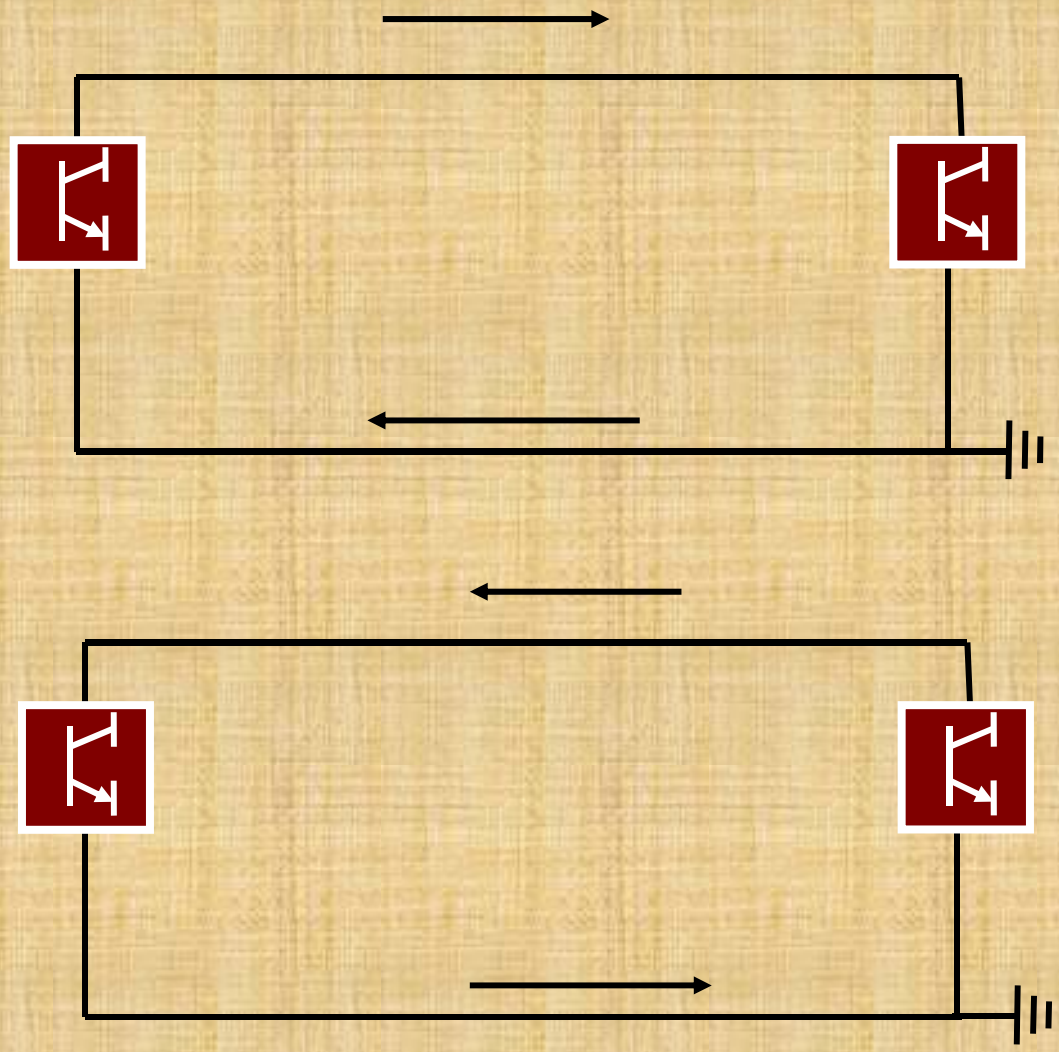


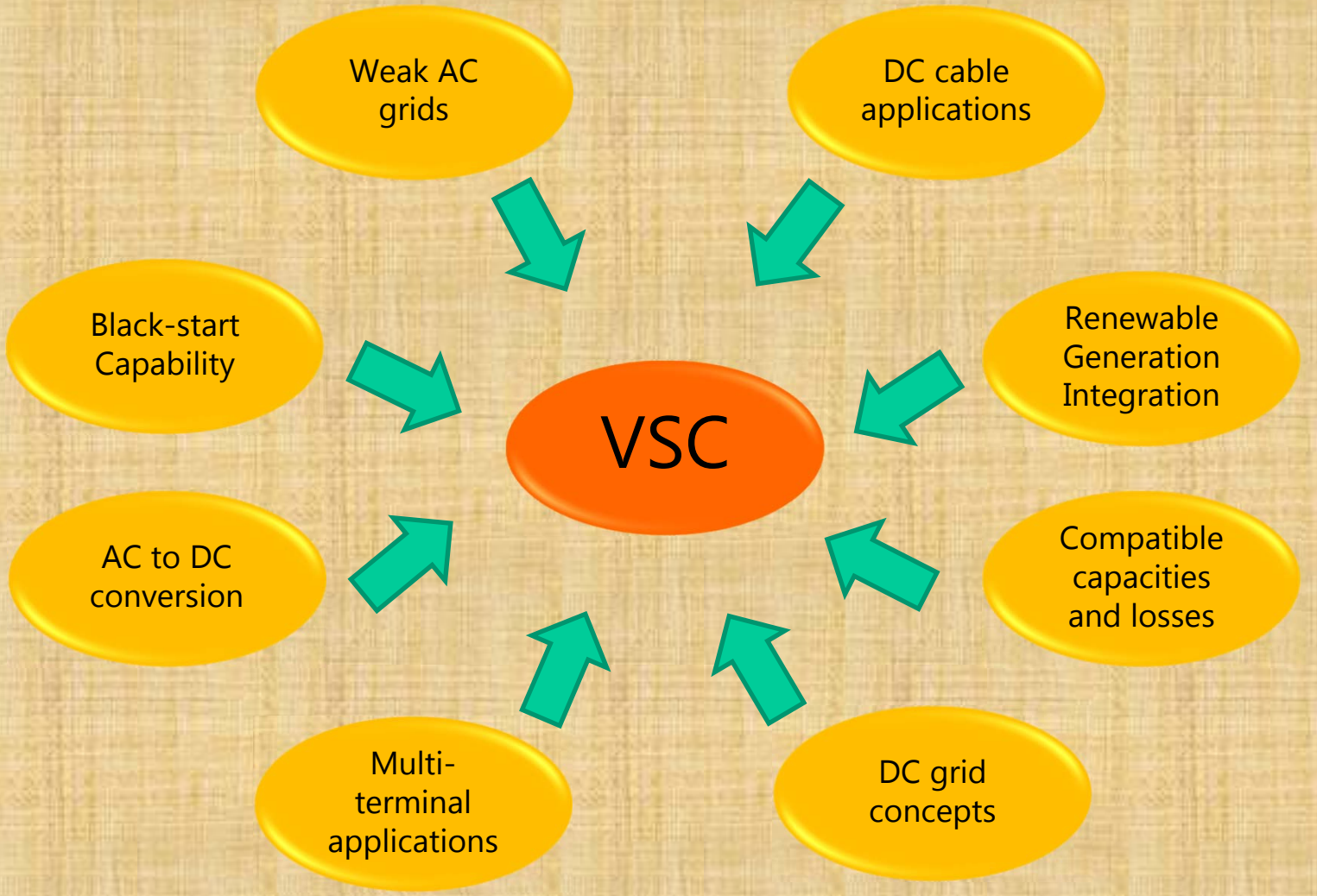
HVDC developments

- VSC started with the two and three level converters similar to the technology in the Cross Sound Cable Project and a moderate rating of 320 MW (2002), but the losses were high (2.5%).
- In 2011 The Multi level converter (MMC) was introduced in the TransBay Cable project in San Francisco, the rating increased to 400 MW and the losses came down drastically to around the 1% level
- Presently VSC in a Symmetrical Monopole configuration is at a rating of 1000 MW and +/- 320 kV.

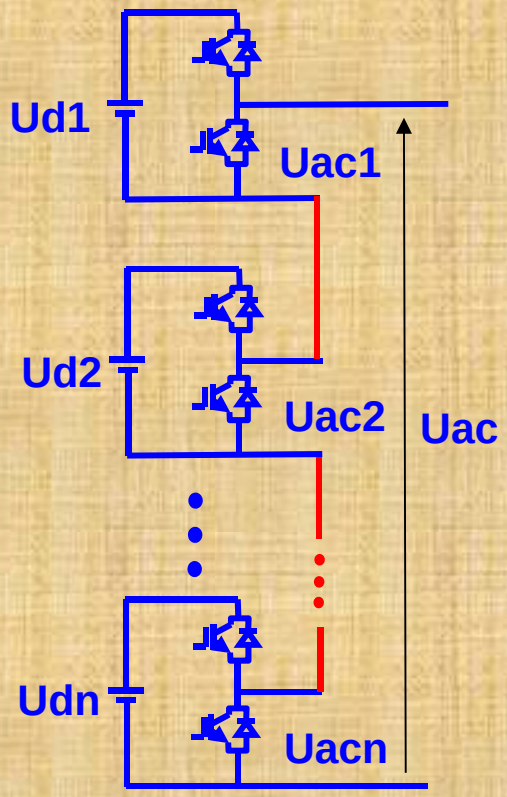
HVDC developments

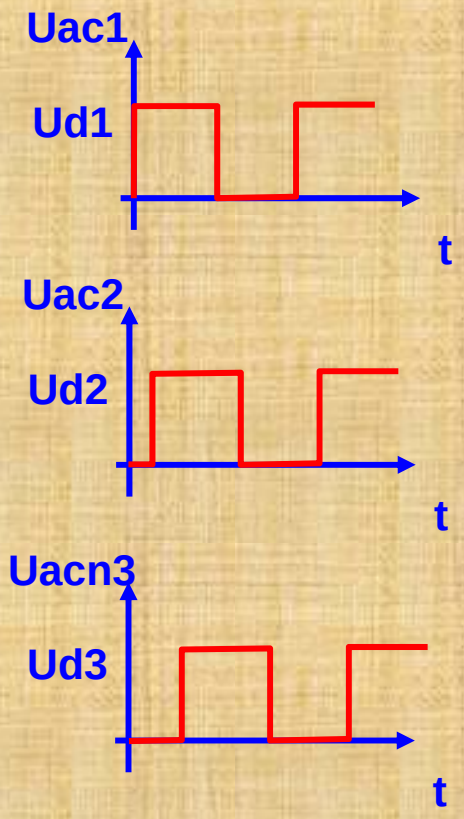
- However with the recent 525 kV XLPE cable it means with same IGBTs we can reach 1600 MW per Symmetrical monopole.
- With overhead lines and bipolar systems ratings of 2000-3000 MW are possible
- There is great interest in the conversion of ac lines to dc lines to get more capacity in the same right of way, obviously this results in HVDC and AC may be on the same tower. It has challenges but it can be handled

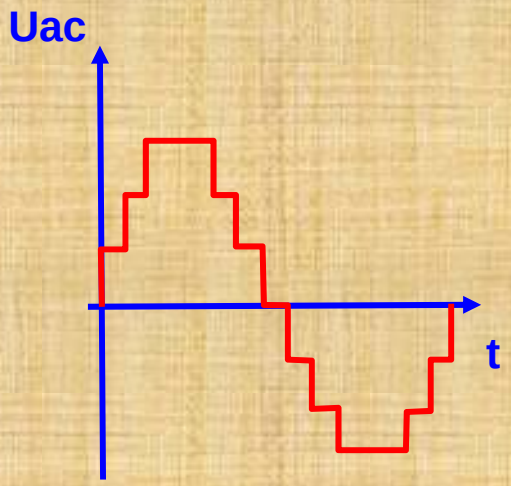
VSC HVDC is getting popular



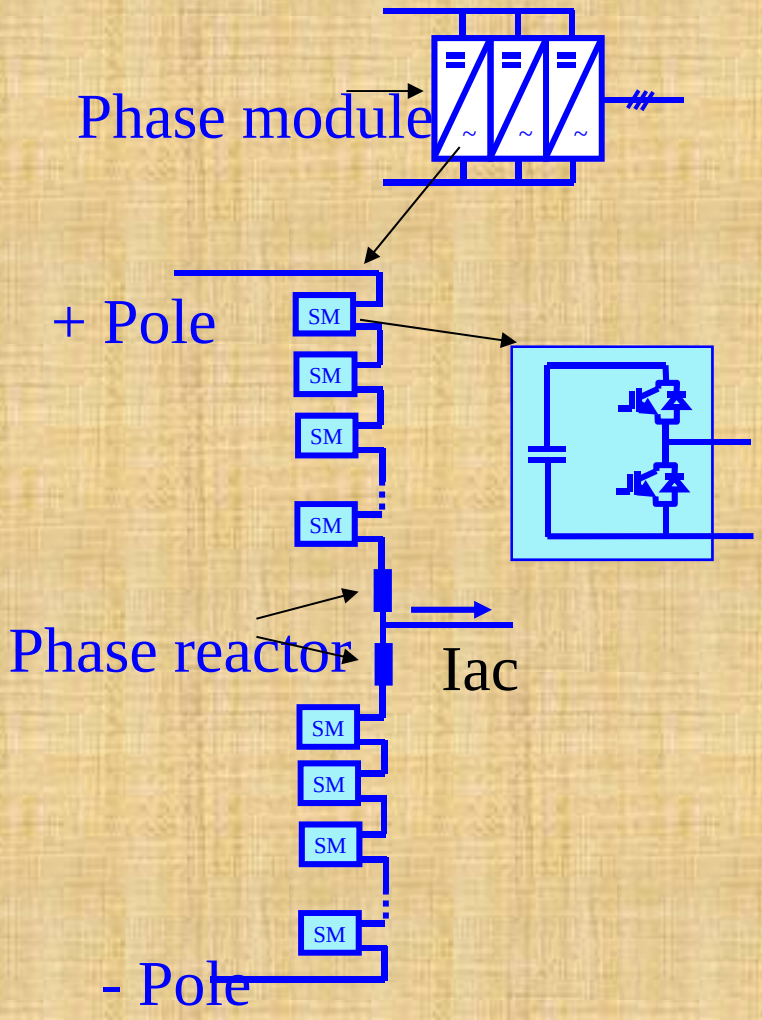
VSC HVDC Technologies







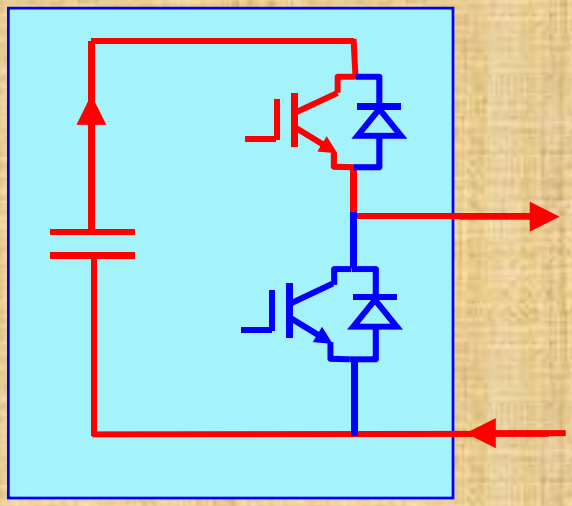
Multi-Module VSC – Operation Principles



- Equal number of submodules are connected between positive and negative DC poles and the AC terminal
- SM Capacitor voltages are kept almost equal
- The total capacitor voltages in each half phase module is equal to the peak phase-to-ground voltage
- Each SM can be either OFF or bypassed (lower IGBT triggered, zero voltage at terminals) or ON (upper IGBT triggered, capacitor voltage at terminals).

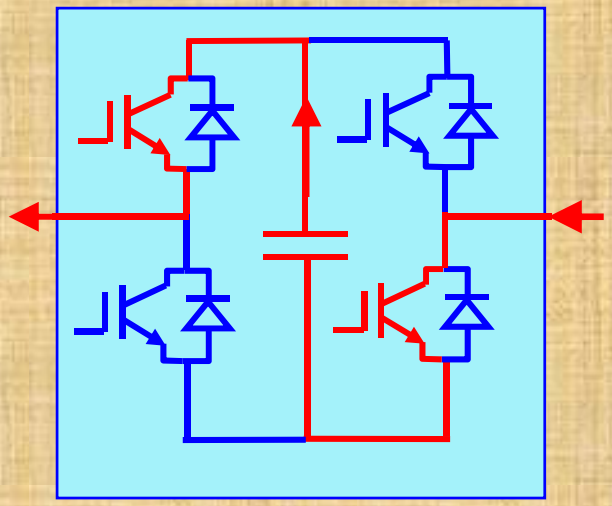
VSC HVDC Technologies

- Module Technology – Half Bridge
  - Most common for symmetrical monopole applications
  - Less losses compared to full bridge
  - Not possible to extinguish the DC fault current fed from the AC system
  - Symmetrical monopoles up to 1000 MW are in service



VSC HVDC Technologies

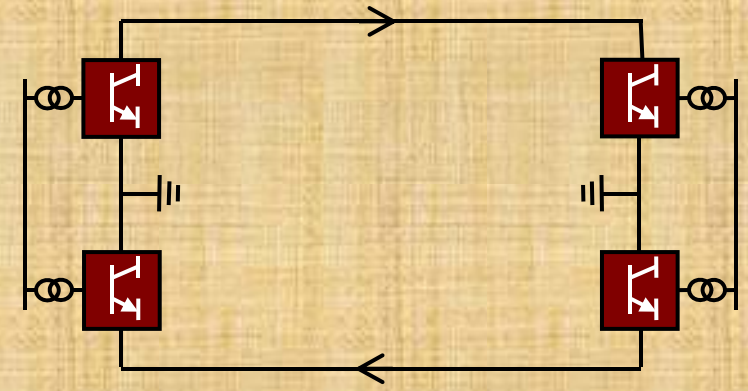
- Module Technology – Full Bridge
  - Can extinguish the DC fault current
  - Attractive for over-head applications (AC to DC conversions)
  - Relatively higher losses
  - Better controllability



VSC HVDC Systems

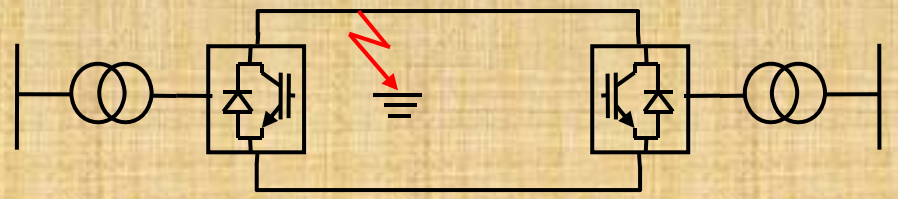
- Symmetrical monopoles

VSC bipole



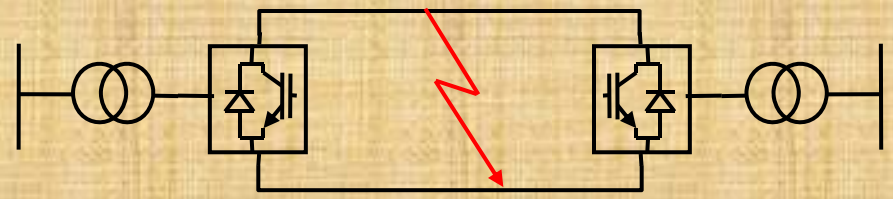
DC Faults in VSC HVDC Systems

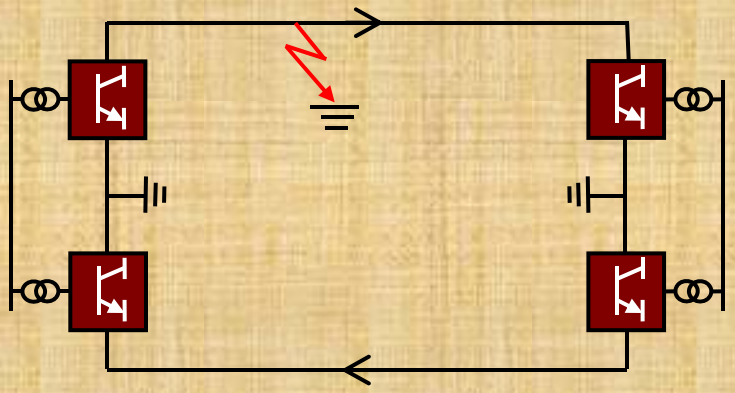
- Symmetrical monopoles – Pole to Ground Faults
  - High voltages on the healthy pole (>2pu)
  - DC current may start to oscillate (a resonance circuit)
  - Blocking the converter is required



DC Faults in VSC HVDC Systems

- Symmetrical monopoles – Pole to Pole Faults, or
- Bipoles - Pole to Ground Faults
  - Capacitors start to discharge in to the faults
  - AC systems keeps charging the capacitors
  - DC current quickly rises to very large values
  - Fault current limiting mechanism is required





Selection of Technology

Half Bridge (with DC breaker) or Full Bridge?

- Both can ride through DC faults without opening AC breakers
- Both can provide reactive power support during DC fault
- DC fault does not suppress the AC voltage for both
- FB has higher losses

Economic decision

- HB requires DC breakers to suppress DC faults and PHG faults between transformer and converter

DC Grids

- .Multi-terminal is not a dc grid.
- We need to consider protection
  - control, fault clearing, dc voltage levels
  - DC breakers
  - DC-DC converters

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Thank You