Day 2

- Key concepts of HVDC substation components
Technical Considerations

- **Bulk transmission of Power at voltages up to 800kV**

- **Back-to-back HVDC converters are used to connect two AC systems with different frequencies –two regions where AC is not synchronized**

- **Submarine Cable Transmission**

- **Transmission at reduced voltage**

- **Inherent Overload Capability**
FUNDAMENTAL OF HVDC OPERATION

- Power Transmission Solutions
- Cross Border Electricity Transmission with High Voltage Direct Current (HVDC) - Executive Exchange Dhaka

Diagram showing the fundamental operation of HVDC systems with voltage, current, and resistance values.
HVDC Long Distance Transmission Systems

- **Monopolar**
  - Transmission Line
  - Terminal A
  - Terminal B

- **Bipolar**
  - Pole 1
  - Pole 2
  - Transmission Line
  - Terminal A
  - Terminal B
HVDC Cable Transmission Systems

- **HVDC Classic Bipole**
  - Terminal A
  - Transmission Cable
  - Pole 1
  - Pole 2
  - Terminal B

- **HVDC PLUS Symmetrical Monopole**
  - Terminal A
  - Transmission Cable
  - Pole 1
  - Pole 2
  - Terminal B

**Cable Systems**
- Submarine Cable Systems
- Land Cable Systems
COMMUNICATION

- Highly reliable and effective telecommunication system should be available between the terminals.

- Telecommunication link can be either PLCC or OPGW.

- Optical Ground Wire (OPGW) can be installed on one of the peaks of the HVDC line.

![Diagram showing communication setup between Terminal 1 and Terminal 2 with OPGW connection between R1, R2, and Rn.]

\( n \) : depends on the Mux power and distance between the HVDC terminals
Basic Design Process

**Specification**

- Main transmission Data
  - $P_{dc}$
  - $U_{dc}$
  - $I_{dc}$
  - etc.

- Main data of converter station ($U$, $I$, $a$, $Q$)

- Design data for all equipment of the HVDC-system

**AC-Network**
- Load flow study
- Stability study

**Computer**
- Simulation study

**DC-Harmonics**

**AC-Harmonics**

**Insulation coordination and arresters**

**Thyristor valves**

**Smoothing reactor**

**DC-Filters**

**DC-Line**

**AC-Filters**

**Converter transformer**
Basic HVDC Single Line Diagram

- Thyristor Valves
- Converter Transformer
- Smoothing Reactor
- DC OH Line
- DC Filter: DT 12/24, DT 12/36
- Thyristor Valves
- Converter Transformer
- Smoothing Reactor
- DC OH Line
- AC Filters, Reactors
- 400 kV AC Bus
- AC Filters
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Isometric view – Conventional Bipolar HVDC
Key Components of HVDC
Bipolar HVDC Terminal

1. AC Switchyard
2. AC Filters
3. Transformers
4. Converter Valves
5. Smoothing Reactors and DC Filters
6. DC Switchyard
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Main Equipments

- Thyristor Valves
- Valve Cooling
- Converter Transformer
- Smoothing Reactor
- DC Switches
- AC Filters
- DC Filters
- PLC Filter
- Ground Electrode
- Control and Protection
Thyristor Valves

- The rectification and inversion process is carried out by the Thyristor valves

- Housed inside the valve halls
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Thyristors

- Thyristor Technology with direct Light-Triggered Thyristors
- Rated Voltage up to 800 kV
- Rated Current more than 3,000 A
- Free from Oil and exclusive Use of Flame-retardant self-extinguishing Materials ⇒ Reduced Fire-Hazard
- Efficient and Corrosion-free Water Cooling
- Excellent Seismic Performance
Direct Light Triggered Thyristor LTT

High Reliability

- 80% less Electronic Components
- Direct Laser Light-triggered Thyristor
- Thyristor Blocking Voltage: 8 kV
- Thyristor Wafers:
  - 4" for currents up to 2,200 A
  - 5" for currents up to 3,700 A
HVDC Station Design and Equipment: Thyristor Valves – Light Transmission from Ground to Thyristors

VBE: Valve Base Electronics
MSC: Multimode Star Coupler
LG: Light Guide

up to 100 m
HVDC Thyristor Valves – Principle Circuit of a 12-Pulse Group

Valve Tower Arrangement

12-Pulse Group

Multiple Valve Unit (Quadruple Valve)

Valve Arm

Neutral

to DC Line: + or -

Example 500 kV
Parallel Water Cooling

The Siemens employs Parallel-Water Cooling which has been in operation for more than 30 years.

- It provides all thyristors with the same cooling water temperature.
- Electrolytic currents are minimized by the use of grading electrodes.
- Careful choice of materials allows operation without de-oxygenizing equipment.
- None of these systems had corrosion problems.

a  Thyristor
b  Heat Sink
c  Piping
d  Manifold
Thyristor Valves in Pre Fabricated Building
Simplified Cooling Circuit

DI: Deionising
EXP: Expansion Vessel

Optional for colder environments
Air Blast Cooler

Spray of Soft water foreseen for ambient conditions in excess of 45 deg C
Valve Hall-External View
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Talcher Kolar, India
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PEB Valve Hall
Converter Transformer

- Provide the AC voltage for the converter
- Subject to DC voltage and currents on the Valve side.
- Can be two winding or three winding depending on MVA rating and size ........ unit weight of transportation is an important consideration
- Subject to special tests such as DC withstand, polarity reversal and heat run test with harmonic currents taken into account
Winding Arrangement

Core

R - Regulating Wdg
L - Line Wdg
V - Valve Wdg
Winding arrangement

Core

R-Regulating Wdg
L-Line Wdg
V-Valve Wdg
Converter Transformer
Converter Transformer
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**Smoothing Reactor**

- Removes ripples from DC voltage
- Limits rate of rise of current in case of DC line faults
- Limits higher order harmonics in DC line
- Limits possible resonance at fundamental and 2\textsuperscript{nd} harmonic frequencies
HVDC Smoothing Reactor

Oil immersed Design

- 270 mH
- 500 kV DC
- 3,000 A

Air-Core Design

- 150 mH
- 500 kV DC
- 1,800 A

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High Speed DC Switches

Switches to commutate direct current (MRTB, MRS, HSNBS, HSGS)

Metallic Return Transfer Breaker (MRTB) and Metallic Return Switch (MRS)

Use of standard SF$_6$ circuit breakers
HVDC Basic Design – Filter Configurations

- **AC-Filter Type 1**
  - Single Tuned (ST)

- **AC-Filter Type 2**
  - Double Tuned (DT)

- **AC-Filter Type 3**
  - Triple Tuned (TT)
HVDC Basic Design: Examples of AC Filters

Shenzhen Converter Station (500 kV, 3000 MW) – HVDC LDT Guizhou-Guangdong II, China
AC and DC Yard – The Protection Zones

- 1 AC-Busbar Protection
- 2 AC-Line Protection
- 3 AC-Filter Protection
- 4 Converter Transformer Protection
- 5 Converter Protection
- 6 DC-Busbar Protection
- 7 DC-Filter Protection
- 8 Electrode Line Protection
- 9 DC-Line Protection
HVDC Control and Protection: Win-TDC * System Hierarchy

Operator Control Level
SIMATIC WinCC

Control and Protection Level
SIMATIC TDC

Field Level
I/O Unit

HMI: Human Machine Interface
LAN: 100 Mbit/sec
Field Bus: FO, Profibus DP

* SIMATIC WinCC and SIMATIC TDC
Decentralized Control and Protection System for Bipole Long-Distance Transmission

Control and Protection Hierarchy, one Station

Most of the Equipment is redundant (for Simplification not shown in the Figure)

SER: Sequence of Events Recording System
TFR: Transient Fault Recording System
Operator’s AC and DC-Control Room:
Example of TIAN GUANG HVDC Project
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Operator’s Control & Screen Layout:
Configuration for Bipole Long-Distance Transmission
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SIMATIC WinCC and SIMATIC TDC
Win-TDC Control Software – Programming Language CFC
(Continuous Function Chart)

- One programming Language for all Control and Protection Functions
- Over 300 tested and well proven Standard Function Blocks
- Fully graphically configurable – easy for Engineering
HVDC Basic Design: Arrester Arrangement

AC-Filter Bus

AC-Filter

L1

C1

Fac_{hv}

L2

Fac_{lv}

C2

AC-Bus

Arr A

Arr B1

Arr B2

Arr B3

Arr B4

Arr C

Arr E1

Arr E2

Arr D

DC Line

L_{smooth}

F_{dc}

Neutral

1

2

3

4

5

6

7

8

9

10

11
TYPICAL LAYOUT OF ELECTRODE STATION
Ground Electrodes Effects

- Local Effects (Up to < 1 km)
- Safety of Humans and Animals
- High temperature rise of Ground and drying of soil.
- Remote Effects (may be up to 50 Km and beyond)
- Potential rise can cause DC current flow in transformer Neutrals
- Corrosion of buried metallic objects.
Design Requirements

Local Electrode parameters.

- Ground Electrode resistance $\leq 0.3 \ \Omega$
- Touch Voltage $\leq 40 \ \text{Volts}$
- Step Voltage $\leq 6 \ \text{Volts}$
- Current Density $\leq 0.5 \ \text{A/m2}$
- Temperature on the surface of sub-electrode: $\leq 100 \ ^\circ \text{C}$.

Remote Effects.

The Ground potential rise and electric field shall decay fast and shall be negligible (few Volts) within 15-20 kms of electrode site.
Auxiliary and Other Systems* - HVDC

- Auxiliary Power
- LT Power System
- DG Set
- DC Power/UPS
- Air Conditioning/Ventilation
- Fire Detection / Fighting
- Illumination
- PA System
- Valve Cooling System
- Oil Filtration System
- Service Water
- Telephone & PA System
- CCTVs, Maintenance equipment
- Tools and Tackles
- O&M Equipment

* Typical; subject to specification of individual contract9
Auxiliary Power Sources

- Usually two 33kV/11kV sources
- DG Set connected on LT bus
- Voltage Variation: ±10%
- Frequency Variation: ±5%
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Typical Aux Power Scheme for HVDC Station

FROM ICT1, 400/132/33kV,200MVA TRF TERTIARY;
FROM ICT2, 400/132/33kV,200MVA TRF TERTIARY;
Valve Hall Ventilation Requirements*

- Inside DB temperature 50°C±2°C
- Inside R.H. 43% ±5%
- Clean room to ISO class 7 as per ISO 14644-1:1999
- Positive pressure – 3mm of water column
- Dedicated one running and one standby AHU
- Supply air through high efficiency filters to main desired clean room condition

*Typical; subject to specification of individual contract*
Fire Protection - Choice of Material

- Fire Protection Walls
  - Dry Composite Transformer Wall Bushing
  - Minimised Inflammable Materials
  - Dry Composite Wall Bushing

*Typical; subject to specification of individual contract*
Fire Protection – Valve Hall & Transformers

- Buchholz Relays
- VESDA* Detectors
- Air Sampling Tubes
- Ultra Violet Detectors
- Infra Red Sensors

* Very Early Warning Aspirating Smoke Detection

*Typical; subject to specification of individual contract*
Fire Protection - Control Rooms

- Optical Smoke Detectors
- Ionisation Smoke Detectors
- Fire Protection Walls
- CO₂ Fire Fighting

* Typical; subject to specification of individual contract9
Fire Protection - Deluge System

Selective Initiator of Transformer and Valve fire fighting

Deluge System

Hydrant System (if required)

* Typical; subject to specification of individual contract
Thank you for your attention please!