HVDC OPERATION - OVER VIEW
HVDC OPERATION

Possible control location:-

- **System level functions**
  1. Local Workstations
  2. Local MIMIC
  3. Remote Workstations
  4. LDC

- **Station level functions**
  1. Local Work Stations
  2. Local MIMIC
  3. Remote Workstations
Transfer of Control Location

- By default all the station level controls are with respective station.
- System level controls are with master station.
- For transfer of control location:
  - Request to be sent from one station and same needs to be released from the station having that particular control.
  - Local station can always take the control of system level functions from the LDCs without their release.
  - Within local station transfer of control from mimic to WS or vice versa are also done by request and release method.
Control levels

- Signals / commands – Operator to the field through the control systems
- Control of HVDC
  - System Level functions – pertains to both the stations and can be operated from only one of the stations at any point of time
  - Station Level functions – pertains to individual stations and if required can be done from the other station provided telecontrol is available
Station level functions

Can be categorized into

- **DC station functions**
  1. DC yard configuration
  2. DC sequences
  3. Tap changer control modes
  4. DC filter control
  5. RPC control etc.

- **AC station functions**
  1. Breaker switching
  2. AC Disconnector operation
  3. Monitoring of auxiliary system etc.
  4. Monitoring of connected feeders etc.
MASTER – SLAVE STATIONS – Control concept

Master
- Operator Control
  - Mimic
  - I&M A

Slave
- Operator Control
  - SRLDC

Station A
- HVAC Functions
- DC Station Functions
- DC System Functions

Station B
- HVAC Functions
- DC Station Functions
For performing the system level functions, one of the station becomes Master Station for control location and the other station becomes slave station and automatically synchronizes from the master station.

**SYSTEM LEVEL FUNCTIONS:**

- Bipole power control settings (reference value, ramping speed, power limit)
- Current control settings (reference value, ramping speed, current limit)
- Pole / bipole Power direction
- Power / current ramping control (stop / release ramp)
- Energy transfer mode (P-Mode, I-Mode)
- Reduced voltage operation (including voltage ramp control)
- Block / Deblock firing pulses
- Metallic / ground return switching
- Stability function control (run ups / runbacks, FLC, power swing damping)
SYSTEM LEVEL FUNCTIONS

- Bipole power control settings
  - Power reference value – Operator can set the desired power order
  - Power ramp rate – Rate of power ramp in MW/min can be set
    - Typical settings allowable are 1MW/min-300MW/min
  - DC power limit – maximum allowable power limit can be set by the operator – less than or equal to Bipole power capability

- Current control settings
  - Current reference value – Current order can be set by the operator when the pole is in I-Mode. If Pole is in P-Mode operators current order setting has no relevance. Pole control generated current order will be considered
  - Current ramp rate – Ramp rate of Current can be set
    - Typical settings – 1A/min to 300A/min
Pole / Bipole Power direction
- Power direction can be set in either direction

Power / current ramping control (stop / release ramp)
- During the ramping up /down of power the ramping can be stopped / released by the operator
- Similarly current ramp can be stopped / released

Energy transfer mode (P-Mode, I-Mode)
- In I-Mode current reference is set by the operator – can be done when any limitation for the pole exists
- In P-Mode current reference is generated by the pole control such that both poles carries equal powers

Reduced voltage operation
- Individual pole can be put in reduced voltage operation during any contingencies in the DC line
SYSTEM LEVEL FUNCTIONS

- Block / Deblock firing pulses
  - Operator from the Master station can Block / Deblock the Pole – Pole controls of both the stations will automatically coordinate such that
    - while Deblocking, Inverter will Deblock first and then Rectifier
    - While Blocking Rectifier Blocks first and then Inverter

- Metallic / ground return switching
  - Operator can switch to ground return mode or Metallic return mode

- Stability functions control
  - Stability functions can be enabled or disabled individually at each station
  - Power swing damping feature which modulates the DC power during disturbances can be enabled / disabled
  - FLC – Frequency Limit Control can be activated – under contingencies, this will be enabled automatically
SYSTEM LEVEL FUNCTIONS – I&M system

Kolar Station BP Power 1220 MW

Talcher Station BP Power 1290 MW

F1: DC SYSTEM CONTRO LOC. OWN STATION
F2: CONTROL LEVEL
F3: ENERGY TRANSFER MODE
F4: BLOCK OR DEBLOCK
F5: BP POWER CONTROL
F6: P1 CURRENT CONTROL
F7: P2 CURRENT CONTROL
F8: REDUCED DC VOLTAGE
F9: METALLIC - GROUND RETURN
F10: STABILITY FUNCTIONS AND BD LIMIT
F11: OVERLOAD CAPABILITY
F12: MENU
DC STATION LEVEL FUNCTIONS

Station level functions can be performed from either the local I&M and MIMIC board / remote station / concerned Load dispatch Center

DC Station level functions from Local I&M and MIMIC:

- Pole status of operation sequences (earthed to blocked) – DC sequences
- DC switchyard configuration (exception: MR ↔ GR changeover)
- Tapchanger control (control mode, operating mode, higher / lower step)
- DC filter control (connect / isolate)
- Reactive power control (Qq / Uac-band settings, connect / isolate AC-filters / C-banks)
- Open Line Test
- Cooling system control (valve cooling, converter transformer cooling)
- Operation of DC switchyard circuit breakers and disconnectors

DC station function control location is the remote I&M (either other station or RLDC), then the following control functions are available

- Pole status of operation sequences (earthed to blocked)
- DC switchyard configuration (exception: MR ↔ GR changeover)
- DC filter control (connect / isolate)
- Reactive power control (Qq / Uac-band settings, connect / isolate AC-filters / C-banks)
Pole status of operation sequences

- earthed to blocked
  - Earthed mode – All earth switches of Valve hall and Converter Transformer are closed and valve hall door can be opened for Maintenance works
  - Stopped – all the earth switches are open and valve hall door in closed condition
  - Standby – Transformer disconnector is closed and DC filters connected (if in Auto mode)
  - Blocked – Transformer breaker is closed and Converter Transformer is charged. While going to this mode Pole control checks for Valve Cooling in service

DC Station level functions from Local I&M and MIMIC:
DC Station level functions from Local I&M and MIMIC:

DC switchyard configuration (exception: MR ↔ GR changeover)

- Pole Connect
  - HV and LV earth switches will be opened and Closes the neutral side disconnectors and high speed DC switches and HV side disconnector – Checks for the status of other station switches if telecontrol is healthy

- Pole Isolate
  - HV and LV disconnectors will be opened and corresponding earth switches will be closed
DC STATION LEVEL FUNCTIONS – I&M system
DC Station level functions from Local I&M and MIMIC:

- **Tapchanger control**
  - **Control mode** – Auto / Manual
  - **Operating mode**
    - Angle mode – In angle mode, pole control monitors the firing angle limits and adjusts the tap changer – Normal operation
    - **Udio mode** – In this mode pole control calculates the no-load DC Voltage Udio and adjusts the tap changer to keep this voltage constant – effective at low loads for absorbing reactive power

- **DC filter control**
  - **Connect** – Can be connected automatically while going to standby mode or manually any time. DC filter can be connected in charged condition also.
  - **Isolate** - Can be disconnected automatically while going to from standby to stop mode or manually any time
DC Station level functions from Local I&M and MIMIC:

- Reactive power control
  - Q-mode – Reactive Power control mode
  - U-mode – Voltage control mode
Reactive Power Control

Reactive Power Level and Bus Bar Voltage are influenced by:
- connected number of double tuned AC-filters
- connected number capacitor banks
- reactive power consumption of the converters

Main Functions of Reactive Power Control
- measuring functions for AC busbar voltage and reactive power
- control and monitoring of AC filter switchgear
- subbank switching according to reactive power conditions
- subbank switching according to busbar voltage conditions
- subbank switching according to AC overvoltage conditions
Reactive Power Control

- Reactive Power Control is mainly achieved by switching individual reactive power sub banks

- Provided Reactive Power Sub Banks
  
  Typical sub banks for a bipolar system
  
  - filter sub-bank; double tuned 12/24 harmonic (type A)
  - filter sub-bank; double tuned 3/36 harmonic (type B)
  - shunt capacitor sub-bank (type C)
  - shunt reactor sub-bank (type L)
Reactive Power Control

Switching criteria of individual sub banks and their hierarchy:

- AC busbar voltage within operator reference values
- Combination of sub banks according to Harmonic Filter Performance
- Total station reactive power within operator reference values
Reactive Power Control
AC Voltage Limitation Control

- Independant of the manual subbank control or manual Reactive Power Control the AC voltage limitation is permanently active.
- Switching on further sub-banks is inhibited if the AC voltage is above the CONNECT INHIBIT level to avoid exceeding the steady state voltage limit and consequently trip because of AC over voltage protection.
- Above the ISOLATE level capacitor or filter sub banks are switched OFF in 0,5 seconds interval.
- TRIP limit results in a fast step wise switching off of the sub-banks in 150ms intervals. The minimum number of AC filters remain connected to the AC busbar to enable a converter pole restart after fault clearance.
- Further switching off of sub-banks is blocked if the AC voltage drops to the ISOLATE INHIBIT.
- Additional banks will be switched on (in 1 second interval) if the AC voltage reaches the CONNECT limit.
- Sub-banks that are in Manual Control will also be switched-off by the AC voltage limitation Control!
<table>
<thead>
<tr>
<th></th>
<th>Rectifier</th>
<th>Inverter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONNECT</strong></td>
<td>360 kV (=400kV - 10%)</td>
<td>360 kV (=400kV - 10%)</td>
</tr>
<tr>
<td><strong>ISOLATE Inhibit</strong></td>
<td>380 kV (=400kV - 5%)</td>
<td>380 kV (=400kV - 5%)</td>
</tr>
<tr>
<td></td>
<td>400 kV = 1 p.u.</td>
<td></td>
</tr>
<tr>
<td><strong>CONNECT Inhibit</strong></td>
<td>420 kV (=400kV + 5%)</td>
<td>428 kV (=400kV + 5%)</td>
</tr>
<tr>
<td><strong>ISOLATE</strong></td>
<td>440 kV (=400kV + 10%)</td>
<td>440 kV (=400kV + 10%)</td>
</tr>
<tr>
<td></td>
<td>□ t =500 ms</td>
<td>□ t =500 ms</td>
</tr>
<tr>
<td><strong>TRIP</strong></td>
<td>480 kV (=400kV + 20%)</td>
<td>480 kV (=400kV + 20%)</td>
</tr>
<tr>
<td></td>
<td>□ t =150 ms</td>
<td>□ t =150 ms</td>
</tr>
<tr>
<td><strong>U&gt; TRIP</strong></td>
<td>520 kV (=400kV + 30%)</td>
<td>520 kV (=400kV + 30%)</td>
</tr>
<tr>
<td></td>
<td>□ t =0 ms</td>
<td>□ t =0 ms</td>
</tr>
</tbody>
</table>
DC Station level functions from Local I&M and MIMIC:

- **Connect / Isolate AC-filters / C-banks**
  - Filters will connected / Isolated automatically if they are in auto mode and the above said limits are met
  - If filters are in manual, operator has to switch according to the requirement
DC Station level functions from Local I&M and MIMIC:

- **Cooling system control**
  - Valve cooling – before charging the Converter Transformer, it is to be ensured that valve cooling is switched on and healthy
  - Converter transformer cooling – Cooling will be switched automatically the moment converter transformer is charged. Manual switching ON of the cooling system from I&M is also possible when transformer is not energised

- **Operation of DC switchyard circuit breakers and disconnectors**
  - Apart from the above automatic sequences of DC switchyard configuration, manual switching of individual switches is also possible from local I&M system
AC STATION LEVEL FUNCTIONS

AC Station level functions can be performed from either the local I&M and MIMIC board / remote station / concerned Load dispatch Center

- Operation of circuit breakers and disconnectors in the AC-filter sub-banks
- Connect converter transformer to AC side
- Open / close converter transformer disconnector switches
- Operation of bay AC breakers and disconnectors
### SER Screen Display

#### Event Selection

- **Date:** 27-10-1998
- **Time:** 16:51:37
- **Event:** STAT
- **Device:** U1
- **Description:** TAP CHANGER RUNNING UP

#### Acknowledge

- **Number of Alarm(S):** 0018

#### Display Range

- **From:** 129
- **To:** 146
- **Of:** 1236
- **Event(S):**
  - **27-10-1998 16:51:37.148 02451 000:** STAT =1V00+U1-SER TAP CHANGER RUNNING UP +
  - **27-10-1998 16:51:43.090 06648 267:** MNOR =XJ01+XJ1-SER REACT POWER EXCHANGE EXCEEDED –
  - **27-10-1998 16:51:51.520 06648 267:** MNOR =XJ01+XJ1-SER REACT POWER EXCHANGE EXCEEDED +
  - **27-10-1998 16:52:20.668 02451 000:** STAT =1V00+U1-SER TAP CHANGER RUNNING UP +
  - **27-10-1998 16:52:24.027 02215 000:** MNOR =1V00+U1-SER SYSTEM 2, SOFTWARE WARNING +
  - **27-10-1998 16:52:27.627 02215 000:** MNOR =1V00+U1-SER SYSTEM 2, SOFTWARE WARNING –
  - **27-10-1998 16:52:29.490 06648 267:** MNOR =XJ01+XJ1-SER REACT POWER EXCHANGE EXCEEDED –
  - **27-10-1998 16:52:30.050 06648 267:** MNOR =XJ01+XJ1-SER REACT POWER EXCHANGE EXCEEDED +
  - **27-10-1998 16:52:30.988 02451 000:** STAT =1V00+U1-SER TAP CHANGER RUNNING UP +
  - **27-10-1998 16:52:31.467 02296 000:** CMD =1V00 GENERAL ACK OF STATUS OF OPER SEQU FLT +
  - **27-10-1998 16:52:40.907 02451 000:** STAT =1V00+U1-SER TAP CHANGER RUNNING UP +
  - **27-10-1998 16:52:42.980 06648 267:** MNOR =XJ01+XJ1-SER REACT POWER EXCHANGE EXCEEDED –
  - **27-10-1998 16:52:51.147 02451 000:** STAT =1V00+U1-SER TAP CHANGER RUNNING UP +
  - **27-10-1998 16:53:09.067 02452 000:** STAT =1V00+U1-SER TAP CHANGER RUNNING DOWN +
  - **27-10-1998 16:53:12.970 06661 000:** CMD 800902A BKR 800902A CLOSE +
  - **27-10-1998 16:53:12.970 06664 000:** CMD 800902C BKR 800902C OPEN +
  - **27-10-1998 16:53:13.426 05002 000:** STAT 800902A BKR 800902A CLOSED +
  - **27-10-1998 16:53:13.467 05081 000:** STAT 800902C BKR 800902C OPENED +
  - **20-08-1999 16:07:37.578 00280 000:** WRN =XJ01+XJ1-SER AC FILTER/CAP PROTECTION =RF13 WARNING –
  - **20-08-1999 16:07:38.579 00281 000:** EMCY =XJ01+XJ1-SER AC FILTER/CAP PROTECTION =RF13 TRIP +
  - **20-08-1999 16:07:39.579 00282 000:** WRN =XJ01+XJ1-SER AC FILTER PROTECTION =RF15 WARNING –

#### Functions

- **F1:** PAGE UP
- **F2:** PAGE DOWN
- **F3:** EVENT SELECTION
- **F4:** EVENT SELECTION
- **F5:** DISPLAY SELECTION
- **F7:** EVENT ARCHIVE
- **F8:** JUMPER EVENT
- **F9:** REMOVE EVENT
- **F10:** RETURN TO PRESENT CONDITIONS
Trend System

- Important system parameters both analog and digital are recorded with a time sampling of around 10 sec.
- Operator can archive the parameters and observe the trend of various parameters.
- Parameters can be displayed in various forms like pie chart, bar chart, X-Y plot etc.
- At any one time four different charts can be monitored and each can have 8 parameters.
- Automatic backup in magnetic tapes and can be retrieved at any time.
Operational Modes of HVDC

- Bipolar Mode of operation – Normal mode of operation
  1. When both poles and both lines are available / healthy, this is preferred mode of operation
  2. Both poles shares equal power – both poles in P-mode
  3. No ground current
  4. During any contingency (reduced capability of one pole) one pole can be operated in I-mode and in this case there will be unequal sharing of power
  5. Ground current
  6. Least losses among all operation modes
  7. Rated station capacity can be utilized only in this mode
BIPOLAR MODE OF OPERATION
Monopolar Metallic return operation

1. When both the lines are available / healthy but one pole is out of service, this is preferred mode of operation
2. In bipolar mode when any one of the pole trips, automatic changeover to this mode takes place and healthy pole will continue to run with half of the rated station capacity
3. Mainly used when valve hall or other equipment pertaining to any of the pole is under maintenance / shutdown
4. Have higher losses compared to bipolar mode
5. Electrode will be out of circuit
6. Half of the rated station capacity can be utilized
MONOPOLAR METALLIC RETURN OPERATION
– POLE 1

Diagram showing a circuit with poles 1 and 2, DC filters, and various components.
MONOPOLAR METALLIC RETURN OPERATION
– POLE 2
Operational Modes of HVDC

- **Monopolar Ground return operation**
  1. When only one line is available / healthy this is the mode of operation
  2. When any pole trips due to line fault or shutdown of one line, station operates in this mode
  3. Scarcely operated mode due to limited electrode life
  4. Losses less than MR mode
  5. Electrode will be in circuit
MONOPOLAR GROUND RETURN OPERATION – POLE 1
MONOPOLAR GROUND RETURN OPERATION – POLE 2
Reduced Voltage Mode (RVO) of operation

In this mode of operation, operating voltage is 80% of the rated voltage

- Abnormal mode of operation
- The pole switches to this mode automatically after unsuccessful recovery from DC line fault
- This allows operation of HVDC even during weak insulation in the line or associated equipment (insulators puncture etc)
- After patrolling / inspection of the line, HVDC can be switched to normal voltage mode
- Under worse or foggy weather conditions, when atmospheric insulation level is reduced operator can switch to this mode
- In this mode, power transfer capability of the pole reduces to 80% of the normal rated capability
- Higher losses than normal voltage mode
In order to determine the healthiness of the DC line, Open line test is conducted.

- To conduct open line test respective station should be switched to rectifier mode.
- Other station should be isolated from the line.
- If there is any ground fault on the line, open line test will fail.
- The duration of the test is 10 minutes.
Open Line Test (OLT) Pole 1
Open Line Test (OLT) Pole 2
Sequence of Events Recording Functions

- Commands initiated by the operator from HMI is reported in the SER.
- Status of all the equipments is updated in the SER in addition to their respective screen display.
- Alarms occurring from any of the yard equipments or control & protection equipments are reported.
  - Alarms are classified into three categories depending upon their severity – Emergency, Major and Minor
- All the events reported in the SER are time tagged with millisecond resolution.
- Each event is assigned an unique number and they are divided in groups.
- Events can be sorted time wise or device wise for easy analysis.
- Events can be filtered based on equipment, group, source of origin, hardware generated event, software generated event.
- Automatic archiving of the events into magnetic tape and same can be retrieved whenever required.
THANK YOU