UTILIZING SYNCHROPHASORS FOR INTEGRATED OPERATION OF EHVAC & HVDC IN INDIAN POWER SYSTEM

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Outline: Synchrophasor Utilisation in integrated HVDC-HVAC Operation from System Operator’s Perspective

• Evolution of National Grid of India
• Evolution of HVDCs in India (2)
• Case studies based on Synchrophasors
  – Problem in communication links or station switchyard leading to oscillation of HVDC power order
  – Identification of commutation failures in HVDC due to severe faults near terminal HVDC stations
  – Close monitoring of Power Order setting and HVDC pole outages
  – HVDC power flow can be optimised for keeping angle spread in the grid within limits
  – Several HVDC related phenomenon as filter switching, Sub Synchronous Resonance etc. can be captured in PMUs
GROWTH OF AC-DC INTEGRATION IN INDIAN POWER SYSTEM
Evolution of National Grid

- **Five Regional Grids**
  - Five Frequencies
  - Pre – October 1991

- **October 1991**
  - East and Northeast synchronized

- **March 2003**
  - West synchronized
  - With East & Northeast

- **August 2006**
  - North synchronized
  - With Central Grid

- **Five Regional Grids**
  - Two Frequencies
  - Post August 2006

- **December 2013**
  - One Grid-One Nation

- **One Frequency**
## Evolution of HVDC system in India

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of HVDC</th>
<th>DC Voltage (kV)</th>
<th>Capacity (MW)</th>
<th>Year of Commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HVDC Sileru–Barsoor</td>
<td>±200</td>
<td>400 (Now Defunct)</td>
<td>1989</td>
</tr>
<tr>
<td>2</td>
<td>HVDC Vindhyachal BtB</td>
<td>±70</td>
<td>500</td>
<td>April 1989</td>
</tr>
<tr>
<td>3</td>
<td>HVDC Rihand-Dadri Bipole</td>
<td>±500</td>
<td>1500</td>
<td>June 1991/Dec 1990</td>
</tr>
<tr>
<td>4</td>
<td>HVDC Bhadrawati BtB</td>
<td>±205</td>
<td>1000</td>
<td>Dec. 1997</td>
</tr>
<tr>
<td>5</td>
<td>HVDC Gazuwaka BtB</td>
<td>±205/±177</td>
<td>500+500</td>
<td>Feb. 1999/ March 2005</td>
</tr>
<tr>
<td>6</td>
<td>HVDC Chandrapur-Padghe Bipole</td>
<td>±500</td>
<td>1500</td>
<td>Nov. 1999</td>
</tr>
<tr>
<td>7</td>
<td>HVDC Sasaram BtB</td>
<td>+205</td>
<td>500</td>
<td>Sep. 2002</td>
</tr>
<tr>
<td>8</td>
<td>HVDC Talcher-Kolar Bipole</td>
<td>±500</td>
<td>2000 (2500 for 10 hours)</td>
<td>Feb. 2003</td>
</tr>
<tr>
<td>9</td>
<td>HVDC Balia-Bhiwadi Bipole</td>
<td>±500</td>
<td>2500</td>
<td>Sep. 2010/ July 2012</td>
</tr>
<tr>
<td>10</td>
<td>HVDC Mundra-Mahendergarh</td>
<td>±500</td>
<td>2500</td>
<td>July 2012</td>
</tr>
<tr>
<td>11</td>
<td>HVDC Bheramara BtB</td>
<td>±158</td>
<td>500</td>
<td>Sep. 2013</td>
</tr>
<tr>
<td>12</td>
<td>HVDC Biswanath Chariali – Agra</td>
<td>±800</td>
<td>3000 (of total capacity 6000)</td>
<td>Nov. 2015</td>
</tr>
</tbody>
</table>
HVDC Systems in India

- 4 back to back HVDCs
- 5 bipole HVDC links
- 2 bipoles under construction
- MTDC under commissioning
Case Studies based on Synchrophasors
Case I

- Bipole antecedent power order = 1225 MW
- Fire in Valve hall => Pole-1 hand tripped
- Pole-II went to 1225 MW for 5 sec, and then settled at 825 MW (10% overload)
- Anomalous pattern observed in HVDC power flow (as per Dadri PMU)
- Initially LFO suspected => No findings from OMS
- Patchy communication link between the two poles => Power order ramped to 825 MW (at sending end) on healthy communication and reduced to 790 MW (at sending end) when link failed
- Corrective action: Power order manually reduced to 750 MW
Case II

- Bipole antecedent power order => 2400 MW
- Y phase to ground fault in nearby 400kV Hissar-Bhiwadi II line close to one end
- Voltage dip to 50% in faulty (Y) phase
- Fault Clearance time : 200ms (as per PMU)
- It was communicated later that HVDC Pole tripped due to commutation failure at that end
- Frequency rise = 0.13 Hz (Estimated load loss ~800 MW)
- SPS Case-II linked for the HVDC tripping operated
- Actual load loss => Planned loss
Case - III

- Bipole antecedent power order => 2000 MW
- 3-phase fault in station yard close to HVDC station => Several lines and ICTs from this station tripped
- 220 kV side lines opened manually (no indication of fault in PMU) to isolate fault
- Patrolling => Bush/garbage fire in station
- Repeated commutation failure in HVDC due to nearby fault
- Power order reduction to 75% of initial value i.e. (2000 MW to 1500 MW).
- From PMU => Fault captured in the voltage plots and proper cause of HVDC runback ascertained
Case-IV

- Bipole antecedent power order => 1350 MW
- Filter bank tripping at one end of HVDC => HVDC Bipole blocked
- AC lines in the parallel path got overloaded and reached 1300 MW (400 kV Singrauli – Anpara S/C)
- SPS designed for Bipole tripping mentions load shedding in designated group loads and generation backing down of 500 MW at generation complex but neither was there i.e. sufficient load shedding nor was there any generation backing
- Difficult condition for System operator => Manual action taken
Case-V

• Antendent power flow in Bipole = 1500 MW
• HVDC Pole 1 taken in planned shutdown for AMP work
• After outage, spikes in Voltage, Current, Power and Frequency at nearby terminal station
• Repetitive spikes with period of exactly 2 minutes
• High time constant for generators => HVDC is likely source
• Patrolling => Electrode line conductor jumper was damaged.

• Unbalance current in both electrode conductor => Caused overload of one of the electrode
• Operation of Electrode current supervision => Checks difference between the direct current in each electrode line conductor (IDEL1 and IDEL2
• The similar alarms appeared after each two minutes at one end and spike were observed in grid at the same time.
Case - VI

- Transient fault occurred in one pole of 500kV HVDC Bi-Pole
- From PMU, maximum fault current of 1.78 kA in HVDC AC interconnection
- Pole tripped to isolated the fault
- Pole restart after approx. 100ms
- The event was captured in PMU located at AC-DC connection feeder.
- Good example of successful Auto restarting of HVDC Pole.
Case - VII

- 2 cases of HVDC runback
- MACH2 control system initiated runbacks on two consecutive days => Power flow reduction from 500 MW to 137 MW
- Case 1: Problem in Valve cooling system at Agra (Master station)
- Case 2: Code could not be updated in control system due to humidity issues
- PMU gave visualisation of runback by the stepwise voltage rise at nearby PMU to HVDC terminal
THANK YOU

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