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

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NASPI North American SynchroPhasor Initiative

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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

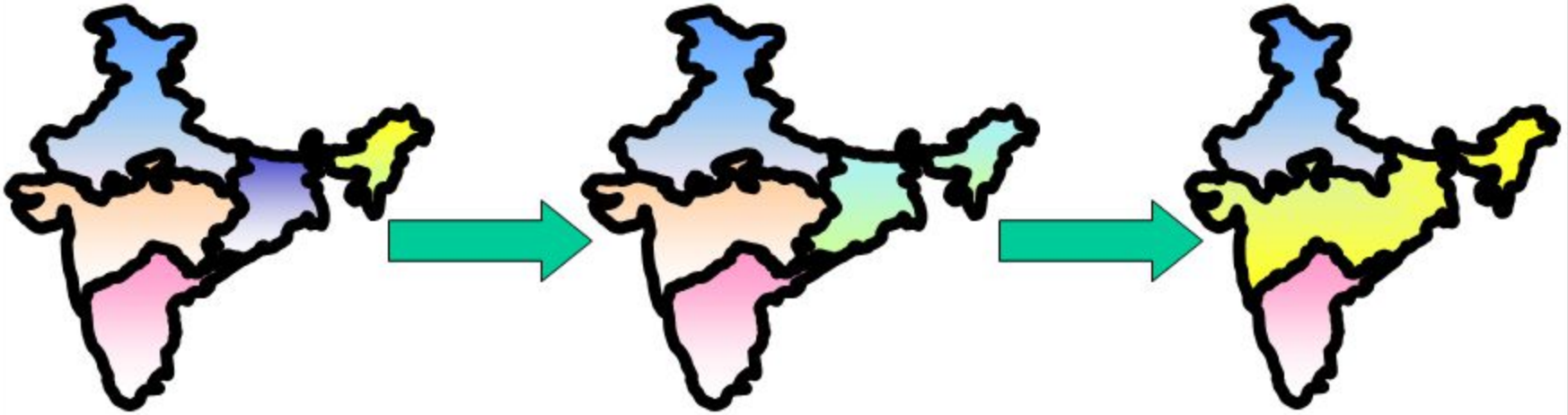
GROWTH OF AC-DC INTEGRATION IN INDIAN POWER SYSTEM

Evolution of National Grid

Five Regional Grids
Five Frequencies
Pre – October 1991

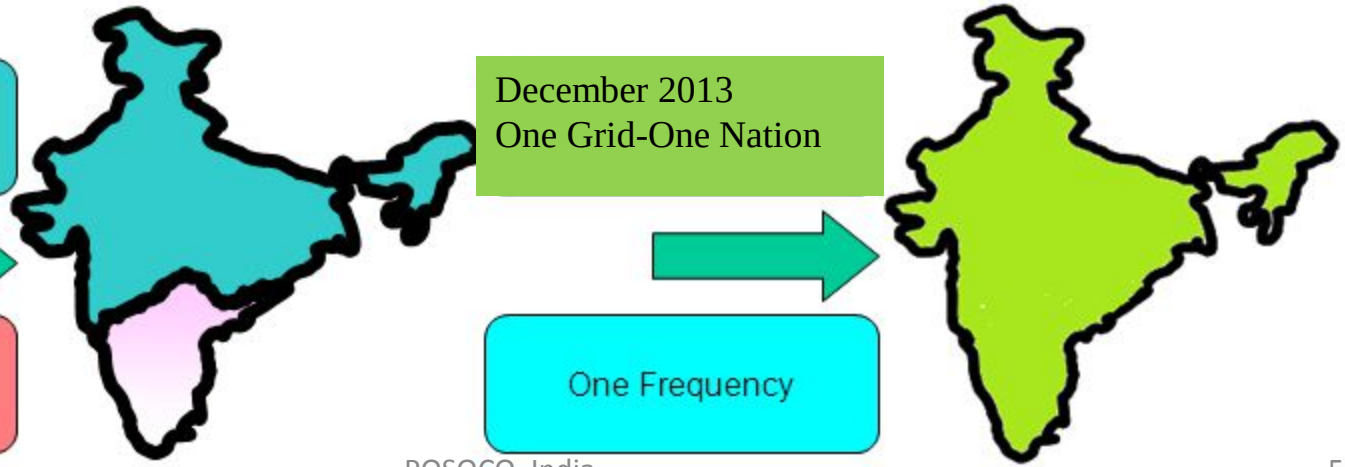
October 1991
East and Northeast
synchronized

March 2003
West synchronized
With East & Northeast



August 2006
North synchronized
With Central Grid

Five Regional Grids
Two Frequencies
Post August 2006



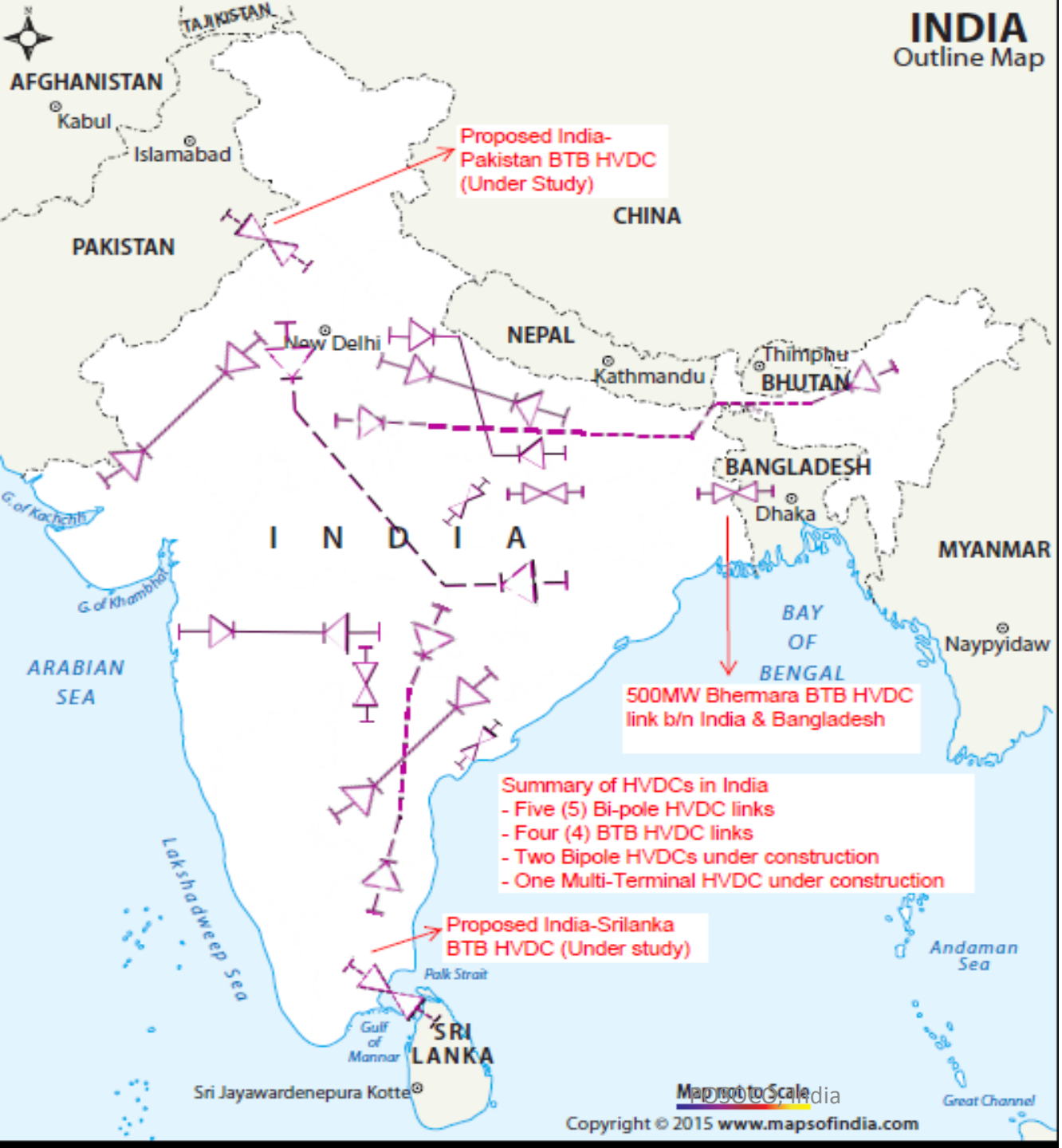
December 2013
One Grid-One Nation

One Frequency

Evolution of HVDC system in India

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

HVDC Systems India

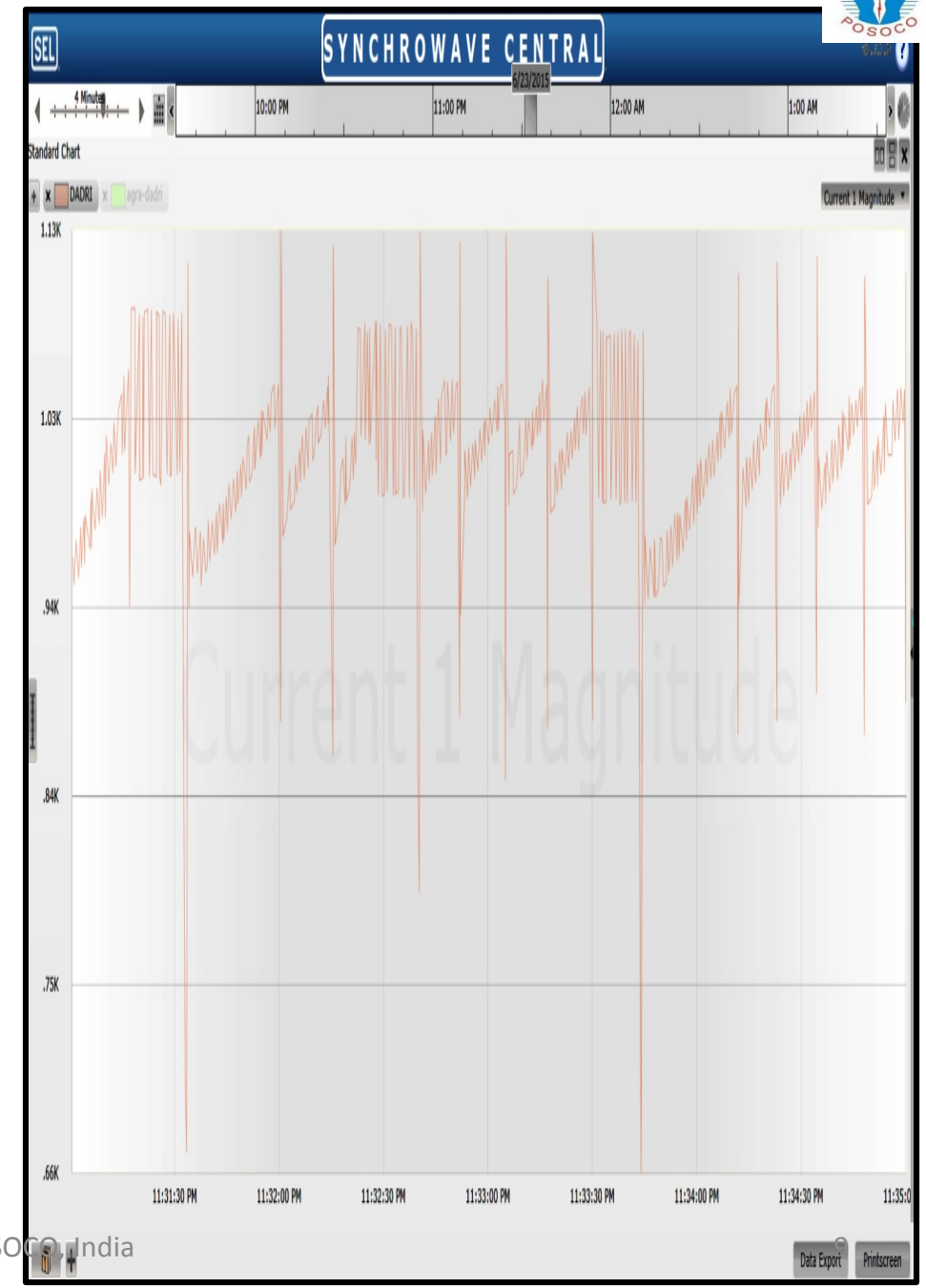


- 4 back to back HVDCs
- 5 bipole HVDC links
- 2 bipoles under construction
- MTDC under commissioning

Case Studies based on Synchrophasors

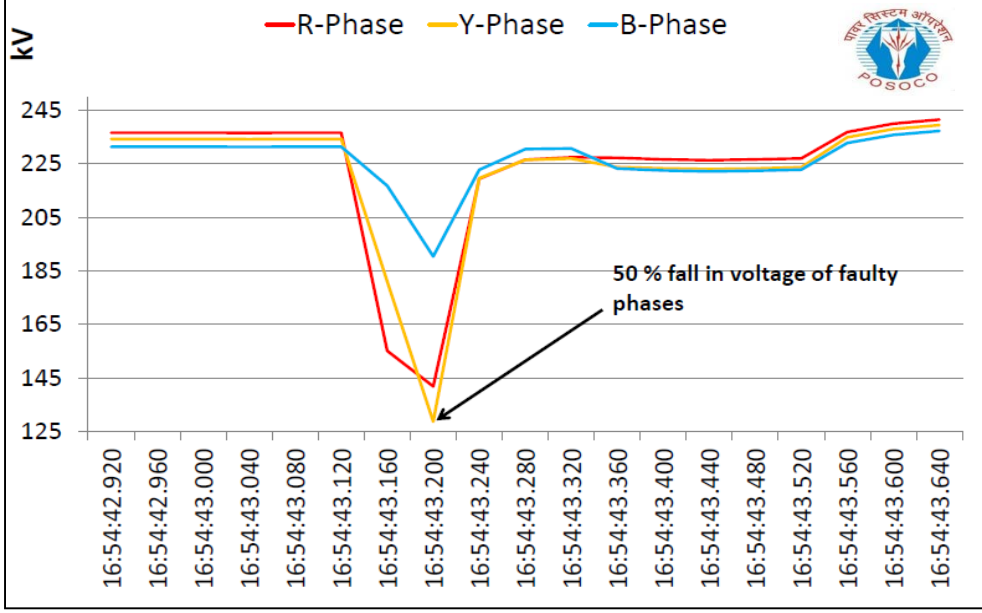
Case I

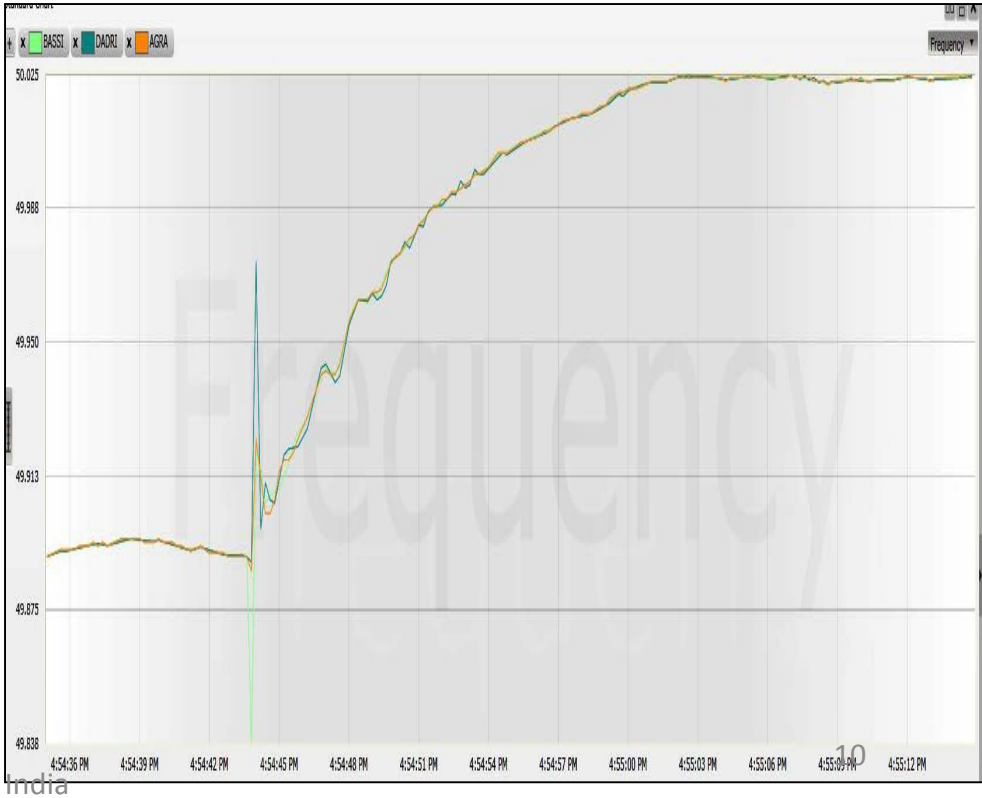
- Bipole antencedent power order = 1225 MW
- Fire in Valve hall => Pole-1 hand tripped
- Pole-II went to 1225 MW for 5 sec, and then settled at 825 MW (10% overload)
- Anomalous pattern observed in HVDC power flow (as per Dadri PMU)
- Initially LFO suspected => No findings from OMS
- Patchy communication 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

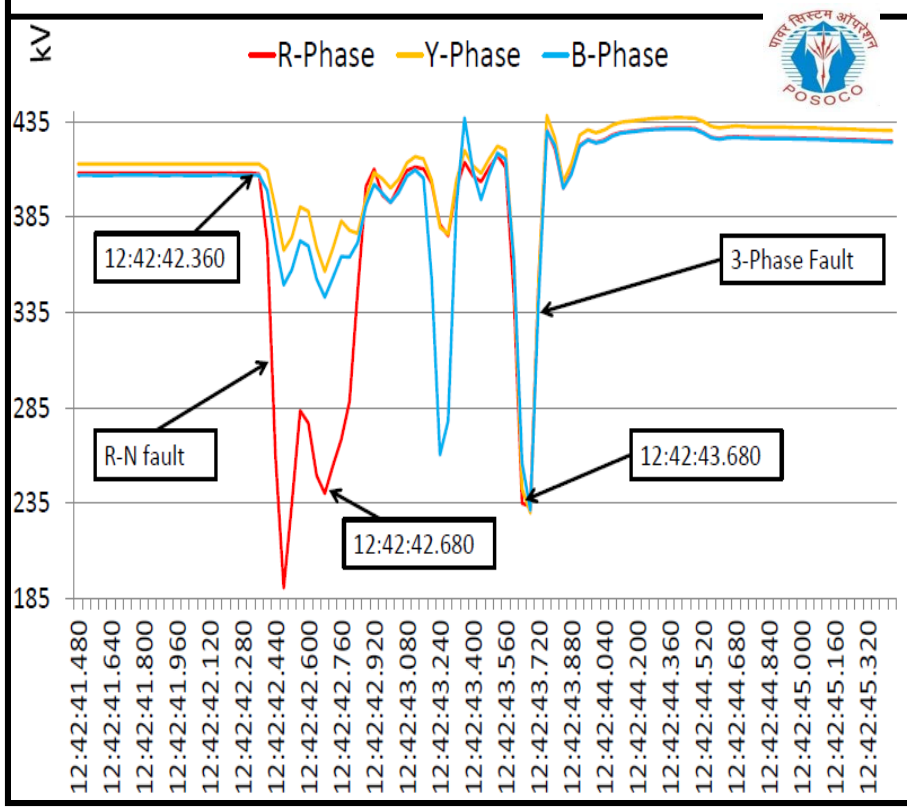
- Bipole antecedent power order => 2400 MW
- Y phase to ground fault in nearby 400kV Hissar-Bhiwadi II line close to one end
- Voltage dip to 50% in faulty (Y) phase
- Fault Clearance time : 200ms (as per PMU)
- It was communicated later that HVDC Pole tripped due to commutation failure at that end
- 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

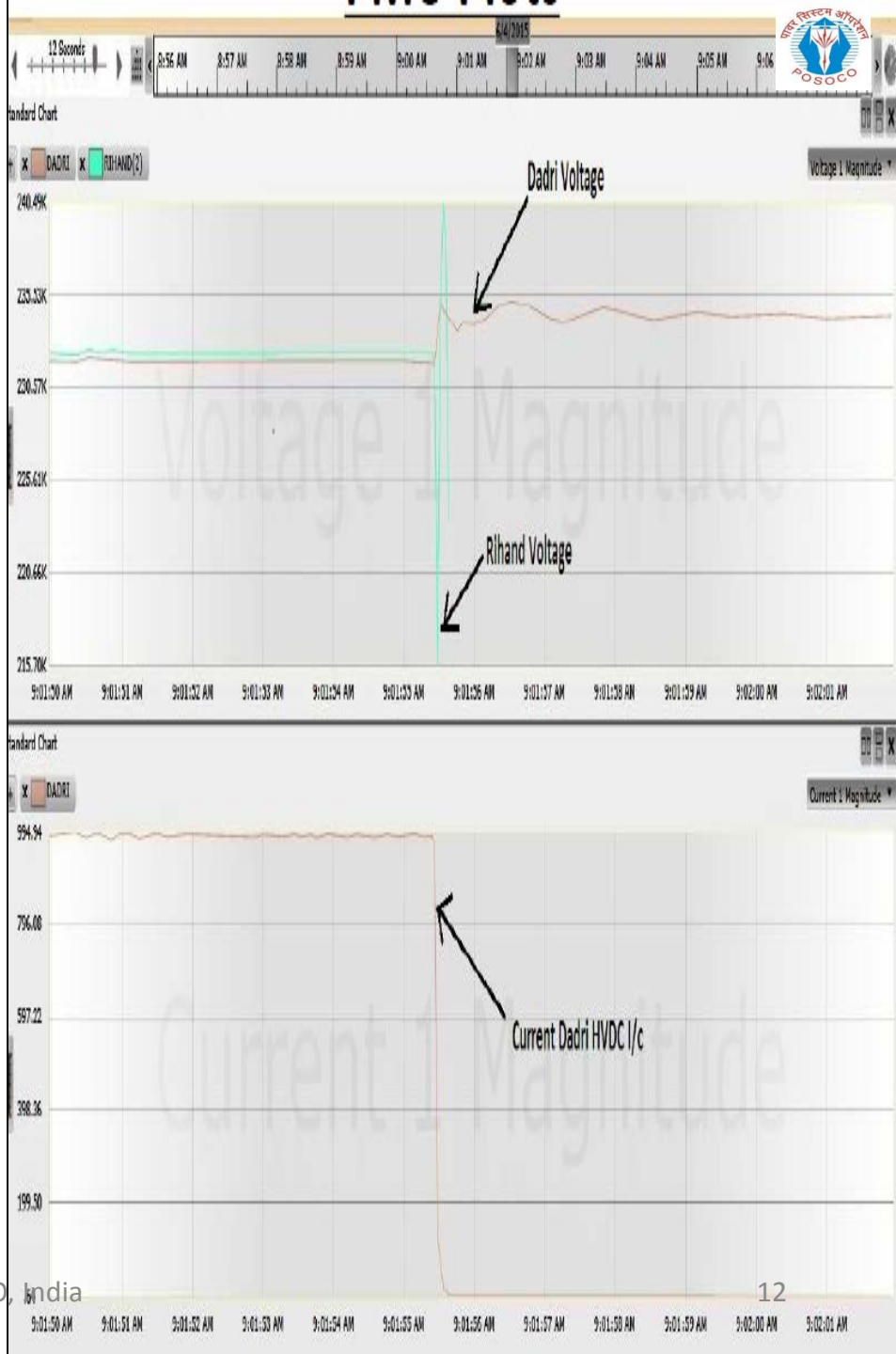
- Bipole antecedent power order => 2000 MW
- 3-phase fault in station yard close to HVDC station => Several lines and ICTs from this station tripped
- 220 kV side lines opened manually(no indication of fault in PMU) to isolate fault
- Patrolling => Bush/garbage fire in station



- 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

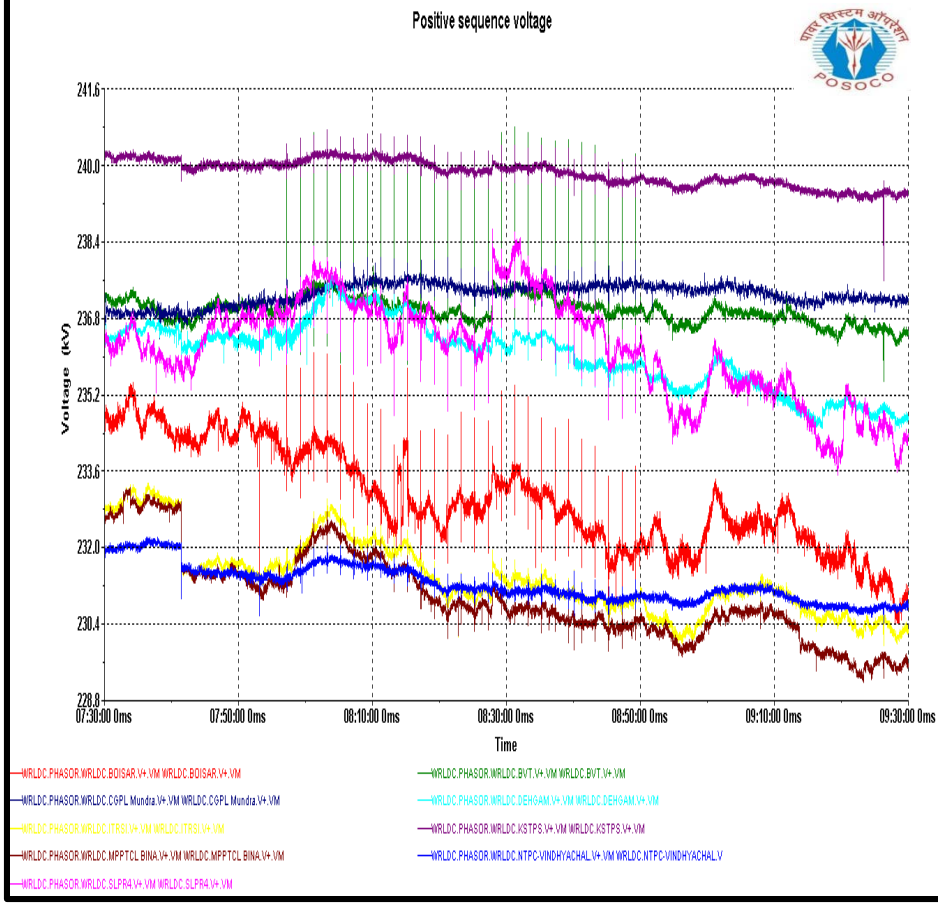
Case-IV

- 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

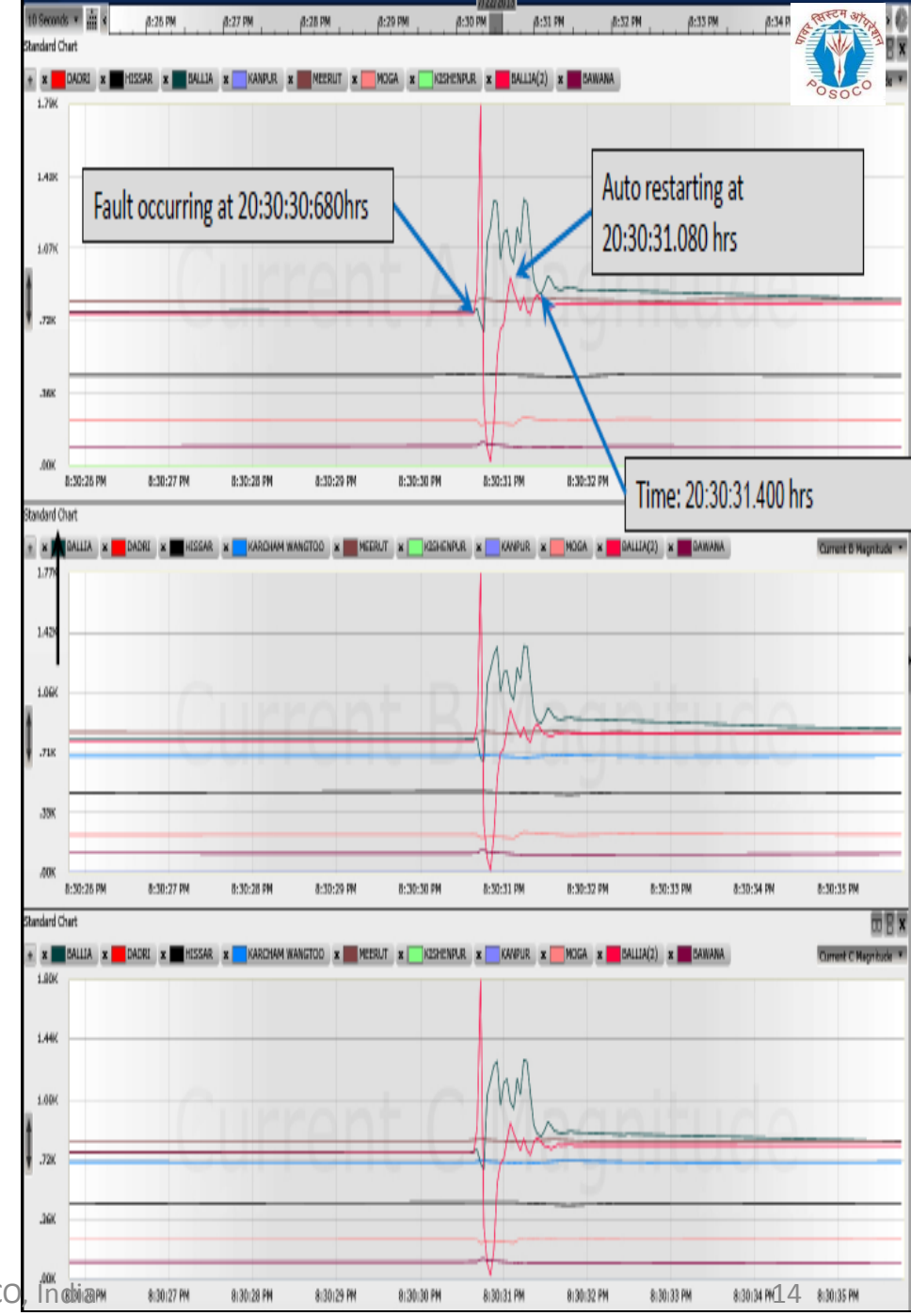
- Antendent power flow in Bipole = 1500 MW
- HVDC Pole 1 taken in planned shutdown for AMP work
- After outage, spikes in Voltage, Current, Power and Frequency at nearby terminal station
- repetitive spikes with period of exactly 2 minutes
- High time constant for generators => HVDC is likely source
- 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
- IThe 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 run backs on two consecutive days => Power flow reduction from 500 MW to 137MW
- 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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