

# Analysis of Oscillation in RE Complex of Indian Power System

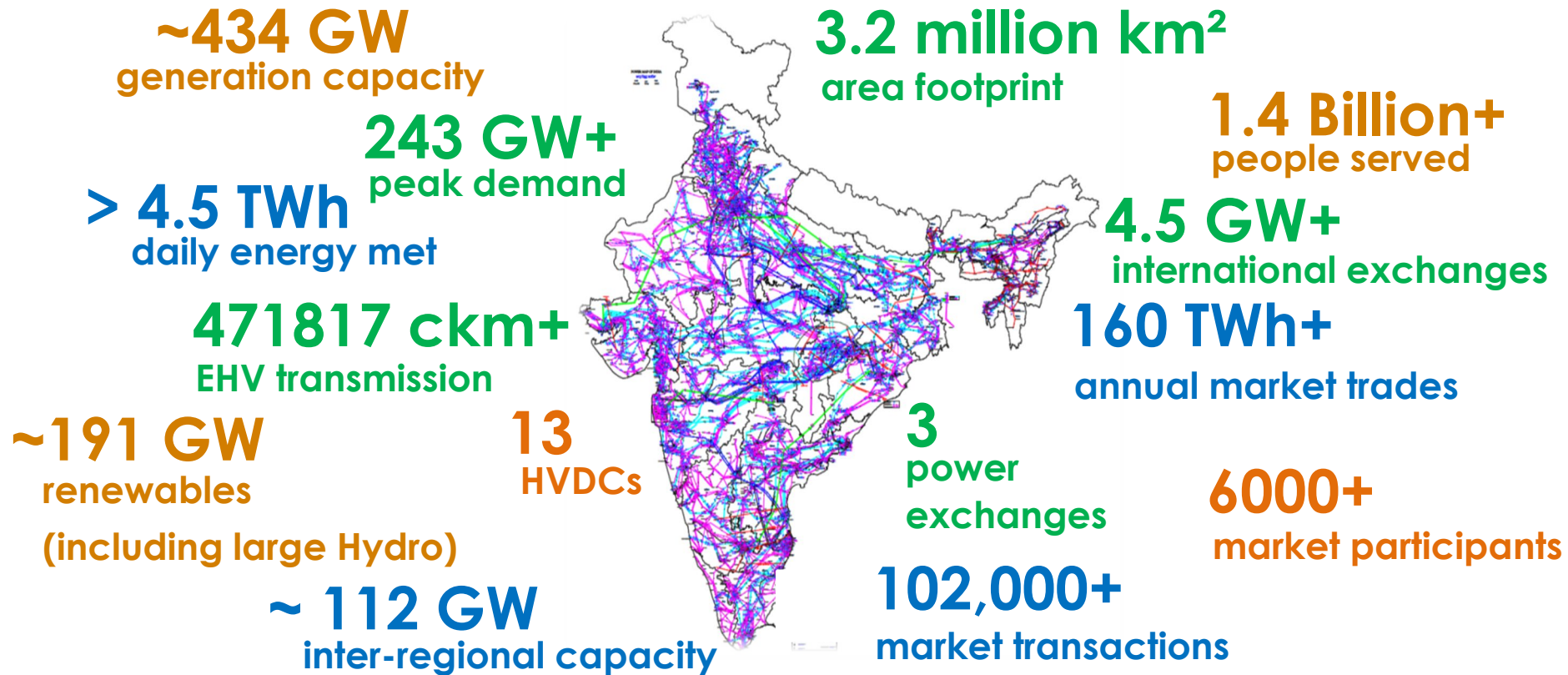


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**Grid Controller of India Limited**

formerly Power System Operation Corporation Ltd. (POSOCO)

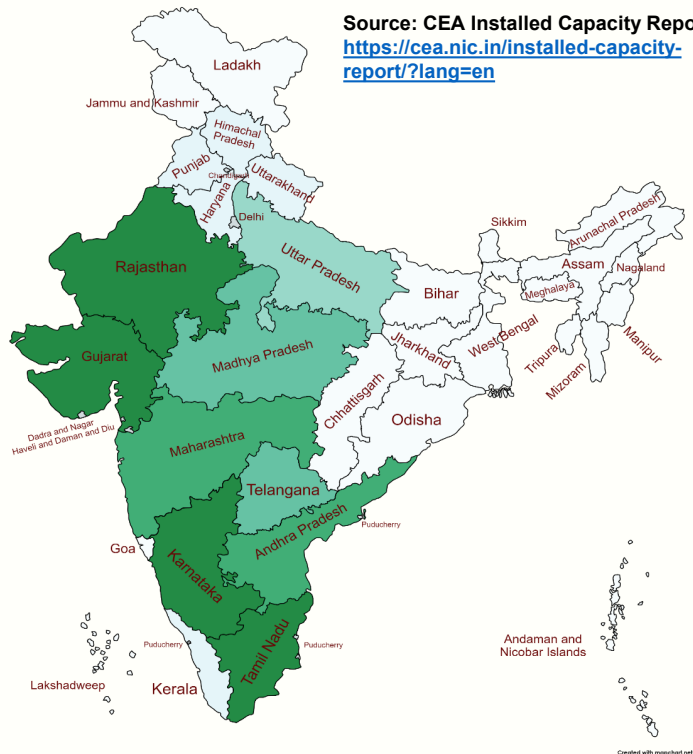
# Dimensions of Indian Power System & Bulk Electricity Market



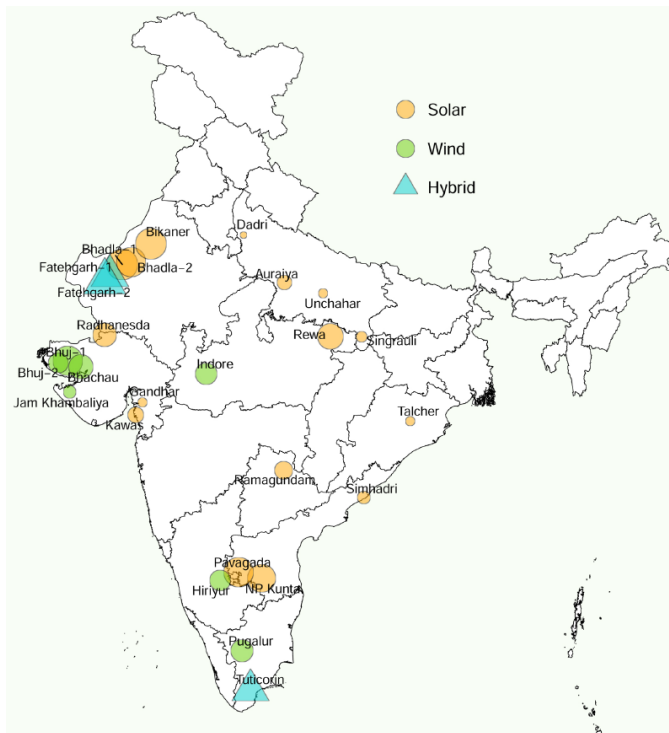
# Renewable Energy Footprint in India

STATEWISE FOOTPRINT OF RENEWABLE ENERGY INSTALLED CAPACITY IN INDIA  
 (INCLUDES SOLAR, WIND, SMALL HYDRO, BIOMASS & WASTE TO ENERGY)

Source: CEA Installed Capacity Report  
<https://cea.nic.in/installed-capacity-report/?lang=en>



## ISTS RE Pooling Stations



# Renewable Energy in India : Target 2030

ALL INDIA INSTALLED CAPACITY (MW)			
Resource	Mar 2023	Mar 2030	% Addition
Hydro	42104	53860	28%
PSP	4746	5350	13%
Small Hydro	4944	18986	284%
Solar PV	66780	292566	338%
Wind	42633	99895	134%
Biomass	10802	14500	34%
Nuclear	6780	15480	128%
Coal+ Lignite	211855	251683	19%
Gas	24824	24824	0%
<b>Total</b>	<b>415469*</b>	<b>777144**</b>	<b>87%</b>
<b>BESS</b>	0	41650 (5-hr)	

\*Excluding 2136 MW of Hydro imports from neighboring countries and 589 MW Diesel based capacity

\*\*Excluding Hydro Imports of 5856 MW

Source: CEA Report On Optimal Generation Capacity Mix for 2030 (Ver 2.0)

[https://cea.nic.in/wp-content/uploads/notification/2023/05/Optimal\\_mix\\_report\\_2029\\_30\\_Version\\_2.0\\_For\\_Updating.pdf](https://cea.nic.in/wp-content/uploads/notification/2023/05/Optimal_mix_report_2029_30_Version_2.0_For_Updating.pdf)



**Maximum Demand Met (GW)**

**2023**

~240#

**2030**

366^



**Total Generation Installed Capacity (GW)**

425\*

777



**Non-fossil Fuel Based Generation Installed Capacity (GW)**

185\*

500



**Wind & Solar Installed Capacity (GW)**

116\*

393

# As on 31<sup>st</sup> October'23 as per Operational Data of Grid-India

• As on 31<sup>st</sup> July'23 From CEA Installed Capacity Report

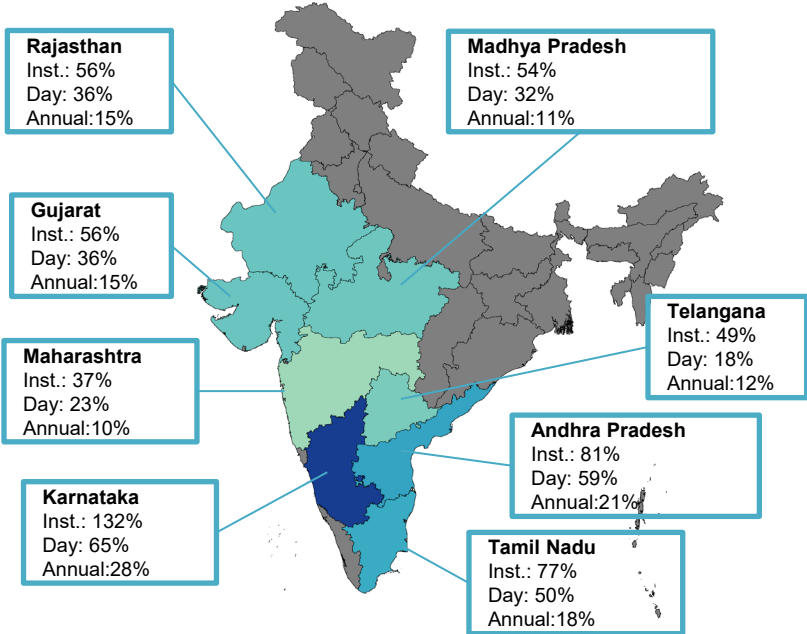
• <https://cea.nic.in/installed-capacity-report/?lang=en>

• ^ 20<sup>th</sup> EPS Survey by CEA:

[https://cea.nic.in/wp-content/uploads/ps\\_lf/2022/11/20th\\_EPS\\_Report\\_Final\\_16.11.2022.pdf](https://cea.nic.in/wp-content/uploads/ps_lf/2022/11/20th_EPS_Report_Final_16.11.2022.pdf)

# Growing penetration of Renewables in the grid

Maximum Wind+Solar penetration in instantaneous MW and energy (day/year) terms



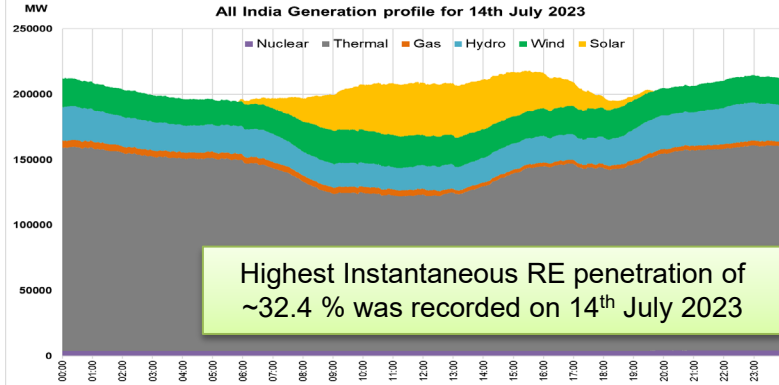
11% All India VRE penetration on annual basis



## Region wise summary of Grid Connected ISTS RE Plants##

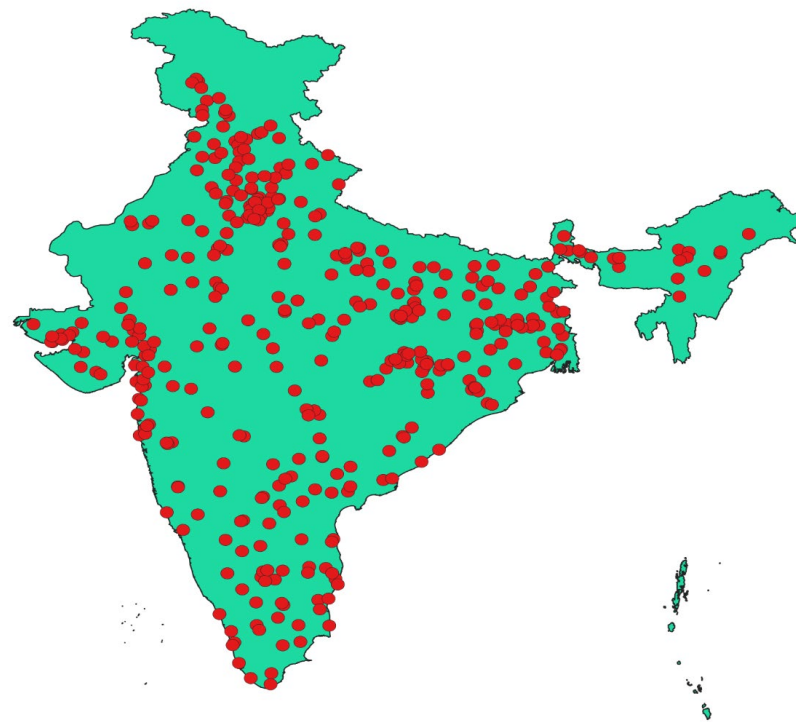
	NR	WR	SR	Total
RE Installed Capacity at ISTS level	12620	4224	5334	22178
RE installed Capacity at Intra-state level#	13311	31342	38381	83034
No of Inverters (at ISTS)	34812	1780	8131	44723
No of WTGs (at ISTS)	403	1753	725	2881
No of Developers (at ISTS)	13	34	36	83
No. of ISTS RE Plants	48	21	36	105
No. of ISTS RE Pooling station	9	9	7	25
Maximum size on inverter (MVA) (at ISTS)	3.125	3.85	3.125	3.85
Maximum Size of WTGs (MVA) (at ISTS)	2.2	2.7	2.7	2.7

## As on 31<sup>st</sup> March 2023



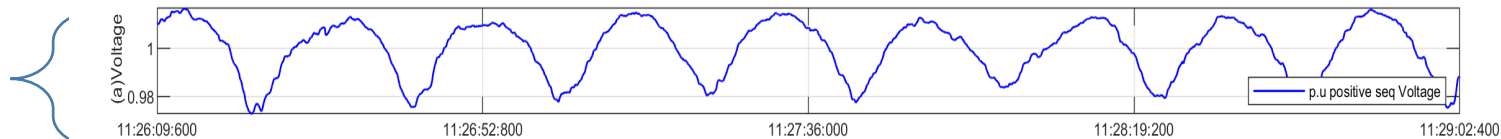
# PMU Locations in India

Region	PMUs
NR	600
WR	640
ER	339
NER	80
SR	370
<b>Total</b>	<b>2029</b>



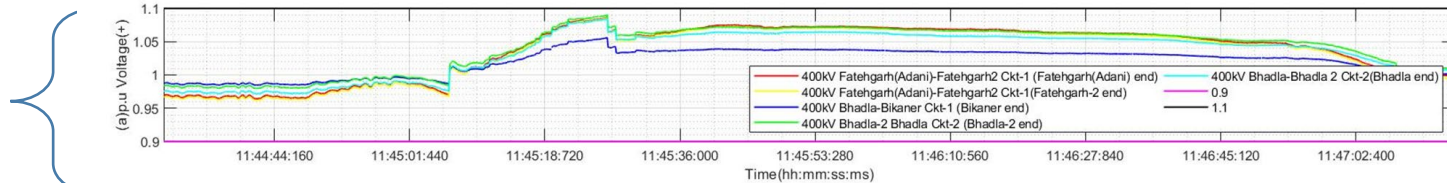
# Use of PMUs in Event analysis of IBR

Oscillations detection

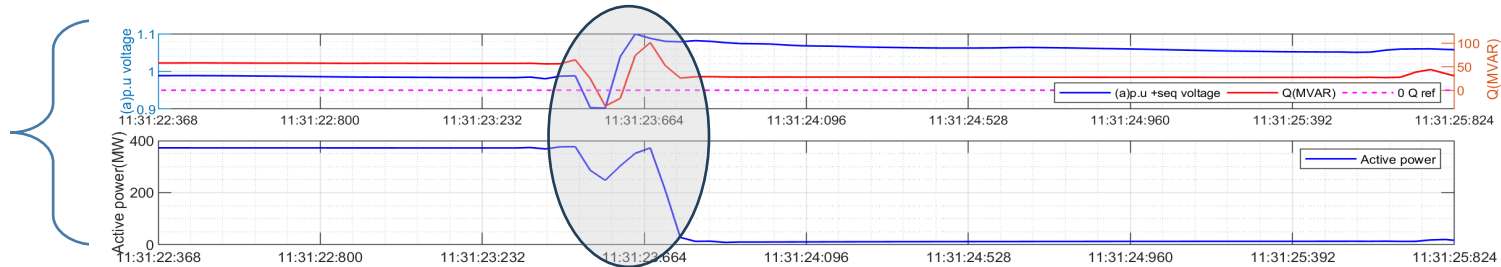


Grid analysis

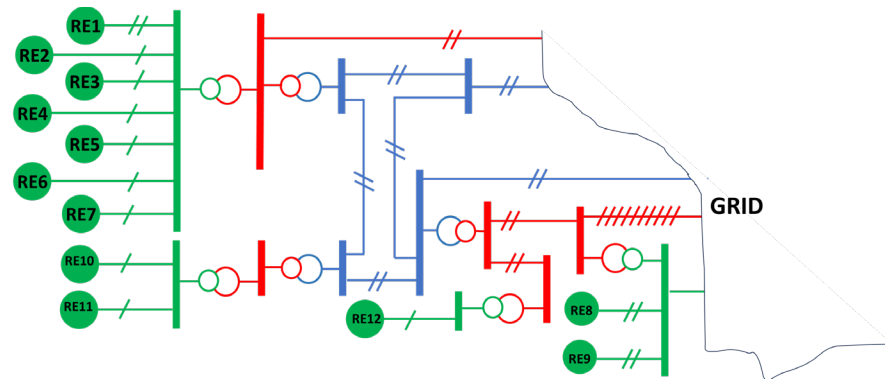
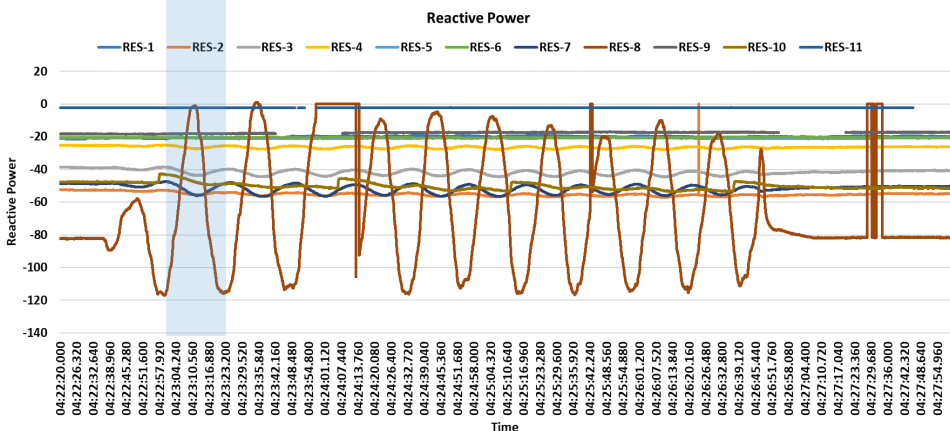
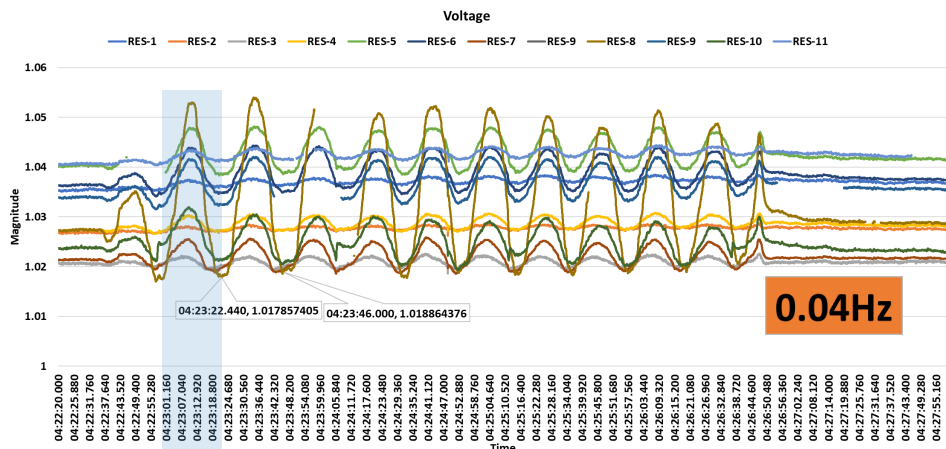
event



Compliance monitoring



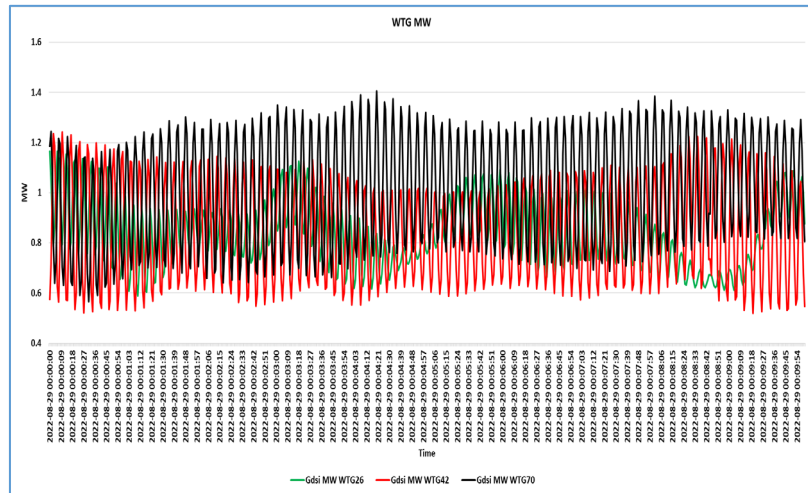
# Reactive power oscillations



- RES-8 having an installed capacity of 555 MW,
- 3 types of IBRs, 2 MW, 2.1 MW & 2.2 MW
- Total 261 nos IBRs
- Multi plant controllers (Master-Slave)
- Voltage and reactive power were in phase
- One particular make slave PPC had issue of polling rate issue



# Active Power oscillations



**0.15Hz, ~0.6MW in WTGs**

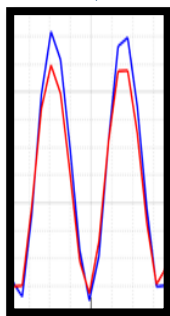
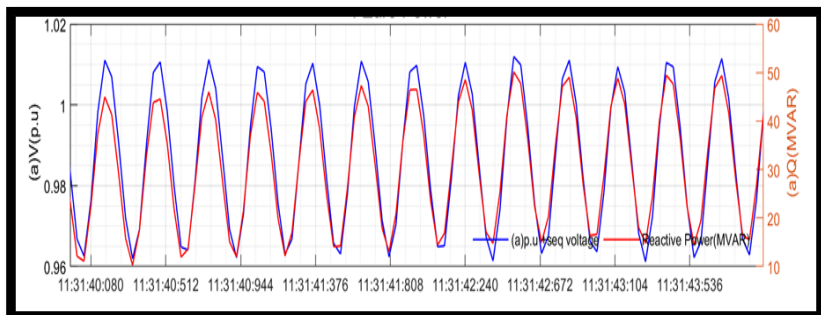
300 MW wind project  
 2.5 MW, 120 nos WTGs  
 Wind turbine blade mass imbalance

## Low frequency oscillations (LFO) in Rajasthan RE Complex

- LFO occurred during peak solar period & low voltage scenario in RE complex in Rajasthan Network.
- Visibility with PMU located at the evacuating transmission line of the RE network.
- No triggering events (Reactor switching, line charging, etc.)
- LFO with frequency of 2-4Hz and 0.03-0.1Hz.
- Oscillation is predominantly observed in voltage and reactive power.
- Maximum voltage variation during these oscillations is observed in RE pooling stations with low short circuit strength)

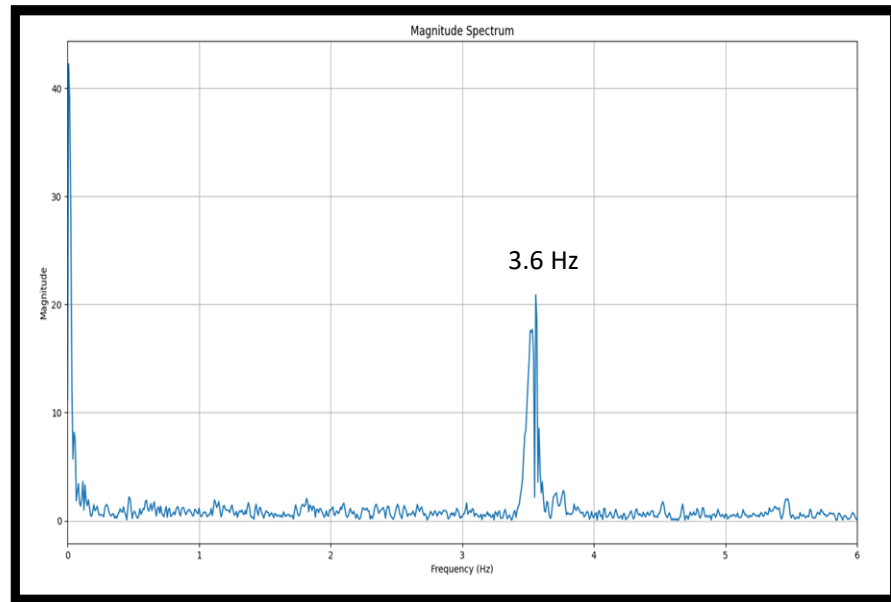
Voltage Oscillation Freq	Dominant Mode	Voltage oscillation magnitude (220kV line)
Mode 1: 2-4 Hz	3.6 Hz	0.01-0.04 p.u. (2-4kV)
Mode 2 : 0.03-0.1Hz	0.08 Hz	0.1 p.u. (20-22kV)
Mode 3 : Multi mode	0.069 Hz	0.15p.u. (30-35kV)

# Mode-1: Voltage oscillations with frequency 3.6 Hz (12-07-2023)



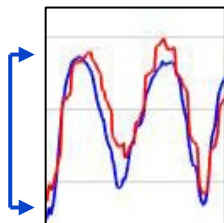
Voltage variation of 0.045 pu i.e. 9.9kV at 220kV

Variation of Reactive Power to the tune of 33 MVAR in FTCH RE plant



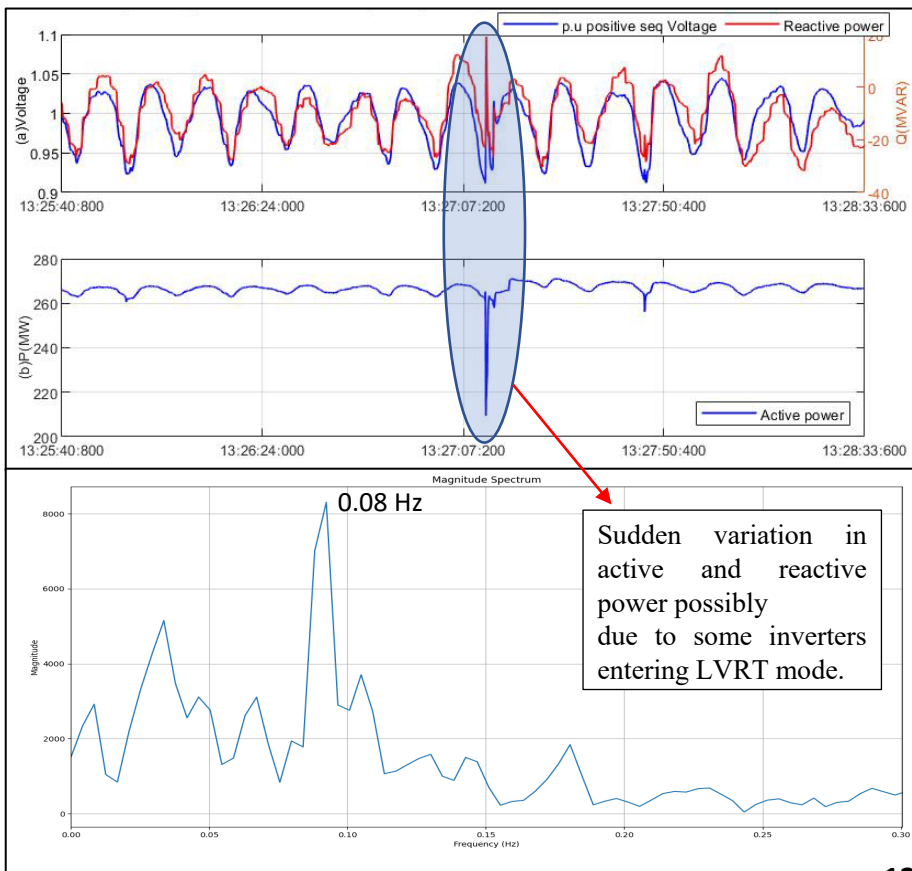
## Mode-2: Voltage oscillations with frequency 0.08Hz Hz (30-01-2023)

Voltage variation : of 0.1pu i.e. 9.9kV at 220kV

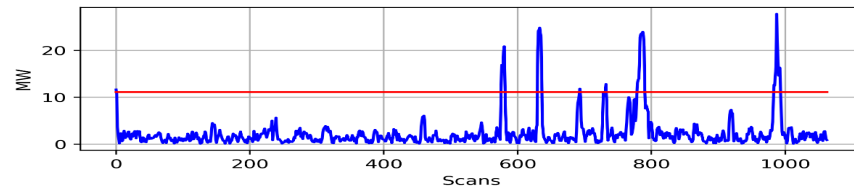
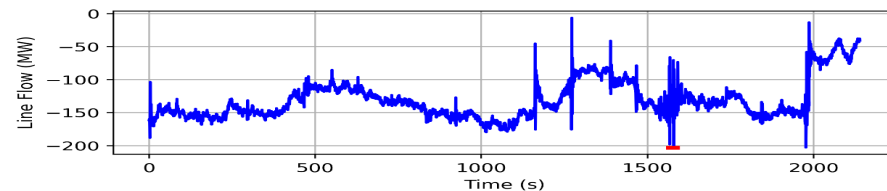
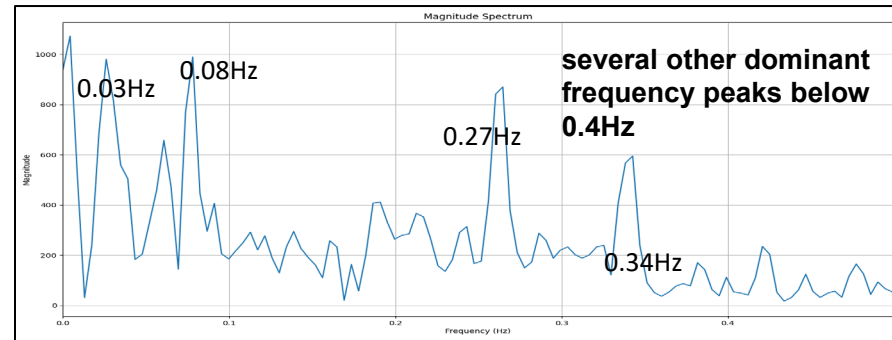
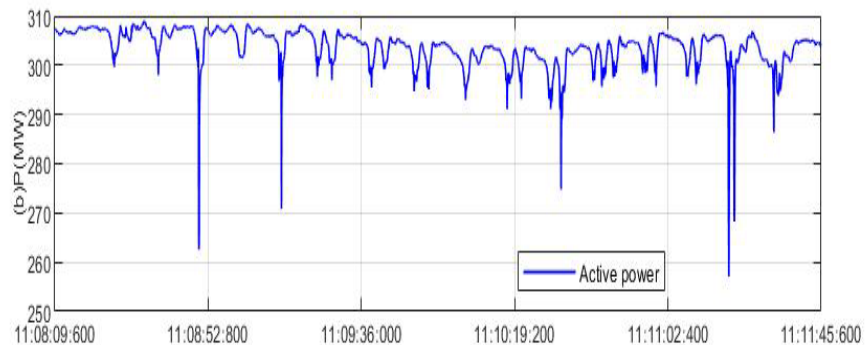
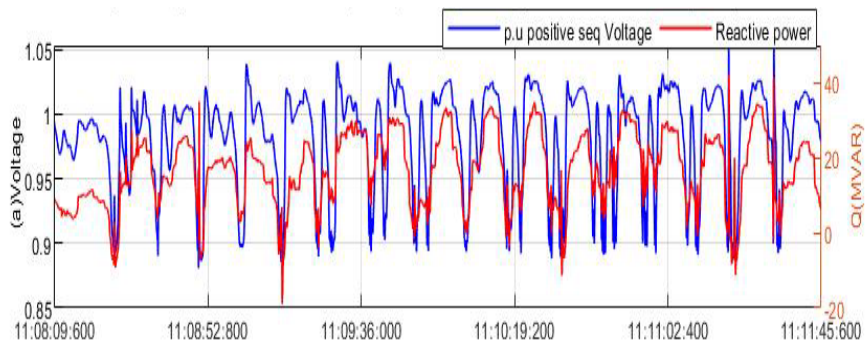


Q Variation of of 30 MVAR in FTHE plant

Parameters	Old settings	New settings	Functions
K-factor	0.5	2	Improve the reactive power support when the power grid drops in depth.
LVRT threshold	0.9	0.85	Reduce the probability of inverter frequent entry to LVRT mode , reduce the active power fluctuations
HVRT threshold	1.1	1.15	Reduce the probability of inverter frequent entry to LVRT mode , reduce the active power fluctuations
Inverter normal operating range	0.9-1.1	0.85 to 1.15	Extend the inverter operating voltage range



## Mode-3: Multi-mode oscillations observed in PMU (27-01-23)

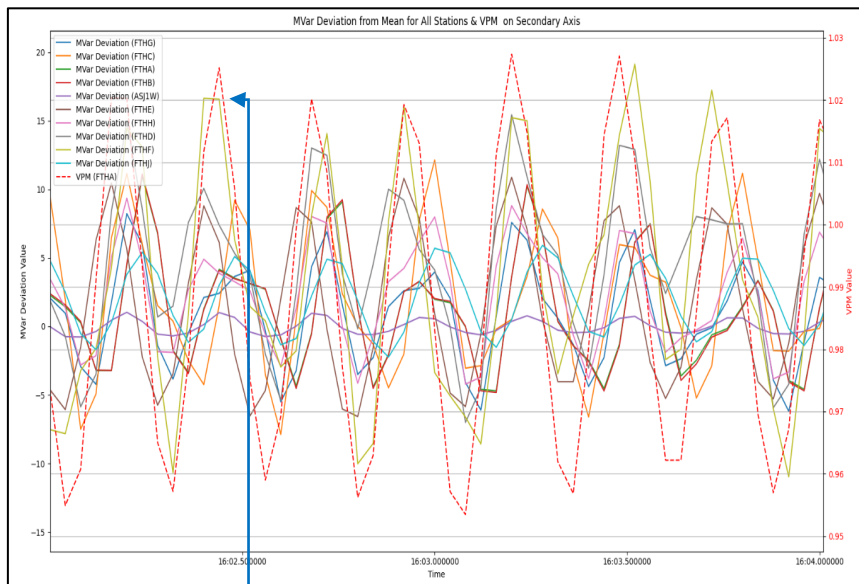


- Voltage variation of 0.15 p.u. i.e. around 30kV in phase voltage (220kV transmission line) and around 60-80kV in 765kV level.

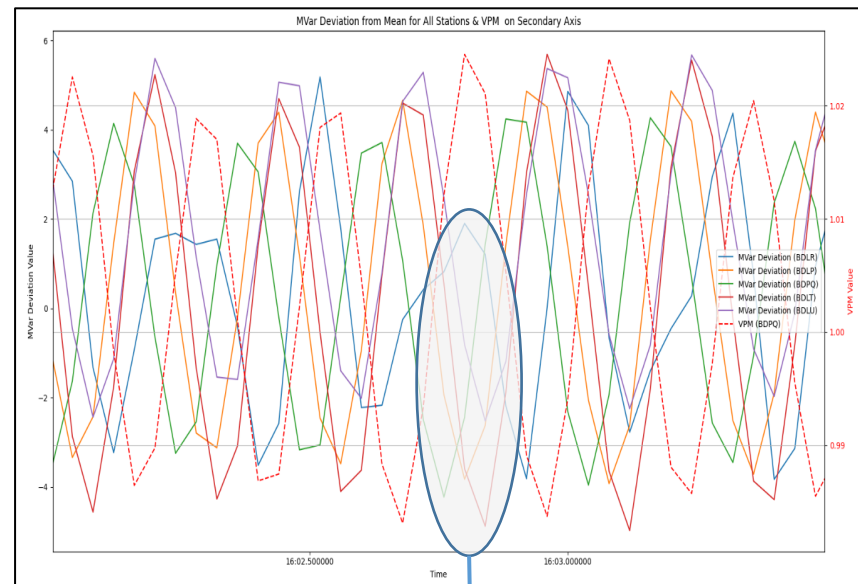
## Analysis of Plant Behavior During oscillation

Classification based on plant response	Behaviour	Analysis
<b>Category-1:</b> Limited variation of reactive power in phase with voltage.	Non responsive	<i>A limited reactive power variation is observed from these RE plants as they are operating in constant p.f mode and in fixed Q mode.</i>
<b>Category-2:</b> Large variation of reactive power nearly <b>in phase with voltage</b> .	Detrimental i.e. Aggravating the oscillation	<i>These plants are responding to the variation in pooling station voltage by action of their voltage controller. The communication delay associated within the plant results in delayed injection of reactive power from RE plants and thereby leads to amplification of voltage oscillation.</i>
<b>Category-3:</b> Large variation of reactive power nearly <b>out of phase with voltage</b> .	Supporting i.e. Damping the oscillation	<i>These plants with high gain and minimum PPC delay exchange reactive power in response to the grid voltage in phase opposition as per the desired characteristics of the plant voltage controller resulting in damping of voltage oscillation</i>

## Reactive power variation of RE plants (01-09-23)

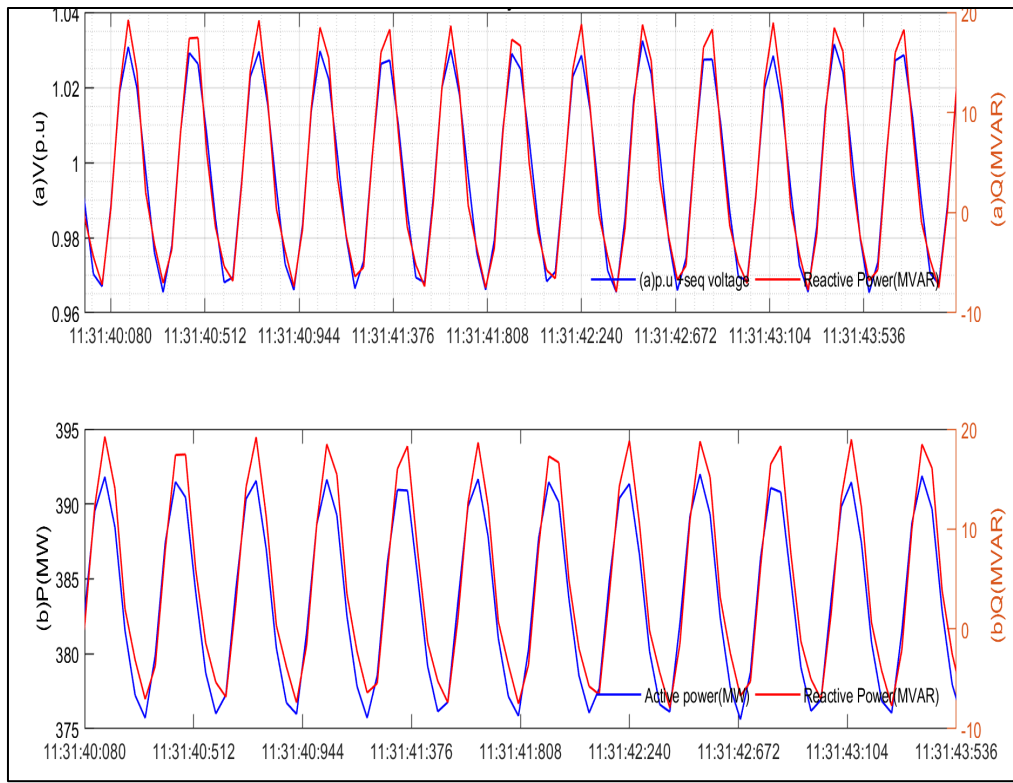
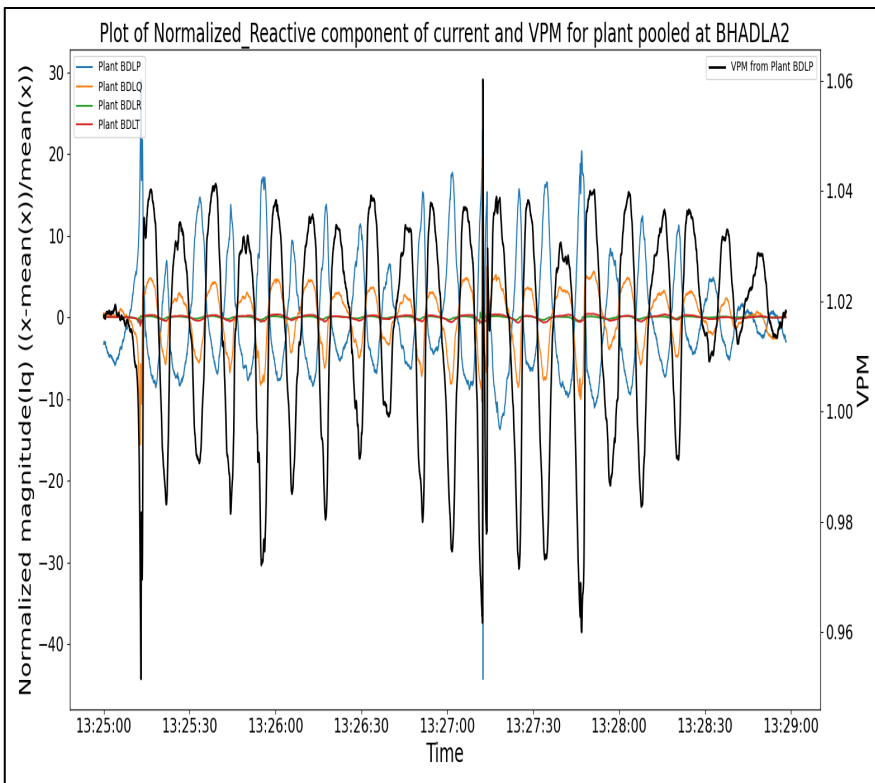


Category -2 performance of Plant FTHF as the reactive power variation of almost (30MVAR) is in phase with the variation in voltage.



Category-3 performance of most RE plants at Badla Pooling Station as the reactive power variation is out of phase with the variation in voltage.

# Reactive Power Control w.r.t Voltage

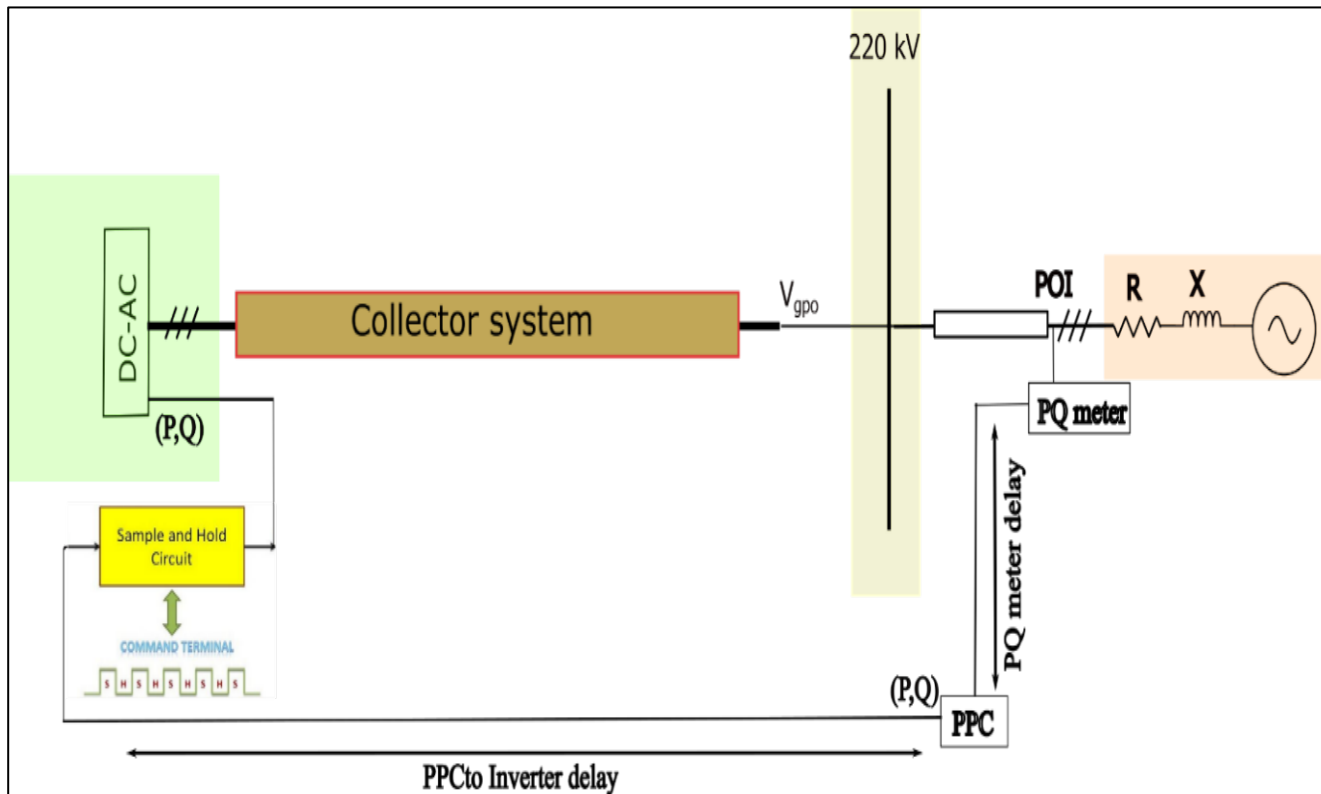


Normalized  $\frac{(I_q(n) - I_{qmean}(n))}{I_{qmean}(n)}$  reactive current injected by different plants at Bhadla-2 during oscillation (14<sup>th</sup> January 2023)

Voltage oscillations with frequency 3.5 Hz in evacuating line of Plant BDLA (14-07-2023)

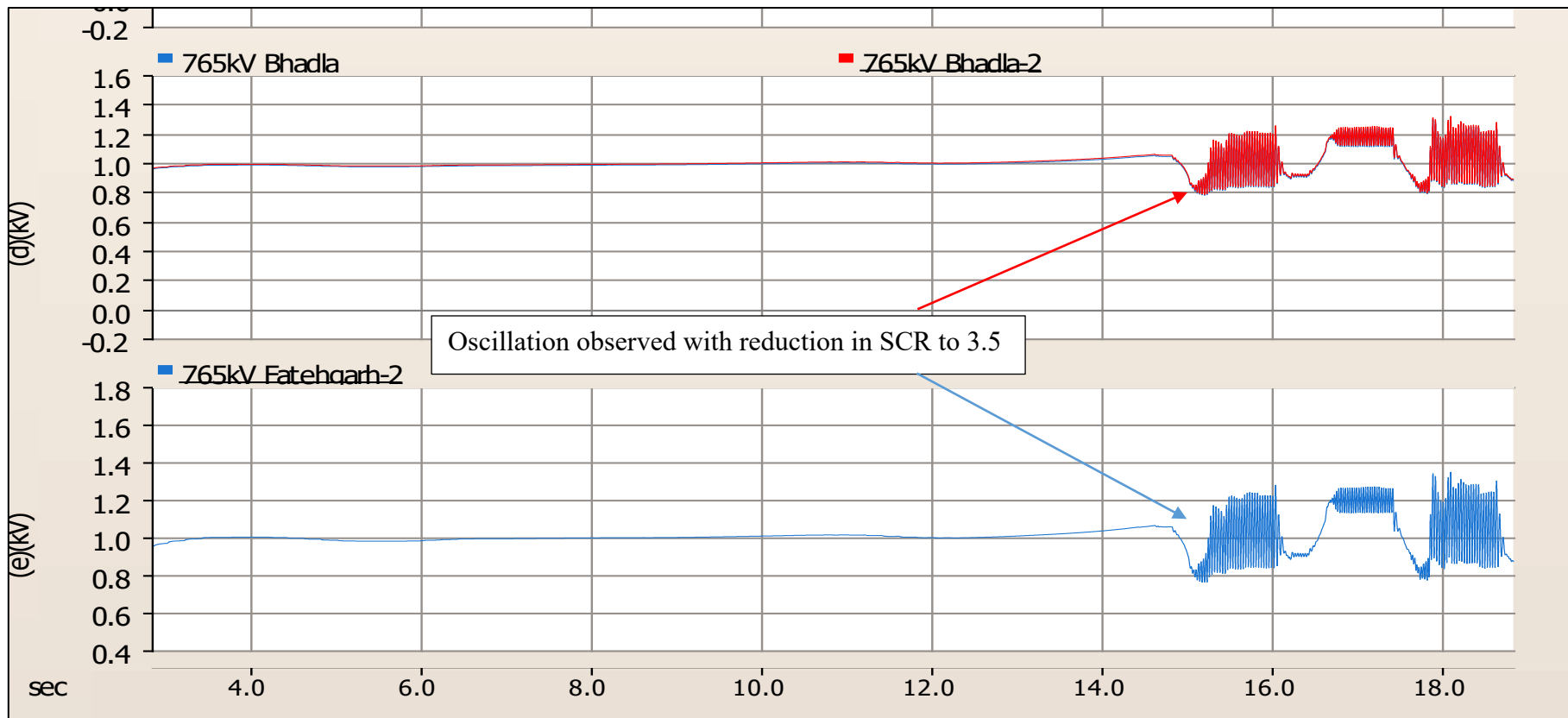


## Delays Associated with in inverter controls receiving PPC command.

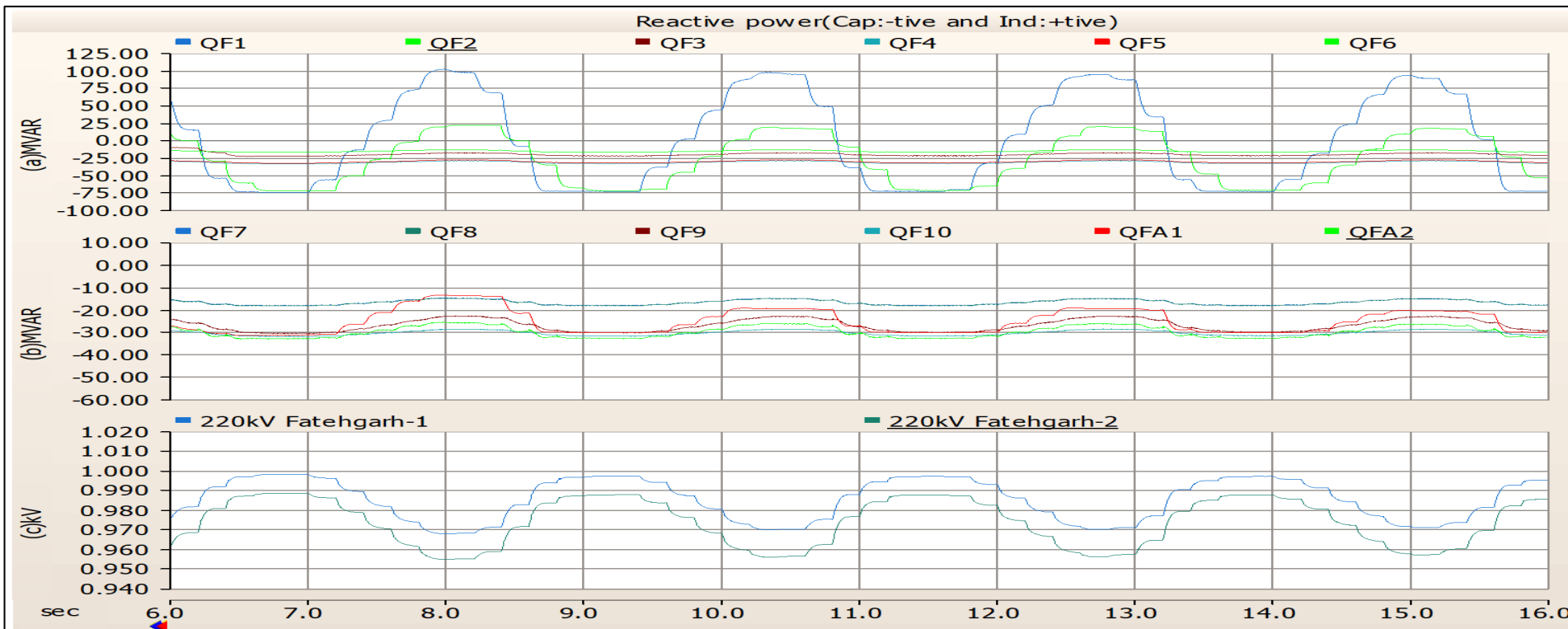


- ✓ PQ meter to PPC delay  
200ms to 500ms
- ✓ PPC to Inverter delay  
100ms to 1000ms
- ✓ Inverter polling rate  
200ms to 500ms (Depends on  
inverter manufacturer and Inverter  
models)

## Voltage Oscillations with réduction in Short Circuit Ratio(SCR)



## Reactive Power variation in plants (QFA1, QFA2, QF1, QF2) -voltage control dead band of 1%



# Thank You