Synchrophasor Technology: Addressing Integration of Renewable with Synchronous Grid by Real Time Monitoring through WAMS

By

D N SHAH

Executive Engineer, SLDC-GETCO.

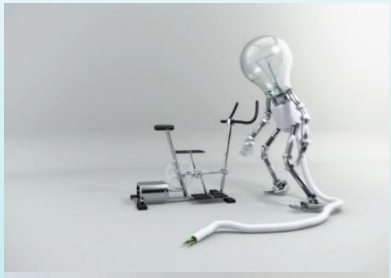
At

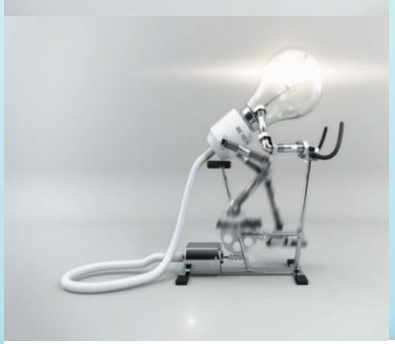
2nd International Conference on Large-Scale Grid Integration of Renewable Energy in India from 4 - 6 September 2019 New Delhi.

Out line of Presentation:

- Industry In Transition
- RENEWABLE ENERGY AND INTEGRATION CHALLENGES
- Statistic of Renewable Energy
- SYNCHROPHASOR – Predicting What Matter to gric
- Case Studies
- Synchrophasor Tools for Addressing RE Integration Issues
- Concluding Remarks

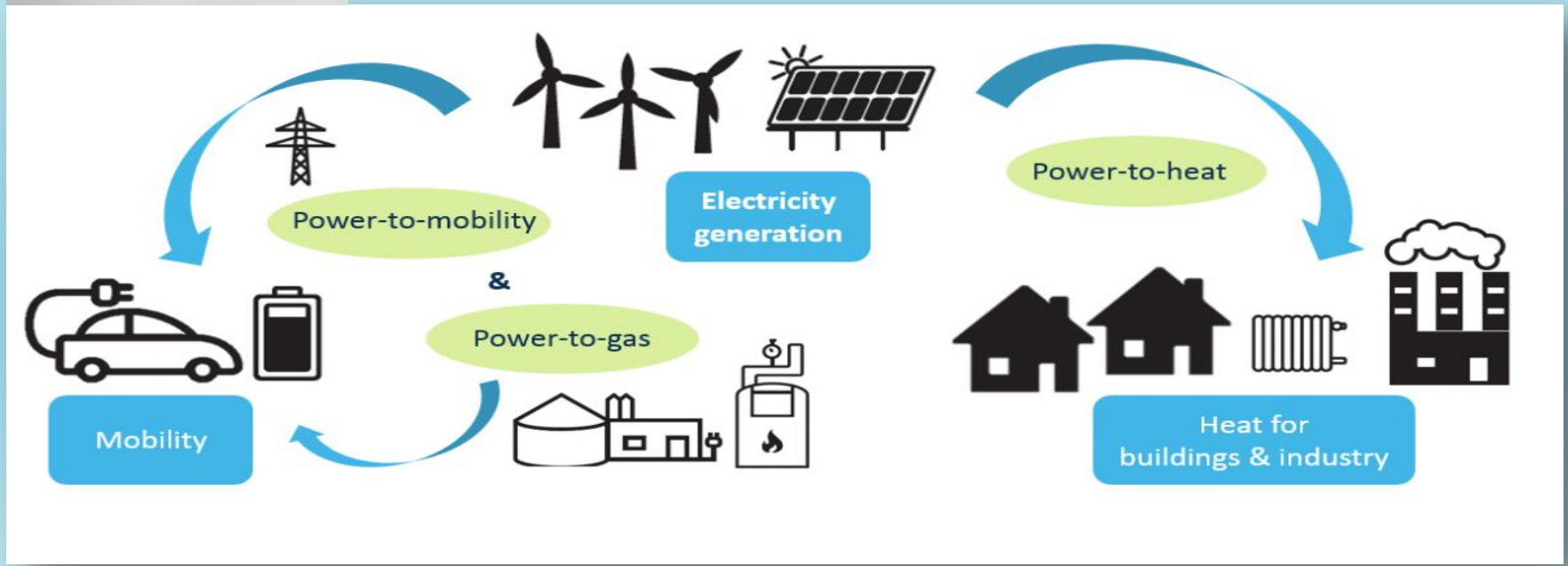
INDUSTRY IN TRANSACTION:





- There was focus on conventional generation on large scale in India till now, which require integration of power at transmission level,

- Rising trend to integrate generation at distribution level / near consumption point with solar roof top, in future may small wind mill penetration may increase at distribution level / nearby consumptions point.







Started with scattered generation for self sustain by individual. (Without grid support)

Then town level & brings under state level.

(With local grid support)

Then bigger size concentrated generation at central sector generation having share of more than one state. (With Inter state Grid support)

then UMPP projects with a capacity of 4000 + MW with merchant power. (With Inter regional grid support)

Now again generation at distributed level near consumptions point but (with micro grid / grid support).








CHALLENGES OF RE INTEGRATION

- Variability, Unpredictable and Uncertainty Nature
- Voltage Monitoring & Frequency response
- System Stability & Systems Balancing
- Reactive power control
- Oscillation detection & damping
- Harmonic Injection

STATISTIC OF RENEWABLE ENERGY

Gujarat Installed Capacity (31/03/2019)			
Winds 21.00 %	Solar 8.0 %	Total RE 29.00 %	Rest 71.00 % %
5784 MW	2113 MW	7197 MW	20129 MW

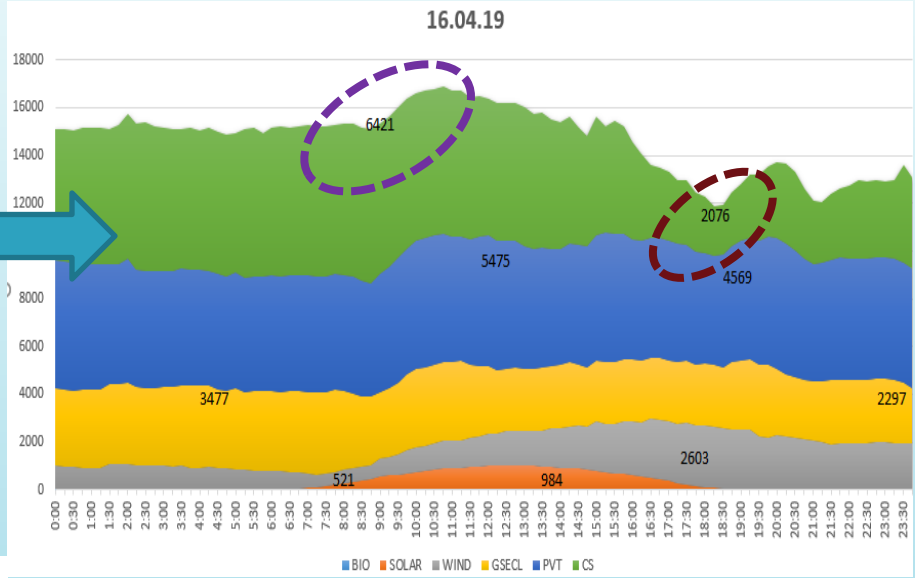
Maximum Generation in MW		Maximum Generation in MUs	
Winds (11/07/2019)	Solar (19/04/2019)	Winds (11/07/2019)	Solar (19/04/2019)
4565	1477	94.68	11.178

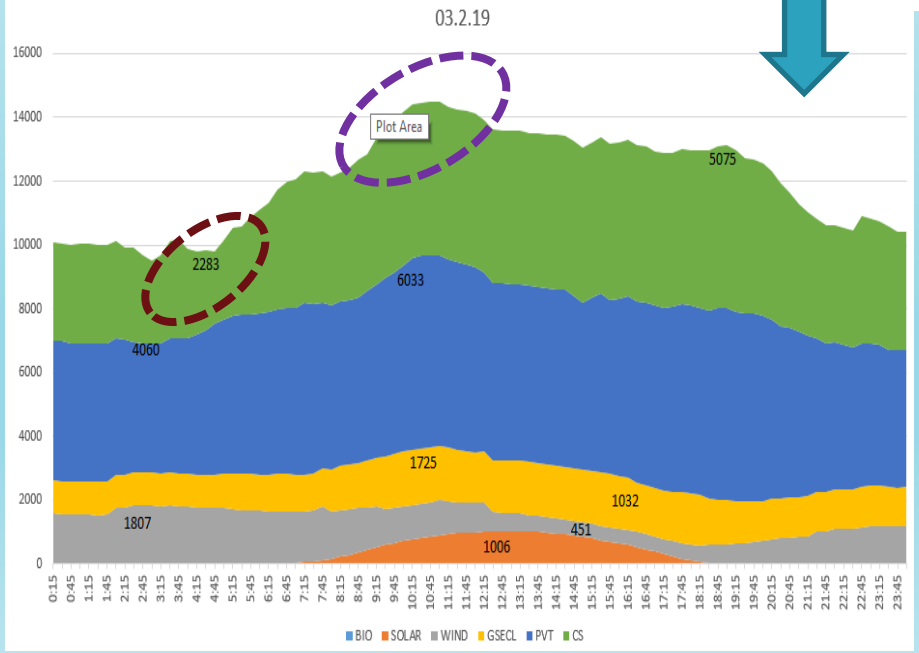
Gujarat (By 2022)	Wind	Solar	Rest RE
17.133 GW	8.8 GW	8.02 GW	0.313 GW

Conventional generation used to balance renewable generation

Solar generation profile on date: 16.04.19 and how balanced with conv. generation to meet demand of the day

Wind generation profile on date 03.02.2019 v/s back down/pick up of conventional generation to meet the demand of day





Fast dispatch with **PMU signals may help in managing the variation in renewable generation, with faster dispatch load and generation can more linearly matched.**

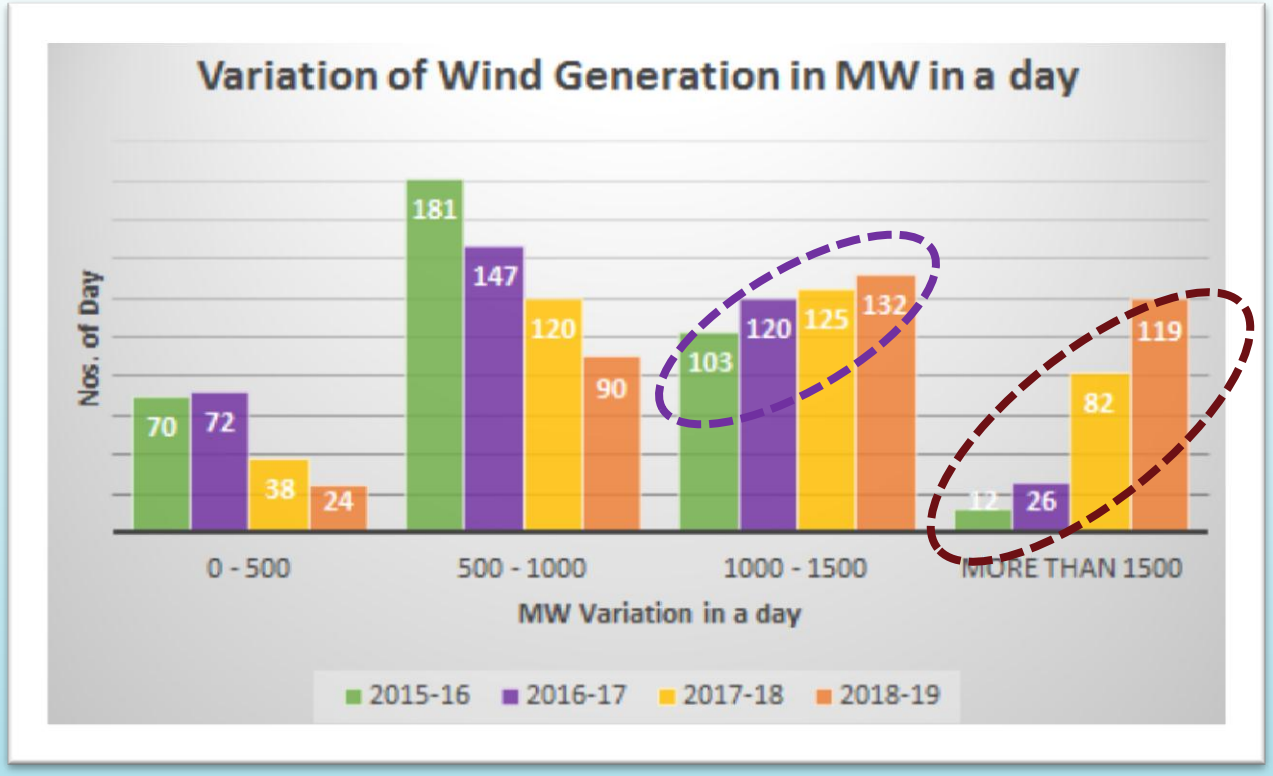
Cyclone Fani struck North – Eastern parts of India in Odisha and Uttar Pradesh and Bangladesh but impact on wind generation at western part of India i.e. Gujarat effected.

New M/c taken on bar			Machines desynchronized		
Time	Unit	MW	Time	Unit	MW
00:36	WTPS 5	210	15:54	UTRAN 2 STG	146
00:43	STPS 4	250	15:57	UTRAN 2 GT	228
00:46	UTRAN II STG	146	17:05	GSEG 2 STG	129
08:07	GSEG II STG)	129	17:09	GSEG 2 GT	222
		733	16:22	JGPP STG)	224.5
Huge MW difference in taking M/C on bar and off bar, ultimately leads to load reschedule as shown table 2.			18:06	JGPP	144
			19:17	GTPS 3	210
			21:50	STPS 3	250
			23:34	WTPS 4	210
					1762.5

For smooth operation of grid, compel to reschedule load.

Time in hrs.	MW
01.20 to 01.40	575
06.50 to 07.00	200
06.50 to 07.05	180
07.00 to 07.05	50

Counter corrective action can be address-using PMU.



With the increasing penetration of RE, variation of wind generation in a day in tune of 1000-1500 MW and more than 1500 MW is increasing drastically.

Variation of 1500 MW in day became 119 in 2018-19 against 12 in 2015-16, which is very tough operating condition for grid operator particularly when operational band is tighten day by day.

To handle such variation's PMU base real time grid monitoring tools requires for expansion and integration of renewable with grid.

SYNCHROPHASOR - PREDICTING WHAT MATTERS TO THE GRID

- High-speed, wide-area, continuously time-synchronized grid monitoring and sophisticated analysis become a fundamental element of grid modernization for transmission system.
- Installation of PMUs at each turbine is not practical, but it essential at pooling station wise to improve aggregate wind generator behaviour.

Synchrophasor data offers substantial insight for interaction between generators and the power grid, and with help of sophisticated engineering analysis improve grid design and protection. Which help in the expansion and integration of renewable generation.

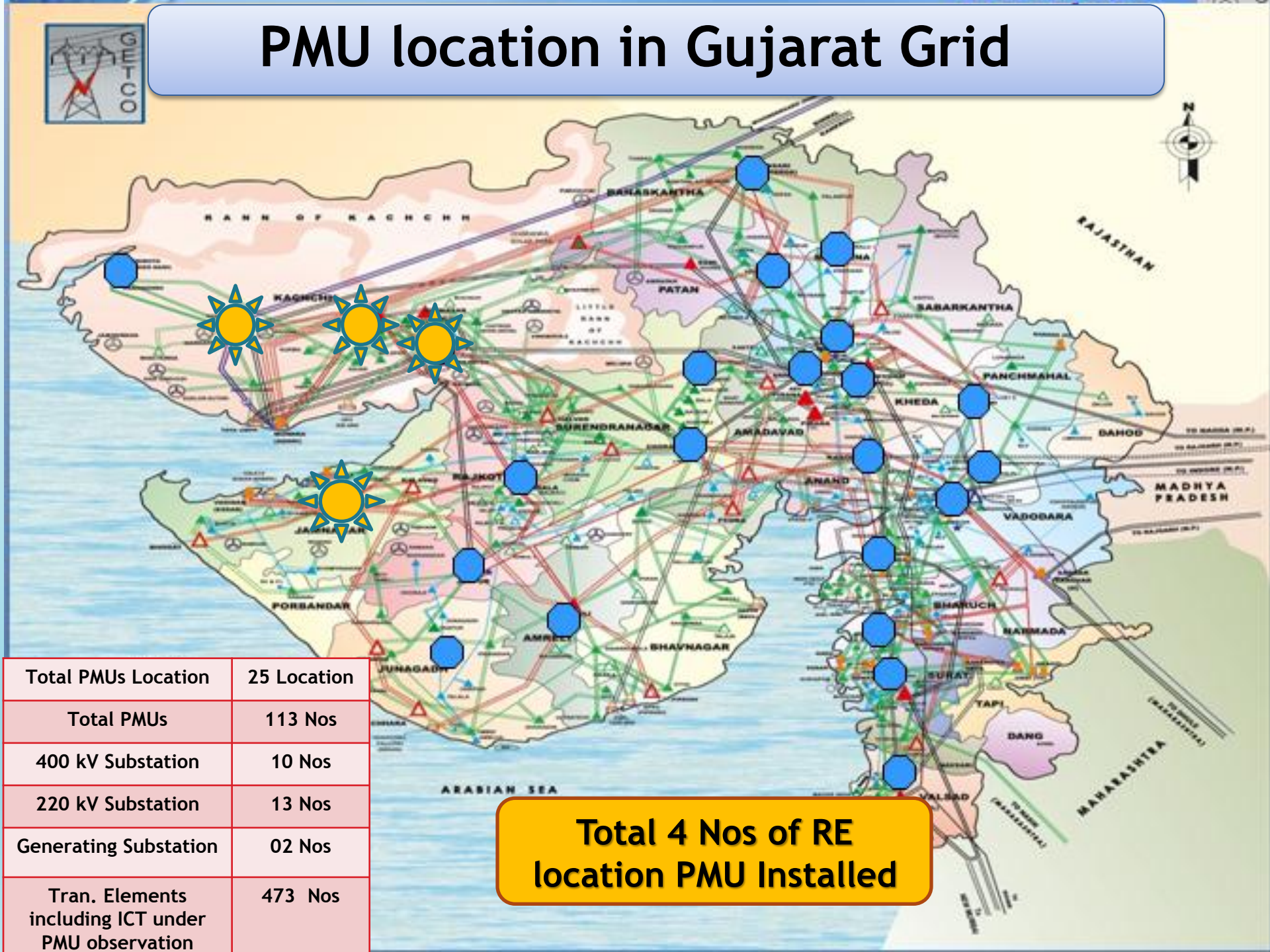
- Real-time monitoring of active and reactive power, frequency, determine the grid impact of renewables on inertia and primary frequency response
- Detect of oscillation and calculation of damping, calculate real time inertia perform active and automated control of wind and solar plants using PMU data, model validation.

PMU based real-time data can be utilised for the management of wind assets and on-line system stability assessment, for better visualization of wind farm voltage/var output.

RE Integration and PMUs- How can we use synchrophasors?

- Real-time monitoring of primary frequency.
- Power flows from a point of high voltage angle to a point of low voltage angle.
- Assist for line reclosing and system restoration after events, and disturbances using Phase Angle Differences.
- Oscillation detection and damping & Assessing real-time inertia
- Power flows from bus with high phase angle to lower phase angle in AC systems.
- Determination of variable generation impacts on primary frequency and inertia.
- Assess grid stress and line reclosing using phase angle measurements.

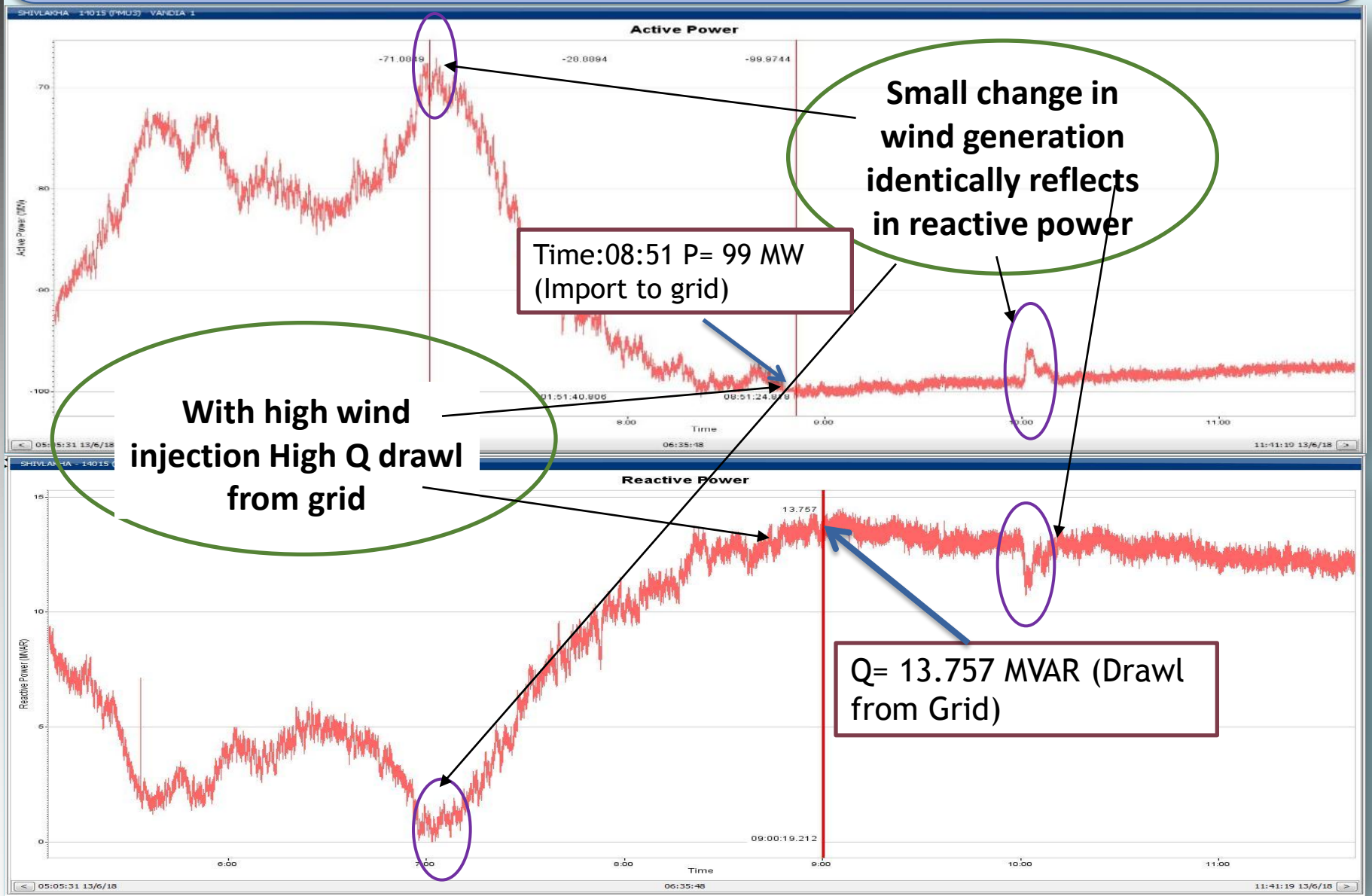
PMU location in Gujarat Grid



Total PMUs Location	25 Location
Total PMUs	113 Nos
400 kV Substation	10 Nos
220 kV Substation	13 Nos
Generating Substation	02 Nos
Tran. Elements including ICT under PMU observation	473 Nos

Total 4 Nos of RE location PMU Installed

CASE-I Impact of high wind generation on reactive power (Q) flow from grid is identify using real time data of PMU, drawl of Q flow from systems date:13.06.18, 05:05 to 11:41 Hrs of Shivlakha S/S



OBSERVATION OF CASE:I WITH PMU DATA

8:51 P_{max} is @ 99 MW (Import to grid at Shivlkha GETCO S/S) at same time wind farm pooling station absorbing Q @ 13.757 MVAR from grid.

Grid importing active power from wind farm. However, injection of active power in the grid is **not linear.**

Power factor, also drops significantly with more number of induction generators connected to grid.

A sharp increase observed in Q req. from grid when machines switched in simultaneously. Necessity to keep the load perfectly balanced.

Active Power monitoring of renewable energy systems using PMUs.

PMU measurements/data will provide better situational awareness for dispatchers to track voltage stability during fast wind ramps.

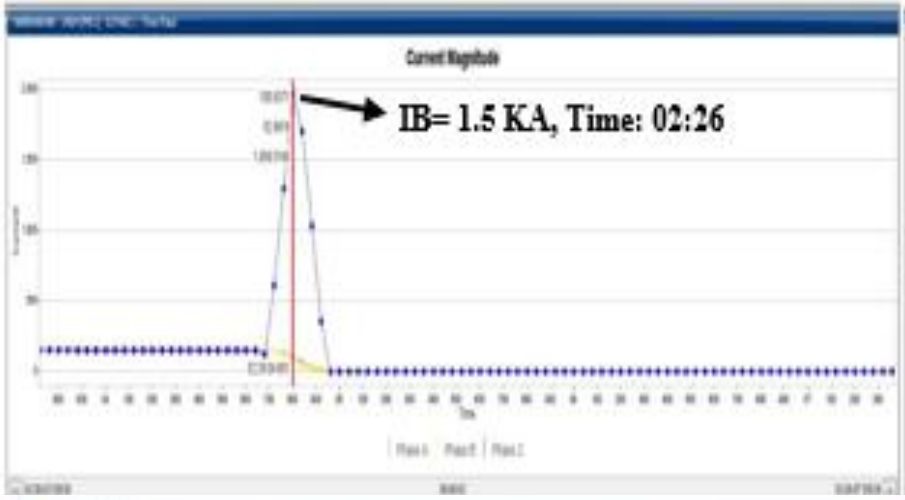
It can be possible for operator to real time tracking of P & Q from control centre if synchrophasor data is available of wind pooling s/s.

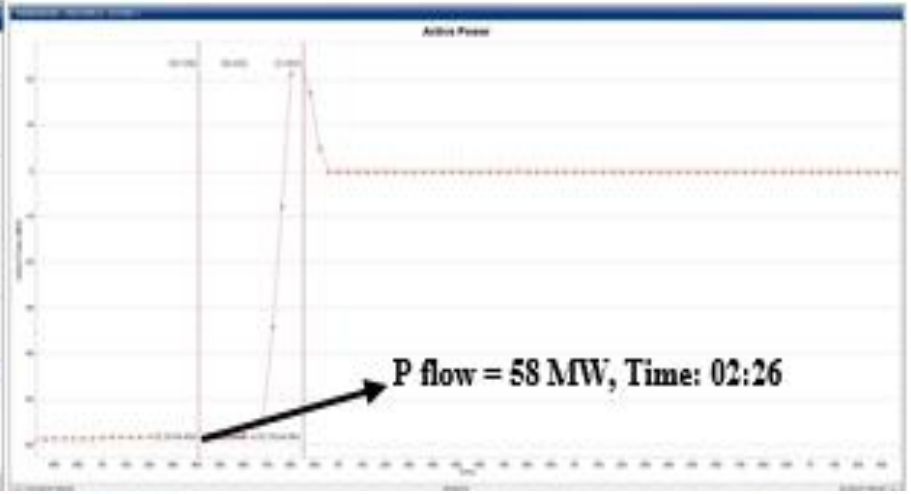
Time:08:51 Hrs V @ Bus is 222 KV, which is reasonably good V profile observed in high wind injection because of strong leading local VAR support is available at GETCO grid s/s

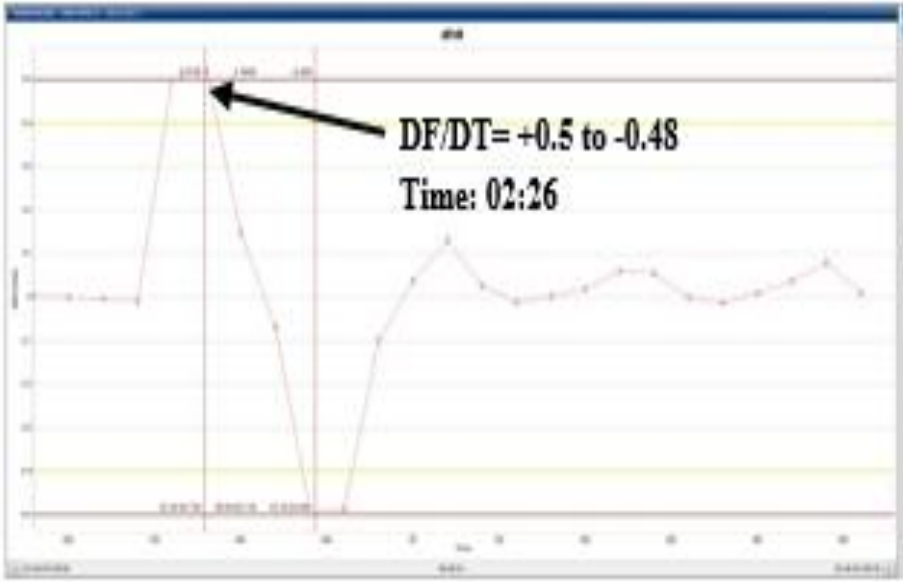
At 10:06 to 10:24 Hrs small variation in generation reflected identical in bus voltage at 220 KV Shivlakha s/s.

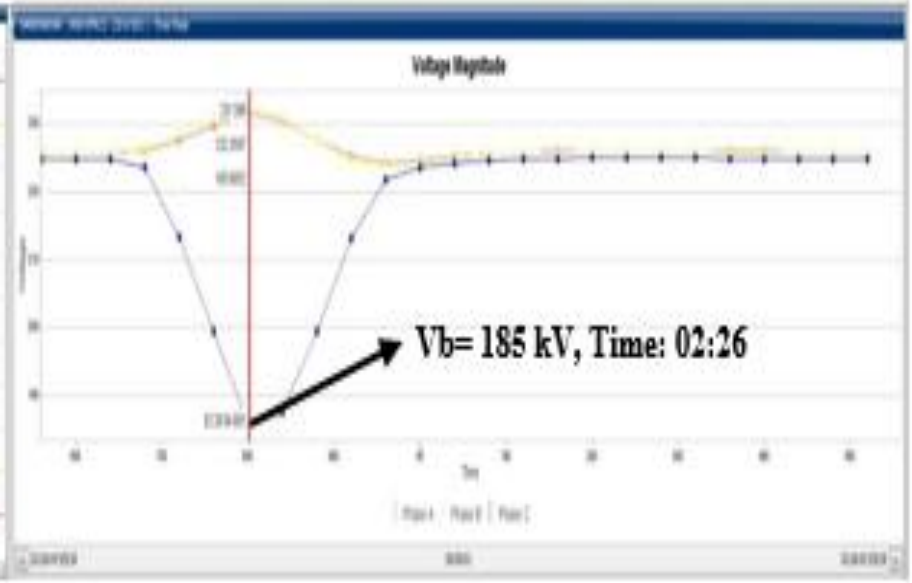
Case II: Impact of RE generation tripping on synchronous grid

At 220 kV Nanikhkhar S/S, wind farm line of 220 kV Suthari line-1 was tripped on single phase to earth fault on date: 05.09.18, 02:26 hrs. As per PMU data

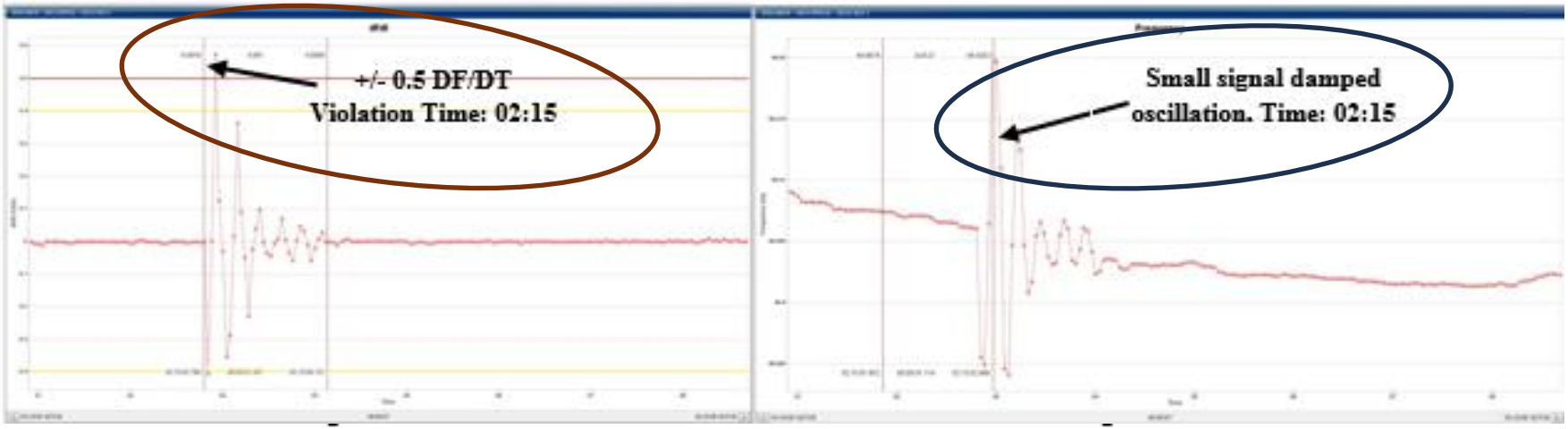


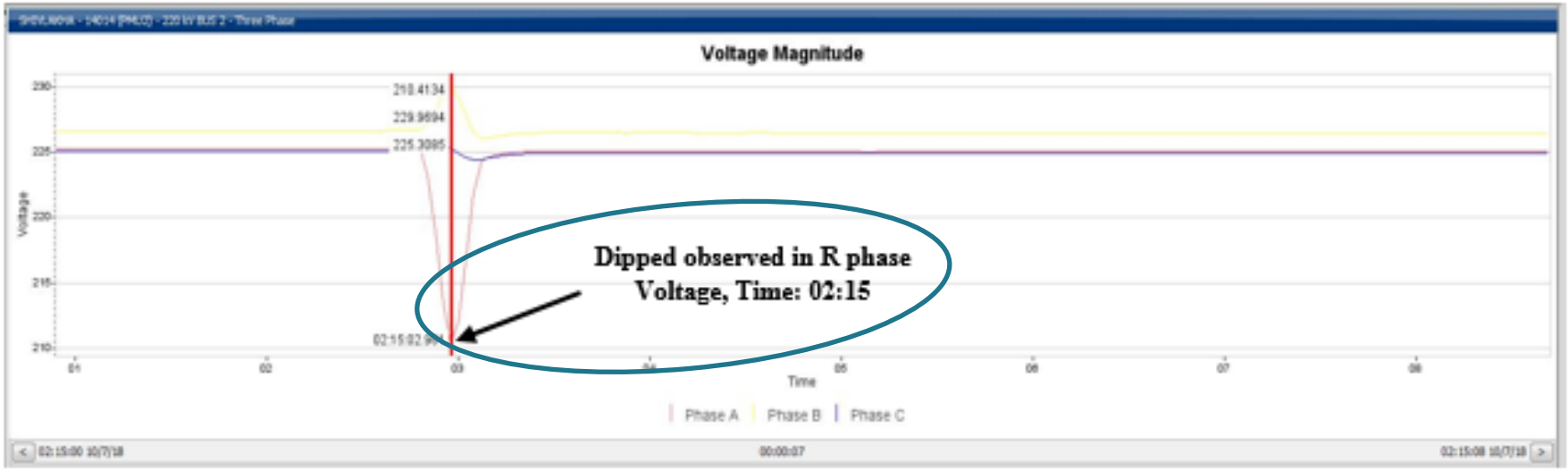




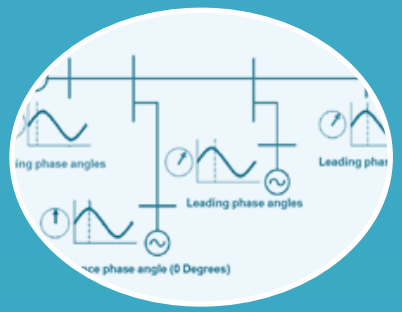


GETCO has installed PMU at 400 kV & 220 kV voltage level, No direct observability of 66 kV Grid through PMU, on date: 02.10.18, 66 kV Shivlkha-Shikarpur line-1 of wind generation tripped at 02:15 hrs. disturbance effect on **220 kV Shivlkha bus** is observed with PMU data.

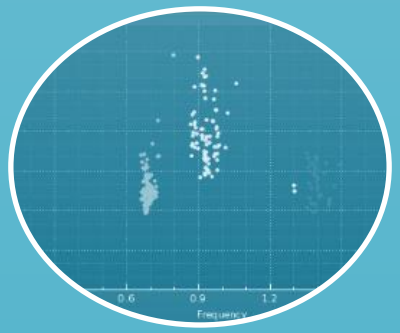




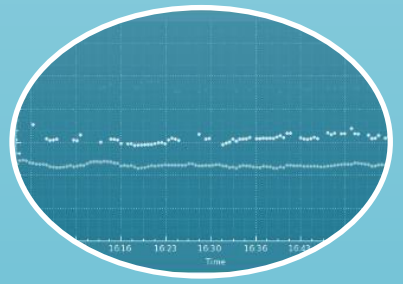
CASE-III Identification of low frequency oscillation during high wind penetration On date: 04.09.18 16:00 Hrs at 220 kV Shivlkha SS bus,



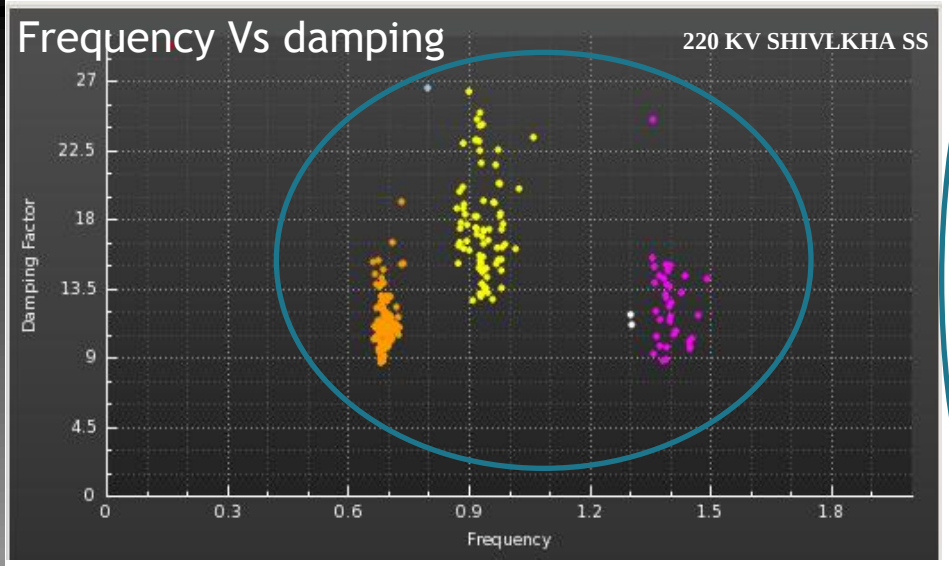
Low frequency oscillation may be induce by the variation of the wind power, which is also referred as forced low frequency oscillation.



Frequency vs damping, low frequency oscillation was observed in the range of 0.690, 0.796, 0.934, 1.301, 1.398 Hz



Damping is reasonably good in the range of 10 to 20 %.

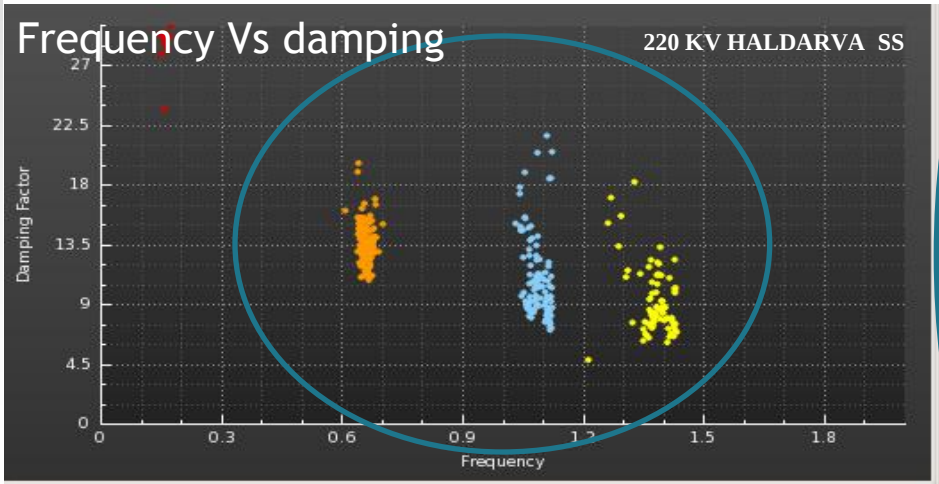


f (Avg)	f (Std Dev)	ζ (Avg)	ζ (Std Dev)
0.158	0.000	29.286	0.000
0.690	0.016	11.410	1.657
0.796	0.000	26.563	0.000
0.934	0.037	17.621	3.308
1.301	0.001	11.492	0.329
1.398	0.034	12.540	2.873

Frequency

Damping

- Comparative analysis is carried at 220 kV Haldarva ss in south region of Gujarat grid,
- Low frequency oscillation in narrow frequency band observed.
- Range of low frequency oscillation observed at nearby wind farm pooling station is relatively more as compare to oscillation observed at other location of Gujarat grid.



f (Avg)	f (Std Dev)	ζ (Avg)	ζ (Std Dev)
0.159	0.009	28.379	1.745
0.659	0.014	13.608	1.553
1.085	0.024	11.066	3.183
1.377	0.041	9.239	2.486

Frequency

Damping

Realistic Challenges for synchrophasor technology

- Voltage control
- Effective reactive power sharing
- Power from conventional plant need to transfer via stability-limited path
- System operators respond & understanding of phasor data with available options for action.
- Institutional problems with putting PMUs on generator terminals.
- Lack of policy support like incentive to extend PMU deployments with any technological advancement.

PMU provides high resolution measurements of power system states, It can provide aid to close-loop control, dynamic modeling, frequency response studies.

SYNCHROPHASOR-BASED TOOLS FOR RE INTEGRATION ISSUE:

State estimation to increase situational awareness with wide-area visualization for operators, improve visibility of remote wind generation.

Transport wind energy through long transmission lines is a challenge. One of the solution is PMU based application having real time data.

Many distributed generators are not monitors, with PMUs at the distribution level can be enhance monitoring of generation / load.

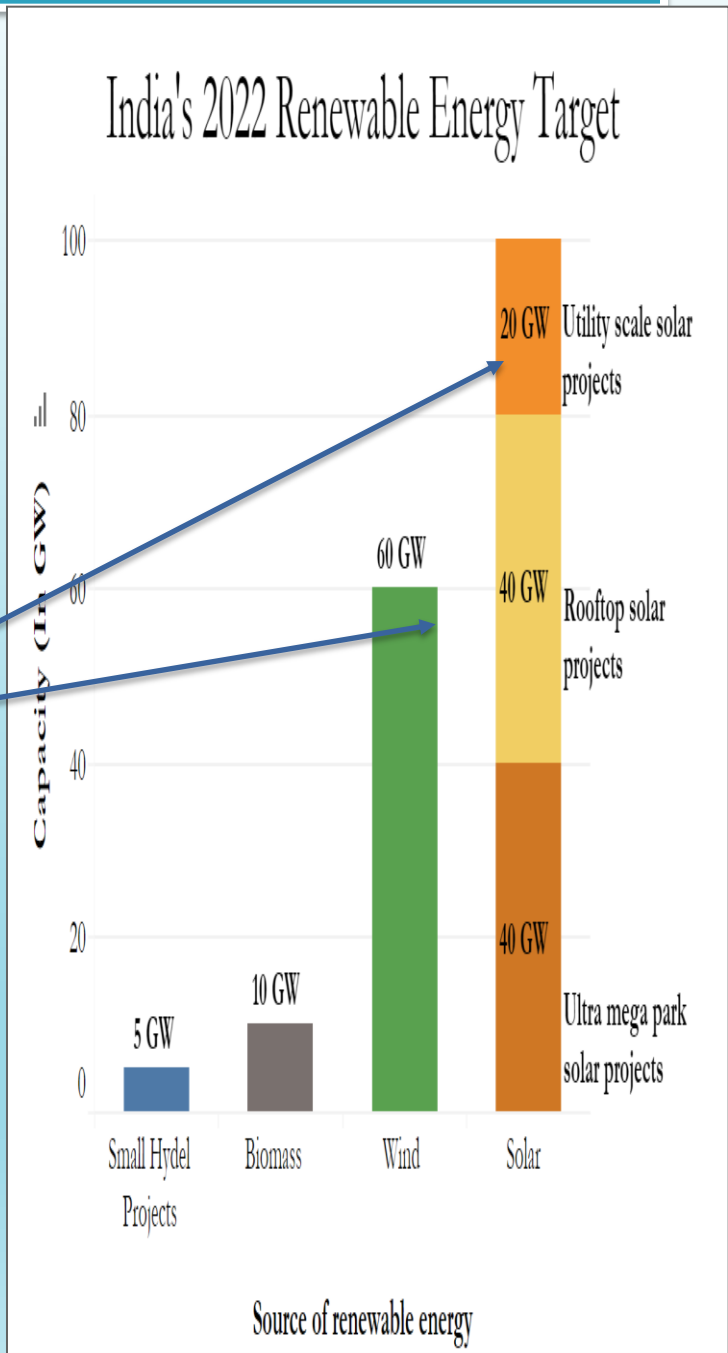
Voltage control coordination of Pooling station,

PMUs enable dynamic line ratings that could reduce wind curtailments

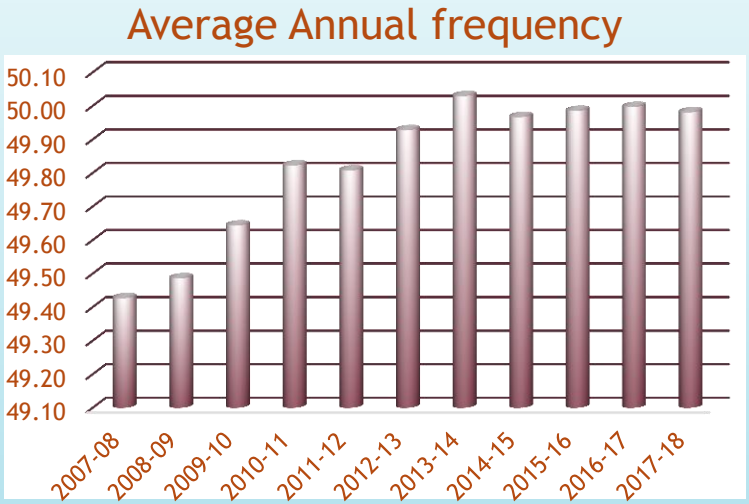
Automatic detect oscillations using PMU at the point of interconnection

Concluding Remarks

- Different type of renewable generation have different behaviour pattern, present measuring system is not able to capture the dynamics of the system due to slow rate of capturing data, synchrophasor technology having high sample rates (25-50 samples per second) required to replace the SCADA
- In future more focus will be on small wind mill integration at distribution level or nearby consumptions point.
- Distribution level wind and solar generation will increase by 2022.
- Transmission-level solar/wind power plants real-time generation data is availed.
- Distributed solar power plants Real time data is un available, so it difficult for a system operator to know whether any change in net load is due to increasing demand or dropping RE generation, with help of PMU same can be identified.



- Gradually Indian power system journey climbing towards maturity.
- Year by year frequency band tighten step by step.
- With implementation of DSM 4 & 5, operational band will be tighten near zero crossing, and to avoid huge penalty compulsory sign change required at least after 12th/6th time block (From 01.04.2020).



- There is not feasibility of immediate revision in power sale / purchase, when RE/conventional generation variation/tripping or deviation, in demand/forecast occurred.
- Different type of generator have different ramp up/down rate.
- With huge RE integration we cannot change the weather but we can manage around it with PMU measurement, by converting in to a corrective action towards ancillary services, and assist for smooth running of power grid.

Conclusion:

- Synchrophasor technology enhances the planning, designing and operation of the RE network with optimum utilization of available assets
- The synchrophasor technology also has the potential to improve significantly the operator's confidence to carry out real time grid operation, detect, and respond to possible disturbances.

- Use of PMU for reactive power planning in renewable energy increases the reliability of the power system stability.
- Presently, Power systems is so capable to absorb fluctuation of F, V, Var but to achieve target of 175 GW, systems to be more robust & responsive by using PMU data/Analytics.
- Required policy framework to continue and widen PMU placements on renewables generation.
- It is like instead of self-medication detail diagnosis and then Doctor's Prescription and healing effect without human intervention.

Thank You!