

Grid Planning / Management for integration of RE (Tamil Nadu case study)

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Shocking NEWS

- It is feared that the CO_2 level in the ice samples on of north arctic has increased three folds in the last quarter of last century , because of indiscriminate utilization of fossil fuels and world scientists advocate that **the renewable sources of power generation shall be increased to 20 % to 30 % of conventional generation methods in future**
- An economically available alternative is Wind power generation.



Installed Generation Capacity in Tamilnadu

- Hydro2186 MW (21.4 %.)
(1349 MW-TNEB command Non-Irrigation;837MW-PWD Irrigation)
 - Thermal.....2970 MW
 - Gas..... 424 MW (4.1 %)
 - Central Sector Share.. 2825 MW
 - IPPs..... 1180 MW
 - CGP..... 215 MW
 - Biomass..... 78 MW
 - Cogen..... 336.MW
 - Wind Generators..... 17 MW
 - **Total..... 10214 MW**
 - **Wind Generators..... 4566.MW as on 30.11.2009**
(4549 MW-Private. 65% of Energy 65 % own use and 35 % sales to TNEB)
- Note: WG installed capacity is 44.7 % of the Conventional generation.



State wise Installed Wind Generation Plants as on 31.03.2009

Sl Nr	State	WG potential in MW	Installed cap MW	% share in the Nation
1.	AP	8968	122.5	1.11
2.	Gujarat	10645	1566.6	15.29
3.	Karnataka	11531	1327.4	12.96
4.	Kerala	1171	27.0	0.263
5.	MP	1019	212.8	2.07
6.	Maharashtra	4584	1938.4	18.92
7.	Orissa	255	--	---
8.	Rajasthan	4858	738.0	7.20
9.	Tamilnadu	5530	4304.5	42.02
10.	Others	705	7.30	0.07
	Total.....	49266	10244.5	99.90

Note: In SR, wind and RE component aggregates to 7048 MW, being 17.5 % of the total capacity of 40097 MW in SR grid.



World Wind Power Installed Capacity in MW-India 5th

No.	Nation	2005	2006	2007	2008	2009
1	United States	9,149	11,603	16,819	25,170	33,170
2	Germany	18,428	20,622	22,247	23,903	25,000
3	China	1,266	2,599	5,912	12,210	22,500
4	Spain	10,028	11,630	15,145	16,740	18,263
5	India	4,430	6,270	7,850	9,587	11,587
6	Italy	1,718	2,123	2,726	3,537	4,850
7	France	779	1,589	2,477	3,426	4,410
8	United Kingdom	1,353	1,963	2,389	3,288	4,070
9	Denmark	3,132	3,140	3,129	3,164	
10	Portugal	1,022	1,716	2,130	2,862	
11	Canada	683	1,460	1,846	2,369	3,249
12	Netherlands	1,236	1,571	1,759	2,237	
13	Japan	1,040	1,309	1,528	1,880	
	Rest of Asia & Oceania	27	27	27	36	
	World total (MW)	59,024	74,151	93,927	121,188	140,000

Note: - Tamil Nadu's wind installed capacity as on 1-1-2010 is 4579,240 MW

Wind Generation growth in Tamilnadu

Year	Installed capacity	Increase	% Growth	Wind Energy penetration	YearlyAvg
	in MW			MU	%
2003-04	1361.5	371.30			
2004-05	2037.06	675.40	49.60	2260	4.47
2005-06	2894.66	857.60	42.09	3444	6.26
2006-07	3459.66	565.00	19.52	5251	8.66
2007-08	3856.77	397.11	11.48	6248	9.59
2008-09	4287.75	430.98	11.17	6654	10.19
Note :As on 30.08.2009, WEG Muppandal Pass..... -1630 MW Palkkad Pass.....-1789 MW Shencottah Pass..... - 934 MW Cumbum.....- 44 MW					

Wind generation area

- **The wind farms are primarily located in the Muppandal, Kayathar and the Coimbatore areas.** The growth of wind farm capacity was in the order of 400 MW/year during the last 5 years.
- **Annual average wind speeds of 18-20 km/h are found, and the effective wind season starts in May and continues until October. Annual average capacity utilisation factor of 27 % has been observed.**
- The wind generation for the **six months from May during 2008-09 had been 5417 MU out of the annual generation of 6654 MU** and during 2009-10 also it was 6819 MU for the same six months.
- The power system is connected to the other three states in the Southern region through 400 kV lines.
- The wind farms in Tamil Nadu are installed on private lands. In 1990's Tamil Nadu Electricity Board (TNEB) had seldom been given an adequate notice to strengthen the grid for new wind farm installations. In some cases it had been necessary to connect new wind farms to existing (overloaded) lines and to restrict the production hours. Thus **TNEB had allowed overloading to the limit of the overcurrent protection.**



Kadamparai 4*100 MW Pumped Storage scheme

- **Run as Motor to absorb any excess generation due to sudden ramp up of wind generation and as generator at the time of ramp down of wind generation or ramp up of loads during peak hours reducing the impact on power system stability.**
- Now that 20 % power cut (earlier 40%) in force with evening peak load restriction, Kadamparai is run as generator during morning peak hours and at times rarely during day times
- Kadamparai most beneficial after the introduction ABT regime.
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Challenges for Utility Grid–Wind Integration.

- Stochastically-Highly Variable wind power injected into the Utility Grid.
- Increased Wind MW- **Power penetration Level.**
- Low SCR-Weak Distribution/Sub Transmission/Transmission Networks
 - Mostly of a Radial Configuration
 - Large R/X ratio distribution Feeder with high Power Losses (4-10 %), **Voltage Regulation Problems/Power Quality/Interference Issues.**
- **Required Reactive Power Compensation** & Increased Burden brought by the induction generator

Net work Problem
and
compensation Equipment



Issues Related To Wind Generation Integration.

The field study has identified the following issues related to wind generation Integration.

1. **Grid availability and capacity**
2. **Reactive power**
3. Voltage unbalance
4. Voltage ranges
5. Frequency range
6. Harmonics and inter-harmonics
7. Voltage fluctuations
8. Islanding and overcompensation
9. Grid operation due to variations in Wind power output



Real time operation issues related in integrating wind power-1. Grid availability and capacity

- Grid availability and capacity-in **early 90's due to insufficient evacuation capacity, insufficient Power Transformer capacity, outages occurred and even WEGs backed down in Muppandal area with 386 MW induction generators out of total installed capacity of 720 MW.**
- The SSTns were Aralvoimozhi, with 3.6 Mvar switched capacitors, Radhapuram, Karunkulam with VS induction Gen connected to 11 kV bus with 4.8Mvar cap.
- **In Muppandal area the Wind Farm 11 kV or 33 kV SS connected to 110 kV ring line, then to 230 kV main transmission line through 230 KV SR Pudur SS. 110 kV main ring line connected to Kodayar PH I & II and consumer loads.**
- To cope with Fast growth of WIND farms, exclusive 230KV SS were erected at, Sangneri and Udayathur for evacuation of wind energy in Muppandal and Aralvoi areas directly to 230 KV network.
- **As on date there are 48 Nos Substations in 230 KV AND 110 kv voltage level to integrate the wind forms distributed in 11kv and 33KV levels. PGCIL has erected 400 kV SS at Tirunelveli facilitating easy transmission to northern area of Tamilnadu**
- **Similarly in Udumalpet area one 230 kV and 14 numbers 110 kV Sub Stations and sufficient feeders have been erected for full evacuation**
- **Now evacuation is not a problem**

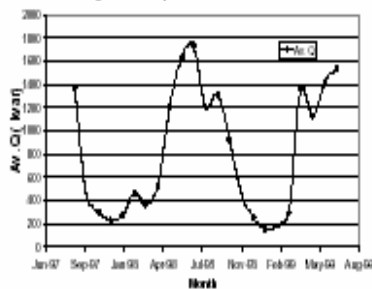


Reactive Power

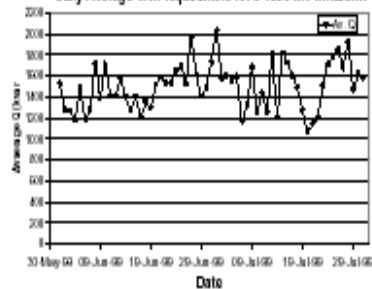
- In late 90's, the var requirement of the consumers and WG were met by the Tuticorine Thermal Pr Stn, Kodayar PH I & II.
- Most WG in Muppandal area and var demand met in Arumuganeri-Kodayar 110 kV grid feeder and their var demand met from Arumuganeri SS. Whenever Arumuganeri end trips on transient fault, Kodayar end holding, the entire var loading thrown on Kodayar m/cs, beyond its var capability, encountering Stator earth fault in two occasions.
- Subsequent to this, TNEB insisted provision of capacitors to 50 % of the AP capacity, with stipulation of pf penalty of 10 p / kvarh, if pf was 0.7
- IREDA specified pf of 0.95 at full load for financing
- A better pf in TN indicates the influence of pf penalty.
- As per the Order of TNERC, 25 p/kvarh is chargeable, if the RP drawal is less than 10 % of the net AP generation and the charge will be doubled, if it exceeds 10 %.



Average VAR requirement for a 4800 kW windfarm



Daily Average VAR requirement for a 4800 kW windfarm



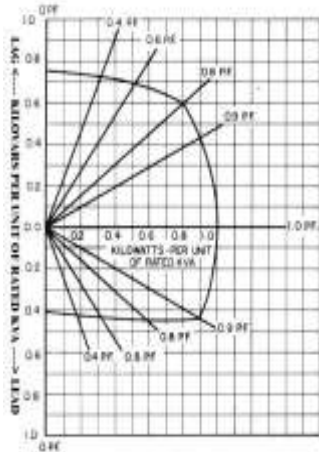
Reactive Power...Contd

- RP consumption leads to increased T&D losses, poor voltage profile, reduced voltage stability margin, over loading and life reduction of T&D equipment and blocked capacity.
- **As RP consumption is widely and dynamically varying with time, provision of fixed capacitors not a solution**
- The reactive power compensation system is normally configured as **mechanically switched capacitors or thyristor switched capacitors**. Due care must be taken in proper sizing and provision of protection & **control features to prevent over compensation / self-excitation** and subsequent damage to WEG. Considering the nature of the load (induction generator), the compensation system should incorporate special control & protection features to prevent self-excitation. **Mechanical switches are prone to failure due to frequent switching operations.**
- Compensation through **ASVC, though technically feasible is not an economically viable solution** and also has larger real power losses in the compensation system.
- **A hybrid reactive power compensation is the optimal solution.** This incorporates a fixed capacitor branch a semi-variable mechanically switched bank and a fully variable thyristor switched capacitor panel.. Use of asynchronous link also eliminates the reactive power requirement from the grid. Though this proposition is very expensive for reactive power compensation, use of asynchronous link has advantages

Reactive Power...Contd

- **About 400 MW WGs supplied by a company are of variable speed from 18 to 65 c/s system converted to DC and then to AC. synchronous type with excitation system capable of supplying RP requirement.**
- **Others have mostly fixed capacitor of about 50% capacity along with switched capacitors of 25 kvar or so in steps, as dynamic compensation is costly**
- The better power factors in TN is due to installation of 0.1 – 0.15 p.u. capacitor banks on 11 kV busbars to compensate for the RP consumption of the WGs, except Radhapuram where all WG have IGBT based power converters. 48 Mvar Cap Banks connected on the 110 kV Buses in 230 kV SR Pudur to relieve Hydro Stations at Kodayar from undue RP demand.

Benefits of Operating Generator at a Higher Power Factor



- This Machine is rated to deliver a power output of 1.0 p.u with a capability to generate var of 0.42 pu @ 0.9 PF .
- **If the generator is made to deliver a var demand of so as to meet a load PF of 0.8 pf, the active power shall have to be reduced to 0.8 pu, as the RP delivery will be 0.6 pu.**



Various types of Wind Generators

- Type 1 – conventional induction generator
- Type 2 – wound rotor induction generator with variable rotor resistance
- Type 3 – doubly-fed induction generator
- Type 4 – full converter interface
- Simple schematics of these four topologies are shown in Appendix F (again, courtesy of the WECC WGMG). Dynamic simulations performed have been based on available industry data and current state-of-the-art models of these different generators.

Various types of Wind Generators.....Contd

- **Type 1 machines operate in a very narrow speed range, and always consume reactive power during operation.**
 - The reactive power consumption is a function of active power production and grid conditions, and it cannot be controlled.
 - Consequently, both the reactive power consumption of the generator and the reactive power requirements of the grid must be supplied by additional equipment — usually switched shunt capacitors.
- **Type 2 machines have wider speed variation and tend to exhibit slower active power fluctuations than Type 1 machines,** but have similar reactive power characteristics. Under load, the machines consume reactive power equal to approximately half of the MW output.
- **Type 3 and Type 4 machines use substantial power electronics to provide wider speed range and finer control of active power production.**
 - **The power electronics also inherently provide the ability to produce or consume reactive power.**
 - It is largely controllable independent from the active power production. In this regard, these machines resemble conventional synchronous generators with excitation systems and automatic voltage regulators (AVR).
 - The details of performance are different between manufacturers. Generally, wind plants with Type 3 or Type 4 generators have the ability to provide relatively fast voltage or power factor control.
- The ways in which each manufacturer controls and coordinates the reactive power production and balance differs. **The great majority of wind generation built in the U.S. in 2006 was of Type 3 or 4. We can also prefer this type of WG in future**



Voltage Unbalance

- The unbalance of voltage or current in a power system is defined as the ratio between the negative phase sequence component (or simply the “reverse”) and the positive phase sequence component.
- **MNES has specified that the grid should not exceed 15 % unbalance.**
- the voltage unbalance specifies the grid, whereas the current unbalance specifies the combination of the grid and a particular induction generator. The 15 % are assumed to specify limits for current unbalance in the wind turbines. IREDAs Technical Specifications require that the wind turbines are capable of operating with 12.5 % unbalance, which is also assumed to mean current unbalance. The European voltage quality standard EN 50160 requires 2 % as limit for the 95 % percentile of the voltage unbalance on the medium voltage level.
- **The voltage unbalances measured on the primary sides of the 5 selected substations and it was seen that the measured ten minutes average voltage unbalance is less than 2 % during the entire measurement period, and the voltage unbalance is not correlated with the wind farm output power**



Voltage ranges and grid availability

- **The Indian voltage quality standard IS 12360-1988 specifies a tolerance of $\pm 12.5\%$ on 66 kV level and above.**
- 10 minutes averages of the measured voltages on the 110 kV level of the substations in Tamil Nadu in **May 1999 varied from 0.85 p.u. to 0.93 in Radhapuram 110 kV.**
- **After introduction of penalty for reactive power consumption, the wind power producers have installed capacitor banks and situation has improved**



Harmonics and inter-harmonic distortion**

- The European standard EN 50160 specifies 8 % as limit for the total harmonic voltage distortion. To include all distortion, we use the total voltage distortion factor TDFU .
- **As per recommendation of IEEE 519-1992, the THD (Voltage) limits are 3% for special system, 5% for general system and 10% for dedicated system**
- **All the measurements confirm that the total harmonic distortion is less than 8 %**, because the total harmonic distortion will always be less or equal to the distortion factor, i.e. $THDU\% \leq TDFU\%$.
- The most significant distortion encountered is from the Radhapuram substation. The reason for the distortion could be the frequency converters in the wind farm. To study the possible sources to the distortion in Radhapuram, the waveforms were logged in October, recording 30 milliseconds every 1 minute with 25 kHz sampling frequency. The logged waveforms were Fourier transformed to give the harmonics. The measurements were in a period with high distortion This power converter generates distortion in a much larger bandwidth. According to the operator, the switching frequency of the converter in this wind turbine is 20 kHz. It is not a familiar harmonic distribution.



GRID SIDE POWER QUALITY ISSUES**

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- Grid power quality problems that affect the WEG are mainly concerned with the quality of voltage that is being supplied by the utility. The supply of “Good” quality voltage is utility responsibility. Some of the parameters (attributes) of voltage are
- v Voltage magnitude and its limits (the steady state & short time voltage must be within specified limits)
- v Frequency and its limits
- v Voltage Unbalance and its limits (the unbalance on the voltage must be within specifications)
- v Voltage distortion & limits (the distortion/ harmonics on voltage must be within specified limits)



Voltage Variations**

- Voltage variation implications on both real and reactive power associated with wind farms.
- A low voltage condition increases the current through the generator, associated power equipment and the lines (for the same power) increasing the losses. affects the power factor as the capacitive var generated out of the installed capacitor decrease (as square of) as voltage decreases.
- Higher voltages increase the stress on the insulation (leading to reduced life), increase the magnetizing var requirement of the transformers. Most of the steps up transformers (ranging from 315 kVA to 750 kVA) are operated near saturation and even a marginal increase in voltage causes the magnetizing current to increase drastically, there by affecting the power factor.
- The increase in voltage is compounded by the fact that most systems operate always at lower than rated frequencies, thereby increasing the flux (v/f) substantially. This phenomenon also increases the no load losses in the transformers, there by reducing the net real power generated by the WEG. In extreme cases transformer saturation can also lead to generation of appreciable amount of current harmonics.



Voltage variation – solutions**

- **Possible solutions to minimize the effect of voltage variations :**
- · Use of on-load tap changers with transformers. central sub-station transformer or into each of the individual WEG transformers based on a through analysis of system conditions.
- · Use an asynchronous link for interfacing the WEG to the grid . By proper control algorithm the WEG side voltage can be kept a constant irrespective of grid side variations.
- · Use amorphous metal transformers instead of conventional CRGO transformers with individual WEG's. .
- The no-load power loss as well as the magnetizing var requirement with these transformers is much lower compared to conventional CRGO core transformers. Also the increase in magnetizing current with over-fluxing is lower with amorphous metal transformers. (Refer figures 7 & 8). (the power law index is 6.7 for AMT as against 10.7 for CRGO transformers).
- Amorphous metal transformer s are less sensitive to over fluxing and harmonics.



Frequency Variation**

- The variation in frequency affects :
- the power generation in a WEG to a large extent, by affecting the aerodynamic efficiency to reduce at non-optimal tip speed ratios.
- These lead to reduced energy capture and power output of wind turbines. This can be appreciated by studying the nature of the aerodynamic efficiency
- at low frequencies the VAR out put of power factor correction capacitors reduce thereby affecting the power factor.increases the flux in transformer thus pushing them near saturation resulting in increased VAR consumption and increased losses (and reduced generation)
- One possible solution is to interface the individual WEG to grid using an asynchronous link. By appropriate control logic the WEG side frequency is kept constant even as the grid side frequency is varying.
- Interfacing the WEG to the grid apart from enhancing the energy capture by a variable speed operation also eliminates the problem of VAR consumption. With a properly designed asynchronous link, this can be used as a VAR management tool also.
- Various possible configurations exist for interfacing the WEG to the grid through this AC-DC-AC link.



Voltage Transients**

Large voltage transients created due to switching of capacitors using mechanical switches, provided as an integral part of WEG for reactive power compensation. The magnitude (and frequency of occurrences) of such transients are large, especially if back to back switching is involved (as in the case of a capacitor bank switching). These internally generated transients could result in damage to sensitive electronic devices of the WEG control system.

- Due to repeated exposure to voltage transients the insulation system becomes weak leading to premature failure.
- other switching operations also result in switching overvoltages. The blades are very susceptible to lightning hits. This could cause an induced overvoltage in the electrical system associated with the tower. Use of adequately rated lightning arrestors (gapless type) has been found to be effective in protecting the equipment from transient overvoltages. Use of RC surge suppressor circuits for protection of low voltage electric circuitry has also been well established.



Voltage harmonics**

- The harmonic current drawn by the WEG (during motoring – soft starting) could itself be a problem, as these current harmonics would appear as voltage harmonics, as the fault levels at WEG terminals are quite low. Apart from this the system could itself have voltage harmonics created by non-linear loads connected elsewhere.
- Voltage harmonics cause over heating of transformer and generators. These also cause an increase in currents through shunt capacitors thus leading to failure of such capacitors. Though technical solutions such as series filters (active & passive) and asynchronous links are available, these are not very economical (low benefit —cost ratio). A practical solution would be to provide shunt filters at the PCC of non-linear loads and reduce the harmonic currents flowing all over the network. This would result in lower voltage distortions.
- Adaptive VAR Compensator provides real-time voltage support for voltage sags and dips caused by rapidly-changing dynamic loads, as well as flicker mitigation and power-factor correction. By reducing voltage fluctuations and managing reactive power flow, system stability and reliability are enhanced and capacity of the infrastructure is increased. The microprocessor-controlled Adaptive VAR compensator utilizes power-electronic thyristor switches to insert the appropriate number of multi-stage power capacitors into the system.



Type of compensation**

The classification of Reactive Power compensation is mainly based on the nature of switching device and the basic principle of operation of compensation scheme.

Based on this the types of compensation schemes available are

- 1. Fixed capacitors (FC)
- 2. Mechanically switched capacitors (MSC)
- 3. Thyristor switched capacitors (TSC)
- 4. Static VAR Compensators (SVC) (TSC + TCR)
- 5. Statcom / statcon



Fixed capacitors**

- These are the simplest of compensation and possibly the least expensive.
- But these are not optimal, as they do not provide compensation over the entire operating range.
- As evident from the WEG characteristics the reactive power requirement is not a constant / fixed value but varies with wind velocity.
- So a fixed compensation is not suitable for windfarm application.
- FC can compensate at only one operating point and at other operating conditions there will be heavy export or import.



Various types of compensation- Adv & Disadv

Type of compensation	Advantage	Disadvantage
Fixed capacitors (FC)	<ul style="list-style-type: none"> Simple Least expensive Lowest loss in RPC scheme 	<ul style="list-style-type: none"> Do not provide compensation over the entire operating range Can lead to over compensation and associated problems Not possible to control import / export of RkVAR.
Mechanically switched capacitors (MSC)	<ul style="list-style-type: none"> Simple Low cost Low losses in RPC (but losses are high when current limiting reactors are used, which are a must to ensure better reliability) 	<ul style="list-style-type: none"> Leads to capacitor inrush currents and capacitor overvoltages Poor reliability of capacitors and contractors Derating / decrease in capacitance More compensation required
Thyristor switched capacitors (TSC)	<ul style="list-style-type: none"> High reliability No capacitor inrush currents and over voltages No limit on number and frequency of switching 	<ul style="list-style-type: none"> More expensive than FC, but can be on par with MSC for larger sizes Losses on par with MSC, but losses more than FC
Static VAR Compensators (SVC)	<ul style="list-style-type: none"> Stepless control of reactive power Can supply both leading and lagging current 	<ul style="list-style-type: none"> Expensive More losses than SVC
Statcom / statcon	<ul style="list-style-type: none"> Stepless control of reactive power Can supply both leading and lagging current 	<ul style="list-style-type: none"> Very expensive High losses

Mechanically switched capacitors**

- : These are an improvement over fixed capacitors.
- Here the reactive power output can be controlled and can be made to more or less closely following the requirement. These are simple in construction and are low in cost.
- But mechanical switches have the problem of producing switching inrush currents and associated capacitor over voltages. (
- When mechanical switch opens, the contact volume is filled with ionized matter (plasma) generated to the arc. Due to this the insulation property of the air is low and is susceptible to a flashover. Within 10 ms (for 50Hz) the voltage across the switch can be as high as 1350 V (for a 415 V system at 15 % overvoltage, considering a charge on the capacitor corresponding to the peak voltage) due to the charging effect of the capacitor.
- This is due to the fact that a mechanical switch does not have a point of wave operation and can open when the voltage across the capacitor is at peak.

Thyristor Switched capacitors**

- Unlike mechanically switched capacitors, a point on wave switching is possible with thyristor switched capacitors.
- By this the inrush currents are totally eliminated. Also since there is no chance of a restrike capacitor over voltages are prevented. This improves the reliability of the total system.
- Since there are no moving parts there is no limitation on the number and frequency of switching operations. Unlike MSC, there is no need to wait for capacitor discharge before switching on the capacitors again, there by the full compensation is always available.
- Though the losses in a TSC may seem to be more than a MSC, it is not actually true, since a large value of current limiting reactor is required for a MSC to get a comparable performance. This reactor has large losses, which most often more than compensates for the losses in the thyristor.
- Under these conditions the total losses in the two systems (TSC & MSC) will be more or less the same.
- TSC has a faster response time than MSC and thus makes it more suitable for dynamic compensation for widely varying loads.



MSC and TSC Comparison

Parameter	Mechanically switched capacitors (MSC)	Thyristor Switched capacitors (TSC)
Limitation on number of switching operations	Number of operations are limited due to mechanical / moving parts.	No limit as there is no moving part.
Limitation on switching frequency	Limited due to moving parts and inability to do point of wave switching.	Unlimited as there are no moving parts and point of wave switching is possible.
Switch life	Low. Switch life is limited by pitting of contacts and fatigue in moving parts.	High. Since there is no wear and tear, erosion, pitting etc. switch life is high.
Capacitor life	Low. Due to frequent inrush currents and switching over voltages.	Very high. As there are no switching inrush currents and over voltages.
Availability of compensation	Low. Part compensation is not available for some time due to time delay built in for discharging capacitors before reenergisation.	100%. Since point of wave switching is possible any capacitor can be made ON / OFF at any time instant with out any delay.
Suitability for Windfarm application	Poor. Not recommended for frequent switching as required in WEG application.	Ideal. Suitable for widely and frequently varying power requirements. Can dynamically track and correct power factor.
Point of wave switching	Not possible	Possible



Static var compensators**:

- These have all the benefits of a TSC with the additional benefit that the reactive power can be varied steplessly.
- The normal configuration has a combination of TSC + FC (as tuned filters) + TCR (Thyristor controlled reactor).
- The TCR section is used for smooth control of reactive power. These are more suitable for special industrial applications than Windfarm, mainly due to the high cost associated with them. Also SVC has an additional
- feature that they can operate in both leading and lagging current mode, a feature not required for Windfarm, but
- has to be paid for. Also the losses in a SVC is more due to the presence of TCR.



Statcom**

- These are similar in performance to SVC. Using only capacitors or inductors or batteries, these devices can draw/ supply both leading and lagging currents.
- They have a very good response time and are more suitable for special industrial loads like arc furnaces. They are not suitable for Windfarm applications due to the large cost and loss associated with them.
- The present penalty rates (for VAR consumption) just not justify installation of Statcom.
- Also the losses in the Statcom are more due to the higher switching frequencies and the inherent losses in the devices used (IGBT or GTO).
- Also due to operations at high switching frequencies they generate high frequency harmonics.



Locational benefits and their comparison. **

The compensation can be classified as either

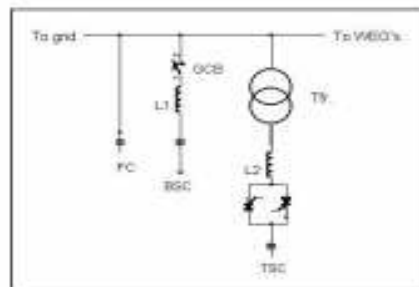
- ❖ individual compensation (or)
- ❖ group compensation

Comparison of types of compensation



Possible Solutions **

- Of the various solutions, the one that is technically simple and economically viable is to provide reactive power compensation system for reactive power control.
- The reactive power compensation system is normally configured as mechanically switched capacitors or thyristor switched capacitors.
- Due care must be taken in proper sizing and provision of protection & control features to prevent over compensation / self-excitation and subsequent damage to WEG.
- The best solution is as shown in the figure



Micro Processor Controlled VAR Compensation**

- Dynamic conditions as wind velocity varies, allowing wind farms to operate within required parameters, the **Adaptive VAR Compensator is particularly suited to wind generation**, where utility interconnect standards require that a power factor be adjustable within certain limits (typically .95 lagging to .95 leading) and voltage sag depths be minimized.



Adaptive var Compensator**

- The Adaptive var Compensator provides real-time voltage support for voltage sags and dips caused by rapidly-changing dynamic loads, as well as flicker mitigation and power-factor correction.
- By reducing voltage fluctuations and managing reactive power flow, system stability and reliability are enhanced and capacity of the infrastructure is increased.
- The microprocessor-controlled Adaptive var compensator utilizes power-electronic thyristor switches to insert the appropriate number of multi-stage power capacitors into the system.
- **AVC's typically respond in ½ cycle (10 ms for 50 Hz systems).**
- The Adaptive var Compensator is particularly suited to wind generation, where utility interconnect standards require that a power factor be adjustable within certain limits (typically .95 lagging to .95 leading) and voltage sag depths be minimized.
- The AVC is capable of responding to dynamic conditions as wind velocity varies, allowing wind farms to operate within required parameters.
- The PureWave AVC can also be applied to industrial facilities to enable problem loads to coexist on the same feeder with more sensitive loads, obviating the need for separate feeders.
- The PureWave AVC is ideal for heavy commercial and industrial processes having varying mechanical cycles, corresponding to rapidly varying reactive power demand. Typical applications include:



DSTATCOM Distributed Static Compensator

- **DSTATCOM®**
Distributed Static Compensator DSTATCOM Distributed Static Compensator Protects and Fixes Utility System Problems

- It protects the utility transmission or distribution system from voltage sags and/or flicker caused by rapidly varying reactive current demand. **In utility applications, a DSTATCOM provides leading or lagging reactive power to achieve system stability during transient conditions.**
- Its small size and modular packaging make it ideal for installation in substations and it can be relocated as system conditions change. The DSTATCOM can also be applied to industrial facilities to compensate for voltage sag and flicker caused by non-linear dynamic loads..
- DSTATCOM instantaneously exchanges reactive power with the distribution system without the use of bulky capacitors or most applications, a DSTATCOM can use its significant short-term transient overload capabilities to reduce the size of the compensation system needed to handle transient events.
- **The short-term overload capability is up to 325% for periods of 1 to 3 seconds, which allows applications such as wind farms and utility voltage stabilization to optimize the system's cost and performance.**
- The DSTATCOM controls traditional mechanically switched capacitors to provide optimal compensation on a both a transient and steady-state basis.
- It allows RES to meet Utility requirement on pf, voltage output and LV ride thro'. Response time is 3 to 6 milli seconds and provides 3.3 Mvar for 3 sec.



DSTATCOM
Distributed Static Compensator

Injection of Fluctuating power**

- Power (energy) in wind by nature not steady but characterized by annual, monthly, daily and hourly variations. This results in generation and injection of a power (current) that is fluctuating leading to operational problems, especially if the grids are weak and the portions of such fluctuating sources are more than certain limits (generally 25%).
- Solutions for this include connection of a large number of WEG's at the point of common coupling, as due to spread in operating point the variations in power at the PCC is lower than with single turbines (due to the averaging effect).
- Another solution is to configure the WEG's as an integrated energy system for operation in conjunction with other renewable energy sources, conventional energy sources and/or storage elements
- Most popular of these are the wind-diesel, wind-SPV-diesel and wind – pumped hydro systems. By proper sizing of the various elements and selection of control logic a near constant output power can be achieved. Also integrated energy systems can be either operated in a grid-connected mode or stand-alone mode. This apart from imparting additional operating flexibility also can be used to address a few other power quality problems

Black out (Non availability Link to other Conventional Generating Sources)

**

- The most significant effect of a breaker opening is the possibility of a self-excitation in a wind farm.
- Recently this has been observed in a large number of wind farms where additional capacitors have been connected to the WEG terminals to improve the power factor and avoid power factor penalties.
- In most cases these capacitors (either fixed or mechanically switched) are connected without any special control or protection features. This leads to self-excitation conditions when an upstream breaker opens and results in large over voltages and over speeds of wind electric generators thus damaging the entire system
- Possible solutions for protection against self-excitation include installation of group reactive power compensation using thyristor switched capacitors with special protection with self-excitation rather than conventional individual compensation with fixed or mechanically switched capacitors.
- Black out / grid drop also wind power generation to come to a halt as power evacuation is not possible without a grid. One possible solution for this is to operate the WEG's in stand alone mode configured as an integrated energy system. With such configurations it is possible to operate the WEG's either in stand-alone configuration or in grid interactive mode.
- In stand alone operation these can be either made to supply some local loads or can be used to store energy (pumped hydro, battery charging etc. depending upon the size & operating conditions) which can be released at a later time to meet the load requirements



Wind Variability

- **Wind a variable output, but not unreliable**
- **Variability not new in electricity since its inception**
- **Variability predictable and manageable**
- Variability has effect in systems where there is larger share in electricity Demand
- In Denmark 21 % total consumption met in 2004 from Wind power and 25 % Demand in normal wind year, sometimes 100 % instantaneous Demand
- **In Tamilnadu during 2008-09, 6654 MU injected into the TN grid being 10.2 % out of total grid input of 62,251 MU**
- **Peak Demand met in SR was 25,601 MW**
- **Peak Demand in TN was 9567 MW in 2008-09 and 9910 MW on 29.06.2009 with consumption of 216.38 MU on that day.**
- **On 30.06.2009, the daily consumption was 205.862 and wind contribution was 45.252 MU, being 22 % !**



Managing the grid operation during normal wind and load variations - Prediction of wind energy

- **Wind energy is variable in nature and has to be harnessed when it is available.**
- When the wind generation level has reached a peak of about 25 % in Tamilnadu grid, a proper prediction of wind energy for the next day and scheduling the other conventional generation hour by hour with adequate spinning reserve possibly becomes a must to meet out the grid adequately.
- **In the present power scenario prevailing in the SR, there is always deficit of generation to the tune of 10 -15 %.**
- **Naturally the central sector share is fully availed by the Tamilnadu irrespective of the wind generation.**
- **The scheduling of other states owned generation sources are planned taking into account the predicted wind generation and assuming a reliability index.**
- **Day to Day demand forecast:- wind generation will be considered based on the speed and direction.**
Annual Forecast :- The total energy contributed by the wind last year same month will be taken.
Planning:-Installed capacity X PLF(16%to20%)X approx 25%.



Managing the grid operation during normal wind and load variations Prediction of next day wind energy.

- Following means are used to predict the next day wind generation.
- 1) The last three days wind generation hour by hour in individual area ie, Aralvoimozhi pass, Shencottah pass and Palghat pass are considered along with wind forecast recorded for these days(wind speed, humidity and direction of wind).
- 2) The probable hourly wind speed and direction for next day is arrived from reliable weather forecast available in Net. (www.accuweather.com)
- 3) The probable generation hour by hour for the next day is arrived.
- 4) Based on the above data the generation schedule for conventional generation sources and power purchase schedules are evolved.
- 5) It is generally accepted that by using good forecasting techniques and an intraday scheduling system the required additional reserves are in the range of 2% to 4 % of installed wind power capacity at 10 % wind penetration.
- 6) The variation in the wind generation during normal season can be accommodated easily by scheduling the Hydro station and IPP gas stations monitoring the frequency conditions
- 7) However hourly wind generations actually available are not communicated by wind generators to the LDC. Action is being taken to collect wind generation data hourly by providing required metering facility. At present wind generation data are monitored only during peak hours from the feeder loading parameters.
- 8) The frequency conditions of 49.2 Hz to 50 Hz prevailed for more than 90 % of the period during the year 2008-09 (as per CEA'S report) shows that the existing operating system is performing better
- In the absence of Major Gas power stations in the SR, the only source for sudden back out of wind generation is load shedding by grouping of feeders.



Managing the grid operations during very fast variations

especially during high wind power integration in monsoon?

- No special tools required for sudden very fast variations especially during high wind integration in monsoon, for the following reason :
- **The highest wind generation reached in Tamilnadu was 2325 MW and in SR around 3500 MW. The peak demand of SR is 25601 MW. The wind generation penetration at peak is roughly 13.6% of the Demand in MW.**
- **During fast variation, suppose the wind generation falls by 1800 MW the frequency will fall by 1.5 Hz (frequency index for the SR grid is 1200 MW/Hz.). Under frequency and df/dt relays are installed and the Regional grid performance is continuously monitored by SRLDC. As far as Tamilnadu is concerned both under frequency relays and df/dt relays are in service.**
- **In case of overloading in the grid, 28 numbers 110 kV feeders set at 48.5 Hz (instantaneous) will trip giving a relief of 607 MW, similarly 18 numbers 110 kV feeders set at 48.2 Hz will trip and give a relief of 512 MW, 20 numbers 110 kV feeders set at 48.0 Hz will give a relief of 989 MW, Further df/dt relays connected to 18 feeders and set at 49.3 Hz @ 0.3 Hz/sec. will come into action to trip and give relief of 562 MW. Similarly for these frequencies AP will give relief of 616 MW to 1767 MW, KSEB being 100 MW to 479 MW and KPTCL 453 MW to 1036 MW at the set frequencies.**
- The tie line flow being monitored by SR grid operators, appropriate action such as cutting in spinning reserve and gas stations, the normalcy will be restored.
- TNEB has evolved islanding schemes to island the TNEB grid from SR at 47.8 Hz / 1 sec so that even at rapid fall in wind generation along with major tripping of conventional generation, the segregated island will survive to get united after suitable operation laid down for this purpose

Attending to the frequent sharp ramp up and ramp down problems of wind power – present scenario

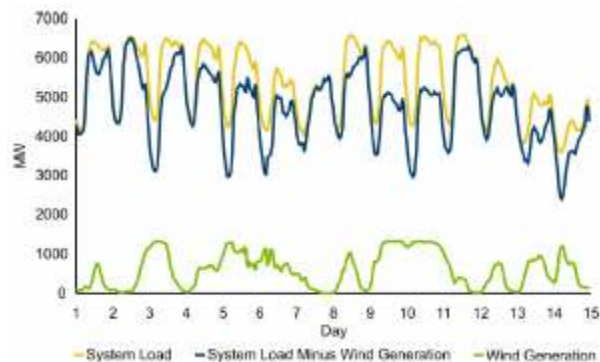
- 4.1. **The 4*100 MW Generators in Kadamparai Pumped Storage Plant are run as motors during night when the grid demand is less and generation is comfortable. They are run as Generators during peak hours and to an extent to meet out the contingency of ramp down.**
- 4.2. **As on date no Special compensating arrangements are made for frequent Ramp Up And Ramp Down problem of wind power. For this purpose the study made in Minnasota will be worth referring.**
- 4.3. The first phase in determining how to integrate wind energy into the power grid is to conduct a wind integration study, which begins with an analysis of the impact of the wind plant profiles relative to the utility load curve. By way of illustration, Figure 1 shows a two-week period of system loads in the spring of 2010 for the Xcel system in Minnesota which is similar to Tamil Nadu Grid. This system has 1,500 MW of wind capacity on a 10,000 MW peak-load system
- **Because both load and wind generation vary, it is the resulting variability—load net of wind generation—that system operators must manage, and to which the non-wind generation must respond.**

Operation of power system

- Although wind plants exhibit significant variability and uncertainty in their output, electric system operators already deal with these factors on similar time scales with current power system loads. It is critical to understand that output variability and uncertainty are not dealt with in isolation, but rather as one component of a large, complex system. **The system must be operated with balance and reliability, taking into account the aggregate behavior of all of its loads and generation operating together.**
- To maintain system balance and security, the electric system operator analyzes the regulation and load-following requirements of wind relative to other resources. **Wind energy contributes some net increase in variability above that already imposed by cumulative customer loads. This increase, however, is less than the isolated variability of the wind alone on all time scales of interest.**

Attending to the frequent sharp ramp up and ramp down problems of wind power-Minnasota example-

Fig : Hourly load shapes with and w/o wind generation resulting variability of net load and wind variabilities !



Attending to the frequent sharp ramp up and ramp down problems of wind power-Minnasota..Contd

- **Although specific details vary, distribution of changes in the load net flattens and broadens when large-scale wind is added to the system.** The resulting reserve requirements can be predicted with statistical analysis. It is not necessary, or economically feasible, to counter each movement of wind with a corresponding movement in a traditional energy source. As a result, **the load net of wind requires fewer reserves than would be required to balance the output of individual wind plants, or all the wind plants aggregated together, in isolation from the load.** In the very short time frame, the additional regulation burden has been found to be quite small.
- **Some suggest that hydropower capacity, or energy storage in the form of pumped hydro or compressed air, should be dedicated to supply backup or firming and shaping services to wind plants. Given an ideally integrated grid, this capacity would not be necessary because the pooling of resources across an electric system eliminates the need to provide costly backup capacity for individual resources.** Again, it is the net system load that needs to be balanced, not an individual load or generation source in isolation. Attempting to balance an individual load or generation source is a suboptimal solution to the power system operations problem



Attending to the frequent sharp ramp up and ramp down problems of wind power-Reserve Requirements Calculation illustration

- A hypothetical example is offered to calculate reserve requirements.
- Say that system peak load for tomorrow is projected at 1,000 MW with a 2% forecast error, which makes the forecast error (i.e., expected variability of peak load) equal to 20 MW.
- Wind generation for a 200 MW wind plant in that balancing area is predicted at a peak hour output of 100 MW with an error band of 20%. The expected variability of peak wind generation, then, is 20 MW.
- Assuming that these are independent variables, the total error is calculated as the square root of the sum of the squares of the individual variables (which is the square root of (2×20) squared, or 1.41×20 , which equals 28 MW).
- Adding the two variables to estimate reserve requirements would result in an incorrect value of 40 MW. It is applicable for TNEB Grid also. **As on date no Special compensating arrangements are made for frequent Ramp Up And Ramp Down problem of wind power, except the utilisation of Kadamparai Pumped storage capacity of 4*100 MW.**
- **TNEB has proposed 4*125 MW Kundaf Pumped Storage Hydro Electric Project (KUPSHEP)**



Introduction of short-term forecasting tool in the system?

- So far this has not been done very scientifically and effectively. But in the future years to come when generation capacity addition reaches to ease the system demand, then it will necessitate to go in for short-term forecasting, scheduling and economic and cost effective mix of various sources.
- During the Last meet with CERC at Delhi(18th Jan 2010),the wind generators have accepted to give [schedule.ie](#) 3 hours ahead schedule and 8 switches in a day. A draft regulation will be published shortly by CERC.
- Day to Day demand forecast:- wind generation will be considered based on the speed and direction.
Annual Forecast :- The total energy contributed by the wind last year same month will be taken.
Planning:-Installed capacity X PLF(16%to20%)X approx 25%.



What else can be done to integrate the wind power to SR grid smoothly – Carbon emission

- Electric power generation is considered as a major source of carbon emission and renewable resources are considered as part of the overall solution to replace some of the generation from fossil fuel resources.
- Recent reports by the International Energy Agency (IEA 2008a and 2008b) include projections of the amount of energy related carbon emission reductions needed to meet the commitment by G8 industrialized countries to achieve 50 percent reduction by 2050 compared to 2005.
- Under a “Business as Usual” scenario, the amount of global energy-related CO2 emissions could reach 62 gigatons (GT) compared to 27 GT in 2005. To meet such a goal, significant steps have to be taken to reduce energy-related carbon emissions to below 14 GT. renewable resources are expected to play a major role in achieving such carbon emission reductions.
- WEG delivering 2,00,000 kWh per year will have pollution saving of 2 to 3.2 T of SO₂, 1.2 to 2.4 T of NO, 300 to 500 T of CO₂ and 150 to 280 kG of particles.



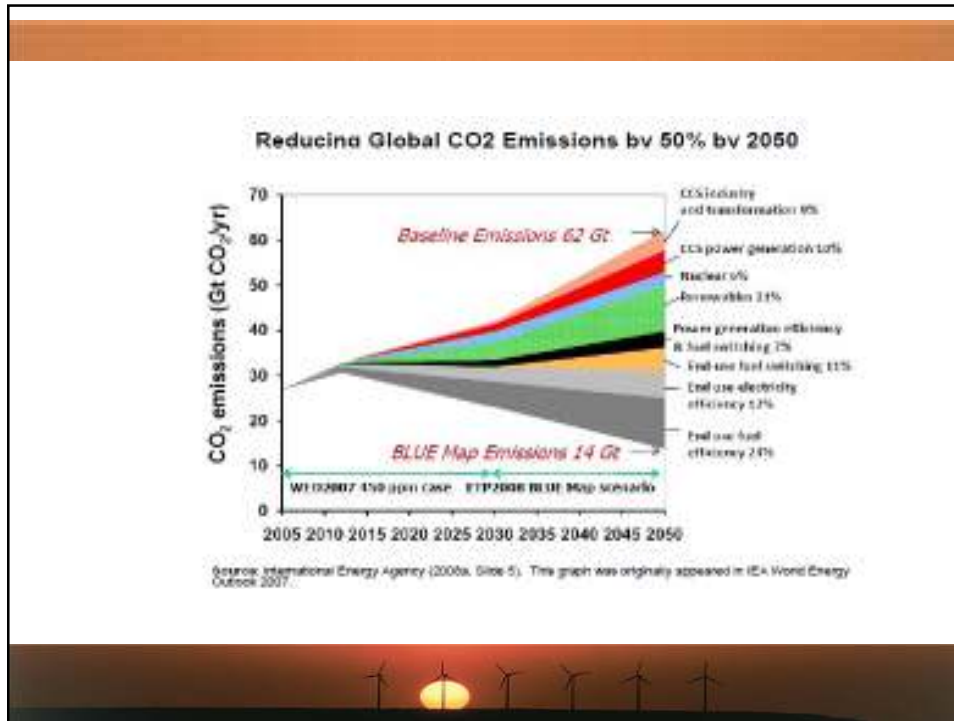
What else can be done to integrate the wind power to SR grid smoothly – For better utilisation of wind energy

- 1. All new wind generation plants must meet LVRT (Low Voltage Ride Through) requirements.
- 2. **All new wind plants should be Type 3 or Type 4 generators that are capable of providing dynamic reactive support. For new wind plants Type 1 or 2 with no dynamic reactive capability, the generator owner must provide sufficient reactive resources to meet the Low Voltage Ride Through standards and voltage control standard**
- 3. Re-evaluate the optimal location and size for the dynamic reactive support (i.e., SVCs)
- 4. Analyze the best solution for improving the nose point of the Q-V analysis for critical 230/400 kV buses under critical contingency conditions. Potential solutions include the use of series compensation and reduction of proposed shunt compensation.
- 5. **Effective usage of forecast facilities to be availed by the system operator**
- 6. **If possible necessary storage facility may be introduced what ever possible**
- 7. **Adequate reserve capacity of gas / hydro generation is essential to meet the system demand, without necessitating load shedding, when there is a sudden and substantial drop in wind generation.**
- 8. **As per Grid code, sudden increase or decrease of 50 MW generation by any generator should be with prior intimation to SLDC. Similar provisions should be made applicable to wind generators also in order to maintain grid discipline and security.**
- 9. **Wind farms have to be scheduled to become part of the settlement mechanism.** uncertainty would attract UI in ABT mechanism. to overcome this the wind farms may need spinning reserves, back-up generation, telemetry is a must for scheduling and monitoring.
- 10. **Studies have indicated that 20% of the total electrical energy consumption may be incorporated with minimal difficulty. The results of any Study on large scale penetration on system stability to be implemented to the extend applicable for Indian context.**



Power Quality Measurements made by a Study committee





- ### Challenges to Operators
- **integrating these environmentally friendly resources dominated by Wind power into the electrical network while maintaining grid reliability.**
 - Face short term and real-time challenges to incorporate intermittent resources into their electric systems. These challenges have operational and reliability consequences, which, if not addressed in a timely manner, could result in undesirable outcomes, including load shedding and harm to grid infrastructure.
 - **One challenge is accurate forecasting for use in unit commitment, scheduling, real-time dispatching, and congestion management**
 - Another challenge is determining the optimal amount of controllable online capacity that will allow for reliable operations while minimizing increases to the total cost of power. Grid operators need the ability to call on renewable resource owners to decrease active power output to manage over-generation situations and local congestion constraints. In addition, these resources are expected to participate in reactive power support to assist grid operators.

Challenges to Operators..Contd

A. Reactive Power Support :

1. Mandate for 24x7 communication between wind generation resource and grid operator or transmission service provider to address voltage support requests
2. Better defined voltage support requirements (i.e. Voltage Ride Through, VRT) for newly / recently developed wind generation projects
3. Address voltage support requirements for legacy wind generation projects. •
4. System Inertia (generator governor response)
5. Use storage technologies as they become available to provide transmission loading and voltage support
6. Build appropriate voltage controls into transmission expansion projects developed to serve "wind pockets"

B. Active Power Control

1. Ability to decrease active power output in Real-Time from wind generation resources during over-generation, or local transmission congestion scenarios
2. Address ramping issues resulting from drastic changes in wind speed
3. Enforce ramping constraints on wind generation resources when output is curtailed and upon release from curtailment
4. System Inertia (generator governor response) in cases of frequency deviations
5. Identify and minimize the negative impacts (additional start ups, lower than optimal dispatch levels, and associated environmental costs) on the operation of conventional resources due to increase in wind generation



Challenges to Operators..Contd

C. Forecasting and Scheduling

1. Incorporate grid operator sponsored Day-Ahead, Hour-Ahead, and Real-Time forecasts into decisions on unit commitment, scheduling, and dispatching
2. Integrate site specific, real-time meteorological data and telemetry systems from wind generation resources into forecasts Ancillary Services
3. Determine minimum amounts of each type of ancillary service required to operate grid reliably considering changing resource mix
4. Use storage technology to minimize reliance on ancillary service and balancing energy driven the growth of wind generation resources
5. Ensure sufficient "faster and more durable ramping" capability to address issues associated with transitions between peak and off-peak periods
6. Ensure sufficient "quick start" units to accommodate Hour-Ahead forecast error and intra-hour wind variations



Wind integration Study reports

- 1) First, **several investigations of truly high penetrations of wind (up to 25% energy and 35% capacity) have concluded that the power system can handle these high penetrations without compromising system operation**
- system- operating-cost impacts need not be significantly higher than results obtained with lower penetrations. This conclusion applies if system-balancing functions are shared among adjacent balancing authorities spanning the geographic region that contains the wind plants, or if that region is served by a single balancing authority with access to a large number of generating units.
- 2) Second, the importance of detailed wind resource modeling has been clearly demonstrated. Meso-scale wind modeling based on multiyear archived weather data and correlated with electrical load data has provided the capability to capture the wind diversification impacts both within individual wind plants and among the various wind plants contained in a balancing region.
- **Accurately estimating intrawind-plant wind variations tends to reduce estimated operating-cost impacts in the regulation and intrahour time frames.** And capturing variations from plant to plant tends to reduce these impacts in the longer time frames, from load following to unit commitment and even out to periods relevant to system reliability estimation in terms of ELCC.



Wind integration Study reports..Contd

- 3) Third, **the value of good wind forecasting has been clearly demonstrated. This result was also evident in 2005, but it has been strengthened substantially by the more recent work in Minnesota, California, and Colorado.**
- 4) Fourth, **for systems that desire to add more wind, the importance of increased flexibility in the non-wind portion of the generating mix has been clearly demonstrated. This flexibility could be provided, for example, by some combination of high-ramp-rate fossil generation, hydro units, pumped storage, and load control.**
- 5) Fifth, there is evidence that shorter-term markets (e.g., ten minutes rather than one hour) can reduce wind integration costs.
- 6) Sixth, **the difficulties of maintaining system balance under light-load conditions with significant wind variability have generators, and wind resources has been clearly demonstrated.**
- In general, the electric sector is moving in this direction, either through RTO-ISO formation or through other means such as area control error (ACE) sharing, because of resulting efficiencies in system operation. The recent studies, particularly the Minnesota and California projects, have shown very clearly that this trend will significantly aid in the integration of larger amounts of wind power through reductions in operating cost impacts arising from wind's variability. been illuminated, particularly in the recent California and Ontario studies. Some combination of system flexibility, wind curtailment, wind ramp-rate mitigation, and new loads added in light-load periods will be needed.
- 7) Finally, and related to the first, the value of sharing balancing functions over large regions with a diversity of loads.



Experience of others with large WEGs

- Germany that have large amounts of wind power in the system shows that the question as to whether there is an upper limit for renewable penetration into the existing grids will be an economic and regulatory rather than a technical issue.
- In the western Energinet supply area, wind energy covers some 25 % of electricity demand in a normal wind year and it is not a technical problem to handle more – it is a regulatory issue.
- For a given wind farm location, the wind forecasts then need to be turned into power forecasts, taking into account the topography of the site and the performance characteristics of the wind turbines.
- The more wind power installed on a power system, the greater the value of accurate forecasts of its output – particularly when wind plant reaches 10 – 20 % of the system's total capacity.
- Since the infirm wind generation contributes about 15 to 20% and at times 25 % of the peak demand during wind season and TNEB has no standby capacity except the kadamparai PSS, to take care of this infirm power fully, the deficit goes upto 2000 MW. This deficit is likely to increase in the next few years since the capacity addition is expected to be less than the projected increase in demand.



Opinion of the System Operators in Tamilnadu :

- **Sudden pumping / withdrawal of power into the grid is threatening system security.**
- **In TamilNadu the sustained maximum wind power reached is 2325 MW, when this power suddenly drops there is no other source to pick-up/ compensate.**
- **Highest capacity of hydro machine is only 100MW in Tamilnadu.**
- During the high wind period the voltage will drop due to the reactive power.
[But field condition is that the voltage in wind area is almost the rated ones, due to the fact that all WEG are maintaining almost unity pf in Muppandal and Palakkadu Pass areas. In Udumalaipet area the voltage is in the range of 96 kV to 102 kV, owing to heavy var drawal by agricultural pumpsets only and not due to WEG, except in few cases where Capacitors are not properly maintained and ofcourse they are paying penalty].
- **The transmission lines provided to evacuate the wind energy power will be less loaded during non-wind season.**
- **Tamil Nadu allows the private developers to bank the surplus energy from 1st Apr – 31st March of succeeding year. If the developers draw this banked energy during the shortage period will make financial loss to TNEB.**
- **Adequate reserve capacity of gas / hydro generation is essential to meet the system demand, without necessitating load shedding, when there is a sudden and substantial drop in wind generation.**
- **As per Grid code, sudden increase or decrease of 50 MW generation by any enerator should be with prior intimation to SLDC. Similar provisions should be made applicable to wind generators also in order to maintain grid discipline and security**



Opinion of the System Operators in Tamilnadu ..Contd

- WIND FARMS HAVE TO BE SCHEDULED TO BECOME PART OF THE SETTLEMENT MECHANISM.
- WIND FARMS MAY NEED SPINNING RESERVES, BACK-UP GENERATION.
- **TELEMETRY IS A MUST FOR SCHEDULING AND MONITORING.**
- There is no generally accepted “maximum” level of wind penetration.
- Studies have indicated that 20% of the total electrical energy consumption may be incorporated with minimal difficulty. Beyond this level, there are few technical limits, but the economic implications & Grid security become more significant.
- Electrical utilities continue to study the effects of large (20% or more) scale penetration of wind generation on system stability and economics.



California Study

1. State of California has made extensive studies and enacted a 20% Renewables Portfolio Standard (RPS) by 2010 (Biomass-1066 MW, WIND-7741 mw, Solar-1944, Geo-thermal-3041 MW and the total being 13792 MW) and 33 % by the year 2020.
- Statewide greenhouse gas emissions will also be reduced to 1990 levels by 2020
 - All new wind generation units must have the capability to meet the WECC requirements of ± 0.95 power factor. This reactive capability is essential for adequate voltage control.
 - Dynamic reactive capability for all new wind generation facilities is essential. This suggests that wind plants with some dynamic reactive capability are necessary to ensure system stability.
 - if the dynamic reactive capability is not inherent in the wind turbine generator, it may need to be added to the WG.
 - **wind plants with some dynamic reactive capability may reduce or eliminate the need for dynamic reactive devices on the transmission system.**
 - **Dynamic reactive power supplied close to where it is needed (e.g., at the Type 1 wind turbine generator terminals) will be more effective than the dynamic reactive power at a remote location for the potential problems identified in this transient stability analysis.**
 - **Potential solutions include the use of series compensation and reduction of proposed shunt compensation**



Use of Storage Technology with Wind Generation

- **Additional storage capability would be of considerable benefit with the integration of large amounts of renewables, especially intermittent resources. Storage systems shift some of the off-peak energy production to deliver at peak periods.**
- 1. Some storage, such as high-speed flywheel systems, can provide regulation services and frequency control. Storage can also help with ramping issues by quickly absorbing excess energy when wind generation ramps up, and it can deliver energy when wind generation ramps down.
- integrating intermittent renewables and mitigating congestion.
- 3. A proven and deployed storage technology is hydro pump 2. Storage devices such as batteries can be located anywhere on the grid (and can be moved) to support the dual needs of storage. The 1,200 MW Helms pump storage facility¹⁰ that is owned and operated by PG&E is the largest storage facility on the system
- 4. Lithium-Ion battery storage has been successfully deployed. All of the other storage technologies appear to be a number of years in the future before they are commercially available
-



- Maximum Peak and Wind generation
Details of Tamil Nadu



Extent of relief for TNEB due to wind in critical times

2008	Morning Peak				Lighting Peak				Minimum Load			
	Load shedd Days/ MW	WE Days/ MW	f Inst/ Avg	OD(+/ UD(-) Day/ MW	Load shedd Days/ MW	WE Days/ MW	f Inst/ Avg	OD/ UD	Load shedd Days/ MW	WE Days/ MW	f Inst Avg	OD/ UD MW
May	13d Upto 850	1571 max		Upto +962 &(-) 257	1 /350	2036 max	49.37 / 49.83	19d Upto +472	1d/60 1d/ 200	1761 Max	49. 66	14d Upto +758
	7/ 500	6/ 1000	49.48/ 49.51	8/ +500		20/ 1500		12d Upto -258		4/ 500		17d Upto -620
	6/ 250	11/ 500		7/ +250		11/ 1000				13/ 1000		
Oct	26d/ Upto 2022	Max 370	49.1/ 49.3	+20d Upto -11d	7d/ Upto 1151	Max 1243	49.08 / 49.40	470 max +24d -7d	19d Upto 1395	max 1080	49. 07	+19d -12d
	8/ 1500	9/ 200		+669 Max	4/ 1000	3/ 1000 5/500		3/ 300 15/ 100	1/1000 14/500	2/ 1000 7/250		1/847 1/519 3/300 4/100
	11/ 1000	2/ 100		-505 Max	3/300	5/500 4/250		1/ -632	3/400	8/100		-940 -264
	5/ 250	8/ 30		8/300 4/100		5/100 11/25		1/ -118	1/50	7/20		-262
2/150	6/10		3/-300 2/-140		5/15		2/ -50		7/18		4/ 100	

1. Due to imposition of Power Cut and Peak load restriction from 11.10.2008, HT relief – 1136 to 1642 MW ,1136 to 1327 in Nov 2008

Exclusive Sub Stations and Feeders erected for wind power evacuation out of the total 44 substations in southern part of Tamilnadu

Year	Sub Stations erected		Nr of Feeders connected		Remarks
	Nr	Total Pr Tr Cap In MVA	11 kV	33 kV	
1990	2	107	23	2	2*24 Mvar Cap Banks on 110 kV and 2*2.4 Mvar CBs on 11 kV feeders had been connected originally in Muppandal, Karunkulam and Pazhavur Sub Stations for RP compensation in WEG areas. After the stipulation of pf penalty, , all had erected capacitors and maintained their pf almost unity and hence all CBs were subsequently disconnected.Now the pf at SS is near unity.
1994	1	76	13	1	
1995	1	48	11	-	
1996	2	198	19	8	
1997	3	306	26	16	
2000	1	132	8	8	
2004	2	414	3	15	
2005	4	394	12	22	
2006	3	212	6	12	
2007	1	200	-	15	
2008	1	100	-	5	
2009	1	50	-	3	
Total	22	2239	131	107	

Sub Stations and feeders erected in Tamilnadu for WE evacuation

- In south Tamilnadu totally 44 numbers substations including five numbers 230 kV substations at SR Pudur, Spic, Veeranam, Sanganeri, have been so far erected.
- Besides these PGCIL has commissioned one 400 kV sub station with six 230 kV feeders, which facilitates easy and hundred percent evacuation
- In Udumalpet area one 230 kV and 14 numbers 110 kV SS with sufficient feeders have been erected.

Wind generation AP & RP delivered and received by TNEB

from 01.01.2010 to 22.01.2010

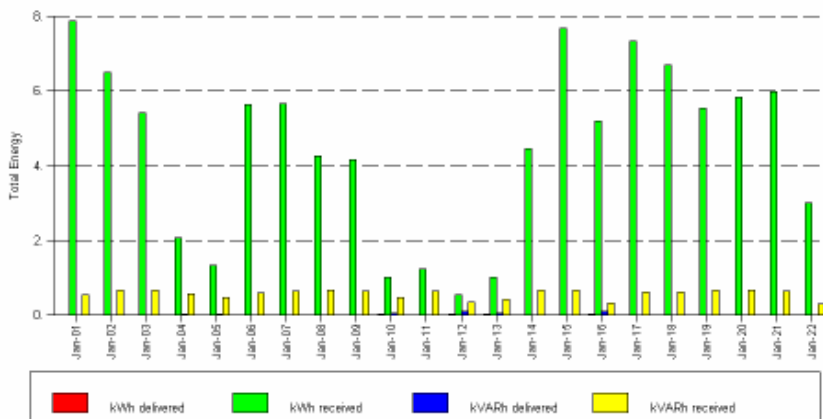
Details (Muppandal)		Delivered		Received		Delivered		Received		CUF:
		kW	kWh	kW	kWh	kvar	kvarh	kvar	kvarh	
Enercon MF: 800 600 kW Synchronous No Capacitors	Total:- With MF- units	-	0.122	-	98.363	-	0.353	-	12.440	25.66
	Average	0.002	0.006	0.456	4.471	0.004	0.016	0.034	0.565	
	Max	0.005	0.036	0.703	7.876	0.013	0.102	0.041	0.676	
	Min	-	-	-	-	-	-	-	-	
Suzlon MF: 1800 1250 kW Induction Gen Capacitors: 16*50+2*25 kvar	Total:- With MF- units	-	0.147	-	91.668	-	0.148	-	21.869	25.82
	Average	0.002	0.007	0.355	4.167	0.003	0.007	0.052	0.994	
	Max	0.004	0.039	0.598	9.199	0.007	0.022	0.054	1.179	
	Min	0	0	0.066	0.303	0.001	0	0.050	0.581	
Vestas RRB MF: 400 Induction Gen 225 kW Capacitors: 12.5+3*12.5	Total:- With MF- Units:	-	0.054	-	76.282	-	0.453	-	4.089	26.53
	Average	0.001	0.002	0.334	3.467	0.007	0.021	0.012	0.106	
	Max	0.003	0.015	0.594	7.451	0.025	0.159	0.013	0.264	
	Min	0	0	0.059	0.166	0	0	0.010	0.036	
Vestas RRB MF: 900 500 kW Induction Gen Capacitors : 4*50+1*25	Total:- With MF- Units	-	0.749	-	16.821	-	0.587	-	23.948	26.22
	Average	0.005	0.036	0.116	0.801	0.008	0.028	0.101	1.14	
	Max	0.006	0.064	0.223	2.215	0.016	0.070	0.155	2.322	
	Min	0	0	0	0	0	0	0	0	

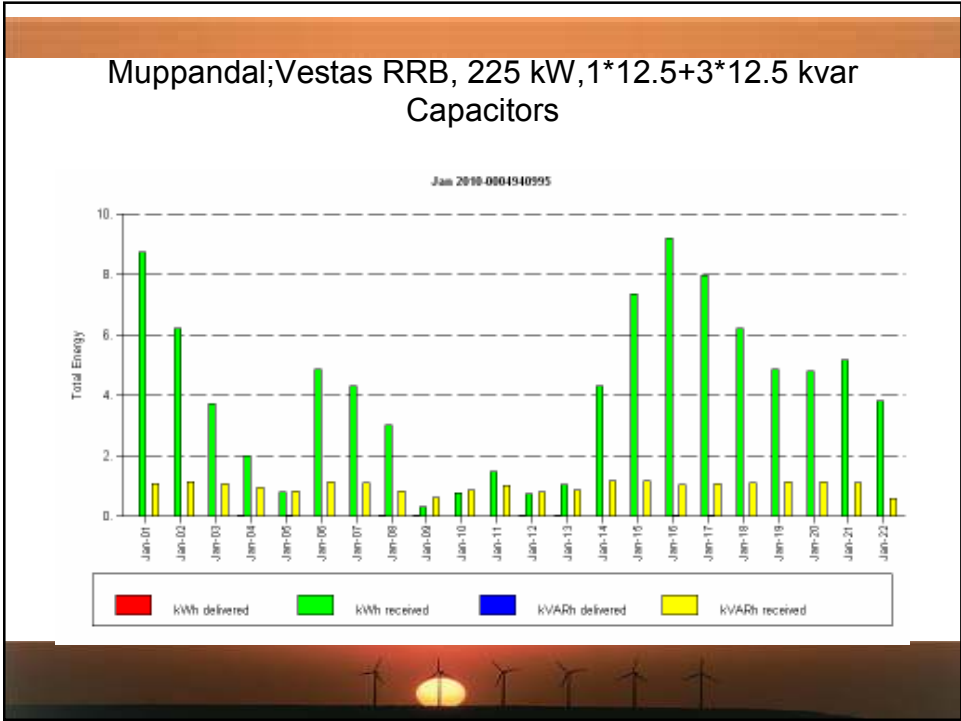
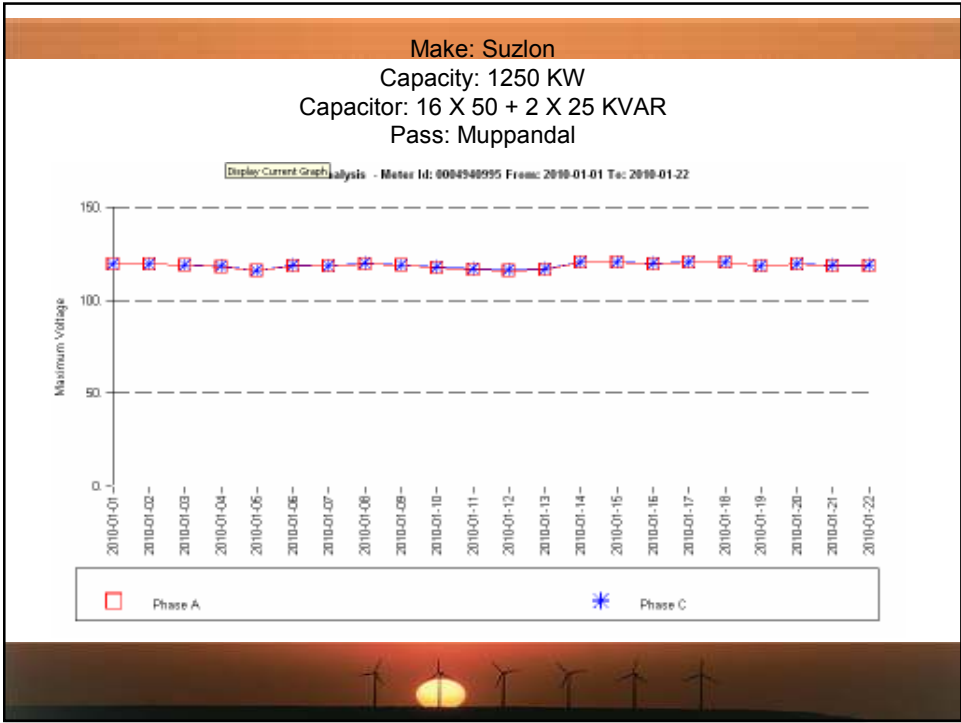
Generation during July 2009 in Thandayarkulam

- Make : Enercon, Synchronous WEG
- Capacity : 600 kW
- Period : 01.07.2009 to 31.07.2009
- kWh import by WEG..... : 84 kWh
- kWh exported from WEG : 212100 kWh
- kvarh imported by WEG : 264 kWh
- CUF for the month of July: 49.09

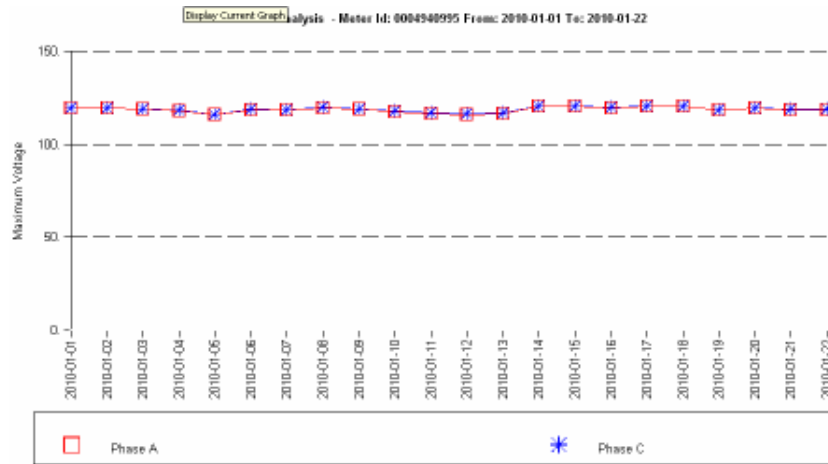


Make: Enercon
 Capacity: 600KW
 Capacitor: NIL
 Pass: Muppandal
Jan 2010-0102278230

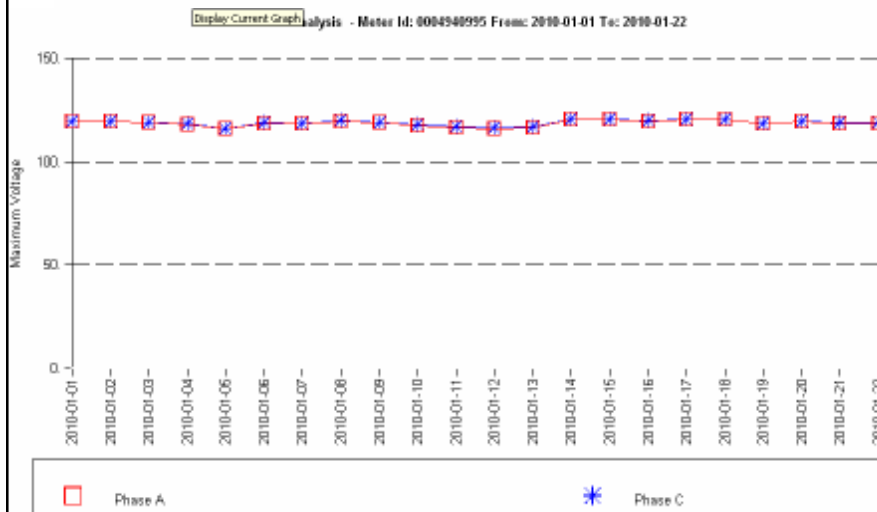




Make: Suzlon
Capacity: 1250 KW
Capacitor: 16 X 50 + 2 X 25 KVAR
Pass: Muppandal

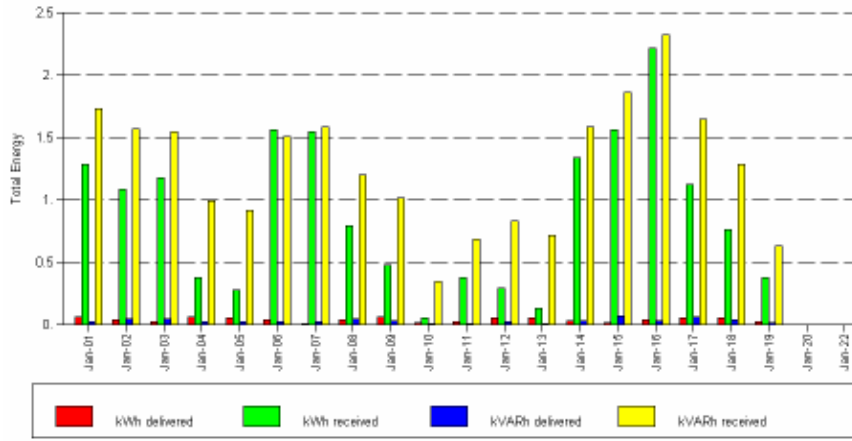


Muppandal;Vestas RRB, 225 kW,1*12.5+3*12.5 kvar Capacitors



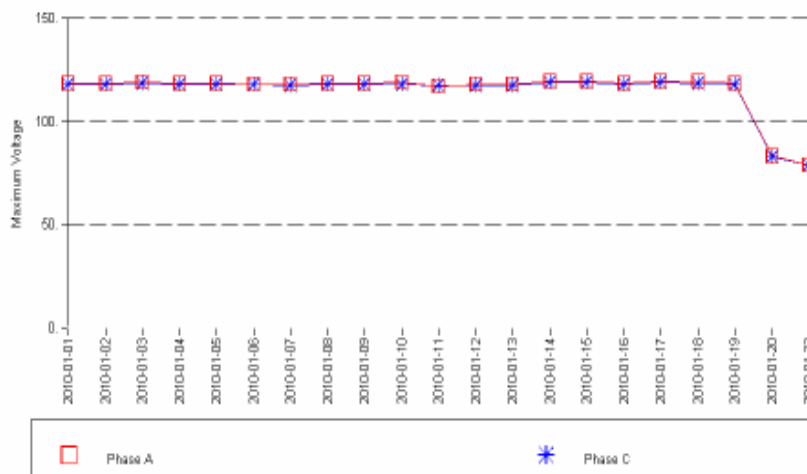
Make: Vestas RRB
 Capacitor: 4 X 50 + 1 X 25 KVAR
 Capacity: 500KW
 Pass: Muppandal

Jan 2010-0004954993



Voltage graph of 500 kW Vestas

Periodic Analysis - Meter Id: 0004954993 From: 2010-01-01 To: 2010-01-22



Conclusion

When more and more Wind power is integrated into the grid :

- Hydro Pumped storage and fast acting gas plants to be set up to have operational flexibility
- Storage technology to store wind energy to be studied.
- Some of them Advocated are
 - Super conducting Magnetic Energy Storage systems(SMES)
 - Super Capacitors
 - Fuel Cells
 - Compressed Air Storage
 - Super Fly wheels
- Integrated Operation of wind ,Solar and Hydel wherever possible
- Spinning reserve is a must. R&D is an imminent necessity that too in TN, where penetration is to the extent of 25 %.
- The necessity for grid infrastructure upgrading is not only to accommodate increasing amounts of wind power cost efficiently, but also other power generating technologies
- The need for infrastructure investments is obviously not arising exclusively from an increased use of wind power, which seems to be the underlying message from many market participants. Consequently, grid extensions, grid reinforcement and increased backup capacity benefit all system users, not only wind power
- Adding wind power to the existing system is contributing favourably to the security of supply by virtue of technology diversification and indigenous production



In a Nut shell

Past :

1. The infra-structure development for wind energy evacuation was not sufficient, resulting in partial backing down of WEG or reducing the Thermal generation, in high wind season and heavy hydro inflow during monsoon.
2. When the generation was low, load shedding was resorted.
3. As the wind generators were mostly of Induction type, they were drawing heavy Reactive Power from the grid causing low voltages in wind areas and have even caused stator earth fault of the nearby hydro station in Kodayar during transient fault in the feeder.

Present :

1. Now sufficient infrastructure like substations and Feeders have been erected, evacuation is not a problem, except marginal overloading at times, 4*100 MW Kadamparai Pumped storage scheme is helpful to meet out the contingency of wind/load ramp up and ramp down
2. Reactive Power drawal from the WEG is virtually Nil, consequent to the penalty imposed and all the WEGs are maintaining the power factor to near unity. In certain cases even var injection into the grid is there. Hence there is no RP or low Voltage problems in wind area due to WEGs.
3. In case of high voltage due to low wind and over compensation due to capacitors in service, Transformer OLTC is being operated at Sub Stations.
4. The operators with the knowledge of previous years monthly wind generation, previous day's wind pattern, the next day/week wind forecast from wind velocity, direction and feeder loading, they are able to schedule the generation to a certain extent. However it is not scientific or fully effective.
5. Though the maximum penetration of wind energy has been to the tune of 22 % to 25% at times in TN grid, this much of penetration has not been detrimental to grid operation, as it is the overall SR grid that is taking this. The total RES installed capacity in SR is 7047 MW out of 40097 MW and as every state is facing power shortage, any amount of injection upto 20 to 25 % of SR capacity can be accommodated without much difficulty.
6. During fast variations and sudden drastic fall of generation the under frequency relays and df/dt relays operate and trip the set feeders, which is being monitored by the RLDC and SLDC operators.
7. Due to the ABT enforcement, overdrawals are restricted and durind 2008-09, the max,min and average frequencies were 50.96, 48.25 and 49.25 Hz respectively.



In a Nutshell ..contd

Future:

1. The 4*125 MW Kundah Pumped Storage Scheme to be expedited for WINDEL (Wind and Hydel) operation.
2. More Sub stations (for every 3 *230 kV sub stations one 400 kV substation) and sufficient feeders with loading limiting to 80% only to be erected.
3. 765 kV substation is a must in Tirunelveli/Kanyakumari area, as the Demand in that area compared to the generation is very less.
4. For effective integrated operation of WEG - Hydel, Gas and Solar, more solar and Gas plants to be commissioned.
5. Effective wind forecast with reliable wind speed, direction, density and the machine's characteristic, for proper scheduling and to meet out contingencies to be done.
6. Being the major contributor of WEG, R&D in this regard is a must for TN.
7. Now that wind generators have also realised the necessity of scheduling and said to have accepted, Regulation by CERC / SERC has to be in place for implementation.

