

# Power Quality Issues & Challenges for RE Sources to Grid Integration

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### Educational Qualifications

M. E. (Electrical), B. E. (Electrical), M. B. A. (Financial Management), B. Sc. (Sci-Maths) Part-I, BEE, Certified Energy Auditor cum Manager, Govt of India, New Delhi.

### Organizations

Presently Working with ReGen Powertech Pvt Ltd, Chennai  
 EMCO Ltd, Thane / Nashik Sub Station Project Execution cum Recovery.  
 Suzlon Energy Ltd, Pune Power Evacuation Planning  
 Rajasthan Rajya Vidhyut Prasaran Nigam Ltd, Jaipur (R.S.E.B.) in EHV Construction, Commissioning, Testing & Protection of SS & Lines upto 400 kV Voltage

### Key Accomplishments

Received Award for Operation & Maintenance and Zero interruptions at 132 kV Soorsagar Sub Station (RRVPN Ltd.) by CMD, RVPN (RSEB) Ltd, Jaipur.  
 Major projects supervised & Commissioned 400/220 kV Mertacity (Nagore) & Soorpura (Jodhpur) Sub Station including some EHV lines state Rajasthan.  
 Huge costs savings on account of attending Emergency and Routine testing & Protection, Faults finding, & Analysis of EHV equipment to minimize unwanted trippings and restoration of power supply in a minimum possible time and Energy Auditing for Static Energy Meters.  
 Important projects of MSETCL Commissioned i.e. 400/220/33 kV Chakan, 220/132/33 kV in Dist Pune, Ahmednagar & 132/33 kV Manmad Sub Station in state Maharashtra.

Power Evacuation Planning for large integrated wind power projects through Power System Design software ETAP 7.5.2 to conduct Load Flow Studies, Earth Grid Design, Harmonic & Transient Stability Analysis, use of VAR Compensators and Short Circuit Studies for submission of Techno Commercial proposals to various SEBs across the country and neighbouring country Sri Lanka & Maldives approx 15,000 MW for Wind Power Projects and saved big Capex on account of Infrastructure Developments.

Involved in Regulatory Affairs, UI Mechanisms, Trends/Policies of SERC/CERC, Indian Electricity Grid Code/Electricity Act 2003 and Interface with Government body

### Paper Presentation & Training Programme

Certified Course on Engineering Design IEEE approved ETAP 7.5.2 software to Conduct Load Flow Studies, Earth Grid Design, Short Circuit Studies, Harmonic & Transient Stability Analysis, Motor Acceleration & Reliability Analysis, Relay Protective Coordination and use of VAR Compensators.

Technical Paper Presented on "Expert System Based Modeling for the Online Optimal Control of injection of Reactive Power in EHV Systems by ANN theory."

Ongoing work in the areas of Loss Minimization & Voltage improvements by Artificial Neural Network & Fuzzy Logic Techniques for Ph. D. in Electrical.

Training programme attended at  $\pm$ 500 kV Bipolar Padgha, Thane HVDC (MSETCL) SS.

Fellow Member of Society of Energy Engineers and Manager(**SEEM**), Thiruvanthapuram

### Family Background

Anita Singhal wife as Post Graduate in Economics & two daughters, 1) Anjali Singhal, M.Tech. II<sup>nd</sup> Yr / II<sup>st</sup> Sem (Computer Science & Engg.) IIT Bombay @ 19.5 Yrs  
 2) Nandini Singhal, B. E. II<sup>nd</sup> Yr / II<sup>st</sup> Sem (Computer Engg.) Pune University, Pune @ 15.5 Yrs



## ReGen Powertech Pvt. Ltd.

We, ReGen Powertech Pvt. Ltd, are one of the recent players in the Wind Energy Sector, using Gearless Technology. We emerged as one of the leading Manufacturer of Wind Electric Convertors (WEC's) and so far we have installed close to 500 MW.

- ✓ Established in 2006 to manufacture and provide turnkey solutions in Wind Energy
- ✓ Technology tie-up with Vensys Germany for 1.5 MW, 2.5 MW & 3.0 MW gearless, synchronous generator with PMG
- ✓ A team of professionals with extensive experience in wind and other relevant industry
- ✓ State of the art manufacturing facility to produce 500 WECs annually (750 MW).
- ✓ 800 MW Project under Execution
- ✓ 1500 MW project under Planning and Development at various stages

# Significant Operational Advantages

- ReGen Powertech delivers high efficiency and reliable Direct Drive Turbines – built upon the Vensys technology platform
- **The direct drive synchronous generator offers significant advantages over conventional gearbox turbines**
  - Fewer components and higher availability: average availability exceeding 98%
  - Lower maintenance costs
  - Higher partial load efficiency; 3-5% higher energy production for Permanent-Magnet Excitation
  - Low voltage, low speed, reliable generator rotor
  - Reduced noise levels due to less moving parts
  - Patented passive cooling system ensures outstanding cooling performance
  - No need for additional fans to eliminate dust and wear
  - Ideal for tropical climates
- Special power converter optimises the usage of given grid capacities, helps stabilise the grid and meets the requirements of network operators



# Technology in Pipeline

- ReGen believes in upgrading and introducing new technology to maximize efficiency resulting in opening new markets
- Technology up gradation plan
  - VENSYS 87 IEC Class IV      Jan 2012
- New Product in pipeline
  - 2.5 MW      2012
  - 2.8 MW      2013
  - 2.8 and 3.0 MW      2014 (International Launch)

## State Wise Wind Energy Capacity Upto- 31-03-2011

State	Installed Capacity in MW till 31.03.2010	Installed in Yr 2010-11 in Mw	Total Installed Capacity upto 31.03.2011 in Mw	Gross Technical Potential in Mw
Tamil Nadu	4906.74	994.55	5901.29	5530
Karnataka	1472.75	257.05	1729.8	11531
Maharashtra	2077.7	268.55	2346.25	4584
Rajasthan	1088.37	436.7	1525.07	4858
Andhra Pradesh	136.05	63.2	199.25	8968
Madhya Pradesh	229.39	48.6	277.99	1019
Kerala	27.75		27.75	1171
Gujarat	1863.64	314.5	2178.14	10645
Orissa			0	255
West Bengal	1.1		1.1	
Others	3.2		3.2	
<b>Total</b>	<b>11806.69</b>	<b>2383.15</b>	<b>14189.84</b>	<b>48561</b>

# Why Grid Connectivity is relevant?

- As per IE Act 2003, clause 86(1)(e) Wind Power to be promoted & Regulatory Commissions have appropriately passed orders for the same including terms of PPA & RP Obligations. However, it is not perceived by all stake holders in the same spirit.
- Connectivity being considered more critical than power flow.
- Commercial issues take precedence over technical matters.

# Classic Definitions related to Power Quality Problems

- Impulses / Transients: High magnitude for extremely short duration.  
Voltage Sag: Reduction in the RMS voltage in the range of 0.1 to 0.9 p.u. for a few seconds.
- Voltage Swell: Increase in the RMS voltage in the range of 1.1 to 1.8 p.u. for greater than half a main cycle & less than 1 Min caused by faults, load and capacitor switching.
- Over Voltage: A Steady State Voltage rise for last for Several Seconds.
- Under Voltage: A Steady State Voltage dip last for Several Seconds.  
Voltage Interruption: Complete loss of voltage for a few seconds to several hours, opening of Circuit Breaker, line, reclosure or fuses.
- Voltage Flickers: A perceptible change in lamp output due to sudden change in Voltage caused generally by arcing condition.
- Current / Voltage Harmonic: The non fundamental frequency components of a distorted power frequency wave forms.

# Power Quality (PQ) Issues in the Grid Integration

- ◆ Power Quality: IEC 61 400 – 21:
- ◆ Measurement & Assessment of Power Quality of Grid connected Wind Turbine.
- ◆ Wind Turbines shall be directly connected to the EHV network through Standard Power Transformers.
- ◆ Analysis of 3<sup>rd</sup>, 5<sup>th</sup> & so on Harmonic Levels presence in the Power Flow to the Grid and Transients Analysis.
- ◆ Maximum THD of the Grid Voltage: 5% (10 Min Average Grid ).
- ◆ Frequency:  $\pm 1\%$  (0.2 Sec Average).
- ◆ Voltage Fluctuation:  $\pm 5\%$  of its Nominal Value (10 Min Average

# KEY DIFFERENTIATORS

- ◆ Uncertain nature of the wind sources & hence infirm source.
- ◆ Sites – located in difficult terrains - from the coastal plains to the hilly hinterland and sandy deserts far flung from densely
- ◆ Populated areas and far away from load centers.
- ◆ Quantum jump in Wind Power, Demands Power Evacuation at higher voltage levels.
- ◆ PLF between 20 to 30 % depending on site.
- ◆ All these makes Grid connectivity & Wind Power Evacuation technically & commercially complex.

# The System Operation is

`a mission critical activity` for uninterrupted, secure, reliable and quality power supply in the country.

- Strict vigil & control on system parameters using ultra modern SCADA / EMS tools.
- Mature market for Ancillary Services
- Competent & sensitive grid operators.

`a relentless pursuit` for optimization of precious power generating resources and minimization of inherent system losses.

- Maintenance of System parameters at optimum level.
- Appropriate setting of controllable parameters.
- Meticulous post dispatch analysis & data interpretation.
- Coordinated corrective efforts by all operators irrespective of their affiliations.
- Reduction of Commercial Losses & Theft of Energy.

# The System Operation is

`an impeccable vehicle` for equitable and fair use of the Transmission infrastructure in the Country.

- Robust market architecture
- Efficient market design
- Meticulous Market Management System
- Unbiased information sharing among stakeholders

`a vital link` between the Administrations, Planners & Regulators on one end and physical system on the other end.

- Uninterrupted feedback from operators to others
- Being flag bearers of reforms and good utility practices.
- Proper planning by the planners consistent with the Act, Rules & Regulations and Orders thereon.

# Power System Security

Time Frame	Instrument
Long - Term	Power System Planning with suitable criteria Reliability Standards Adequacy Reports Control Area Obligations Grid Code Market Design Tariff Design Operator Certification
Mid Term	Protection Coordination Defense plans Maintenance Scheduling Load Generation Balance Continuous Learning

# Power System Security

Time Frame	Instrument
Short - term	Assessment of Transfer Capability Limits & Resources Scheduling
Real time	Planned Outage coordination Ancillary Services: Primary & Secondary Response, Load Flow, Reactive compensation and Static Reactive Compensation Reliable state estimation and Energy Management System (EMS) System Monitoring by experienced and certified personnel On-line Contingency Analysis.
Post dispatch	Event Analysis Power System Performance Review Objective & Ethical Reporting

# Challenges & Remedial Measures in the Large Wind Power Generating Station & Grid Sub Station

S. No.	Challenges to Large Wind Power Generating Station due to Grid Integration	Remedial Measures to overcome/ Minimization of forthcoming threat due to Grid	Challenges to Grid due to large Wind Power Generating Station	Remedial Measures to overcome/ Minimization of forthcoming threat due to large Wind power Generating Station
1	Deficit of Reactive Power (MVar)	Additional VAR Supports required at wind farm pooling sub station like STATCOM, Dynamic Compensation, Series Compensation or IGBT	Deficit of Reactive Power (MVar)	Additional VAR Supports required at wind farm pooling sub station like STATCOM, Dynamic Compensation, Series Compensation or IGBT
2	Overvoltage & Undervoltage problems lies on the Grid side	Over voltage / under voltage protection relays at both grid end as well as wind farm pooling SS must be provided	Low PLF	Creating over voltage problem at wind farm SS. Hence, shunt reactor is the option to reduce the over voltage.
3	Sudden rejection of load due to large interruptions in the integrated EHV network	1. Over voltage protection relays should be provided to protect EHV equipment's. 2 . Sizing of conductor must be to carry the entire wind power generation through the EHV lines.	Wind is unpredictable & unreliable	Methodology to predict correct wind pattern with the help of latest available software.
4	Abrupt fall in the Grid Frequency	Frequency & Energy auditing be made recorded through the ABT Energymeters.	Wide range in the variation of wind power generation	Methodology to predict correct wind pattern with the help of latest available software.
5	Need of strengthening of local and Upstream EHV Grid Network	Types of conductor used at the Upstream EHV Network must be capable to handle excess evacuation of power because of outage of any one or more circuits in the systems.	Limited control over the wind power generation	with the help of latest software available in order to control Generation.

# Challenges & Remedial Measures in the Large Wind Power Generating Station & Grid Sub Station

S. No.	Challenges to Large Wind Power Generating Station due to Grid Integration	Remedial Measures to overcome/ Minimization of forthcoming threat due to Grid	Challenges to Grid due to large Wind Power Generating Station	Remedial Measures to overcome/ Minimization of forthcoming threat due to large Wind power Generating Station
6	Grid availability	Multiple EHV Network must be available to ensure atleast 99% Grid availability even though any one line being contingencies for smoothness of wind power generation.	Due to high wind energy generation , voltage remains high causing frequent failure of lines & equipment's	Design of circuit breakers should be appropriate to withstand fault current occur due to short circuit or over voltage.
7	Windmills tripped due to unbalanced Grid voltage generally created asymmetrical loading	Unbalancing of load & voltage relays should be suitable provided.	Generation of above rated Wind power while grid is either lightly loaded or no load conditions.	with the help of latest software available , we can control the Generation.
8	Adequate protective devices at Grid Sub Station to isolate any faults /short circuit /abnormalities in the Transformer/EHV lines	All kinds of protection systems like Distance relay, Over load protection relays should be available (Normally Available ) in the SEBs Sub Stations.	Generation of far below rated wind power while grid is fully loaded due to demand in the system.	with the help of latest software available , we can control the Generation.

# % Voltage Regulation & Line Losses in various Conductors

S. No	Voltage Level	Dog	Coyote	Panther	Lynx	Drake	Kundah	Zebra	Moose
1	33 kV	% Voltage Reg	0.016	0.013	0.009				
		% Line Loss	0.029	0.024	0.015				
2	66 kV	% Voltage Reg	0.004	0.003	0.002	0.0025			
		% Line Loss	0.007	0.006	0.004	0.004			
3	110 kV	% Voltage Reg		0.001	0.0008	0.0009			
		% Line Loss		0.002	0.0013	0.0015			
4	132 kV	% Voltage Reg			0.0005	0.0006			
		% Line Loss			0.0009	0.001			
5	220 kV	% Voltage Reg				0.0001	0.0001	0.0001	0.00009
		% Line Loss					0.0002	0.0002	0.0002
6	230 kV	% Voltage Reg				0.0001	0.0001	0.0001	0.00009
		% Line Loss					0.0002	0.0002	0.00015
7	400 kV	% Voltage Reg							0.00001
		% Line Loss							0.00002

Note:- The above calculation are on the per Km & per Mw basis for all voltage levels.

# Ampacity of Current Carrying Capacity of various Conductors with regard to Ambient Temp & Solar Radiation

Ambient Temp in °C	Wind Velocity in m / Sec	Solar Radiation in Watt / m <sup>2</sup>	ACSR Zebra Cond at 220 kV Voltage Rdc = 0.06868 Ω, Area of Cond = 484.231 mm <sup>2</sup> , Dia (2*4+1)3.18 = 28.62 mm				ACSR Moose Cond at 220 KV Voltage Rdc = 0.05552 Ω, Area of Cond = 597 mm <sup>2</sup> , Dia (2*4+1) * 3.53 = 31.77 mm				ACSR Kundah Cond at 220/ 110 kV Voltage Rdc = 0.07269 Ω, Area of Cond = 424 mm <sup>2</sup> , Dia (2*4+1)* 1.96= 17.64 mm				ACSR Panther Cond at 132 kV Voltage Rdc = 0.139 Ω, Area of Cond = 261.405 mm <sup>2</sup> , Dia = 21 mm				ACSR Dog Cond at 33 kV Voltage Rdc = 0.2792 Ω, Area of Cond = 118.476 mm <sup>2</sup> , Dia = 14.15 mm			
			Ampacity in Amp at 75°C Temp	Power in Mw @ UPF	Power in Mw @ p. f 0.95	Power in Mw @ p. f 0.9	Ampacity in Amp at 75°C Temp	Power in Mw @ UPF	Power in Mw @ p. f 0.95	Power in Mw @ p. f 0.9	Ampacity in Amp at 75°C Temp	Power in Mw @ UPF	Power in Mw @ p. f 0.95	Power in Mw @ p. f 0.9	Ampacity in Amp at 75°C Temp	Power in Mw @ UPF	Power in Mw @ p. f 0.95	Power in Mw @ p. f 0.9	Ampacity in Amp at 75°C Temp	Power in Mw @ UPF	Power in Mw @ p. f 0.95	Power in Mw @ p. f 0.9
30	0.4	1100	815	311	295	279	934	356	338	320	692	264	250	237	525	120	114	108	332	19	18	17
40	0.4	1100	702	267	254	241	803	306	291	275	600	229	217	206	454	104	99	93	289	17	16	15
50	0.4	1100	555	211	201	190	632	241	229	217	482	184	174	165	363	83	79	75	234	13	13	12
30	0.45	1100	840	320	304	288	963	367	349	330	713	272	258	245	541	124	118	111	342	20	19	18
40	0.45	1100	725	276	262	249	829	316	300	284	619	236	224	212	469	107	102	97	298	17	16	15
50	0.45	1100	576	219	209	198	656	250	237	225	499	190	181	171	376	86	82	77	242	14	13	12
30	0.5	1100	863	329	312	296	989	377	358	339	732	279	265	251	556	127	121	114	352	20	19	18
40	0.5	1100	746	284	270	256	854	325	309	293	637	243	231	218	482	110	105	99	306	17	17	16
50	0.5	1100	595	227	215	204	679	259	246	233	515	196	186	177	389	89	84	80	249	14	14	13
30	0.55	1100	885	337	320	303	1014	386	367	348	750	286	271	257	570	130	124	117	360	21	20	19
40	0.55	1100	766	292	277	263	876	334	317	300	653	249	236	224	495	113	108	102	314	18	17	16
50	0.55	1100	613	234	222	210	699	266	253	240	530	202	192	182	400	91	87	82	256	15	14	13
30	0.6	1100	905	345	328	310	1038	396	376	356	768	293	278	263	583	133	127	120	368	21	20	19
40	0.6	1100	784	299	284	269	898	342	325	308	669	255	242	229	507	116	110	104	332	19	18	17
50	0.6	1100	630	240	228	216	719	274	260	247	544	207	197	187	411	94	89	85	263	15	14	14
30	0.4	1200	805	307	291	276	922	351	334	316	685	261	248	235	519	119	113	107	329	19	18	17
40	0.4	1200	689	263	249	236	787	300	285	270	591	225	214	203	447	102	97	92	285	16	15	15
50	0.4	1200	538	205	195	184	611	233	221	210	471	179	170	162	354	81	77	73	229	13	12	12
30	0.45	1200	830	316	300	285	951	362	344	326	706	269	256	242	535	122	116	110	339	19	18	17
40	0.45	1200	712	271	258	244	814	310	295	279	610	232	221	209	462	106	100	95	294	17	16	15
50	0.45	1200	559	213	202	192	636	242	230	218	488	186	177	167	367	84	80	76	237	14	13	12
30	0.5	1200	853	325	309	293	977	372	354	335	725	276	262	249	550	126	119	113	349	20	19	18
40	0.5	1200	734	280	266	252	839	320	304	288	628	239	227	215	476	109	103	98	303	17	16	16
50	0.5	1200	579	221	210	199	659	251	239	226	505	192	183	173	380	87	83	78	245	14	13	13
30	0.55	1200	875	333	317	300	1003	382	363	344	744	283	269	255	564	129	122	116	357	20	19	18
40	0.55	1200	754	287	273	259	862	328	312	296	645	246	233	221	488	112	106	100	311	18	17	16
50	0.55	1200	598	228	216	205	681	259	247	234	520	198	188	178	391	89	85	80	252	14	14	13
30	0.6	1200	896	341	324	307	1026	391	371	352	761	290	275	261	577	132	125	119	366	21	20	19
40	0.6	1200	773	295	280	265	884	337	320	303	661	252	239	227	500	114	109	103	318	18	17	16
50	0.6	1200	615	234	223	211	701	267	254	240	534	203	193	183	402	92	87	83	259	15	14	13

Source: IEEE Std 738 - 2006

# Commercial issues related with integration of Wind Energy

- The objective of Availability Based Tariff (ABT) mechanism is to bring responsibility & accountability in power generation and consumption to maintain Grid Frequency and voltages to ensure Grid Stability and Discipline in order to help the System Operator in flattening of load curve and to ensure merit order dispatch.
- Wind Energy being Green Power and excessively available in monsoon season, the load dispatch is compelled to back down even the cheaper, firm and reliable power from Thermal and Hydro Power Stations.
- Due to low Plant Load Factor (PLF), it is not economical to plan Evacuation Network considering contingency condition as per transmission planning guidelines of CEA / Grid Code.
- The network planned considering peak wind generation remains unutilized / not optimally loaded for most of the time during low wind regime thereby resulting in undue burden to the Wind Farm Developer.

# Critical Issues related with integration of Wind Energy

- Maximum wind generation is available during monsoon / off peak period of the year, when total system demand crashes steeply & it becomes very difficult for the dispatcher to handle the system effectively.
- The system peak demand occurs during summer months and Rabi season. It is generally observed that wind generation doesn't help the grid during these seasons.
- Due to large oscillations in the wind generation at every moment, electrical grid is affected in its voltage control & Transient Stability.
- Less consumptions in local area due to wide variations in load of Agriculture, less & variable industrial demand and low demand in industrial Holidays.
- Variable local load pattern leads to overloading of transformers & main transmission lines which requires high capacity of strengthening of network.

# What Wind Energy Sector expects ?

- Revisit specs and guidelines for Wind Farm Sector. The presently defined capacities of conductors at various voltage levels as per CEA Transmission planning criteria correspond to Wind velocity of 2 Km per hour and higher Solar Radiation are OK for normal lines but Wind farm generates power between the wind speeds varies from 10 Km / hr to 47 Km / hr. Hence current carrying capacity can be much higher.
- This occurs during June to December when ambient temperature is low and even Solar Radiation is also low and can enhance current carrying capacity.
- Therefore the loadability of the EHV lines connecting to Wind Farms has to be equal to Thermal Rating.
- Since, these lines are at the far end of the system & short lines as well, so they can be loaded beyond SIL, but up to the Thermal Rating of conductors.
- Standardization of specifications of Substation equipment's and auxiliary systems.
- Since, a variable cost of Wind Energy Generation is negligible, Wind Energy to be considered for absorption as a "must run" station similar to Run of the river Hydel Power Stations.

# What Wind Energy Sector expects in terms of Grid Integration?

- Amperes and power flow should be the criterion and not connected load due to diversity and non-simultaneous peak.
- Infrastructure should be technically optimum and cost effective.
- Suggest a single window clearance for all issues related to Power Evacuation instead of Transco, Discom & Nodal Agencies.
- There is need for uniform policy through out the country in respect of Tariff for Wind Power and its Banking & Banking.
- The technical and regulatory framework should be pan-India investor- friendly as windy sites are limited.
- Wind Energy should be given open access in the same way as for captive power as per the Act.
- Regulator may consider RP Obligations as minimum and not maximum.

# Solution of Power Quality Problems

- Static VAR Compensator (SVC)
- Passive Filters
- Active Filters
- Multi – Pulse Configuration
- Distribution Static Compensator (D – STATCOM)
- Dynamic Voltage Restorer (DVR)
- Unified Power Quality Compensator (UPQC)
- Static Series Compensator (SSC)

# Conclusion

- Real Time Data from Wind Farm SS to system operator to be made available for effective grid discipline.
- Reserve capacity with high ramp up generators such as a Hydro and Gas shall be kept.
- Reinforcements of main transmission network and interstate power corridors.
- Augmentation & Reinforcement of voltage regulating equipment's such as Reactors, Switched Capacitor including FACTS devices.
- Cost of Evacuation has to be in line with viability of site without compromising technical & smart Grid management requirements.



**Thank You !!!**