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EDITORIAL

Sustaining the growth rate, above 20% even during recession, India is steadily growing up in installed capacity of wind Electric Generators which are Grid connected. During this period, 2 major manufacturing plants of Wind turbines, starting from Blade to integrated system have been inaugurated in the suburbs of Chennai. With this, Chennai is beginning to be a manufacturing hub of mega watt class Wind Turbine, next to Pune and Ahmedabad. At this juncture, while Indian Wind Atlas project is in an advanced state of completion at C-WET the potential of wind energy in India needs a relook considering the increased hub heights of wind turbines available in the market.

Thus wind resource assessment involves a thorough analysis of wind power potential in the off-shore regime as well, since India has got a long coastline of over 7600 Kms. Worldwide, off-shore wind power projects are going to be a reality with Europe spearheading the growth of off-shore wind farms.

Denmark has 619 MW of installed capacity of off-shore wind farms, and United Kingdom has 598 MW. The other countries having off-shore wind farms are Ireland, Sweden, Netherlands, Norway, Finland and Belgium. Over all we have more than 2 GW installed off-shore wind farms which are operational around the World. The main challenge in off-shore wind energy is that of high cost and requirement of undersea cabling and foundation sub-structures. In addition, the wind turbines are economically viable only with water depths up to 15-30 meters. In India under National wind monitoring, wind resource has been collected at 54 locations along the coast line, however, so far none off-shore. In general, the western coastline has shown modest potential at sea level but the islands on the western/Arabian sea are likely to have good winds. Preliminary studies have shown that some part of southern peninsula of India and Gujarat-Kutch region is prone to have good off-shore wind potential. The narrow strip of land jetting towards Srilanka with 9 km length and about 200 metres wide promises economic wind measurement off-shore which C-WET is planning to make use of.

The main advantages of off-shore wind farm would be steady wind speed, no land acquisition issues, better capacity utilisation factor, and increased reliability of the equipment under steady-state wind. Currently, the costs of off-shore wind power projects in India are more than twice that of on-shore. However, the relative cost of off-shore projects in Europe are higher than that is possible in India.

We have to be optimistic that off-shore wind is less turbulent and it is possible to generate about 30% more energy and most of the off-shore wind farms use MW class machines that ranges from 2-3 MW. India has adopted so far the highest capacity of 2 MW type even in the on-shore wind power as on date. C-WET has started a programme to measure off-shore wind potential earlier in June using SODAR (SOund Deduction And Ranging) measurements near Dhanushkodi Coast. It has indicated significant potential off-shore, in the area. C-WET is processing the various required Governmental, strategic, environmental, maritime clearances for getting the project of off-shore wind resource assessment using instrumented mast planned to be started next year. There are additional requirements of Civil Aviation, Navy, Coast Guard and special project clearances along with compliance of Coastal Regulation Zone (C.R.Z) limits, to go ahead with off-shore wind power projects.

The R&D Unit of C-WET has made one Acoustic Measurement on the request of a manufacturing company at Tenkasi Taluk, Tamilnadu in accordance with IEC 61400-11. The unit has made efforts to measure power quality and to form a draft of Indian Wind Grid Code for seamless Grid Penetration of wind power.

The Wind Resource Assessment unit has taken up few studies on due diligence and production estimates with long standing wind farms near Thevarkulam at Tirunelveli, apart from the routine daily projects of establishing new wind monitoring stations, wind data analysis, verification of wind data from private sector and micrositing projects.

Testing Unit of C-WET had signed agreements to test one 1.65 MW machine at Satara and another 750 kW wind turbine at Poigai near Tenkasi, Tamil Nadu. The unit has also signed an agreement with M/s. WinWind and M/s Inox Wind Limited for testing project.

S&C unit has been active to carry out few renewal of certification of previously certified wind turbine models and improvement of quality management system as per ISO 9001-2000.

ITCS Unit has completed a display facility with working models of water pumps and wind turbines for educating School and College Students and several other visitors who are new to Wind Energy technology. C-WET also has participated actively in exhibitions and industrial/academic technical events related to energy.

With your active feedback and support, C-WET would be interested to provide value added services with the ever growing expertise and experience of "Team-C-WET".

S. Gomathinayagam
Executive Director

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Developments in R&D UNIT

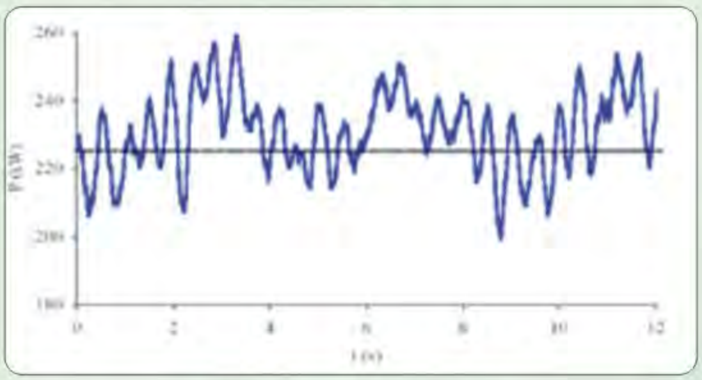
Acoustic measurement of 750 kW wind turbine

It is often felt that the wind turbine gets older it starts emitting noise thereby causing noise pollution to the local inhabitance. In view of the above, acoustic measurements were undertaken on GWPL 750 kW constant speed active stall controlled wind turbine at Tenkasi Taluk, Tirunelveli District in Tamil Nadu, as a consultancy project. The measurements were carried out strictly in accordance with IEC 61400-11

The sound pressure level and one third octave band spectra were measured. The A weighted sound power level and tones were calculated for wind speeds ranging from 8 to 10 m/s at 10 m height.

Measurement of Power Quality of 600 kW wind turbine

The power quality of a wind turbine, characterized by peak power, reactive power absorption, voltage fluctuations and harmonic emissions at the wind turbine terminals helps assessing its effect on the local grid to which it is connected. An experimental study was therefore under taken to determine the power quality parameters for the full operations range of the pitch regulated wind turbine at R&D wind farm.



Active power versus time

Indian Wind Grid Code

Wind turbines are installed in areas with sufficient wind power density (> 200 W/ sq.m at 50 m hub height level) with provision to connect to the grid. Areas with good wind power density are not necessarily places with a strong grid, as they are mainly concentrated in rural areas away from locations with major generating stations. With the increasing penetration of wind turbines, as high as 42 % in terms of installed capacity in states like Tamil Nadu, the need was felt to establish a standard operating practice for the wind turbines. A project was therefore sponsored to M/s Power Research and Development Consultants Pvt. Ltd., Bangalore, to develop the Draft Indian Wind Grid Code. The Draft Report has been prepared and submitted to Cental Electricity Regulatory Commission (CERC) who have formulated a Task Force for integration of renewable energy into the grid.

Move on in WRA UNIT

During the period of July to September, 8 new Wind Monitoring Stations in 4 states (Uttar Pradesh, Madhya Pradesh, Karnataka and Uttrakhand) have been installed. Presently, 98 wind-monitoring stations are operational in 21 states and one in union territory under various wind monitoring projects funded by the Ministry and Consultancy projects.

Projects on Verification of Procedure of Wind Monitoring at Phalodi in Rajasthan (Extn.) for M/s. Suzlon Energy Limited, Pune, Harpanahalli-1, Davangere district in Karnataka for M/s. Vestas Wind Technology India Private Limited, Chennai, and Gorsar Mocha, Varvada, Balambha, Adodar in Gujarat for M/s. Suzlon Infrastructure Services Ltd, Pune have been taken up.

Projects on Micrositing for Wind Farming at Guledagudda & Kappataguda in Karnataka for M/s. Karnataka Power Corporation Ltd, Bangalore have been taken up.

Production Estimate of wind farm projects at Hassan & Harpanahalli in Karnataka for M/s. ITC Limited, Bangalore, 50.4 MW wind farm at Khandke in Maharashtra for M/s. Enercon India Ltd, Mumbai and Chakla & Bothe in Maharashtra for M/s. ITC Limited, Bangalore and Evaluation of power curve demonstration for M/s. Suzlon Energy Limited, Pune have been started.

Projects on Wind Measurement Studies at three locations in Siddavvannadurga site, Chitradurga District, Karnataka for M/s. NSL Power private limited, Hyderabad, Tehri Dam in Garhwal district, Uttarakhand for M/s. Tehri Hydro Development Corporation Ltd, Rishikesh and Devarkulam, Tirunelveli District, Tamilnadu for M/s. Tamilnadu Newsprint and Papers Limited (TNPL), Chennai have been undertaken.

Projects on Wind Data Collection, Processing and Analysis at Toranahalli Village, Belgaum district in Karnataka for M/s. Mysore Mercantile Co. Limited, Bangalore have been initiated.

The unit has completed the following projects and submitted reports during this period.

- Verification of Procedure of Wind Monitoring at Akal & Pohra (Jaisalmer District in Rajasthan), Shiravalli (Satara district in Maharashtra), and Harpanahalli-1 (Davangere district in Karnataka) for different wind farm entrepreneurs.
- Site Validation & Generation Estimate of Proposed 50 x 600 kW Wind Farm Project at Surajbari, Kachchh District, Gujarat and 11 x 600 kW Wind farm project at Harihar in Davangere District, Karnataka for M/s. MSPL Limited, Hospet and Hassan & Harpanahalli in Karnataka for M/s. ITC Limited, Bangalore.
- Wind Resource Assessment study at Sanadongri, Senoi District, Madhya Pradesh for M/s. Narmada Wind Energy Private Limited, Jabalpur.

Steps forward in TESTING UNIT

- An agreement was signed between C-WET and M/s. Ghodawat Industries (India) Pvt. Ltd on 14th August 2009 to test their G1650 kW model wind turbine at Kaledhon near Satara, Maharastra.
- An agreement was signed between C-WET and M/s. Pioneer Wincon Pvt Ltd on 26th August, 2009 for Power Curve Measurements of 750 kW wind turbine at Poigai near Tenkasi, Tamil Nadu.
- An agreement was signed between C-WET and M/s. WinWind Power Energy Pvt. Ltd on 14th September, 2009 for Safety and Function Test of 1000 kW wind turbine at Ayyanaruthu, Kayathar, Tamil Nadu.
- An agreement was signed between C-WET and M/s. Inox Wind Ltd on 24th September, 2009 to test their 2000 kW wind turbine at Chettikurichi near Kayathar, Tamil Nadu.
- Mr. Erkki V. Jaatinen, Product Head, M/s. METSO, Finland visited C-WET on 7th September, 2009 and had discussion on the SENSODEC 6 S-Wind Turbine Health Monitoring System and delivered a lecture on Health Monitoring Systems for wind turbines.

Marching ahead in S&C UNIT

- Agreement has been signed with M/s.RRB Energy Limited for renewal of Provisional Type Certificate of Pawan Shakthi – 600 kW wind turbine model as per TAPS-2000 (amended).
- Agreement has been signed with M/s.RRB Energy Limited for inclusion of 65m hub height tubular tower in the Provisional Type Certificate of Pawan Shakthi – 600 kW wind turbine model under category – II as per TAPS-2000 (amended).
- The renewed Provisional Type Certificate has been issued to M/s. RRB Energy Limited for Pawan Shakthi – 600 kW wind turbine model, upon successful completion of review of documentation.
- Quality Management System of certification services as per ISO 9001:2000 has been recommended for continuation during the periodic audit conducted by Det Norske Veritas (DNV).
- The certification projects, taken up as per TAPS-2000 (amended) are under progress.
- The continual improvement and maintaining the Quality Management System are ongoing.

Highlights from ITCS UNIT

Display facility

Working model of water pumping wind mill and information for revolving unit is being prepared towards the establishment of display facility in display hall explaining C-WET activities and wind turbine technologies. All works pertaining to setting up of the display hall facility were completed and many visitors comprising of college and school students, faculty, industrialists and dignitaries across the country visited and appreciated the facility as informative.

Participation in the CLIKTRONICA 09 Exhibition

C-WET stall has been put up in CLIKTRONICA 09, a 2 day Trade Show and Conference on Renewable Energy during 16th to 19th July 2009 at Bangalore organized by Consortium of Electronic Industries of Karnataka, where in the information about C-WET's activities and services has been disseminated. Many participants and visitors visited the stall and the technical explanation at the stall was well appreciated.

Sponsorship for ECOFEST 09

C-WET has extended its support by sponsorship toward the successful organization of the National Level Symposium of 'ECOFEST' organized by the Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore held on 28th July 2009.

Participation in AARUUSH 09

C-WET stall has been put up in the National level TECHFEST, AARUUSH 09 organized by SRM University, Chennai during 9th-11th September 2009. A number of students visited the stall and learned about wind energy.

C-WET campus visit

The following visits have been arranged, wherein the C-WET activities, services were explained and the facilities available in the campus were shown.

- 30 students along with two faculties from Crescent School, Vandalur visited on 13th July 2009.
- 15 participants along with the faculty from National Institute of Technical Teachers Training and Research, Taramani visited on 23rd July 2009.
- Mr. Stephen Miner, Senior Vice President for conference, American Wind Energy Association visited on 12th August 2009.
- Mr. Tetsua Enomoto, from Mitsubishi Research Institute visited on 17th August 2009.
- Mr. Steve Sawyer, Secretary General, Global Wind Energy Council (G-WEC) visited on 8th September 2009.
- 6 M. Tech. (Bio Energy) students along with two faculty members of Tamil Nadu agricultural university (TNAU) Coimbatore visited on 8th September 2009.

INDIAN WIND GRID CODE

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1. Introduction

India today stands fifth in the world with an installed capacity of 10242.5 MW of wind power (as on March 2009) which constitutes 7% of the total 1,52,000 MW connected to the grid. This has grown from 3.5% in 2004 to the present capacity it is today.

Wind turbines are installed in areas with sufficient wind power density (> 200 W/ sq.m at 50 m hub height level) with provision to connect to the grid. Areas with good wind power density are not necessarily places with a strong grid, as they are mainly concentrated in rural areas away from locations with major generating stations. However, in the initial days due to the low penetration of wind energy in the grid, impacts on the overall power system were limited to local effects. Local impacts like voltage fluctuations, flicker, reactive power absorption were observed at the point of connection to the grid. With the exception of penalties by state electricity boards for VAR drawl from the grid, there were no technical regulations to govern the connection of the wind turbines to the grid. However, with the increasing penetration of wind turbines, as high as 42 % in terms of installed capacity in states like Tamil Nadu, the need was felt to establish a standard operating practice for the wind turbines . This has lead to the draft Grid code for wind turbines to establish the guidelines specific to wind turbines.

2. Grid behaviour of wind turbines

Important aspects which determine the grid behaviour of wind turbines are that majority of these are fixed speed turbines consisting of induction generators. This is unlike the conventional generators which are synchronous generators / alternators and have characteristics different from the induction generators. Machines with induction generators need capacitor banks for VAR support, otherwise reactive power will be drawn from the grid. The drawl of reactive power affects the voltage profile at the point of connection to the grid. However, wind turbines of variable type, which use wound rotor or permanent magnet synchronous generators, do not need a reactive power support. They may have to deal with issues like harmonics generated by the power converters, which has to be kept under control.

Another major characteristic is the behaviour of the wind turbine during system faults/ disturbances. The wind turbines are designed to disconnect from the grid during system faults, when the voltage at the point of connection drops beyond a certain percentage of the nominal value If wind turbines are to remain connected to the grid during system fault, a source of reactive power must be able to sustain the wind turbine in the generation mode during such fault conditions.

The variable nature of wind, which is talked of as one of the drawbacks of wind energy is also an important grid aspect. Wind generation cannot be scheduled due to its unpredictability. Moreover, different manufacturers follow different operating standards and the system behaviour in the absence of any grid code will be unpredictable.

3. World scenario

Internationally the countries who are leaders in terms of installations have framed grid codes for wind. USA, Germany, Spain, Denmark, China, Nordic Countries Canada, Ireland have enforced their grid codes. Each of these grid codes have a common framework dealing with issues specific to wind, however the regulations take into the nature of the grid, installed capacity, penetration of wind, high wind potential zones etc. For instance, the Danish grid code has been formulated keeping in mind the high penetration of wind power in the country.

The grid codes for wind, in general deal with the following issues:

- Active power control
- Frequency
- Voltage and reactive power issues
- Fault ride through capability
- Protection
- Power quality issues like flicker, harmonics etc.

4. Grid code requirements

4.1 Active power control

This is the ability of the wind turbine generators to regulate the active power output of the wind turbine according to system requirements. Active power control of wind turbines is to ensure a stable frequency in the system, to prevent overloading of transmission lines, to avoid large voltage steps and in-rush currents during start up and shut down of wind turbines. In a wind turbine, the power output is a function of the wind speed and the power fed into the grid by the turbine is irrespective of the frequency of the grid. However, with this feature the active power controller will take into account not only the wind speed, but also the requirements of the grid. The wind turbines will also have to regulate the in rush currents during start up.

During a fault, if the turbine were to stay on line, the active power output has to be reduced in a controlled manner to prevent tripping of the generator. All the same, the active power output should be brought back to the pre fault value after the fault is cleared.

The rate at which the power is ramped up after a system fault or during start up should not cause significant power surges.

4.2 Frequency requirements

System frequency is a major indicator of the power balance in the system. A decrease in generation vis-a-vis the demand causes the frequency to drop below the nominal frequency and vice versa. In India, the frequency varies from 48.5- 51.5 Hz due to the power imbalance. This imbalance can be mitigated by primary control and secondary control of conventional synchronous generators. During an increase of load, the energy stored in synchronous generator can balance the power, which leads to a decrease in rotational speed of generator and hence the frequency. The primary control unit acts within a time span of 1-30s to stabilize the frequency. The secondary control, which is by automatic generation control or manually by system operator, acts within a time span of 10-15 min.

Low penetration of wind turbines does not affect the system frequency. High penetration of wind turbines can have a significant impact on the grid. Even so, the wind turbines may not be able to contribute to primary control. The power output of the wind turbine can be regulated during high frequency, if need be. However, during low frequencies the output of the wind turbine cannot be controlled to contribute more power to the grid.

4.3 Voltage and reactive power issues

Wind turbines with induction generators need reactive power support. Capacitor banks are the preferred method of reactive power compensation in wind farms, though dynamic VAR support devices like the STATCOM are available. If not properly compensated reactive power drawl from the system can cause increased losses, overheating and de- rating of the lines. Doubly fed induction generators and synchronous generator based wind turbines do not have any constraints with respect to reactive power. Thus, the behavior of different types of wind turbines can be standardized by means of the grid code.

4.4 Fault / low voltage ride through

This refers to the ability of the wind turbine to remain connected to the grid without tripping from the grid for a specified period of time during a voltage drop at the point of connection. The period of fault ride through depends on the magnitude of voltage drop at the Point of Common Coupling (PCC) during the fault and the time taken by the grid system to recover to the normal state.

During system disturbances, if generators of large generating capacity connected to the grid continue their operation, this aids the system in returning to normal operation. On the other hand, disconnection of such a generator would further aggravate the disturbance and may lead to a system collapse. If the fault causes loss of a conventional generating unit, the system would need sufficient spinning reserve to cover the loss of the generator. Hence the need for fault ride through capability.

During a fault that causes a voltage drop at the wind turbine terminals, the reactive power demand of induction generators increases. Unless a reactive power support is available at the generator terminals, the reactive power will be drawn from the grid. This will reduce the thermal capacity of the conductors connecting the turbine to the grid, to transfer active power and cause further drop in voltage at the point of common coupling.

4.5 Wind farm protection

In case of large wind farms connected to the grid, wind turbines are required to remain connected to the grid within specified voltage and frequency limits. High short circuit currents, under voltages and over voltages during and after the fault can damage the wind turbine. The relay protection system of the wind turbine should take in to account:

- Normal operation of the system and support to network during and after the fault.
- Secure wind farms from damage originating from faults in the network.

Wind turbines are required to be equipped with under frequency and over frequency protection, differential protection of the generator transformer, and back up protection. The protection system requirements have been mentioned in some of the grid codes, while others have not exclusively mentioned about wind farm and system protection.

Grid codes require that wherever low voltage ride through schemes and frequency protection schemes are applied on the wind turbines, the settings should be done in proper coordination with the transmission system protection relaying.

4.6 Data requirements

Monitoring of large wind farms to obtain up-to-date information on the real time status of the wind farm is essential. This will help in tracking the dynamic changes that the wind farms will undergo. The system operator can change the set point according to the operating conditions.

4.7 Power quality issues like flicker, harmonics etc

Flicker is defined as the visual fluctuations in the light intensity as a result of voltage fluctuations and is caused by wind turbines, both during continuous operations and switching operations. Human eye is most sensitive to frequencies in the range 1- 10 Hz. The flicker from wind turbines is mainly caused by the effect of tower shadow, which lies in the range of 1-2 Hz. Power fluctuations due to wind speed fluctuations lie in the frequency range of < 0.1 Hz and hence are less critical to flicker. Flicker in variable speed turbines is found to be lower than that of fixed speed wind turbines due to smoothening of the power fluctuations.

During switching operation, the generator cuts in and the large in-rush current of the generator is limited by the soft starter. A few seconds after the generator is connected, capacitors are switched in for reactive power compensation. These power fluctuations, both active and reactive power, during switching operation cause flicker. However, for variable speed turbines such in rush currents do not arise.

Harmonics are generated by variable speed turbines with power converters, like doubly fed generator and full variable speed wind turbine. Induction generator based wind turbines which are directly connected to the grid, do not have harmonic issues.

The grid codes specify limits for flicker and harmonics due to their impact on the grid. Flicker is a main concern for fixed speed wind turbines connected to weak grids. As regards, harmonics, many grid codes do not speak of limits for harmonics in their grid codes. IEC 61400-21 recommends measurement of harmonic emissions only for variable speed turbines. IEEE STD-519-1992 is followed by many countries for grid integration of turbines.

Voltage imbalance is another power quality issue which can affect the performance of induction generators. The effect is severe during fault conditions. Most of the grid codes impose the same voltage requirements for unbalance as for conventional generators.

5. Indian Wind Grid Code

The draft Indian Wind grid code addresses issues related to the wind energy plant as an addendum to the existing Indian Electricity Grid Code (IEGC).

The IEGC lays down the rules, guidelines and the standards to be followed by the various agencies and participants in the system to plan, develop and operate the power system in an efficient, reliable, economic and secure manner. The IEGC broadly covers the planning code for inter state transmission, the connection conditions (minimum technical and design criteria which are complied with by the transmission utility), operating code for the regional grid and scheduling and dispatch code for conventional generators. The IEGC would be suitably amended to incorporate the criteria to be complied with for wind turbine generators and any additional features would be a part of a supplement to the IEGC.

The following are proposed in the draft Indian Wind Grid Code:

5.1 Planning Code for transmission systems evacuating wind power

Wind power evacuation shall feature as a part and parcel of the overall grid planning.

The transmission utility / transmission system operator shall consider both short term and long term expected wind generation in the region. The planning criterion should consider the following scenarios:

i. System peak load with high wind generation

ii. System light load with high wind generation

iii. Local light load with high wind generation

The high wind generation shall be classified as a percentage of the overall wind farm capacity, based on the voltage level to which it is connected. For instance, wind farms connected below 66 kV levels may reach their peak capacity during the windy months as wind turbines see the same wind over a smaller geographical spread; this must be taken care of during the transmission planning.

The N-1 contingency criteria may be adapted for planning of transmission lines wind farms connected above 220 kV or of capacity 100 MW and above at 220 kV levels. The underlying idea is that N-1 contingency planning does not make economic sense for smaller wind farms and loss of generation of small wind farms does not have a significant impact on the grid.

The Wind power addition plan for every five years issued by the Ministry of New and Renewable Energy shall be considered for planning of transmission lines. Wind farm owner shall also give the requisite planning data to the transmission utility.

5.2 Connection code for wind farms

Wind farms shall maintain certain minimum technical standards for grid connection with respect to the following:

5.2.1 Transmission voltage range

The wind farms must be capable of normal operation for the following voltage ranges. The limits are taken from the standards set for conventional generators in the IEGC / state grid codes:

Table 1: Voltage withstand limits for wind farms

Voltage (kV)			
Nominal	% Limit of variation	Maximum	Minimum
400	+5% to -10%	420	360
220	+11% to -9%	245	200
132	+10% to -9%	145	120
110	+10% to -12.5%	121	96.25
66	+10% to -9%	72.5	60
33	+5% to -10%	34.65	29.7

5.2.1 Voltage unbalance

Voltage unbalance, defined as the ratio of the deviation between the highest and lowest line voltage to the average of the three line voltages, can cause negative sequence current to flow in the rotor of the wind turbine. As per the Grid Standard (CEA) followed, the following limits have been specified:

Table 2: Voltage unbalance limits for wind farms

Voltage level (kV)	Unbalance (%)
400	1.5
220	2
<220	3

5.2.3 Reactive power capability

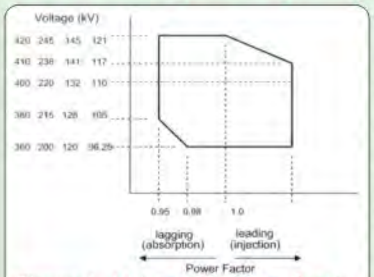

Figure 1: Voltage vs. power factor characteristics of wind farms connected above 66 kV

The wind farms shall be able to maintain a power factor of 0.95 lagging to 0.95 leading at the grid connection point. Wind farms at higher voltage levels (66 kV) shall maintain the following characteristics (refer figure 1):

At system voltages higher than nominal, the requirement is a lagging power factor, whereas at lower voltages, the wind farm can operate at leading power factor injecting reactive power to the grid.

5.2.4 Frequency tolerance range

The frequency tolerance range for wind farms is 47.5 – 51.5 Hz. Beyond this, the frequency tolerance shall be manufacturer specific. Wind farms shall be able to withstand change in frequency up to 0.5 Hz/sec.

5.2.5 Active power control

For wind farms at high voltage levels (66 kV), active power control of the wind farm output shall be possible on system operator's request.

The active power response of wind farms to frequency should be such that the power injection into the grid is limited at frequencies above nominal.

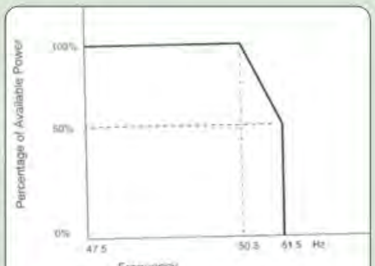

Figure 2: Variation of active power output of wind farms with respect to frequency

5.2.4 Low voltage ride through

Wind farms connected at 66 kV and above shall have low voltage ride through capabilities. The operating characteristics are depicted below (refer figure 3):

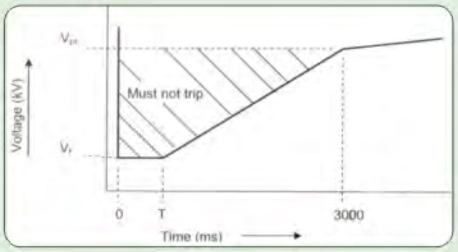

Figure 3: Fault ride through characteristics

Vf : 15% of nominal system voltage

Vpf : Minimum Voltage for normal operation of the wind turbine

Table 3: Fault clearing time and voltage limits

Nominal system voltage (kV)	Fault clearing time, T(ms)	Vpf (kV)	Vf (kV)
400	100	360	60.0
220	160	200	33.0
132	160	120	19.8
110	160	96.25	16.5
66	300	60	9.9

The fault ride through requirement brings the wind farms at par with the conventional generators, which have this feature. The fault clearing times are as specified in the IEGC / state grid codes. However, the timeline for implementing the same shall be based on the penetration levels of wind farms, the additional cost involved and usefulness in terms of grid management strategies.

5.2.4 Protection schemes for wind farm protection:

The minimum requirement with respect to wind farm protection are:

I) under/over voltage protection
ii) under/over frequency protection
iii) over current and earth fault protection
iv) load unbalance (negative sequence) protection
v) differential protection for the grid connecting transformer
vi) capacitor bank protection
vii) tele-protection channels (for use with distance protection) between the grid connection point circuit breaker and user connection point circuit breaker.

5.3 Operating code for wind farms

The wind farm shall adhere to the operating code for safety and reliable operation of the grid.

5.3.1 Voltage at the grid connection point

Table 4: Operating voltage limits for wind farms

Voltage (kV)			
Nominal	% Limit of variation	Maximum	Minimum
400	+5% to -10%	420	360
220	+11% to -9%	245	200
132	+10% to -9%	145	120
110	+10% to -12.5%	121	96.25
66	+10% to -9%	72.5	60
33	+5% to -10%	34.65	29.7

5.3.2 Frequency of operation for wind farms

The operation of the wind turbine shall be as shown in figure 2. Wind turbine shall not be started above 51.5 Hz.

5.3.3 Reactive power and voltage control

The requirement with respect to reactive power and voltage control will be as mentioned in the IEGC.

i) VAR drawl from the grid at voltages below 97 % of nominal will be penalized.

ii) VAR injection into the grid at voltages below 97 % of nominal will be given incentive.

iii) VAR drawl from the grid at voltages above 103 % of nominal will be given incentives.

iv) VAR injection into the grid at voltages above 103 % of nominal will be penalized.

As such VAR drawal from the grid when voltage is below 95 % of nominal and injection into the grid when voltage is 105 % above nominal shall be minimize by the wind farm operator. The charges for VAR exchange shall be specified by the Central / State Electricity regulatory Commissions.

5.3.4 Ramp rate limits

Ramp rate limits aims at regulating the active power generated from the WTG and minimizing the sudden variations in generated power due to variations in the wind.

The ramp rate limits specified for wind farms of 50 MW and above are:ory Commissions.nge shall be specified by the Central / State electricity minal in the IEGC.

Table 5: Ramp rate limits for wind farms

Wind Farm Installed	10 min Maximum	1 min Maximum
Capacity (MW)	Ramp(MW)	Ramp(MW)
50-150	Installed Capacity/1.5	Installed Capacity/5
>150	100	30

The ramping down of wind generators would be as per the request of the system operator.

5.3.5 Power Quality

The assessment of power quality of wind farms is done as per the requirement of IEC 61400-21: Wind Turbine Generator Systems, Part 21: Measurement and Assessment of Power Quality Characteristics of Grid Connected Wind Turbines"

As regards voltage flicker limits, the IEC 61000-3-7 shall be followed. IEC 61000-4-15 gives the guidelines on measurement of flicker.

The harmonic content will be governed by Total harmonic distortion of voltage, V_{THD}

$$V_{THD} = \sqrt{\sum_{n=2}^{n=50} \frac{V_n^2}{V_1^2}} \times 100$$

Where V_n: n^{th} harmonic of current

V_1: fundamental frequency (50 Hz) current

$$I_{THD} = \sqrt{\sum \frac{I_n^2}{I_1^2}} \times 100$$

The limits for the harmonic contents are as follows:

Table 6: Voltage harmonic limits

System Voltage (kV)	Total Harmonic Distortion (%)	Individual Harmonic of any Particular frequency (%)
765	1.5	1.0
400	2.0	1.5
220	2.5	2.0
132	3.0	2.0

Table 7: Current harmonic limits

Voltage level	<69 kV	>69 kV
ITHD	5.0	2.5

5.3.6 Operation during transmission congestion

During network congestion, wind farms shall operate as per instructions of system operator. Wind shall be backed down as a last resort and shall be considered like overflowing reservoir in Merit Order Dispatch

5.3.7 The demand estimation for operational purposes and demand management shall be as described in the IEGC / state grid codes. Wind energy forecasting shall be considered for demand estimation. The demand management shall take into account variable nature of wind.

5.3.8 Forecasting

Wind energy forecasting will become a necessity with increase in penetration of wind power. Scheduling of other generating plants can be carried out based on the forecast data for wind.

Centralised forecasting facility will be a requisite in an area with aggregated capacity of 200 MW and above. The forecast will be for the following time intervals:

I) Day ahead forecast: Wind power forecast with an interval of one hour for the next 24 hours for the aggregate wind farms. This will help in assessing the probable wind energy that can be scheduled for the next day.

ii) Hourly forecast: Wind power forecast with a frequency of one hour and interval of 30 minutes for the next 3 hours for the aggregate wind farms. This helps in minimizing the forecasting error that can occur in the day ahead forecasting.

Scheduling of other generators shall consider available wind generation for the duration. The spinning reserve shall be necessary to account for sudden loss of wind generation, based on the wind power forecast information.

As mentioned earlier, the forecasting will be implemented after considering factors like the penetration level of wind farms, cost and tariff.

6. Summary

The Indian Wind Grid Code has been designed keeping in mind the growth of wind energy in the power sector scenario over the past years. Today, wind constitutes the largest share of the 12 % capacity of renewable energy sources in the country. As such, the framing of the grid code has been timely, as it will bring 'Wind' at par with the conventional generators. The technical requirements for small wind farms have been kept minimal and have been limited to operating voltage limits, frequency tolerance limits, reactive power drawal and protection schemes. Conditions like fault ride through capability and forecasting that are stringent in the present context have been specified for larger wind farms and will be implemented in due course of time taking into account the penetration levels of wind energy, cost of implementation, tariff structure and usefulness in terms of grid management strategies.

References:

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