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EDITORIAL

With 14 GW of installed capacity wind power in India retaining its fifth position in the world certainly has contributed to significant energy generation mix to the tune of 3%–4% considering all the fluctuations in wind as well as grid. These wind speed fluctuations are termed as infirmity of wind power. It's time for India to raise above these infirmity and move towards sustainability of life and power.

There are several methods of overcoming infirm power such as wind and solar. One of the proven methods is electrical energy storage techniques. When there is good wind the wind turbine should not be backed off from generating electricity. There should be "must-run condition for wind power", for those 95% of private investors, who are generating electricity for the state owned utilities for distribution.

The high wind penetration in energy mix, that is observed in Tamil Nadu having 55% of the base power capacity, as installed capacity of wind has the possibility of generating more than 20-25% of the electrical energy in the state, certainly avoiding frequent power-cuts for the masses. At the same time, it is suffering severely by the infirmity of wind. We need to think of using compressed air storage devices, pumped storage Hydel system and flow battery backed-up wind farms to overcome these infirmity of wind. Spinning reserves for wind can also be cost-effectively made with natural gas based power generation. In addition, region-wise forecasting in the wind farm locations and then effective scheduling and load dispatching of wind and solar power seamlessly into the overall energy mix of the regional grid are essential.

It is proven that smart meter, smart demand based power generation, data controlled electrical network with user choosable Time of the Day (TOD) costing of power, are some of the modern scientific methods of managing power shortage (using good penetration of renewable energy) in the country. Let's use the abundantly available free fuel such as wind, which does not require the storage and transportation in addition to being renewable green power.

C-WET has started to do health monitoring in experimental wind turbine at Kayathar and has several small wind aero generators under performance testing, apart from sponsoring two major projects with the industry tie-up (in collaboration with IWTMA) for special purpose courses in the area of wind energy including Operation and Maintenance (O&M) of wind farms.

Several verifications of private wind monitoring and consultancy of WRA projects on micro siting, due-diligence are being completed during the period. The WRA team in co-ordination with R&D has been active in the project of off-shore wind in India, and it is in the process of formulating a feasibility report with compiled data from other agencies.

Three full scale testing have already been in progress instrumented by WTT unit and one more wind turbine is under instrumentation at Thirunelveli district to be tested during this windy season.

More than 45 models were scrutinized by S&C unit of C-WET in terms of their valid certification or status of certification including the type testing evaluation to release the first main Revised List of Models and Manufacturing (RLMM) list in this year. For the reference of all stake holders, the RLMM list has been already hosted in C-WET website.

All the Unit Chiefs of C-WET along with ED had several Brain Storming sessions at the Ministry to give various inputs that are needed to finalize the 12th five year plan documents in the wind sub-group meetings.

The ITCS unit completed its 10th National Training Course on Wind Energy Technology and distributed the certificates. Almost 60 participants from all over India participated. It is in the process of planning the 7th International Training programme (under ITEC Programme of MEA) during August 2011.

The mission mode project entrusted to C-WET for Solar Radiation Resource Assessment (SRRA) has been showing good progress, as per schedule with 21 stations from all over India streaming the data into the Automatic Central Receiving Station (ACRS) located at C-WET.

C-WET acknowledges with thanks the cooperation / guidance of R&D council and Governing Council which have completed the discussion during this period and guided the necessary action plan for C-WET. It is not only the experts in the committees who have given successful guidance to C-WETs' activities but also your valuable feedback on PAVAN would lead us through.

S. Gomathinayagam
Executive Director

Contents

Editorial Board

Developments in R&D UNIT

Testing of Small Wind Turbine

The unit is presently in the process of type testing seven Small Wind Turbines (SWT) of ratings 1.4 kW, 3.2 kW, 3.5 kW, 4.2 kW, 5 kW and 5.1 kW at the Wind Turbine Research Station (WTRS), Kayathar as per the requirements of IEC-61400-2 together with IEC 61400-12-1. The measurements are underway and is likely to be completed during the current windy season (April - Sep.2011).

Array of SWT under test at WTRS

Health / Condition Monitoring on the 2 MW R&D Experimental Wind Turbine

The 2 MW Experimental / Research Wind Turbine at WTRS, Kayathar has been procured for the purpose of conducting pioneering & cutting edge research whose results would be disseminated for the benefit of the wind energy stakeholders. As a part of this endeavor the unit has successfully completed the instrumentation for health/ condition monitoring for the drive train and blades. The measurements from the components would be used to study the dynamics of the system and to identify areas of defect / malfunction or deviation in operational characteristics. This defect prediction method of prognosis would in the future become the guiding line for any kind of operation and maintenance activity that the wind industry would want to perform.

Instrumentation on the drive train

Instrumentation on the blade

PG Diploma Courses in Wind Energy

The R&D unit has recently initiated a short term Post Graduate Diploma courses in Wind Power development & Wind Resource Analysis and for the purpose, an MoU was inked with Amrita Vishwa Vidyapeetham University, Coimbatore on 12th May 2011. Under this MoU, C-WET shall support the courses for three years period starting from 2011 till 2014. The courses would help developing skilled manpower which is the need of the hour for the wind industry.

Signing of MoU between C-WET, AMRITA & IWTMA

Move on in WRA UNIT

During the period of April to June 2011, 13 new wind monitoring stations have been established, 4 stations in Jammu & Kashmir, 3 stations in Andhra Pradesh, 2 stations each in Orissa & Bihar and 1 station each in Maharashtra & Meghalaya. Presently, 83 wind-monitoring stations are operational in 19 States and 1 Union Territory under various wind monitoring projects funded by the Ministry of New and Renewable Energy as well as various entrepreneurs.

Projects on Verification of procedure of wind monitoring have been done for the following sites.

- Uchangidurga, Suro Ki Dhani SE, Hopardi, Kaladonger, Kavdya Donger and Ratkuriya-V for M/s. Suzlon Infrastructure Services Ltd, Pune.
- Banswara-3, Banswara-4 and Chavaneshwar for M/s. Enercon India Limited, Mumbai.
- Nesevandiapalli and Gollapalli for M/s. Rayalaseema Wind Energy Company Pvt. Ltd, Hyderabad.
- Pohra, Akal and Muggaon for M/s. RRB Energy Limited, Chennai.
- Madugupalli for M/s. Helios Infratech Pvt. Ltd., Hyderabad and
- 9 sites in Maharashtra for M/s. Maharashtra Energy Development Agency, Pune.

The following consultancy projects have been completed and submitted reports.

- Micrositing of wind farm project at Vajrakarur, Anantapur District in Andhra Pradesh for M/s Axis Wind Energy Limited, Hyderabad.
- Site Validation & Generation Estimation of proposed (29 x 850 kW) wind farm project at Rasipalayam, Tiruppur District in Tamil Nadu for M/s. Gamesa Wind Turbines Private Limited, Chennai and
- Hanamsagar, Koppal District in Karnataka for M/s Hanamsagar Wind Power Project, Davangere.

Steps forward in TESTING UNIT

Measurements are under progress for Type testing of 250-T wind turbine of M/s. Shriram EPC I & II at Pavoor Chathiram, Tenkasi.

Measurements for the Type Testing of GARUDA 700 kW wind turbine at Melamaruthappapuram Village, in (SF.N.141/5) V. K. Pudur Taluk and Tirunelveli District is expected to start during the windy season of 2011.

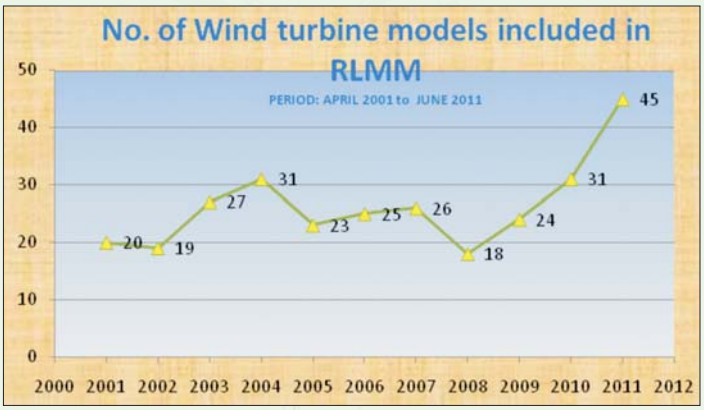
Factory Instrumentation

Field Work

Marching ahead in S&C UNIT

Based on the MNRE guidelines, Revised List of Models and Manufacturers of Wind Turbines (RLMM), finalized by the Committee appointed by MNRE, is being issued by C-WET periodically. The Standards & Certification Unit which serves as a secretariat for RLMM has successfully completed ten years in issuing the RLMM list.

Presently, the review of the documentation / information obtained from various wind turbine manufacturers for the issue of RLMM - Main List has been completed and RLMM - Main list dated 22.06.2011 has been issued. The number of Wind turbine models included in RLMM is in the upward trend.



Agreement has been signed with M/s. RRB Energy Limited for renewal of Provisional Type Certificate (PTC) of V 39/500 kW with 47m Rotor wind turbine model under Category- II as per TAPS-2000 (amended). Upon successful review of documentation, the renewed PTC has been issued to M/s. RRB Energy Limited.

The continual improvement and maintaining the Quality Management System are ongoing.

Advances in SRRA Cell

Honorable Prime Minister of India has announced setting up of 20, 000 MW of solar power under Jawaharlal Nehru National Solar Mission (JNNSM) to mitigate the adverse effects of environmental pollution on climatic changes. As a part of JNNSM, Centre for Wind Energy Technology, Chennai is implementing Solar Radiation Resource Assessment Project fully funded by Ministry of New and Renewable Energy, New Delhi with the following objectives,

- To assess the ground data of solar radiation
- To establish initially 51 Automatic Solar Radiation Monitoring Stations covering potential areas in the country
- To collect the data automatically at a Central Receiving Station established at C-WET, Chennai through GPRS mode
- To establish a Calibration Laboratory for solar radiation measuring equipments at C WET, Chennai

ASRMS at C WET, Chennai

For the effective implementation of this project of national importance, C-WET has established SRRA cell by posting exclusively scientific and technical group consisting Scientist E from the Ministry, two Scientists, five Project Engineers and supporting staff. The project envisages measuring solar data on Global, Diffused, Direct radiation and weather parameters, such as, Rain fall, ambient temperature and pressure, relative humidity by installing equipment and system in each station. The data from Field Stations is being transmitted to Central Receiving Station (CRS) by GPRS. The data, thus transmitted will be analyzed and made available to various stakeholders.

A network of 26 Automatic Solar Radiation Monitoring Stations has been completed & commissioned and Central Receiving Station, which has already been established at C-WET, is receiving data from all these stations and the remaining stations are expected to commission before the end of August 2011.

Highlights from ITCS UNIT

Global Wind Day 2011 Celebration

C-WET has been celebrating Global Wind Day every year on June 15th since 2009. This year we had planned for quiz and painting competitions among students from schools in and around Chennai and it was deferred because of the belated re-opening of the schools. As part of the celebration, slogan writing contest on wind energy was organised for C-WET staff and the best three slogans were prized. In the contest, 49 C-WET staff members participated and top 3 slogans were selected by the jury. The first prize was won by Mr. P. K. Vineeth, Project Assistant, WRA for the slogan "Embrace the Wind, Experience the Power", the second prize was awarded to the slogan "Wind can blow light, can glow light……Choose!" by Ms. M. Jayalakshmi, Project Assistant, SRRA-Cell and third prize was given to the slogan "Windy Environment, Winning Environment" by Ms. D. Krithika, S&C.

This year, the C-WET's Global Wind Day celebration not only focused on wind energy, it also looked at the environmental benefits of renewable energy and other alternative energy sources such as Hydrogen. Dr. K. S. Dhathathreyan, Head of Centre for Fuel Cell Technology, Chennai was the special invitee on the occasion to deliver a special talk on "Sustainable Hydrogen Energy – Role of Wind Power". The talk was well received by the participants and provided lots of information about how to interlink the Hydrogen and wind energy.

Dr. K. S. Dhathathreyan delivering special talk

During the celebration, Dr. K. S. Dhathathreyan along with Dr. S. Gomathinayagam has distributed the prizes to the winners of slogan writing contest.

Embrace the Wind,
Experience the Power - Mr. Vineeth

Wind can blow light,
can glow light……Choose! - Ms. Jayalakshmi

Windy Environment,
Winning Environment' - Ms. Krithika

Winners of Slogan Writing Contest From left, Vineeth, Jayalakshmi and Krithika

Wind Day-2011 celebration - Flagging of signature campaign for Wind Day at Marina Beach, Chennai on 15th June 2011

10th National Training Course

ITCS Unit had successfully organized 10th National Training Course on "Wind Energy Technology" during 25th to 27th May 2011 with an objective to provide basic knowledge on wind turbine technology and provide a platform to exchange views & experience with wind energy experts. The programme has provided comprehensive knowledge right from Wind Resource Assessment to Installation & Commissioning of wind farms along with technical and financial challenges. The course was highly appreciated by the participants for its content and the way of organization. In the programme, 60 participants have participated. The participants have been from dynamic mix of background, developers, manufacturers, academicians, utilities, SNAs etc. The lectures were delivered by C-WET Scientists, Industry and Academic experts and other national experts.

The course was inaugurated by Shri. Ramesh Kumar Khanna, I.A.S., Principal Secretary to Government, Energy Department, Government of Tamil Nadu.

Shri. Ramesh Kumar Khanna delivering Inauguration Address

Dr. N. Lakshmanan, Project Director, Structural Engineering Research Centre delivered the valedictory speech and Distributed certificate to the course participants.

Dr. N. Lakshmanan awarding certificate to a participant

Visitors to the Campus

During the period April to June 2011, the following visits were arranged. A brief presentation about basic wind energy and C-WET activities services were made for student visitors and the campus facilities were also demonstrated. The visitors were students, delegates from foreign countries and stakeholders

- As part of collaboration with the Scottish Development International (SDI) for conducting Off-shore wind energy related feasibility studies, two students from Doctoral Training Centre (DTC), University of Strathclyde, Scotland visited on 4th April 2011. C-WET has hosted the students from 2nd April to 17th April 2011 and arranged visits to events, institutions and industries dealing with wind energy.

- 10 faculty members from Jerusalem College of Engineering visited on 28th April 2011.

- 30 ME Energy Engineering & ME Solar Engineering Students from Institute for Energy Studies, Anna University visited on 5th April 2011.

Exhibitions

- C-WET stall was established in Wind Power India 2011 conference cum expo during 7th to 9th April 2011 at Chennai Trade Centre organized by IWTMA, WISE and GWEC.

- C-WET participated and put up stall in World Environment Day Celebration on 3rd June 2011 at Cognizant, MEPZ, Tambaram, Chennai

Invited Lecture / Presentation Delivered by C-WET Scientists in External Forum / Meetings / Conferences

Dr. S. Gomathinayagam, Executive Director

- Participated as member in the "Indo-Mauritius Joint Working Group Meeting on Energy" at MNRE, New Delhi on 01.04.2011.
- Chief Guest in the "10th Graduation Day" organized by Park College of Engineering, Coimbatore on 02.04.2011.
- Participated as invited member in the "Clean Energy - Policy Formulation Meeting" at Secretariat organised by Govt. of Tamil Nadu on 05.04.2011.
- Participated in the "Indo-Denmark Joint Working Group Meeting" at C-WET on 06.04.2011
- Delivered a lecture on "New Horizons for Wind Potential & Resource Assessment" in the Wind Power India – 2011 Conference & Exhibition at Chennai Trade Centre on 08.04.2011.
- Chaired as Panel Member in the "Wind Power India – 2011" and delivered a lecture on "HR Challenges & Employment Creation - Panel Discussion" at Chennai Trade Centre, Chennai on 09.04.2011.
- Delivered a lecture on "Wind Energy Program: An Overview" in the National Seminar on "Green Energy" organised by IITA-Allahabad & Rajiv Gandhi Institute of Information Technology, Amethi on 15.04.2011.
- Participated in the First Meeting of the "Sub-Group on Wind Power – for preparation of 12th Five Year Plan" at MNRE, New Delhi on 23.05.2011.
- Delivered a lecture on "Wind Energy Conversion Technology" in the 10th National Training Course" organised by C-WET on 25.05.2011.
- Chief Guest in the "Diploma Award Function" organized by PSG College of Engineering & Technology, Coimbatore on 26.05.2011.
- Delivered a lecture on "Tower & Foundation Concepts" in the 10th National Training Course organized by C-WET on 27.05.2011.
- Participated in the Second Meeting of the "Sub-Group on Wind Power – for preparation of 12th Five Year Plan" at MNRE, New Delhi on 06.06.2011.
- Delivered a special address in the "Global Wind Day - 2011 Celebration" organised by C-WET and participated in the inaugural function of "Flagged-off the Signature Campaign – Awareness of Wind Energy" at Marina Beach organised by IWTMA on 15.06.2011
- Participated in the Third Meeting of the "Sub-Group on Wind Power – for preparation of 12th Five Year Plan" at MNRE, New Delhi on 18.06.2011.
- Participated in the one day Workshop on "Revitalizing Wind Energy Potential: Technology, Economics and Policy" organised by C-STEP, Bangalore on 22.06.2011.
- Delivered a lecture on "Wind Power Mitigates Power-cuts: Infirmity or Sustainability" organized by Association of Consulting Civil Engineers (India), Chennai on 25.06.2011.
- Participated in the Standing Parliamentary Committee on Energy & a meeting on "Re-assessment of wind potential in India" at MNRE, New Delhi on 27.06.2011.
- Delivered a lecture on "Wind Power Development in India and Abroad" in the Faculty Development Programme organized by AMRITA School of Engineering, Coimbatore on 30.06.2011.

R&D

- Shri. Rajesh Katyal, Unit Chief made a presentation on "Indian experience of SWT testing and empanelment" at "Wind Power India 2011-International Conference and Exhibition"
- Shri. J. C. David Solomon, Scientist delivered lecture on "Design Aspects of Drive Train" during Tenth National Training Course on 26th May 2011.
- Shri. J. C. David Solomon, Scientist delivered lecture on "Small Wind Turbine and Hybrid System" during Tenth National Training Course on 27th May 2011.
- Smt. Deep Kurup, Scientist delivered lecture on "Generators and Grid Integration of Wind Turbines" during Tenth National Training Course on 26th May 2011.

WRA

- Dr. E. Sreevalsan, Scientist & Unit Chief delivered a lecture on "Wind Resource Assessment Techniques" on 10th National Training course on "Wind Energy Technology on 25.05.2011 at C-WET, Chennai.

- Dr. E. Sreevalsan, Scientist & Unit Chief delivered a lecture on "Wind Energy" at a seminar on "Creating awareness on green energy in Railway" at Southern Railway Head Quarters Office, Chennai on 26.05.2011.

- Shri. K. Boopathi, Scientist delivered a lecture on "Wind as an alternative source of energy" on 23.05.2011 at IMD, Chennai.

- Shri. K. Boopathi, Scientist delivered a lecture on "Wind Turbine Components" on 10th National Training course on "Wind Energy Technology on 25.05.2011 at C-WET, Chennai.

Dr. E. Sreevalsan, Scientist & Unit Chief , WRA has attended the following meetings

- Review meeting of the progress of implementation of Solar and Wind Energy activities in Andhra Pradesh on 16.05.2011 at NEDCAP, Hyderabad.

- Attended a meeting with Dr. Balakrishnan Nair in connection with preparation of offshore wind resource map of India on 16.05.2011 at INCOIS, Hyderabad.

- Attended the first meeting of the sub-group on 'wind power' of the working group on New and Renewable Energy for the 12th five year plan (2012-17) held on 23.05.2011 at MNRE, New Delhi.

TESTING

- Shri S. A. Mathew, Scientist and Unit Chief invited as a guest to attend the International Conference and Exhibition on "Wind Power India 2011" held from 07th to 09th April, 2011 at Chennai Trade Centre, Chennai.

- Shri S. A. Mathew, Scientist and Unit Chief Made a brief presentation on "Wind Turbine Testing" and had interaction with the Two Research Scholars visited from Scotland under the Indo-Scotland Students Exchange programme held at Conference Hall of the C-WET, Chennai during 4th April to 17th April,2011.

- Shri S. A. Mathew, Scientist and Unit Chief Delivered a lecture on "Wind Turbine Testing" during the 10th National Training programme held on 27th May, 2011 in the conference hall of C-WET.

- Shri S. A. Mathew, Scientist and Unit Chief Invited as a guest in the "World Environment Day" at Cognizant and participated in their one-day Expo with knowledge sharing stalls related to the environment followed by the Panel Discussion on "The Future of Non-Conventional Energy Sources" held on 03rd June, 2011 conducted by M/s. Cognizant Technology Solutions India Private Limited at Chennai.

- Shri S. A. Mathew, Scientist and Unit ChiefMade a brief presentation on the topic "Quality Aspects of the Testing Unit" during the meeting of the Sub-Group on 'Wind Power' of the working group on New and Renewable Energy for the 12th Five Year Plan (2012-2017) held on 06th June, 2011 under the Chairmanship of Joint Secretary, Ministry of New & Renewable Energy, New Delhi.

- Shri M. Anvar Ali, Scientist invited as a guest and delivered a lecture on the topic 'Instrumentation in a Wind Turbine' conducted by a Science Club during their 122nd Science Club Meet at Chemical Sciences Auditorium, University of Madras AC Tech Campus on 11th June, 2011.

WTRS

Shri. A. Mohamed Hussain, Scientist and Unit Chief,

- WTRS delivered lecture on "Indian Government Policies" during Tenth National Training Course on 27th May 2011.

- Presided as Chief Guest for "National Level Technical Symposium "Intelectium 2011 at Vikram College of Engineering, Sivagangai 24.3.11.

- Delivered lecture on "Opportunities and Challenges in Renewable Power Generation" in one day National Seminar at Cape Institute of Technology, Levengipuram on 11.2.2011

- Delivered lecture on "Recent Advancement in Renewable Energy" at National Engineering College, Kovilpatti in One day Renewable Energy Conference on 6.8.2010.

- Presided as Chief Guest and delivered lecture on "Renewable Energy Option - in Engineering Institutions" at Einstein College of Engineering in National Conference on 13.11.2010.

- A 5 days in-house practical training given for students of Post Graduate Diploma Course in Wind Energy from Cape Institute of Technology, Levengipuram with special reference to Operation & Maintenance of Wind

Turbines at WTRS, Kayathar from 16.5.2011 to 20.5.2011.

S&C

- Shri. A. Senthil Kumar, Scientist and Unit Chief has participated in the "Wind Power India 2011-International Conference and Exhibition" and made a presentation on "Wind turbine certification experience in India" during the workshop on "Design, Testing and Certification of Wind Turbines".

- Shri. A. Senthil Kumar, Scientist and Unit Chief participated in the Sub-Group Meeting on 'Wind Power' of the Working Group on New and Renewable Energy for the 12th Five Year Plan organized by MNRE, New Delhi. Made a presentation on the "Revised List of Models and Manufacturers of Wind Turbines (RLMM)" in the Sub Group Meeting.

- Shri. N. Raj Kumar, Scientist delivered lecture on "Type Certification of Wind Turbines" in the 10th National Training Programme organized by C-WET

- Shri. S. A. Arulselvan, Junior Engineer delivered lecture on "Control and Safety System of Wind Turbine System" in the 10th National Training Programme organized by C-WET.

ITCS

- Shri. P. Kanagavel, Scientist & Unit Chief (i/c) delivered lecture on "Role of C-WET in Wind Energy Development" during 10th National Training Programme organized by C-WET on 26th May 2011

Visits Abroad

- Shri. P. Kanagavel, Scientist & Unit Chief (i/c), ITCS participated the "Wind Power Development and Use" training programme at Sweden organized by LIFE Academy, Sweden and sponsored by Swedish International Development Agency, Sweden during 18th March to 16th April 2011.

Awards / Achievements by C-WET Staff

- Shri S.A. Mathew has completed a Master Degree in Engineering (Environmental) from Sathyabama University with first class (Distinction 9.0 CGPA).

GENERATORS IN WIND TURBINES

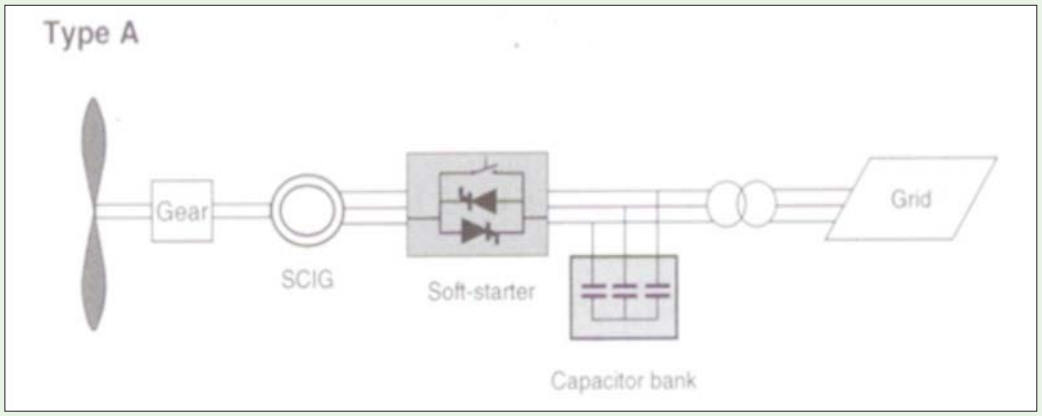
Ms. Deepa Kurup, Scientist, Research & Development, C-WET, deepa@cwet.res.in

With the rapid growth of wind turbine technology in the power sector, the electrical characteristics of different generator types and their behaviour in the grid have become a subject of study. The electrical properties of wind turbines differ from conventional generators. Other key differences that separate wind turbines from the conventional form of generation are the smaller sizes of the individual units and variable nature of wind and type of generator used. Small sizes imply that wind turbines are connected to medium voltage distribution networks and electrical safety is a key issue to be addressed. In the recent years, the electrical system of the wind turbines have evolved and largely adapted to the stringent requirements imposed by the electrical grid. A basic understanding of the integration issues therefore involves the various wind turbine topologies used and their characteristics, grid properties and factors determining the grid behaviour of wind turbines.

Direct connected generator

- **Squirrel cage induction generator**

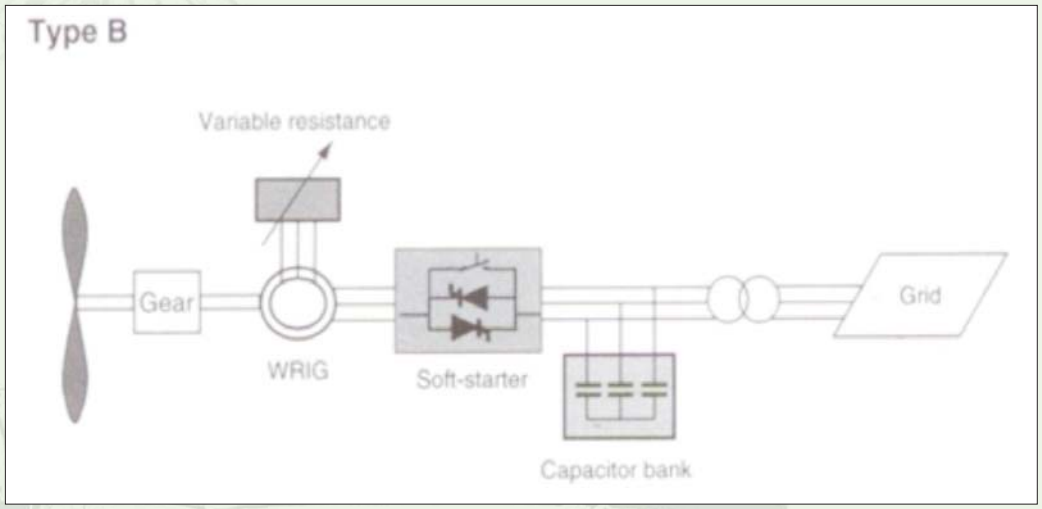
The choice of generator type decides the turbine configuration: constant speed, limited variable speed or variable speed turbine. Before the advent of the power electronic devices, the induction generator with a simple and robust construction was the only viable option for the wind ndustry. The upwind stall regulated three bladed wind turbines with the induction generator considered the conventional 'Danish concept' were employed by several manufacturers for decades. The torque in an induction generator is proportional to the slip speed. The choice of induction generator was thus mainly governed by the requirement of significant damping in the drive train due to the cyclic variations in the aerodynamic rotor torque(Wind Energy Handbook: Burton et al.). Some of the inherent disadvantages of the induction generator that prevented its use in large scale power generation , i.e, high energy loss in the rotor due to the damping action, reactive power requirement for the magnetic circuits, no means of controlling the terminal voltage, problems of voltage instability etc. (Wind Energy Handbook: Burton et al.) were not considered a serious limitation for the relatively smaller wind turbines. The capacitor banks for reactive power compensation and soft starter switch for smooth grid connection solved some of the significant issues involving these generators.



Squirrel Cage induction generator

- **Wound rotor induction generator**

Advances in turbine technology has seen the adoption of pitch and active stall regulation for constant speed wind turbines. Also the wound rotor induction generator enabled dynamic control of the speed by using variable rotor resistance. This external resistance can be electronically controlled. The 'Opti- slip' mechanism of Vestas and the 'Flexi-slip' scheme use this concept and are said to reach slips in the range of 10- 16 % unlike the conventional asynchronous generator with a slip of 2 %. As a result, the fluctuations of power due to wind speed variations are lesser as compared to the squirrel cage machine. The flip side is a more expensive generator and stresses on the insulated winding on the rotor arising from the rotation and vibration, which may reduce the lifetime of the generator (L. H. Hansen et al., 2001).



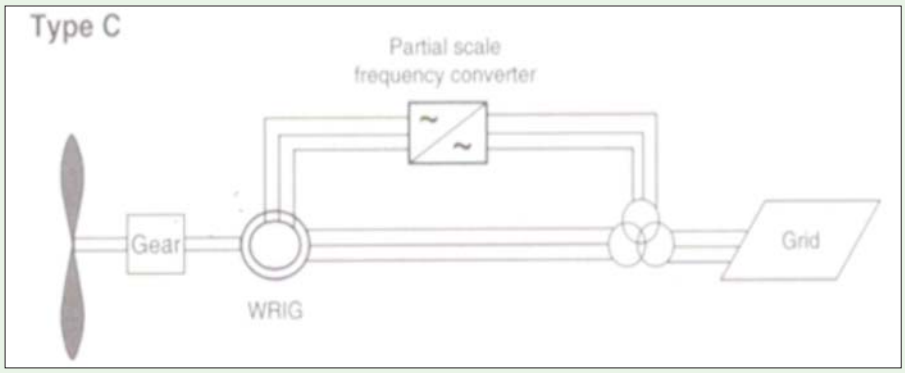
Wound Rotor induction generator

Converter interfaced generator

Power electronic devices capable of handling high power levels are a means of improving the wind turbine performance. It is a rapidly developing technology. They are the electrical analogous of the gearbox in their ability to decouple the generator running at a variable speed from the grid. Commercial topologies using power electronic converters are discussed below.

- **Doubly fed induction generator**

This machine (DFIG) is the induction generator's answer to the variable speed machine using synchronous generator. The characteristics of the induction generator are modified by employing a partial scale power electronic converter connected to the rotor. The stator of the DFIG remains connected to the grid. The rotor mechanical frequency is decoupled from the grid electrical frequency and limited variable speed operation is achieved. The limited variable speed operation improves the aerodynamic efficiency, at the same time the power electronic converter enables reactive power control. As compared to the variable speed machine ,the limited variable speed operation with the partial scale power converter presents an attractive concept economically.

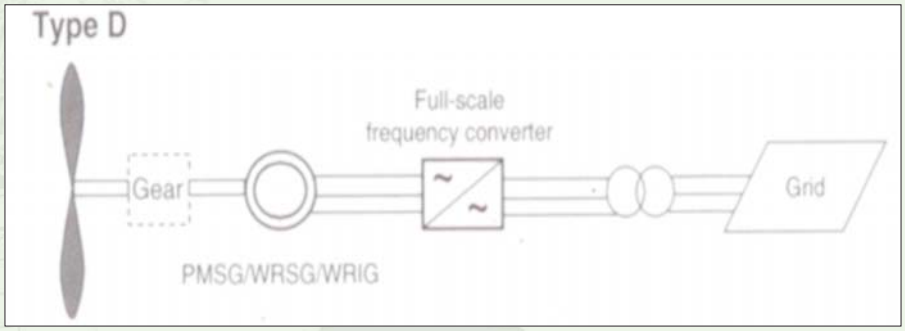


Doubly fed induction generator

- **Wound rotor synchronous generator**

This machine which is otherwise used in the power supply industry for fixed speed operation determined by the grid frequency, comes in various versions, cylindrical rotor and salient pole machine. The wind industry uses the salient pole version suitable for slow running applications. As in the DFIG, the full scale power electronic converter enables variable speed operation. The field winding excitation can be either a dc power through slip rings or brushless exciters with rotating rectifiers.

Synchronous generators in wind turbine applications do not require the gearbox and are larger in diameter than their asynchronous counterpart. The reasons are the direct bearing that D2, L and n have on the power output of the generator, D being rotor diameter , L the length and n the rotational speed(Wind energy Handbook, Burton et al.). The larger diameter requires a larger air gap (for mechanical and thermal reasons) which can only be achieved with a synchronous generator with a separate field excitation. Hence the obvious choice for variable speed operation.



Synchronous generator

- **Permanent magnet synchronous generator**

Advantages are higher efficiencies due to self excitation. Voltage regulation is an important issue to be addressed in these machines, because in PMSG unlike the WRSG compensation cannot be achieved by varying the magnetising current.

Comparison of electrical generators

Efficiency

Reference is made to the comparison of various wind electric generators shown by Ernest et al. (Wind Power plants and project development) based on the percentage energy produced for a wind turbine mounted with different types of generators for different wind regimes. The PMSG/ WRSG shows higher efficiencies over a wide wind speed range followed by the doubly fed induction generator, wound rotor induction generator and the squirrel cage induction generator.

Power quality

The electrical behaviour of the wind turbine manifests itself as local area impacts and system wide impacts on the grid. The local area impacts namely the voltage fluctuations at the point of connection, flicker, harmonics and behaviour during fault conditions depend on the generator type and the grid characteristic at the point of connection. The short circuit ratio at the point of connection determines the strength of the grid. However it may be difficult to precisely define whether a grid is weak or strong. A grid with few turbines may be strong while the same grid with larger number of turbines may be characterised as weak. Short circuit ratio and short circuit angle may give some insight on the suitability of connection of a wind turbines to the grid . The IEC 61400-21 recommends a short circuit ratio of 50 at the point of common coupling.The grid demands of various wind turbine generator types are; Squirrel cage induction generator: stiff grid Wound rotor induction generator, Doubly fed induction generator, wound rotor synchronous generator and the Permanent magnet synchronous generator: weak / strong grid Harmonics may be of concern for wind turbines employing power electronic converters. However, there are no Indian guidelines or checks that determine the connection of wind turbines based on their power quality characteristic. The power quality parameters specified in the IEC 61400 -21 can help in determining the possible impacts of connection of such wind turbines to the various grid types.

Grid codes

Countries with high wind penetration are adopting technical regulations to ensure that the wind turbines meet the same standards as specified for conventional generators; fault ride through capability, voltage control, frequency control, to name a few. Fault ride through and voltage control capabilities are determined by the type of generator. Fault ride through capability requires the generator to remain stable and connected to the network during the occurrence of a fault just like conventional systems are required to remain connected to the system during faults in the adjacent circuits; so as to avoid further loss of generation and drop in frequency. Constant speed turbines may not be capable of fault ride through unless additional equipment is supplied for grid support during fault conditions. Wind turbines with doubly fed induction generators and synchronous generators are capable of fault ride through.

Voltage control requires that the wind turbine operate continuously at normal rated output in normal voltages ranges, maintain terminal voltage constant, and stay connected during voltage step changes within the voltage ranges specified. A squirrel cage induction machine may require additional equipment for a faster control of the reactive power, centralized compensation at wind farm level may be an option. Doubly fed induction generators and synchronous generators are capable of fulfilling the reactive power requirements.

With a modest penetration of wind energy in the Indian grid, we are yet to implement such a grid code. However many of the present day turbines which have to cater to a global market come with these additional in built features. If such a grid code is implemented, the induction generator based machines would have to rely on FACTS based devices to meet the power system requirements. Also, in the present day multi MW class machines, the trend is towards semi geared variable speed machines which achieve higher efficiencies and are designed to meet the grid requirements.The choice of generator would thus largely depend on the cost economics and the operational characteristics ; weight of active materials, protection considerations, service and maintenance aspects being some of the other factors.

Recruitment / Promotion / Retirement

Name	Cadre	Unit
M. Saravanan	Scientist - B	Testing Unit

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