



EDITORIAL



Renewable energy is poised to become a mainstay in the Indian as well as world energy requirement having achieved the grid parity in terms of the price and also meeting the advanced grid requirements. This has

opened new chapter in the grid management and also interesting avenues for harnessing it. One such avenue is on focus is on offshore wind development as India has a long coastline. Tapping into the offshore wind business will be interesting chapter unfolding in India. Indian onshore wind industry has matured with strong manufacturing/Assembling base of about 10GW adhering to international standards & certification and some of the turbines manufactured in India are being exported to Asia, Europe, and USA. Transitioning on shore wind experience into offshore project development and an ocean of other opportunities stares at the wind industry and awaits its move to make it to one of the global leaders.

In this context, our WRA&O Unit has installed the first offshore LiDAR in Gulf of Khambhat in Gujarat coast in November 2017 and are collecting the wind profile. Under First Offshore Wind Park in India (FOWPI) the unit has supported the consultants to carry out Geophysical survey adjacent to the LiDAR location of about 70 sq. km area which can accommodate 200 MW Wind Farm. The survey covers Bathymetry information such as water depth, sea depth, and Seabed topography sub-bottom profile to have a better understanding about the sea bed conditions.

Further, as part of effort to streamline the process of wind generation information in the country, an on-line registry with 'Geo-tagging' of each wind turbine is undertaken. Under this project, each wind turbine would be given a Unique Identification Code, which would facilitate collection of static and dynamic data. This will facilitate asset mapping of wind turbines across the country and at the same would provide great

impetus for better forecasting of wind generation.

Forecasting of Variable generation (wind and solar) is critical for large scale grid integration of wind and solar. In this regards, NIWE has established the Centre for Excellence in Variable Generation Forecasting (Wind & Solar generation). In order to improve the accuracies in forecasting, we have signed MoU with ISRO SAC Ahmedabad for High Resolution Numerical Model outputs. Further, as part of indigenous process, our team has designed forecasting model for intraday forecasts, which is under various stages of testing.

In order to disseminate the knowledge in forecasting, we are organizing an International Workshop on "Current Practices on Wind & Solar Forecasting" to be held on 22nd January, 2018.

It is a momentous occasion to state that FOUR Solar Radiation Resource Assessment (SRRA) stations have been included in the BSRN Global Network out of nine in Asia. The Baseline Surface Radiation Network (BSRN) is the project under the umbrella of World Climate Research Program (WCRP) aimed at detecting important changes in the Earth's radiation field at the Earth's surface. Radiation measurements are indispensable for climate research as they provide the best check for the theory of radiative transfer in the Earth's atmosphere and can be used for the evaluation and improvement of models designed for weather and climate prediction. Furthermore, long-term measurements of surface radiation provide an opportunity for the detection of climate change.

As part of our commitment to knowledge transfer and capacity building, several invited lectures have been delivered by our officials in both external forum as well as internal course programs.

NIWE has been awarded Shield & Citation for having secured First position for best performance in the progressive use of Official Language during the year 2015-17 in the 55th Town Official language Implementation Committee (TOLIC) meeting held at Chennai.

Dr. K. Balaraman, Director General

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Wind Resource Assessment & Offshore

OFFSHORE WIND MEASUREMENTS AT GULF OF KHAMBHAT

NIWE has installed its first offshore wind monitoring station at Gulf of Khambhat, Off Gujarat Coast. Windcube V2 has been installed by the October 2017 and LiDAR commissioned on 1st November 2017. The LiDAR was installed on the platform jointly by NIWE/FOWIND team 31.10.2017. The measurements were commenced from 01.11.2017 after configuring the LiDAR instrument. The offshore structure and Remote sensing device, LiDAR is shown in Figure 1 and Figure 2.

LiDAR has been configured to measure the wind profile at 12 different heights suitable to the wind turbines available for offshore. The data collected and analysis is underway.



Figure 1 Monopile platform at Gulf of Khambhat



Figure 2 LIDAR at Offshore Platform

Geophysical Survey for Offshore Wind Farms

First Offshore Wind Park in India (FOWPI), a project funded by European Union lead by M/s COWI A/s, Denmark has been working on various aspects of wind farm development such as Met ocean modeling, Geophysical Studies, Foundation report, Environmental Impact Assessment (EIA) for a designated capacity of 200 MW wind farm in a 70 Sq. Km at Gulf of Khambhat off Gujarat Coast near LiDAR location. The Survey has been done by

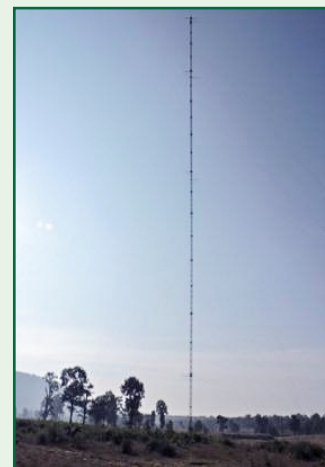
Fugro Survey India. The survey has been covering the geophysical aspects like Bathymetry, Seabed Topology, Sub – bottom profile for finding the seabed sedimentation, geo hazards, sea bed depressions, and ferro-metallic anomalies in and under sea bed. The survey started during the month of December 2017 and expected to be completed by January 2018. The Survey vessel MV Kamrup is shown in Fig 3.



Figure 3 Survey Vessel - MV Kamrup

Wind Resource Assessment

During the period of October to December 2017, 17 Wind Monitoring Stations (WMS) have been commissioned in 7 States (1 in Tamil Nadu, 3 in Nagaland, 2 in Manipur, 2 in Tripura, 2 in Chattisgarh, 6 in Meghalaya and 1 in Gujarat) and 2 stations have been closed down (1 each Madhya Pradesh and Rajasthan). Presently 43 WMS are



100m WMS in Chattisgarh

operational in 10 States under various wind monitoring projects funded by the Ministry of New and Renewable Energy (MNRE) as well as various entrepreneurs.

Consultancy Projects

The following consultancy projects have been completed and reports have been submitted during this period.

- Verification of Procedure of wind monitoring for 12 sites.
- Technical Due Diligence and Energy Yield Estimation for the proposed 481.5 MW wind farm projects.

GEO-TAGGING OF WIND TURBINES INSTALLED ACROSS THE COUNTRY

As on date, the wind turbine installed capacity in India stands at approx. 33000 MW with equivalent number of wind turbines. However no centralized system of maintaining this vast database exists. Considering the advantages of the centralized system, it is proposed to develop a geo-tagged data base / online registry of wind turbines installed and proposed to be installed across the country with the support of central and state agencies. The proposal is data-centric and presently, NIWE is working to devise the methodology for the static data collection and suitable procedure / guidelines for dynamic data collection will be developed in due course. On successful completion this would be helpful,

- To create a database of static information of wind turbine installations (like location of the wind turbine, type of wind turbine, its rating along with critical technical information and year of commissioning, etc.) of all the turbines installed and proposed to be installed in the country.
- To map the spatial / geographical distribution of the

installed wind turbines vis-à-vis the potential areas.

- This also will facilitate in wind power forecasting - Forecasting of wind power based on clustering methods helps achieve better accuracies and reduce computational costs compared to power forecast methods based on one representative wind turbine for the entire wind farm. The database on spatial distribution of wind turbines can be used for evaluating various clustering methods for forecasting studies. In addition, the correlation can be established between NWP models and wind potential data from wind resource maps.

A framework that will enable data collection from all the relevant stakeholders and consolidation at a single point (at NIWE) needs to be put in place.

A 'unique identification code' which will help in identification of wind turbine will be evolved. This 'unique ID' mechanism will have to be seamlessly integrated at some point in the wind turbine commissioning process, starting from the submission of the project proposal to the issue of the commissioning certificate. This is necessary for the successful implementation of the project.

Testing & Forecasting

FORECASTING

Testing & Forecasting officials visited Madhya Pradesh SLDC and made a detailed presentation to Madhya Pradesh Urja Vikas Nigam (MPUVN) officials on 3rd October 2017 regarding Wind Power Forecasting and Scheduling for the entire State of Madhya Pradesh.

Testing & Forecasting officials visited Maharashtra State Electricity Transmission Co. Ltd and made a detailed presentation to Chairman & Managing Director / Maharashtra SLDC officials on 11th October 2017 regarding Wind Power Forecasting and Scheduling for the entire State of Maharashtra.

Testing & Forecasting officials visited Andhra Pradesh SLDC and made a detailed presentation to AP SLDC officials on 24th October 2017 regarding Wind Power Forecasting & Scheduling for the entire State of Andhra Pradesh.

Signing of MOU between NIWE & ISRO SAC on 3rd November 2017 for Development of Wind and Solar power forecasting using High Resolution Numerical Model at Ahmedabad.

Testing & Forecasting officials visited Telangana SLDC, Hyderabad and attended the meeting on 28th November 2017 in connection with pilot project on wind power forecasting for the entire State of Telangana.

NIWE indigenous framework has been developed for Wind Power Forecasting Model version 1.0.

Framework has been developed for continuous monitoring of dayahead and intraday forecast, Vortex, NCMRWF (4 km and 25 km), ISRO SAC, Tamil Nadu and Gujarat Real time generation data.

Prepared error analysis report (both dayahead and intraday) of NIWE's forecast and the same was uploaded in NIWE's forecasting portal monthly.

Established an automation system to obtain the data from GETCO website and as well as from GETCO's FTP. Automated the entire task from extracting data from FTP / website and segregation of data to respective NIWE standard format for integrating the real time generation data in operational wind power forecasting system.

Carried out various activities to organize a one-day workshop on "Current Practices on Wind & Solar Forecasting" scheduled at Chennai on 22nd January 2018.

Actual Data Report for the months of October & November, 2017 has been sent to IWPA.

Error Analysis report for Vortex Dayahead and Intraday forecast value for 107 numbers of substation has been carried out and the same has been communicated to M/s. Vortex, Spain.

Updation of feeder-wise static information and resolving errors of real time generation data is under progress.

TESTING (Large Turbine Testing)

The measurements completed as per the signed agreement for Type Testing of XYRON 1000 kW wind turbine at Richadewda, Ratlam District, Madhyapradesh of M/s. XYRON TECHNOLOGIES LTD.

The continuous measurement is on-going for Power Curve Measurements of INOX 2000 kW wind turbine with 113 meter rotor diameter at Ranipat Village, Muli Taluk, Surendranagar (Dist), Gujarat.

The continuous measurement work is under progress for Power Curve Measurements & Special Measurements for Loads of Pioneer 750 kW wind turbine W49-HH60 a wind turbine with 49 meter rotor diameter at HTSC no. 2988, SF.No. 95/4, 5&6B Part, Poigai Village, Tenkasi Taluk, Tirunelveli District, Tamil Nadu.

SMALL WIND TURBINE TESTING

The measurement work is under progress for Type testing of SM2 (1 kW) at Wind Turbine Research Station, Kayathar of M/s. Windstream Energy Technologies India Pvt. Ltd.

Type Testing assignment of Nalwin 600 W at Wind Turbine

Research Station, Kayathar of M/s. Aparna Renewable Energy Sources Pvt. Ltd. has been undertaken.

The measurement work is under progress for Type Testing of model Vaata Smart, Vertical Axis WT (5.5 kW) at Wind Turbine Research Station (WTRS), Kayathar of M/s. Vaata Smart Ltd.

NEW INFRASTRUCTURE

Establishment of Centre of Excellence in VG Forecasting (Wind & Solar) at NIWE

Infrastructure work has been completed in Forecasting Laboratory



Low Voltage Ride Through (LVRT) facility

Conducted meeting with various service providers regarding the procurement of LVRT.

Awaiting for the summary report regarding the mode of purchase and expectations from the service providers.

To finalize the specifications of LVRT equipment in suitable with Indian grid code is under progress.

Award - Shield and Citation

National Institute of Wind Energy has been awarded 'Shield and Citation' for having secured **First Position** among Central Government Offices (smaller) category, in Chennai, for the best performance in the progressive use of Official Language during the year 2015-17. This Award "Shield and Citation" were received by Dr. K. Balaraman, Director General NIWE in the 55th Town Official Language Implementation Committee (TOLIC) Meeting / Function held on 30th November 2017 in Chennai.



Standards and Certification and Research & Development / Scientific & Technical Research

Review / Verification of documentation has been carried out for the Certification project viz., "Inspection for the Manufacturing Evaluation at a wind turbine tower production unit". Based on the review / verification and inspection carried out, Certification report for three tubular steel tower variants viz., HH80m tower of DF/2000/100 wind turbine model, HH92m tower of DF/2000/100 wind turbine model, HH92m tower of DF/2000/113 wind turbine models have been issued under NIWE-TUVR Co-operation.

Carried out the Witnessing of Safety and Function test, personnel safety assessment (and technical specification verification) for the Certification project viz., "Witnessing of Safety and Function test and Personnel Safety for a wind turbine model at the test site as a part of Type Certification".

A technical due - diligence project with IREDA is under progress.

Review / verification of documentation received for two wind turbine models in connection with installation of prototype wind turbines as per MNRE guidelines are ongoing.

Shri.A.Senthil Kumar, Director & Group Head, S&C and R&D / S&T as Management Representative (MR) provided the support for DNV-GL First Periodic Audit of QMS as per ISO 9001:2008 held at Kayathar.

DNV-GL has conducted First Periodic Audit of Quality Management System as per ISO 9001:2008 for NIWE. Based on the audit conducted, DNV GL recommended for continuation of Certification as per ISO 9001:2008 for NIWE.

Co-ordination with wind turbine manufacturers in connection with documentation to be submitted as per MNRE guidelines on prototype wind turbine models after issue of letter in connection with grid synchronization of prototype wind turbines are ongoing.

Director & Group Head, S&C and R&D / S&T along with Director General, NIWE attended the Electrotechnical Division council (ETDC) meeting on 20.12.2017 at Bureau of Indian Standards (BIS) Head Quarters, New Delhi.

S&C unit is providing technical support to CMD of BIS on IECRE activities. Based on review of draft IECRE documents sent by BIS, voting recommendation has been prepared and sent to BIS for further forwarding to IECRE.

Co-ordination works with Bureau of Indian Standards (BIS) and members of working group on standards in connection with preparation of draft Indian standards on wind turbine related activities are ongoing.

The continual improvement and maintaining the quality management system are ongoing.



First Periodic Audit of QMS as per ISO 9001:2008 conducted by DNV-GL

Recruitment



Dr. K. Balaraman

has taken over the charge of **Director General** of National Institute of Wind Energy, Chennai on 8th November 2017.

Staff Retirement



Shri. M. Anvar Ali

Additional Director & Group Head, ESD, NIWE has retired on superannuation on 30th September 2017.

Wind Turbine Research Station

Periodic regular Operation and Maintenance activities like preparation of 9 nos of 11 kV / 400 V, 1 no of 11 kV / 690 V, 1 no 11 kV / 600 V & 1 no 33 kV / 690 V transformers of 200 kW MICON, 600 kW SUZLON, 2000 kW KENERSYS & 2000 kW INOX Wind Electric Generators, transmission lines including transformer yards are being carried out as a part of O&M preparation of the machines for uninterrupted operation during the windy season 2018.

Case studies on active power and reactive power injection to the Grid from the solar inverter of Grid integration of 75 kWp Solar PV Power with Existing one of the 29 years old 200 kW MICON WEG @WTRS, Kayathar were Completed during this off season period.

As part of endeavor to reach out to next generation, WTRS had coordinated the following visits by students, researchers and training participants and showcased the facilities of Small and Large Wind Turbine Testing, R&D and WRA.

- 11 M.Tech. students and one faculty from Department of Renewable Energy, Rajasthan Technical University, Kota, Rajasthan on 3rd October 2017.
- 20 international delegates of Special International Training Course on Design, Installation & Maintenance of Small Wind Turbine on 3rd November 2017.
- 18 M.Tech. (Energy) students and Two faculty members from Central University of Jharkhand, Ranchi on 7th November 2017.
- 28 international delegates of Special International Training Course, specially for African Countries on Wind Turbine Technology and Applications on 1st December 2017.
- 46 Students and 10 faculty members of Electrical & Electronics Engineering Department from Fx. Engineering College, Tirunelveli, Tamil Nadu on 6th December 2017.



Explaining the facilities to the various visitors

Information, Training and Customized Services

Special International Training Course

NIWE had successfully conducted the 17 days Special International Training Course on "Design, Installation and Maintenance of Small Wind Turbine" during 25th October to 10th November 2017, sponsored by the Ministry of External Affairs (MEA), Government of India under ITEC programmes. The course was attended by 20 participants from 10 countries (Afghanistan, Argentina, Egypt, Ethiopia, Jordan, Kenya, Myanmar, Suriname, Uganda and Zimbabwe).

The training course was inaugurated by Shri D.Lakshmanan Deputy Director General (F&A) & Group Head, F&A and ITCS, NIWE.



Course Inauguration

The course provided an invaluable platform for understanding the Wind Energy Technology and its status, Overview of Wind Turbine Components, The Aerodynamics aspects of Wind Turbine, Wind Turbine Generators, Small wind turbine and hybrid systems, Wind Resource Assessment and Techniques.

As this course was specialised for Design, Installation and Maintenance of Small Wind Turbine, Theory and detailed hands on practical training on Small Wind Turbine Manufacturing such as Building Winding Jigs, Stator, Casting for Stator and Rotor and finishing of Stator/Rotor, Welding Body/Tail, Preparing for Tower Space, Preparing Wood for Blades, Plywood for Moulds, Coil winding of Turbine and Carving of Blades, Building of Stator, Casting for Stator and Rotor, Preparing Tower, Assembling Tower, Preparing, installing of turbine and Blade Assembly, Balancing Blades, Testing, Installation & Commissioning of Turbine and Installation & Maintenance of Turbine were taught practically in a focused manner and the participants had did the above activities themselves with the help of the trainer.

Also, as a part of the course, study visit was arranged to southern part of Tamil Nadu to visit Wind Turbine Test Station / Wind Turbine Research Station at Kayathar, where they got exposure on small and large wind turbine testing process apart from visiting wind farms in and around



Glimpses Small Wind Turbine manufacturing Practical Training

Kanyakumari, where wind turbines are installed in large numbers like coconut trees.

Dr. K. Balaraman, Director General, National Institute of Wind Energy (NIWE) chaired the Valedictory function, interacted with all participants and distributed the course certificates to all the participants.



Dr. K. Balaraman distributing the Course Certificate to the participant

The course structure and conduction of the training was highly appreciated by the participants. The participants were very much satisfied by the quality of lectures, practical sessions and hospitality of NIWE and India.

Special African International Training Course

The 24 days International Training Course on “Wind Turbine Technology & Applications” specially for African Countries under AIFS-III had been successfully conducted during 22nd November to 15th December 2017, sponsored by the Ministry of External Affairs (MEA), Government of India under AIFS-III.



Release of Course Material

The course was attended by 28 participants from 8 countries (Cameroon, Egypt, Ethiopia, Ghana, Kenya, Tanzania, Uganda and Zambia).

The training course was inaugurated by Dr. K. Balaraman, Director General, NIWE and the course material was also released by him.

During the 24 days training, 40 classroom lectures were delivered and handled by NIWE scientists and external experts, Wind Turbine Manufacturers, Wind Farm Developers, Consultants, Academicians, Utility and IPP to provide complete knowledge transfer. Also arranged practical training at NIWE Laboratories, study visit to i) M/s. Regen Power Tech at TADA for exposure on large wind turbine manufacturing process (ii) WTTS / WTRS, Kayathar for large and small wind turbine testing facility (iii) M/s. Suzlon Wind Farms for knowledge SCADA System (iv) M/s. RS WindTech Engineers (P) Ltd. to know the operation and maintenance process and (v) Apollo Transformers and Filters to know the Controllers and Transformers and to witness the physical material and operation activities near Kanyakumari.

Shri K. S. Popli, Chairman and Managing Director, Indian Renewable Energy Development Agency (IREDA), New Delhi was the Chief Guest for the valedictory function and distributed the course certificates to all the participants.



Shri K.S. Popli Distributing the Course Certificate

Students Internship / Project Work

The following students have done internship / project work at NIWE:

The student of Amrita School of Engineering has completed the Internship in ITCS Unit during 23.11.2017 to 08.12.2017.

Two students of Sri Venkateswara College of Engineering, Sriperambudur have completed the internship at WTRS, Kayathar during 27.11.2017 to 01.12.2017.

Visitors

To create awareness and to motivate towards research on wind energy, achieving the indigenization and also to create awareness about the activities and services of NIWE, schools and college students are encouraged to visit the campus. During the period October to December 2017, the following visits were coordinated.

- 19 training participants of the programme 'Energy Conservation' from Ordinance Factories Institute of Learning, Chennai on 6th December 2017.
- 35 students and two faculty members from Tamil Nadu Agricultural University, Coimbatore on 9th December 2017.
- 83 students of V Standard and 6 staff from SAN ACADEMY, Pallikaranai, Chennai on 12th December 2017.
- 63 students of III & IV Year, B.E. (Aeronautical) and two staff from Apollo Engineering College, Chennai on 21st December 2017.

Engineering Service Division

15 kW SPV Power Generation

The Power Generation of 15 kW SPV plant for the period from October to December 2017 is 1209 KWh and the Cumulative generation is 39.98 MWh.

10 kW+20 kW SPV Power Generation:

The Power Generation of 30 kW SPV plant for the period from October to December 2017 is 7383 KWh and the Cumulative generation is 63.24 MWh.

Civil Works

The following civil construction works have been completed:

- General maintenance works at surrounding area of nacelle and northern side of the NIWE campus road.
- The electrical wiring and cabling work in SRRA main cabin.
- Fabrication and construction work towards Provision of Sunshade arrangements for prevention of water leakage in WRA&O containers work under progress.
- Construction of safety fencing and staircase for 20 kW SPV power plant work has proposed.

Solar Radiation Resource Assessment

Calibration of 6 pyranometers & 3 Pyrliometers from the state of Odisha were carried out.

Draft data from Tiruvallur BSRN station submitted to BSRN, Bremerhaven, Germany for their comments and remarks on 13th October 2017. Baseline Surface Radiation network (BSRN) is a project of the Data and Assessments Panel from the Global Energy and Water Cycle Experiment (GEWEX) under the umbrella of the World Climate Research Programme (WCRP) and as such is aimed at detecting important changes in the Earth's radiation field at the Earth's surface which may be related to climate changes. In 2004 the BSRN was designated as the global baseline network for surface radiation for the Global Climate Observing System (GCOS). The BSRN stations also contribute to the Global Atmospheric Watch (GAW). Since 2011 the BSRN and the Network for the Detection of Atmospheric Composition Change (NDACC) have reached a formal agreement to become cooperative networks.

Dr. G. Giridhar, Deputy Director General & Group Head, SRRA held discussions with TESREDCO officials in Hyderabad in connection with solar forecasting on 20th October 2017.

Dr. G. Giridhar, Deputy Director General & Group Head, SRRA held discussions with APSLDC officials at Vijayawada in connection with Wind-Solar Power forecasting on 24th October 2017.

Project proposal for conducting training on Solar Energy submitted to M/s. Mytrah Energy (India) Pvt. Ltd., Hyderabad.

SRRA & WRA officials carried out site survey at Ramakkalmedu in Kerala in connection with wind-solar feasibility study for ANERT.

Meeting on finalizing the specifications of SRRA instruments for two SRRA stations in Kerala for ANERT and one SRRA station at Parbhani in Maharashtra for MEDA held on 8th November 2017.

Energy Storage and Renewable Energy - Part-1

K S Dhathathreyan, Former Associate Director , ARCI and Head, Centre for Fuel Cell Technology, ARCI, Chennai; ksdhatha@gmail.com

Introduction

The growth in the global economy which is set to grow several folds in the coming decades is coupled inextricably to the growth of energy demand. Energy is becoming expensive as the resources are dwindling. Fossil fuels, which constitute the bulk of energy source is fast diminishing which is a serious concern as the gap between supply and demand continues to increase. New sources such as shale oil, gas hydrate are expensive and the process of fracking has been reported to lead to some ecological issues. The present growth and demand for energy, especially in developing nations is not sustainable and these countries are highly susceptible. In addition, the need for transportation fuel is also on the increase, especially in the developing countries. Accompanying the energy production from fossil fuels is the Green House Gas emission issues and the concurrent climate change. Several approaches are required to bridge the gap between supply & demand of energy and at the same time mitigate the GHG emissions. We need to develop methods to produce & use the energy in a method that is sustainable. There is a need for a complete transformation of the way we produce, consume, distribute and most importantly conserve energy.

Energy Storage and Why Store Energy?

Energy is available in many forms: chemical energy, electric energy, potential energy, latent heat, kinetic energy etc., But energy is required in different sectors at different time scales and in different forms. Electricity has two important characteristics. First, electricity is consumed at the same time as it is generated. The proper amount of electricity must always be provided to meet the varying demand. An imbalance between supply and demand will threaten the stability and quality (voltage and frequency) of the power supply. The second characteristic is that the places where electricity is generated are usually located far from the locations where it is consumed (other than the grid independent systems). Generators and consumers are connected through power grids and form a power system. Owing to concentrated usage (heavy load), there may be congestions in some power lines leading to transmission failures and the supply of electricity will be interrupted. The generating plants are required to be equipped with a “kilowatt function”, to generate sufficient power (kW) when necessary. Further they also need a frequency control function. Renewable energy facilities such as solar and wind do not possess both a kilowatt function and a frequency control function unless they are suitably modified. Energy storage is expected to be able to compensate for such difficulties. [International Electrotechnical Commission White Paper Electrical Energy Storage- iecWP-energy storage-LR-en, 2011]

Energy storage involves converting energy from forms that are difficult to store (electricity, kinetic energy, etc.) to more conveniently or economically storable forms. This subject of Energy Storage is very important as storage could provide energy when it is needed, just as transmission provides energy where it is needed. Energy storage technologies are projected to support energy

security and climate change goals by providing valuable services in already developed and developing energy systems. Energy storage technologies can help to integrate electricity and heat systems and can play a crucial role in energy system decarbonisation by:

There are several industry drivers which have created new interest in energy storage systems. [Ref: Electrical Energy Storage Technology Options : A White paper Premier on Applications, Cost and Benefits, EPRI Palo Alto, CA, 2010, 1020676, December 2010]. These include:

- increased deployment of renewable generation,
- high capital cost of managing grid peak demands, and large investments in grid infrastructure for reliability and smart grid initiatives
- increase in fossil fuel prices,
- development of deregulated energy markets including markets for high-value ancillary services especially in developed nations
- challenges to siting new transmission and distribution facilities,

Renewable Energy:

To bridge the gap between supply and demand gap in the energy sector and as a means to providing sustainable energy, Renewable Energy (RE) sources such as Solar, Wind, Ocean, and Bio-, Geothermal are expected to play a significant role. Besides these renewable sources, waste heat recovery from several industries are also being investigated. Among the various forms of renewable energies, solar and wind energy (VRE) dominates widespread implementation. International Energy Agency (IEA) World Energy Outlook foresees that 45% of global electricity coming from renewables by 2035 and solar & wind energy are expected to dominate widespread implementation and are expected to contribute about 17%.

At the beginning of its development, RE generation technology focused more on tapping the maximum power from RE resources. It neglected to address the power system reliability & stability. Further, in the absence of any standards for integration, the RE systems were not designed to operate in a coordinated fashion with the rest of the system. This was not a serious issue as long as RE penetration was low and the power system operators could accept this limited intrusion. But as RE penetration grew, and especially as the capacity of RE power plants became larger and larger, integration has become a serious issue and is impacting the system operation.

Integration Issues can be classified into (i) Technical issues and (ii) Financial Issues.

Technical Challenges:

Energy generation from Wind, Solar, Wave and Tidal suffer from two major limitations: Intermittency and Dependence on resources that are location dependent. Intermittency is a combination of non-controllable variability and partial unpredictability. [I. Perez-Arriaga: Managing Large Scale Penetration of Intermittent Renewables,

MITEI Symposium on Managing Large-Scale Penetration of Intermittent Renewables, Cambridge/U.S.A, 20 April 2011]. The predictability (forecasting) aspect has improved in recent years. Because wind and sun energy are both temporally and spatially outside human control, integrating wind and solar energy into the larger power system, namely non dispatchability. Secondly, wind and solar are relatively mature for use in large capacities and in wide areas, and so have a significant impact on the power grid that is likely to increase over time. Integration into the electricity grid involves managing other controllable operations that may affect many other parts of the grid, including conventional generation. Some of the impacts of higher penetration of variable renewables on the power system are :

- Requirement to enlarge the Balancing area ,
- shifting of the load,
- Requirement of building more flexibility in the grid.

In most of the traditionally designed electrical networks, a low unidirectional energy flow from large remote power generation stations is observed. While small amount of introduction of energy from VRE may not affect this arrangement , large VRE introduction may result in bi-directional flow and likely exacerbate problems with fault management, voltage and frequency. Several integration studies indicate that a higher penetration of renewables requires the availability of more ancillary units of longer time frame, which is essentially the tertiary reserve. Having more standby reserve adds to the operational costs for utilities. Therefore, smooth integration of variable renewables needs to draw on a portfolio of solutions, including generation, interconnections, transmission, distribution and demand-side management .

It is in this context that energy storage is expected to play an important role.

Energy Storage and Renewable Energy :

In the era of low cost peaking fuels interest in energy storage was not seriously pursued. Energy storage systems are increasingly being considered as an important aspect critical for VRE integration as they can help balance variable renewable generation and when properly deployed and integrated, can help increase electric grid reliability, ensure power quality and asset utilization, uninterrupted power supply solutions & initial power to restart the grid after a black out levelling the load – storing power in times of excess supply and discharging it in times of deficit. Energy storage systems can provide a variety of application solutions along the entire value chain of the electrical system, from generation support to transmission and distribution support to end-customer uses [Ref: Electrical Energy Storage Technology Options : A White paper Premier on Applications, Cost and Benefits, EPRI Palo Alto, CA, 2010, 1020676, December 2010]

The How of Energy Storage ?

There are a number of methods reported for storing electric energy, each with unique operational, performance, and cycling and durability characteristics. Pumped Hydro Storage (PHS) is the most matured technology . Several others are still in the development & demonstration stage and currently struggle to compete with other non-storage technologies due to high costs. The storage options that have been presented frequently are focused on its role in smoothing over the variability in renewable power sources like solar and wind.

The suitability of an energy storage resource for a particular discharge time-frame is determined by its power density and energy density. Power density refers to the energy storage technology's ability to provide instantaneous power. A higher power density indicates that the technology can discharge large amounts of power on demand. Energy density refers to the ability of the technology to provide continuous energy over a period of time. A high energy density indicates that the technology can discharge energy for long periods. Generally, energy storage technologies with the highest power densities tend to have the lower energy densities; they can discharge enormous amounts of power, but only for a short time. Technologies with the highest energy densities tend to have lower power densities; they can discharge energy for a long time, but cannot provide massive amounts of power immediately.

The terms normally used in when energy storage is discussed are Storage Capacity (kWh/kg, kWh/m³); Charging / Discharging Power (W/kg, W/m³); Storage Efficiency ; Storage Period (Time) and Cost (rate per kWh, rate per W) .

Energy Storage Technologies can be classified by Storage Application [Short-term , Medium term and Long-term energy storage] or by the Type of storage . The type of storage is classified into Electrochemical [e.g., Lead Acid Battery, Sodium-Sulfur battery (NaS), Flow Batteries (Vanadium Redox Battery (VRB), Zinc Bromine Battery (ZnBr) etc.,), Lithium Ion Battery and Hydrogen (Electrolyser, Fuel Cell), Non-Electrochemical [Pumped Hydro Storage (PHS), Compressed Air Energy Storage (CAES), Flywheel, Ultra-Capacitor, Superconducting Magnetic Energy Storage (SMES)], Chemical and Thermal . Some of these storage techniques are suitable for power application and few for energy applications. The choice of an energy storage device depends on the application ; these applications are largely determined by the length of discharge. [International Electrotechnical Commission White Paper Electrical Energy Storage- iecWP-energy storage-LR-en, 2011]

Short discharge time resources discharge for seconds or minutes, and have an energy-to power ratio (kWh/kW) of less than 1.[Examples : double layer capacitors (DLCs), superconducting magnetic energy storage (SMES), and flywheels (FES)]. These resources can provide instantaneous frequency regulation services to the grid that mitigate the impact of RE's uncontrollable variability.

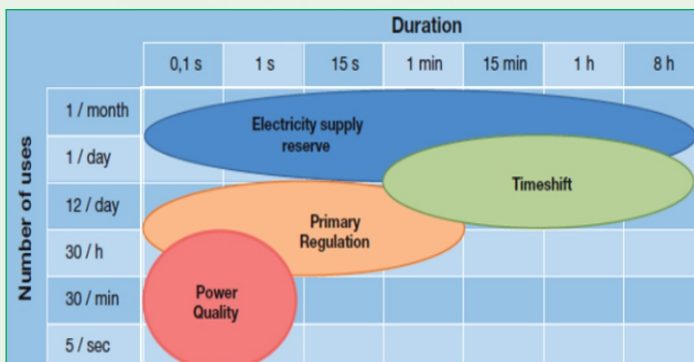
Medium discharge time resources discharge for minutes to hours, and have an energy-to power ratio of between 1 and 10.[Examples: Batteries (Lead acid, Li-Ion, NaS) and flywheels]. Medium discharge time resources are useful for power quality and reliability, power balancing and load following, reserves, consumer-side time-shifting, and generation-side output smoothing. Some batteries may be designed so as to optimize for power density or energy density. They are relevant to both the uncontrollable variability and partial unpredictability that RE generation brings to the grid.

Medium-to-long discharge time resources discharge for hours to days, and have energy-to power ratios of between 5 and 30. [Examples: pumped hydro storage (PHS), compressed air energy storage (CAES), and redox flow batteries (RFBs)]. RFBs are particularly flexible in their design, as designers may independently scale the battery's power density and energy density by adjusting the size of the cell stacks or the volume of electrolytes, respectively.

Technologies in this category are useful primarily for load-following and time shifting, and can assist RE integration by hedging against weather uncertainties and solving diurnal mismatch of wind generation and peak loads.

Long discharge time resources may discharge for days to months, and have energy-to-power ratios of over 10. Technologies in this category are thought to be useful for seasonal time-shifting. For example, large amounts of solar power on the grid will produce large amounts of energy in the summer months, but significantly less in the winter. Storing excess generation in the summer in some form and converting it back to electricity in the winter would allow a time-shift of generation from one season to the next. Such technologies can assist RE integration in the long term by deferring the need for transmission expansion and interconnection that arises due to the locational dependency of renewable resources.

Figure: Different uses of electrical energy storage in grids, depending on the frequency and duration of use [From: Concept of the graphic from EUS GmbH; 2006 ; International Electrotechnical Commission White Paper Electrical Energy Storage- iecWP-energy storage-LR-en, 2011]



Summary:

Energy storage can provide a number of benefits and cost savings to the electric grid, and companies are deploying storage technologies for a number of different purposes. Large scale energy storage will allow today's electrical system to run significantly more efficiently, and thus at lower prices, less emissions and provide more reliable power. With the increased induction of variable renewable energy resources such as solar and wind in electric grids, energy storage will play a very critical role in providing a reliable stable power. Besides warehousing of energy from different sources for use at different times, storage technologies also improve the quality of power through frequency regulation, allows companies to produce power when it is cheapest and most efficient, and provide an uninterrupted source of power for critical infrastructure and services According to market research firm IHS, the global energy

storage market is growing exponentially to an annual installation size of 6 gigawatts (GW) in 2017 and over 40 GW by 2022 — from an initial base of only 0.34 GW installed in 2012 and 2013.

Although some storage technologies can function in all application ranges, most options would not be economical to be applied in all three functional categories. While most of the technologies described above involve storing electrical energy, there is increased consideration for storing electricity in a medium which is amenable for both regenerating electrical energy and also provide fuel for applications such as transport and also produce industrial chemicals such as ammonia used in fertiliser industry. Electricity storage technologies are at very different levels of maturity with many clustered at the high capital requirement and risk stages.

While some energy storage technologies are mature or near maturity, most are still in the early stages of development and currently struggle to compete with other non-storage technologies due to high costs. They will require additional attention before their potential can be fully realised. They require long term (research phase) and high risk investment (demonstration). Governments can help accelerate the development and deployment of energy storage technologies by supporting targeted demonstration projects for promising storage technologies and by eliminating price distortions that prevent storage technologies from being compensated for the suite of services they provide. Energy storage technologies have the potential to support our energy system's evolution, but realising this potential will require government, industry, academia and financial stakeholders to work together to help overcome existing barriers.

The most important drivers for increasing use of energy storage in future will be:

- improving energy system resource use efficiency
- increasing use of variable renewable resources
- rising self-consumption and self-production of energy (electricity, heat/cold)
- increasing energy access (e.g. via off-grid electrification using solar photovoltaic (PV) technologies)
- growing emphasis on electricity grid stability, reliability and resilience
- increasing end-use sector electrification (e.g. electrification of transport sector).

Finally,

“No energy solution can exist outside of the real and competitive pressures of the market. Technical viability and environmental benefits won't be enough to get projects over the line if they can't demonstrate their financial soundness.”



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An autonomous R&D Institution under the Ministry of New and Renewable Energy (MNRE), Government of India
Velachery - Tambaram Main Road, Pallikaranai, Chennai - 600 100.

Phone : +91-44-2246 3982, 2246 3983, 2246 3984 Fax : +91-44-2246 3980

E-mail : info.niwe@nic.in URL : http://niwe.res.in

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