

EDITORIAL



The development of wind power in India began in the 1990s and India was the first country in the world to set up a ministry of non-conventional energy resources. The Wind Power has significantly increased in the last few years.

Although a relative newcomer to the wind industry compared with Denmark or the US, domestic policy support for wind power has led India to become the country with the fourth largest installed wind power capacity in the world.

Wind power capacity is 34,046 MW as of 31st March 2018, mainly spread across Tamil Nadu (7,269.50 MW), Maharashtra (4,100.40 MW), Gujarat (3,454.30 MW), Rajasthan (2,784.90 MW), Karnataka (2,318.20 MW), Andhra Pradesh (746.20 MW) and Madhya Pradesh (423.40 MW) Wind power accounts for 10% of India's total installed power capacity and making India the fourth-largest wind power producer in the world. The country has a strong manufacturing base in wind power with 20 manufactures of 53 different wind turbine models of international quality up to 3 MW in size with exports to Europe, USA and other countries. India has set an ambitious target to generate 175 GW of energy from renewable sources and 60 GW from wind power alone by 2022. India is running one of the largest and most ambitious renewable capacity expansion programs in the world.

India set the record by producing its 100 Billionth Unit of Renewable Energy in a Year. The country's renewable energy production now exceeds all the electricity produced by Israel and Hong Kong combined. Recently, India achieved a renewable energy milestone. Somewhere in the country, a solar panel, a wind turbine or possibly a small hydro plant pushed the country's renewable generation past one lakh Giga Watt hours (GWh) in a single year for the first time.

The Central Electricity Authority reported 93,207 GWh of renewable electricity up to the end of February, and the more updated daily data from POSOCO's National Load Despatch Centre showed that a further 6,832 GWh had been generated by the end of Thursday, March 29, to push the total over the 100,000 GWh line in FY 2017-18 with two days to spare.

The quarterly period, January to March 2018 in NIWE is totally the period for International / National / Customized Trainings, Workshops, meetings of High Power Committees of NIWE, Celebrations of Republic Day, Women's Day, Foundation Day, IREDA-

NIWE Annual Awards, visits by officials from Ministry of External Affairs, Ministry of New and Renewable Energy, Foreign Delegation, etc. I am happy to see the commitments fulfilled and progress reported by each and every group of NIWE. I appreciate them all.

Testing & Forecasting Unit, had organized a well reviewed workshop on Wind and Solar forecasting and also a one-month-hands-on training on "Linux Operating System, Unix Programming, Database Management System and R" for NIWE staff.

Joint Secretary, Ministry of External Affairs, visited NIWE to inspect and review the facilities available at NIWE for conducting the International Training Courses under ITEC programme.

The ITCS unit has organized one International Training (31st January - 23rd February 2018), One National Training (12th to 16th March 2018) and two Special Training courses (28th February to 7th March and 12th to 16th March 2018) to cater to the needs of the Industry and for the benefits of the National and International participants. NIWE has instituted the IREDA-NIWE Annual Awards in Wind Energy under three categories with the sponsorship of IREDA. This award ceremony held along with the celebration of the 21st Foundation Day of NIWE on 21st March 2018. Smt. Gargi Kaul, IAAS, Additional Secretary and Financial Adviser, MNRE was the Chief Guest for the Awards Function.

SRRA Unit jointly with GIZ, arranged a workshop on "Conceptualizing a Virtual Power Plant in India with NIWE" at Chennai.

NIWE and FOWPI had jointly organized the workshop on 'Foundation Design for Offshore Wind Farms In India' on 20th March 2018 which facilitated the transfer of knowledge and technological know-how from the EU experience in Offshore Wind Energy sector and its adaptability to the Indian context.

The S&C unit has organized the 8th meeting of Wind Turbine Sectional Committee (ET 42) of Bureau of Indian Standards (BIS) to provide the technical support to BIS has been provided by S&C unit.

Wind Turbine Research Station had imparted one Intensive field exposure training on Wind Electric Generators, O&M /Met masts measurements and testing of small aero-generators to 8 students and 1 faculty from National Power Training Institute (NPTI).

NIWE has encouraged students internship and project work and many students were accommodated during this period. It is happy to note the number of Visitors to NIWE is increasing on account of NIWE's proactive technical capability & support.

Dr. K. Balaraman, Director General

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[www.Twitter.com/niwe_chennai](https://www.twitter.com/niwe_chennai)

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Wind Resource Assessment & Offshore

Wind Resource Assessment (Uncovered / New Areas)

During the period of January to March 2018, 9 Wind Monitoring Stations (WMS) have been commissioned in 4 States (3 in Tamil Nadu, 1 in Meghalaya, 1 in Tripura, 4 in Mizoram) and 1 station has been closed down in Tamil Nadu. Presently, 53 WMS are operational in 11 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 for promotion of onshore wind farm development in the country.

- Verification of Procedure of wind monitoring for 7 sites.
- Technical Due Diligence and Energy Yield Estimation for the proposed 481.5 MW wind farm projects for various public and private sector clients.

Geo-Tagging of Wind Turbines Installed Across the Country



Wind turbine static information on geo-spatial platform

NIWE is creating a centralised database of existing and proposed installations in the country. NIWE has initiated data collection from SNAs and other Stakeholders. As on date, information of about 15000 MW of wind turbines has been received and the verification process is underway.

Offshore LiDAR based Wind Measurements at Gulf of Mannar

NIWE has initiated installation of offshore wind monitoring station at Gulf of Mannar Off Tamil Nadu Coast. The geotechnical survey at the point of installation of LiDAR platform will be carried out, which will provide useful pointers in designing the offshore substructure (monopile + platform) for mounting the LiDAR for carrying out offshore wind resource assessment.

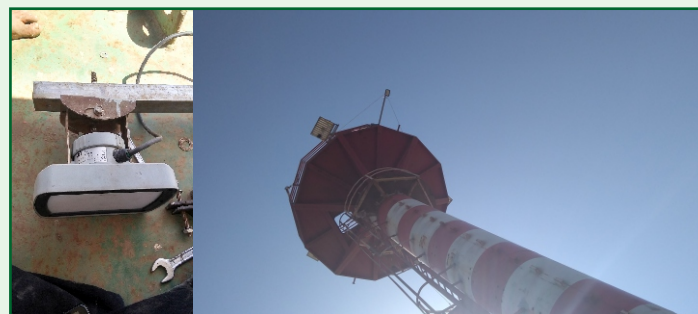
FOWPI – EU Workshop on "Foundation Design for Offshore Wind Farms in India"

NIWE and the First Offshore Wind Project of India (FOWPI - Project Management Team) jointly organized on 20th March 2018 a half-day event on "Foundation Design for Offshore

Wind Farms in India" to showcase the outcome of the studies carried out by FOWPI.

The workshop facilitated the transfer of knowledge and technological know-how from the EU experience in offshore wind energy sector and its adaptability to the Indian context.

Offshore LiDAR based Wind Measurement at Gulf of Khambhat



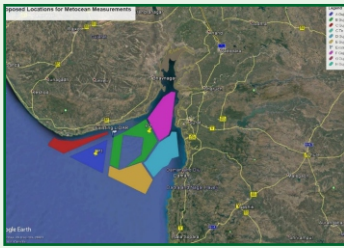
RADAR – Tide level sensor

LiDAR substructure after installation of RADAR level sensor

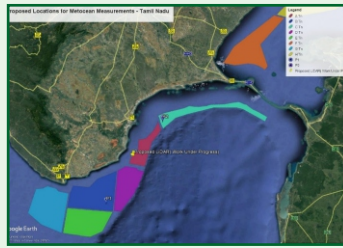
The offshore LiDAR has been successfully installed and the data is being successfully transmitted to NIWE's server. Based on this wind data, the Expression of Interest (EoI) can be prepared. NIWE has further initiated tidal measurements at the LiDAR platform at Gulf of Khambhat. The instrument measures the tide level by using RADAR principle. It consists of two antennas for transmitting and receiving pulses. Transmitting antenna emits the pulses and the reflected pulses will be received by another antenna. The time taken by the RADAR from transmission to reception is calculated as the distance and thus the tide length is calculated. The tidal measurements will be useful to better understand the water level and sea-state conditions for designing of offshore wind farm development in the said area.

Met-Ocean measurements (Wind, Wave, Tide, Current, Water level, etc) at Gulf of Khambhat and Gulf of Mannar for fostering the growth of Offshore wind in the country

NIWE in the process of exploring the largest seabed areas off Gujarat and Tamil Nadu coasts with an objective to identify the potential subzones / blocks for promotion of offshore wind farm development in the country. For the purpose, it is proposed to procure 4 LiDARs (2 for Gujarat and 2 for Tamil Nadu) to carry out extensive wind resource



Proposed met-ocean locations
in Gulf of Khambhat, Gujarat



Proposed met-ocean locations
in Gulf of Mannar, Tamil Nadu



Typical diagram of met-ocean Buoy

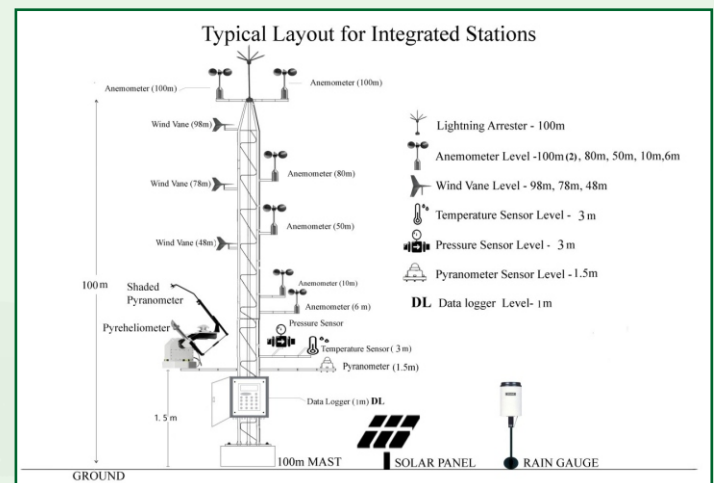
assessment. In addition to this, NIWE proposes to carry out the Oceanographic / Hydrographic measurements, which include Water level, Wave Height and period, Current speed and direction and other

derived parameters such as Significant Wave Height, Wave period, etc., in and around the wind LiDAR platforms or suitable locations off the Gujarat coast and Tamil Nadu coast to understand the sea-state conditions, which are envisaged as essential and necessary to design the foundation of the Offshore wind turbines. Based on the study, NIWE will plan the installation & other survey activities to understand the Weather Window for Operation and Maintenance planning.

Integrated Wind and Solar Resource Assessment through Mapping and Measurements

Reliable background information on the availability of renewable resource and its geographical variation will play a major role in achieving the government's ambitious targets. As the wind speed increases with respect to height,

the hub height extension is being looked into one of the effective solutions to enhance the energy yield from the wind turbines. With the technical advancements, the modern day turbines have reached the hub height of 120m to 130m and a further enhancement in hub height is foreseen, which would require higher height maps. Studies have also revealed that solar and winds are almost complementary to each other. Hybridization of these two technologies would help in minimizing the variability apart from optimally utilizing the infrastructure including land & transmission system and a Hybrid potential map in this regard would be very much helpful for the stakeholders to identify suitable sites for further investigation. NIWE proposes to prepare indicative Renewable Energy potential maps (wind maps at 120m & 150m and Hybrid maps) through advanced numerical meso-scale modeling techniques and validate the maps with Integrated wind and solar masts and remote sensing in-situ ground measurements to move towards achieving the ambitious goals as envisaged by the government.



Typical Layout for Integrated Stations

PROMOTIONS

S.No.	Name	Cadre from	Cadre promoted to
1.	Shri J.C. David Solomon	Additional Director	Director
2.	Smt. G. Arivukkodi	Assistant Engineer	Assistant Executive Engineer
3.	Shri S. Arulselvan	Assistant Engineer	Assistant Executive Engineer
4.	Shri Y. Packiyaraj	Assistant Engineer	Assistant Executive Engineer
5.	Shri M.Karuppuchamy	Assistant Engineer	Assistant Executive Engineer
6.	Shri A.R. Hasan Ali	Assistant Engineer	Assistant Executive Engineer

Testing & Forecasting

LARGE WIND TURBINE TESTING

The measurements completed as per the signed agreement for Type Testing of XYRON 1000 kW wind turbine at Richadewda, Ratlam District, Madhya Pradesh 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 of M/s. INOX Wind Ltd.

The measurement is under progress for Power Curve Measurements & Special Measurements for Loads of Pioneer 750 kW wind turbine W49-HH60 with 49 meter rotor diameter at Poigai Village, Tenkasi Taluk, Tirunelveli District, Tamil Nadu of M/s. PARA Enterprises Pvt. Ltd.

Site Feasibility Study (SFS) for the proposed Type Testing of Pioneer 750 kW wind turbine SF No.917, Cheliyanallur Village, Manur Taluk, Tirunelveli District, Tamil Nadu of M/s. Para Enterprises Pvt. Ltd. has been carried out.

FORECASTING

- The VG (Variable Generation) Forecasting lab has been set up to provide Forecasting service to all wind-rich States of India and Forecast Display system has been installed in the forecasting lab to monitor the entire forecast system.
- MoU for NCMRWF has been finalized for obtaining high resolution NWP data and the same has been approved.

The approved MOU document has been sent to NCMRWF for finalization.

- As per model framework, developed the version 1.0 of Indigenous Wind Power Forecasting model. The model shall use the NWP / generation data to predict the Wind Power up to 7 days ahead.
- Simulation algorithm created for dynamic model selection module. The simulation result will help to decide the model configuration of each substation.
- Uncertainty analysis of Wind Speed and Wind Direction of NCMRWF 25 Km models has been carried out.
- Intraday revision module has been created and necessary training has been imparted to the forecasting team to operate the intraday module.
- Forecasting team had discussion with VORTEX, Spain regarding aggregated forecast for the entire state of Tamil Nadu.
- Various trainings are being imparted for the forecasting team to handle the operational wind power forecasting system on a continuous basis (LINUX Scripting, Python Scripting & R-Statistical tools)
- Substation wise analysis has been done for the State of Gujarat to measure the model performance.

SMALL WIND TURBINE TESTING

The measurement of type testing of model - SM2 (1kW) of M/s Windstream Energy Technologies India Pvt. Ltd. And



Model - Vaata Smart, Vertical Axis WT (5.5kW) of M/s Vaata Smart Ltd. are under progress at Wind Turbine Research Station (WTRS), Kayathar.

ONE-MONTH-HANDS-ON TRAINING

- Testing & Forecasting Unit organized one-month-hands-on training on “Linux Operating System, Unix Programming, Database Management System and R” to NIWE officials including contract staff held from 10.01.2018 to 31.03.2018 at NIWE.

NEW INFRASTRUCTURE

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

New workspace has been created in the forecasting lab to have better interaction amongst the forecasting team.

VISITOR

Dr. Jordi Nadal and Mr. Parvinder Batth, AIA Officials visited NIWE and provided a lecture on “Overview of Machine Learning” held on 23rd January 2018 to Testing & Forecasting team.

NIWE International Workshop on “Current Practices in Wind & Solar Forecasting” on 22nd January 2018 at Chennai

BACKGROUND

NIWE is carrying out forecasting of Wind Power for the entire State of Tamil Nadu as per TANGEDCOs requirement since 2015 in collaboration with Vortex Factoria de Calculs, S.L., Spain. Based on the experience gained, NIWE has developed an Indigenous wind power forecasting model. The same is proposed to be tested and validated in the RE rich States of the country. In this regard, NIWE has signed MoU with Gujarat and Rajasthan SLDC to test the indigenous wind power forecasting model. NIWE is in process on signing MoU with other RE rich States. As directed by MNRE, NIWE is in process of Establishing “Centre for Excellence in RE forecasting” at NIWE, Chennai. Hence, capacity building in latest RE forecasting technique would be helpful to NIWE forecasting team to improve the indigenous wind power forecasting model.

As directed by MNRE and as a part of the Capacity building, NIWE has organized one day International Workshop on “Current Practices in Wind and Solar Forecasting” in association with Indian Wind Power Association on 22nd January 2018 at Hotel Trident, Chennai. The workshop has focused on some of the major issues that concern RE Forecasting which needs to be addressed along with Best Practices in RE forecasting. The workshop has given a comprehensive overview of the technical challenges and how to overcome them through National and International experiences of various RE Forecasters. In the workshop, about 22 speakers presented various aspects followed in RE forecasting, Challenges encountered and possible solutions along with cutting edge technology to carryout forecast.

The workshop witnessed an overwhelming response with 250 participants from MNRE, Utilities, State Load Dispatch Centres, Regional Load Dispatch Centres, National Load Dispatch Centres, Central Electricity Authority, Central Electricity Regulatory Commission, State Electricity regulatory authorities etc. There was a wider participation SNAs FSPs, IPPs across the country have been actively participated and benefited.

STRUCTURE OF THE WORKSHOP

The workshop was designed to get maximum outcome in terms of knowledge and hence, the workshop was divided into 4 technical sessions along with one Thematic Technical session and Panel discussion. Brief deliberation of various technical session are given below:

Thematic Technical session-Wind & Solar Forecasting

In this Technical session, major challenges in Numerical Weather Prediction has been discussed along with necessary solutions to overcome the challenges. National Centre for Medium Range Weather Forecasting (NCMRWF) ensemble prediction system has brought a light in this forum. During the workshop, NIWE has briefed on the indigenous tools developed by NIWE in RE forecasting to various stakeholders which includes developmental works already carried out by NIWE. The various advantages of centralized forecasting have been briefly explained by IWPA. The gist of the points emphasized by different speaker of this session is given below.



Dr. K. Balaraman honouring the chief Guest with flower bouquet



Chief Guest inaugurating the Workshop

1. Dr. Vahan Gevorgian, Chief Engineer, National Renewable Energy Laboratory, USA - Focused on overview of the wind & solar power forecasting & its challenges to improve power system operation by reducing integration cost of renewables.

2. Dr. Greeshma M Mohan, Project Scientist, Indian Institute of Tropical Meteorology, India - Explained the current initiatives that have been taken in the field of solar & wind forecasting using high resolution cloud resolving models & various numerical models.

3. Mr. Sushant Kumar, Project Scientist, National Centre For Medium Range Weather Forecasting, India - Gave brief idea about the NCMRWF unified modeling system, statistical processing for bias correction and NCMRWF Research results that can be useful for forecasting of wind Energy.

4. Mr. A G Rangaraj, Deputy Director (Technical), National Institute of Wind Energy, India - Explained about the NIWE's experience in RE forecasting, operational challenges and overview of indigenous wind power forecasting model developed by NIWE.

5. Mr. A D Thirumoorthy, Chief Technical Advisor, Indian Wind Power Association - Discussed the merit of centralized forecasting over Substation wise forecasting in addition to that, he explained various success story of centralized forecast given by NIWE in the prospective of investor friendly approach.

Hybrid Approach in Wind / Solar Forecasting

In the technical session, the hybrid approach (combination of physical and statistical methods) has been discussed extensively. The importance of using site specific power curves has also been discussed to improve forecast accuracy. During the session, the usage of BEY technology for solar forecasting has been discussed. Various

advantages of the hybrid physical and statistical model have been deliberated. The significance of turbine specific power forecast, high resolution CFD modeling has been discussed. The gist of the points emphasized by different speaker of this session is given below:

6. Mr. Bernd Kratz, CTO, Enercast GmbH, Germany - Focused the current methodology used by Enercast for wind power forecasting, considering different NWP models, artificial intelligence and ensembling algorithm to get better accuracy, also explained the requirement of Bigdata Infrastructure to handle huge amount of data.

7. Mr. Amresh Khosla, Director, Manikaran Analytics Limited, India - Explained about his experience in the field of wind and solar power forecasting and put more focus on getting better numerical weather data for better energy forecasting.

8. Mr. Jordi Ferrer, Managing Director, Vortex S. L, Spain - Focused on the hybrid physical-statistical approach towards achieving better forecast and explained basic obstacle overcoming strategies to initiate a forecast model from the scratch.

9. Mr. G M Vishwanath, Head, Renewable Energy Operations (India), 3TIER R&D India Private Limited, India - Explained about Vaisala's forecasting model in the prospective of forecast provider, along with that he showcased the way to use machine learning statistical algorithm, use of multiple physical models and way to remove the biasing in NWP models.

Advanced Statistical approach used in Wind/Solar power forecasting

The session has thrown light upon various latest technology viz., smart ensemble algorithms, energy digitization and applied artificial intelligence along with the methods like Auto Regressive Moving Average, Auto Regressive Integrated Moveing Average, Artificial Neural Network. The

importance of real time observation has been focused. The various issues in using machine learning algorithms like noisy data, unpredictable weather situations, handling of volume of data has been touched upon. The recommendations for using reduced time horizons has been briefed. The various studies dealing with the uncertainties in the forecast system has been outlined. The significance in the usage of deep learning algorithms for the correction of biases has been discussed. The gist of the points emphasized by different speaker of this session are given below:

10. Mr. Karim Fahssis, Chief Executive Officer, MeteoPole, France - Explained the future of wind & site engineering from the investors prospective, by focusing more on the instant, cost-effective, automatic and auditable accuracy, and application of deep machine learning to achieve the target.

11. Dr. Ayumu Suzuki, Senior Engineer (Forecasting), DNV GL – Energy, United Kingdom - Explained about the DNV GL methodology for short term forecasting of wind & Solar Energy and various refinement procedure for greater accuracy.

12. Mr. Abhik Kumar Das, Director, Del2infinity Energy Consulting Pvt. Ltd, India - Explained Various Advance statistical equations and computational techniques in solving the dynamic problem for wind/solar forecasting.

13. Mr. T.F. Jayasurya, Country Manager, WINDSIM, India - Explained multiple strategies, advanced statistical technique adopted by Windsim to improve the accuracy level of Forecast.

Advancement in Physical Model of Wind / Solar power Forecasting

The advantages of anemos prediction system has been explained by Overspeed GmbH. The evolution from local

wind power to theoretical wind power and finally calibration to real wind farm power has been briefed. The usage of various satellites already launched by India in the forecasting field has been outlined. The Importance of correction of NWP model output with ground observations has been explained. The various factors affecting NWP like the global irradiance, cell temperature and wind speed has been outlined. A brief overview of cloud tracking expensive sky cameras and geospatial statistics has been discussed. The challenges in data assimilation, conversion of energy variables into weather variables has been overviewed. The gist of the points emphasized by different speaker of this session is given below:

14. Dr. Hans – Peter (Igor) Waldl, Managing Director, Overspeed GmbH, Germany - Mainly focused on Physical modeling, factors affecting the physical modeling & technical advancement need for auto-adoptive model tuning.

15. Dr. Prashant Kumar, Scientist, Indian Space Research Organisation – Space Application Centre, India - Covered the various aspects and development in the field of Geo satellite for better physical Weather Research & Forecast model results.

16. Dr. Murali Baggu, Group Manager, National Renewable Energy Laboratory, USA - Gave brief idea about the research work on improvement of various physical models and development of NREL Resource Assessment and database system, Benefits of VG power forecasting, wind and solar forecasting methods based on US utilities.

17. Dr. Guruprasad Srinivasan, Analytics Manager, Utopus Insights India Pvt Ltd, India - Explained about the current methodology used by Utopus Insight India for Wind & solar forecasting. Along with this he projected focus on modeling of wind speed based on Hub Height, hyper local wind condition, wake effect to achieve hyper accuracy level.



Glimpses of Technical Session

Forecasting and Allied Issues

The various REMC activities, Indo-German collaboration, and role of NIWE in GIZ project has been discussed. The RE forecasting and renewable energy management talk explained about the role of Forecast Service Provider and Weather Service Provider (WSP) in the forecasting system. The various challenges in solar forecasting like choose of finer resolution, difference between GHI and the forecast has been briefed. The challenges in forecasting has been discussed which includes data issues, connectivity issues, equipment issues and its solutions has been deliberated. The usage of IR based camera for tracking cloud movements has been explained. The gist of the points emphasized by different speaker of this session is given below:

18. Mr. Kashish Bhambhani, Chief Manager, Power Grid Corporation of India Limited, India - Explained regarding the power system planning for the future of India and the current Renewable Energy Management Centre planning architecture to get better power management based on the future demand.

19. Mr. Vishal Pandya, Co-Founder and Director, REconnect Energy, India - Explained various challenges in the process of RE integration, discussed various key constituents achieving that. He also gave brief idea about the Wind & solar power forecasting obstacle and the strategy used by ReConnect to overcome them.

20. Dr. Jordi Nadal, Data Scientist, AIA Consulting, Spain - Presented the advancement of implementing Machine learning techniques over conventional forecasting techniques. He covered various state of art methods, algorithms for better prediction and accuracy.

21. Mr. Deva P Seetharam, CEO & Co-Founder DataGlen, India - Focused on the practical challenges in prediction of solar power in the remote locations of India and best practices to overcome them resulting better forecast.

22. Mr. O P Taneja, Associate Director, Indian Wind Turbine Manufacturers Association, India - Explained the scenario of Rajasthan RE forecasting and the role of IWTMA. He covered the working model architecture and briefly explained the scope for system integration towards better energy management.

Panel Discussion on current practices in Wind / Solar Power Forecasting

After various technical sessions, the outcome of each technical session has been debated in the Panel discussion

and concluded the best practices available in Wind / Solar Power Forecasting. The members of this discussion session are given below:

1. Dr. K. Balaraman, Director General, NIWE,
2. Dr. Jordi Nadal, Data Scientist, AIA Consulting
3. Ms. A Axilium Jayamary, Director (Operation), TANTRANSCO
4. Dr. Hans – Peter (Igor) Waldl, Managing Director, Overspeed GmbH
5. Mr. Markus Wypior, Director, Green Energy Corridor (GEC)
6. Dr. Vahan Gevorgian, Chief Engineer, NREL

TAKEAWAY FROM THE WORKSHOP

- Accurate Static and Dynamic data are required to model the accurate forecasting.
- Mixture of Physical and Statistical model would give accurate prediction
- Centralized forecasting will help the grid manager to manage the Renewable Energy effectively.
- The significance of turbine specific power forecast, high resolution Computational Fluid Dynamics modeling were understood
- The Importance of correction of NWP model output with ground observations has been emphasized in the workshop

WAY FORWARD

Based on the deliberation of the workshop, the following shall be the way forward in RE forecasting:

- NIWE will carry out necessary capacity building in the advanced Statistical approach.
- Based on the capacity building, NIWE will carry out necessary changes in the existing model to deliver better forecasting results.
- The deliberation of the workshop has created an opportunity to understand the science of RE Forecasting and has appreciated its capabilities to facilitate RE integration into the grid to various stake holders especially the utilities and Load Dispatch Centers (LDCs).
- Many FSPs shared the possibilities of various Forecasting techniques in terms of realistic accuracies. This input shall enable a robust architecture for providing RE

Forecasts to the LDCs with focus on improving accuracies.

- The Workshop had paved the way for interactions between various stake holders to establish RE Forecasting in various RE rich States within a short time frame.
- The interactions shall enable the FSPs to improve their models in different terrain and environmental conditions.
- The NWP data providers shall interact with FSPs to validate with ground stations/meteorological masts and

improve their models.

- This shall facilitate RE integration of 160 GW with ease and expectations of the grid.
- PPTs of the International Workshop on the theme “Current Practices in Wind & Solar Forecasting” held on 22nd January 2018 at Hotel Trident, Chennai has been uploaded on the NIWE website, and link has been shared to all the speakers and stakeholders .
- A detailed report on the theme “Current Practices in Wind & Solar Forecasting” has been prepared and submitted to MNRE.



Panel Discussion



Valedictory Function

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

- Review/Verification of documentation has been carried out 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”. Based on the review / verification and inspection carried out, reports have been prepared.
- MNRE approved NIWE as Testing and Type Certification body in India for all wind related issues.
- Completed review / verification of documentation of two prototype wind turbine models received from the wind turbine manufacturers in connection with installation of prototype wind turbines in India as per MNRE guidelines.
- Organized a committee meeting on Prototype wind turbine models.
- Prototype Committee approval has been issued in connection with grid synchronization of prototype wind turbine “Gamesa G122 2.1MW IEC S” model of M/s. Siemens Gamesa Renewable Power Private Limited to the concerned State Electricity Board, as decided by the Prototype Committee.
- Prototype Committee approval issued in connection with grid synchronization of prototype wind turbine “S128 2.6 MW” model of M/s. Suzlon Energy Limited to the concerned State Electricity Board, as decided by the Prototype Committee.
- An agreement has been signed with M/s. Southern Wind Farms Limited to take up the project on renewal of Certificate of 'GWL 225' wind turbine model as per TAPS-2000 (amended). Review / verification of



Issuing renewed Certificate to M/s. Southern Wind Farms Limited


8th BIS ET 42 meeting held at NIWE, Chennai

documentation in connection with renewal of certificate of "GWL 225" wind turbine model as per TAPS-2000 (amended) has been completed and renewed certificate has been issued to M/s. Southern Wind Farms Limited.

- Carried out review / verification of various documentation for the project on 'Review / Verification of documentation in connection with revision of Certificate of 'V 39-500 kW with 47m Rotor diameter' wind turbine model as per TAPS-2000 (amended). Based on the completion of review / verification, revised Certificate has been issued to RRB Energy Limited.
- Carried out review / verification of various documentation for the project on 'Review / Verification of documentation in connection with revision of Certificate of 'Pawan Shakthi – 600 kW' wind turbine model as per TAPS-2000 (amended). Based on the completion of review / verification, revised Certificate has been issued to RRB Energy Limited.
- An agreement has been signed with M/s. RRB Energy Limited to take up the project on renewal of Certificate of 'V 39-500 kW with 47m Rotor diameter' wind turbine model as per TAPS-2000 (amended). Review / verification of documentation in connection with renewal of Certificate of 'V 39-500 kW with 47m Rotor diameter' wind turbine model is under progress.
- Organized 8th meeting of Wind Turbine Sectional Committee (ET 42) of Bureau of Indian Standards (BIS)

held on 23.03.2018 at NIWE, Chennai. S&C unit provided the technical support to BIS for the meeting. The meeting was chaired by Dr. K. Balaraman, Director General, NIWE and Chairman, ET 42 and members from the industry were present. Shri. A. Senthil Kumar, Director & Group Head, S&C and Member, ET42 participated in the said Committee meeting and explained the status of various Standards related works carried out by NIWE.

- Review of a draft IEC document sent by BIS has been completed. Based on the review, voting recommendation for the said draft IEC document has been prepared and sent to BIS for further forwarding to IEC TC 88.
- S&C unit is providing technical support to CMD of BIS on IECRE activities. Based on review of six draft IECRE documents sent by BIS, voting recommendation for the said draft IECRE documents have been prepared and sent to BIS for further forwarding to IECRE.
- Co-ordination works with BIS 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.
- Director & Group Head, S&C participated in the 41st Governing Council meeting held at NIWE, Chennai on 17.03.2018.

Research and Development / Information Technology / Information, Training and Customized Services

- The 26th Research Council of NIWE was held in the month of March 2018 at NIWE, Chennai. Research projects proposing creation of new Lab facilities for meeting Industry needs were taken up. R&D projects were tabled before the RC and covered areas from Offshore Wind Turbine Technology to Small Wind Turbine Technology. The Council gave its approval and suggested improvements in the projects.
- The unit has contributed towards the drafting of the Energy Storage Mission document as desired by MNRE in the specific area of Standards and Testing. The draft prepared by NIWE as the lead author had been circulated to India Energy Storage Alliance (IESA), National Institute of Solar Energy (NISE) and Central Electricity Authority (CEA), the other members in the sub committee. Final draft is presently under circulation for comments by MNRE.
- The division is presently working to build its skills in the area of Data Analytics, Design Thinking, Machine Learning and Internet of things, which are foreseen as Critical areas of expertise that NIWE will need in this era of big Data.
- The IT division is moving towards creating a lean and efficient infrastructure to enable its personnel for better working environment and Productivity.

INFORMATION, TRAINING AND CUSTOMIZED SERVICES

21st International Training Course

The ITCS unit had successfully conducted the 24 days 21st International Training Course on “Wind Turbine Technology and Applications” during 31st January to 23rd February 2018 which was sponsored by Ministry of External Affairs, Government of India under ITEC programme. This course was attended by 28 participants from 15 different countries (Afghanistan, Azerbaijan, Egypt, Ethiopia, Jordan, Kenya, Malawi, Morocco, Nepal, Nigeria, Palestine, Peru, Russia, Syria and Zimbabwe).

Dr. K. Balaraman, Director General, NIWE, Chennai had inaugurated training course and released the Course Material.



Course Material release during Inauguration

The content of this course was carefully updated for the current industrial requirements and 39 classroom lectures were delivered and handled by NIWE scientists and external experts, Wind Turbine Manufacturers, Wind Farm and Developers, Consultants, Academicians, Utility and IPP to provide complete knowledge transfer. Practical training were arranged at NIWE Laboratories, study visits to (i) Large Wind Turbine manufacturing factory to M/s. RRB Energy Limited, Chennai (ii) Centralized Monitoring Station (CMS) of M/s. Suzlon Wind Farm at Radhapuram, Tamil Nadu, India (iii) M/s. Sridi Saai Engineering Agency, Tirunelveli (iv) M/s. Wind World control room, Vagai Kulam. During the study visit, the participants had listened to the industry experts who are actually in the process of making wind turbines and also visited the manufacturing facilities.

As part of the study tour, all the participants had travelled to southern part of Tamil Nadu to visit Wind Turbine Test



Course Certificates distributed by Dr. K. Balaraman

Station and Wind Turbine Research Station located at Kayathar, a Unit of NIWE. They have learnt about small and large wind turbine testing process and also visited wind farms in and around Kayathar and Kanyakumari, where wind turbines are installed in large numbers like coconut trees. The participants also enjoyed cultural visits as it revealed spiritual heritage of India.

Dr. K. Balaraman distributed the course certificates to all the participants during Valedictory Function. The course was appreciated by the participants on the grade of excellent in terms of lectures, factory and study visits.

Special Training Course for SNA's officials

ITCS unit had successfully conducted the Special Training Course on “Wind and Solar Resource Assessment Technology” exclusively for SNA's Officials during 28th February to 7th March 2018. The 8 days course was attended by 18 participants from 9 State Nodal Agencies (Arunachal Pradesh Energy Development Agency (APEDA), Karnataka Renewable Energy Development Limited (KREDL), Kargil Renewable Energy Development Agency (KREDA), Maharashtra Energy Development Agency (MEDA), Renewable Energy Agency, Puducherry (REAP), Tamil Nadu Energy Development Agency (TEDA), Telangana State Renewable Energy Development Corporation (TSREDCO), West Bengal Renewable Energy Development Agency (WBREDA), Zoram Energy Development Agency (ZEDA) had attended the training course. The syllabus of the course had covered various aspects of wind and solar Resource assessment & Techniques. The lectures were delivered by the NIWE Scientists and Engineers and several external experts on diverse wind energy areas.



SNA Officials during study visit at WTRS, Kayathar

Besides the class room lectures, practical sessions were

also arranged in the NIWE laboratories and explanation about the NIWE facilities were also given. A study visit to Wind Turbine Test Station / Wind Turbine Research Station, Kayathar was arranged during 2nd to 5th March 2018 for getting exposure on small and large wind turbine testing process, practical knowledge on various working wind turbines apart from visiting wind farms in and around Kayathar and Kanyakumari.

22nd National Training Course



Release of Course Material during Inaugural

ITCS unit had successfully conducted the 5 days 22nd National Training Course on “Wind Energy Technology” during 12th to 16th March 2018 to address all aspects of Wind Power starting from introduction to wind and its technology, wind resource assessment, installation, operation and maintenance aspects of wind farms along with financial analysis in a focussed manner. The course was attended by 24 participants from 7 States (Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Tamil Nadu and Uttar Pradesh) with diverse background.



Shri. Bhanu Pratap Yadav, Joint Secretary, MNRE distributed the Course Certificates

Special Training Course for National Power Training Institute, Faridabad

ITCS unit had successfully conducted a Special Training Course for PG Diploma course students of National Power Training Institute, Faridabad during 12th to 30th March 2018. The class room training was imparted along with the 22nd National Training Course during 12th to 16th March 2018 and the part of practical / hands on session were conducted at NIWE laboratories as well as at WTRS/WTTS, Kayathar. A study visit and practical training at Wind Turbine Test Station / Wind Turbine Research Station, Kayathar and visit to Wind Farms in around Kanyakumari were arranged during last week of the training course.



Glimpses of NPTI Training

Students Internship / Project Work

Many applications received for doing Internship and final year project work at NIWE were processed during the month of January, the following students were given permission and have reported at NIWE.

Internship:

1. A.R. Ajith Kanna (ID:14ME002),
2. Aravind A (ID:14ME008),
3. Arun .A (ID:14ME011),

BE- Mech. final year (7th Sem.), SNS College of Tech., Coimbatore- 641 035 under Director & Head, Standards & Certification Unit, NIWE

Project Work:

The following students of Veltech University, Chennai did their project work:

1. Mr. Band Reddy, Hema Sri Datta Akil (ID:VtU5698)

2. Mr. J. Sharath (ID:VtU5230) and
3. Mr. Musaligari Ajay Reddy (ID:VtU5576), B.Tech (ECE) under Dr. G. Giridhar, Deputy Director General & Group Head, SRRA Unit, NIWE
4. Mr. Krishnan (ID:VtU5211) and
5. Mr. Sandeep Yadav (ID:VtU5110) B.Tech (Mech.), under Shri. Mathew, Director & Head (Testing & Forecasting).
6. Mr. Mudit Gupta (ID 14127100), B. Tech (Mech.) Final Year, Hindustan University, Padur, Chennai under the Guidance of Mr. Raj Kumar, Deputy Director (Technical), Standards & Certification (S&C).

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 January to March 2018, the following visits were coordinated and facilities of NIWE showcased and explained.

- 70 participants of the Entrepreneurship Awareness Camp (EAG), funded by DST-NSTEDB, GoI, organised by Prathyusha Engineering College, Chennai on 6th January 2018
- 50 training participants (Govt. Polytechnic teachers) of the Short Term Courses "Non Conventional Energy Sources and Electrical and Electronics systems in wind and solar energy applications", organised by National Institute of Technical Teachers Training & Research, Chennai on 10th January 2018.
- 40 (Higher Secondary School / Undergraduate – B.Sc.) students under DST – INSPIRE 2018, organised by SRM Institute of Science & Technology, Chennai on 11th January 2018.
- 55 students from Dept. of Electronics & Instrumentation Engineering, Pondicherry Engineering College on 12th January 2018.
- 51 BE(CS) students from Apollo Engineering College, Chettipedu Village, Kanchipuram on 19th January 2018.
- 30 training participants (Govt. Polytechnic teachers) of the Short Term Course "Renewable Energy Sources", organised by National Institute of Technical Teachers Training & Research, Chennai on 30th January 2018.
- 7 students from Taiwan under International Internship Training program at SEEK Foundation on 5th February 2018.

- Ms. Nikitha Prasad, PG Diploma Course student of Asian College of Journalism, Administered by the Media Development Foundations, Chennai on 6th February 2018.
- 25 training participants (Govt. Polytechnic teachers) of the Short Term Course “Renewable Energy Sources”, organised by National Institute of Technical Teachers Training & Research, Chennai on 16th February 2018.
- 25 training participants (Govt. Polytechnic teachers) of the Short Term Course “Energy for Rural Development”, organised by National Institute of Technical Teachers Training & Research, Chennai on 1st March 2018.
- 30 training participants of the program “Suryamithra” from G M Shiptech Training Private Limited, Chennai on 16th March 2018.

Joint Secretary, Ministry of External Affairs (MEA) Visit

Mr. Acquino Vimal, Joint Secretary (CNV&I), Ministry of External Affairs, New Delhi visited NIWE on 22nd January 2018 for inspection and to review the ITEC Programmes

offered as well as the available infrastructure at NIWE. The visit held as per the schedule. DDG and Group Head, F&A and ESD received the Joint Secretary and Dr. P. Kanagavel, Additional Director and Course Coordinator for ITEC Training programmes, explained the activities of NIWE in performing the ITEC Training courses to the Joint Secretary, MEA and the facilities of NIWE were also showcased. The Joint Secretary met the Director General. The Course coordinator, ITEC Training programmes, NIWE along with the Group Head of R&D, IT and ITCS discussed in detail and provided the information materials required by the Joint Secretary.

Governing Council Meeting

The 41st Meeting of the Governing Council of NIWE held on 17.03.2018 (Saturday). In this connection, Chairman, Shri. Anand Kumar, I.A.S. Secretary, MNRE, New Delhi; Ms. Gargi Kaul, I.A.A.S. Additional Secretary & Financial Adviser, MNRE, New Delhi, Member and Shri. Bhanu Pratap Yadav, I.A.A.S. Joint Secretary (Wind Energy) MNRE, New Delhi, Member attended the meeting and visited the facilities / Units of NIWE.



NIWE Foundation Day 2018

NIWE has celebrated its 21st Foundation Day on 21st March 2018. As a part of Foundation Day celebration, this day was announced as an 'Open Day' for general public to visit the scientific laboratories of NIWE - Solar Station, Met-Mast, Biogas plant, Wind Turbine Nacelle, Wind Solar Hybrid System etc., between 9.30 am and 12.30 pm. An Advertisement inviting Public to Visit NIWE's facilities was given in Daily Thanthi and New Indian Express on 20.03.2018. The visitors were well received by the volunteers of NIWE from different groups deputed for this purposed and explained the facilities of NIWE. Also, NIWE had celebrated the first Year of the Awards Instituted by NIWE under the sponsorship of IREDA namely IREDA-NIWE Annual Awards for Wind Energy. The NIWE Foundation Day was celebrated in two sessions as follows:

- Session I (2.00 pm to 3.30 pm) - IREDA & NIWE award in Wind Energy
- Session II (04.30 pm to 5.30 pm) - NIWE Foundation Day Celebration

The first session of Award Ceremony of IREDA-NIWE Awards for Wind Energy 2018 is detailed separately.



Glimpses of 21st Foundation Day of NIWE

During the second Session, Dr. K. Balaraman, Director General, NIWE has distributed mementos to the regular staff and also those who had not availed leave during the year. He had given the awards to the wards of NIWE Employees who had secured Centum of Marks in various subjects of the Board Examinations under NIWE Welfare fund scheme.

IREDA – NIWE Awards for Wind Energy 2018

Indian Renewable Energy Development Agency (IREDA), New Delhi signed a Memorandum of Understanding (MoU) with NIWE for the creation of a Corpus for the IREDA-NIWE Annual Awards in Wind Energy. The Awards are to promote innovation, research & development, manufacturing, developing & harnessing Wind Energy at the State and National levels and to motivate individuals, stakeholder to strive for the best in the field.

Accordingly, during 2017-18, NIWE has instituted the IREDA-NIWE Annual Awards in Wind Energy, under the following three broad categories in Wind Energy to recognize, celebrate the achievement and excellences:

- (i) IREDA-NIWE Award for the Best Performing State Nodal Agencies for the Year
- (ii) IREDA-NIWE Award for the Best Institution of Higher Learning in Wind Energy and
- (iii) IREDA-NIWE Award for the Best Research Work

Calls for Nominations in each category were uploaded in NIWE / IREDA Websites and advertised through national daily Newspapers, and through groups & mass communications inviting nominations. The nominations received and selection of the awardees of all the three categories for the IREDA-NIWE awards were done through an eminent Jury Committee consisting of Technocrats from the Wind Energy field and Mass Media and approved by Director General, NIWE. The Awardees were informed of their selection and invited to attend the Award Ceremony of the IREDA-NIWE Annual Awards for Wind Energy 2018, scheduled on 21st March 2018 during the Foundation Day of NIWE, to receive the Award.

Smt. Gargi Kaul, IAAS, Additional Secretary and Financial Adviser, MNRE was the Chief Guest and Shri. Chintan N. Shah, Director-Technical, IREDA was the Guest of Honour at the Awards Function. The Award Ceremony was held during 2.00 - 3.15 p.m. on 21.03.2018, at NIWE Chennai.

The Function started with the welcome address delivered by the Director General of NIWE to the august gathering of professionals and invitees from the Industry, Academia, SNA's and other stakeholders & NIWE staff.

The Chief Guest had delivered the Foundation Day Special Address and the Guest of Honour Mr. Chintan N. Shah delivered the key-note address to the August gathering.

Smt. Gargi Kaul while delivering a succinct address stressing the importance of an enhanced Research Ecosystem which delivers the needs of the RE Sector. She appreciated NIWE for all the efforts put to achieve its targets with reference to renewable energy and encouraged it to further the Research through networking among the various stakeholders in the Wind Sector.



Ms. Gargi Kaul delivering the address

Shri. Chintan N. Shah while congratulating the awardees, stressed the need for a spirited march towards achieving the RE targets of the Ministry and NIWE to explore the possibilities of creating and fostering Research & Business Incubators for new research in Wind Sector and offered all the support from IREDA

The Chief Guest distributed the Awards to the Winners:

(a) The Award for the category of Best performing State Nodal Agencies for the year 2016 -17 was conferred to New & Renewable Energy Development Corporation of Andhra Pradesh Limited (NREDCA) and Shri. M. Kamalakhar Babu, Vice Chairman and Managing Director received the Award with cheque of Rs. 1,00,000/- on behalf of NREDCA which has promoted 2187 MWs of wind power projects in the AP State and the State has stood first in the country for the year 2016-17.



Shri. Kamalakhar Babu receives the Best Performing SNA Award



The Dean of Amrita School of Engineering receives the Best Institution Award

(b) The Award for the Best Institution of Higher Learning in Wind Energy was conferred to Amrita School of Engineering, Coimbatore and the Dean of Amrita School of Engineering, Coimbatore received the Award with cheque of Rs. 1,00,000/- on behalf of Amrita School of Engineering.

(c) The Award for Best Research work in Wind Energy Category was jointly awarded to (i) Ms. Anusha KV, for her research work on "Control of Wind Turbine Driven DFIG in a Stand Alone Micro Grid for Stator Voltage and Frequency Regulation", and



On behalf of Ms. Anusha, her Thesis Adviser receives the Best Research Work Award

(ii) Ms. Vishnupriyadharshini, for her project work on "Wind Speed Forecasting Based on ARIMA & WRF in Today's Power Grid". The two Awardees received the award with cheque of Rs. 50,000/- each.



Ms. Vishnupriyadharshini receives the Best Research Work Award

Also, The Chief Guest has honoured the former NIWE Staff with mementos in connection with the NIWE Foundation Day Celebrations 2018.

Wind Turbine Research Station

- Complete preventive Operation and Maintenance activities like Preparation of Transformer Yard, conditioning of Control Panels, Power Panels, Functionality checks of all the sensors, conditioning of transmission lines & transformers etc. carried out for the Wind Electric Generators installed at WTRS, Kayathar of capacity 6.4 MW comprising nine 30 years old 200 kW MICON, one 600 kW SUZLON, one 2000 kW KENERSYS and one 2000 kW INOX, for the uninterrupted operation of the machines during the windy season 2018.

Visitors

The following visits were coordinated and facilities of Small & Large Wind Turbine Testing, R&D and WRA showcased:

- 28 Delegates of 21st International Training Course on “Wind Turbine Technology and Applications” on 9th February 2018.
- 44 Students and 4 faculties from FX Engineering College, Tirunelveli, Tamil Nadu on 17th February 2018.
- 30 Students and 3 faculties from St. Xavier`s Catholic College of Engineering, Tirunelveli, Tamil Nadu on 2nd March 2018.
- 43 Students and 2 faculties from MEPCO Engineering College, Sivakasi, Tamil Nadu on 2nd March 2018.
- 1 Intensive field exposure training was imparted on Wind Electric Generators, O&M / Met masts measurements and testing of small aero-generators to 8 students and 1 faculty from National Power Training Institute (NPTI), Faridabad, during 26th to 30th March 2018.



Solar Radiation Resource Assessment

Project Activities

- Draft report prepared in connection with the feasibility study at Ramakkalmedu, Kerala submitted to ANERT on 03.01.2018.
- Solar sensors from Similiguda SRRA station in Odisha replaced for calibration and 4 pyranometers are calibrated under commercial mode.
- A team of NIWE officials visited IIM, Trichy on 19.02.2018 for discussion with IIM officials on the implementation of 2 MW Solar Photovoltaic Power plants.
- SRRA officials visited to Charanka SPV solar power plant along with GIZ and German officials on 13.03.2018 & 14.03.2018.
- Prasun Kumar Das visited and inspected 5 SRRA stations in Gujarat and Rajasthan during the period 13.03.2018-16.03.2018.
- Training program on Solar Power Forecasting on capacity building held in NIWE during 16.01.2018-18.01.2018 by Dr. Elena Barykince, Overspeed GmbH, Germany and D. Hans-Peter Waldl, Overspeed GmbH, Germany during 23.01.2018-24.01.2018.
- SRRA jointly with GIZ, arranged a workshop on “Conceptualizing a Virtual Power Plant in India with NIWE” at Chennai on 20.02.2018.

Article continued
from 55th issue of
PAVAN

Energy Storage and Renewable Energy Part - 2

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TECHNOLOGIES

Pumped hydro systems are by far the most widely used. Globally, there are 270 pumped hydroelectric storage (PHS) stations either operating or under construction. This represents a combined generating capacity of over 120,000 megawatts (MW). IRENA's global renewable energy roadmap (REmap 2030) assessed the plans for pumped-storage hydroelectricity in the 26 countries and suggests that the total capacity will increase to 325 GW in 2030. The highest percentage of undeveloped potential is located in Africa (92%), followed by Asia (80%), Oceania (80%) and Latin America (74%). However, large hydro projects encountered a substantial opposition in the latter end of the last century because of their environmental and social implications which led to the slowdown in the hydroelectricity generation between the late 1990s and the early 2000s [IEA, Technology Roadmap, 2012; IEA, Key World Statistics, 2012]. With its strength as a balancing asset for VRE facilities, pumped storage technology is enjoying a renaissance of interest. [<https://www.hydroworld.com/industry-news/pumped-storage-hydro.html>].

Pumped hydroelectric storage facilities store energy in the form of water in an upper reservoir, pumped from another reservoir at a lower level. During periods of high electricity demand, power is generated by releasing the stored water through turbines like a conventional hydropower station. During periods of low demand (usually nights or weekends when electricity is also at lower cost), the upper reservoir is recharged by using lower-cost electricity from the grid to pump the water back to the upper reservoir. Reversible pump-turbine/motor-generator assemblies can act as both pumps and turbines. These plants are typically highly efficient (round-trip efficiencies reaching greater than 80%) and can prove very beneficial in terms of balancing load within the overall power system. Pumped-storage facilities can be very economical if peak and off-peak price differentials are exploited and their potential to provide critical ancillary grid services. A pumped storage project would typically be designed to have 6 to 20 hours of hydraulic reservoir storage for operation

Several variations of PHS are also being attempted:

- Variable Speed Pumped Hydroelectric Storage
- Sub-Surface Pumped Hydroelectric Storage (e.g., sea water)
- Surface Reservoir Pumped Hydroelectric Storage

The last two technologies would require building only one reservoir.

An unconventional PHS (inverse offshore pump accumulation station (IOPAC)) which is a seawater PHS combined with an offshore wind power plant has been described [De Boer, W.W.,

Verheij, F.J., Zwemmer, D. and Das, R., The Energy Island – An Inverse Pump Accumulation Station, in EWEC 2007, European Wind Energy Conference, 2007]. Yet another unconventional PHS system in Estonia involves combination of two different unconventional reservoirs: the sea as upper reservoir and underground chambers, resulting from granite excavations, as lower reservoir [Project ENE 1001, Brief Description of the Muuga Sewer-Pumped Hydro Accumulation Power plant, 2010: http://energiasalv.ee/wp-content/uploads/2012/07/Muuga_HAJ_17_02_2010_ENG.pdf; Pérez-Díaz, J.I., Cavazzini, G., Blázquez, F., Platero, C., Fraile-Ardanuy, J., Sánchez, J.A. and Chazarra, M., Technological developments for pumped-hydro energy storage, Technical Report, Mechanical Storage Subprogramme, Joint Programme on Energy Storage, European Energy Research Alliance, May 2014].

Indian Scenario:

There was no pumped storage scheme/unit in operation India till Fifth Five year Plan. Nagarjunasagar PHS system was the first one to be installed in India which has six units of 100 MW each, the Paithan project in Maharashtra has 1 *12 MW PHS, Kadampari (4*100 MW), Kadana Stage I (2*60MW), Panchat Hill unit 2 (1* 40 MW). The total installed Pumped storage capacity was 614 MW in 6th plan; 1112 MW in 7th Plan and 1494 MW at the end of 8th five year plan (1992-97). The Sardar Sarovar Dam is a gravity dam on the Narmada River near Navagam, Gujarat, India. The dam's main power plant houses SIX 200 MW Francis pump-turbines to generate electricity and afford a pumped-storage capability. The Tehri Dam is a multi-purpose rock and earth-fill embankment dam on the Bhagirathi River near Tehri in Uttarakhand, India. Phase 1 was completed in 2006, the Tehri Dam withholds a reservoir for irrigation, municipal water supply and the generation of 1,000 MW of hydroelectricity. Two more phases with an additional 400 MW run-of-the-river and 1000 MW pumped storage hydroelectricity are under construction. The Purulia Pumped Storage Project of West Bengal State Electricity Distribution Company Ltd (WBSEDCL) has 4 units of 224 MW each. This project can generate 900 MW power instantly by discharging stored water from Upper dam to Lower Dam through reversible pump-turbine and generator motor. In Hydro storage, India has about 5000 MW out of which 3000 MW are under various stages of commissioning (Sardar Sarovar dam, The Teri project, Purulia project). One of the most significant pumped hydro storage projects currently underway is Sillahalla, a 7,000-crore-rupees (\$1.5 billion), 2-gigawatt plant in the Nilgiris District of Tamil Nadu. This project involves construction of a dam across the Sillahalla River and a 2.75-kilometer tunnel connecting it to the existing Avalanche-Emerald reservoir. Other pumped hydro projects known to be under consideration include the 1-

gigawatt Turga project in West Bengal, the 600-megawatt Upper Indravati plant in Odisha, and a 450-megawatt development based around the existing Kundah hydro stations in Tamil Nadu. In all, there are 11 developed PHS sites (4804 MW), 6 sites under development (3680 MW) and 63 sites identified (96524 MW) in India. Recently CEA has announced plans for 10 gigawatts of pumped hydro storage across the country to help store the massive levels of renewable energy it will be producing within a decade. The plan will cost 80,000 crore rupees (about \$17.2 billion) over the next five to six years. The capital costs of the plants would be between 6 and 8 crore rupees (\$1.3 million and \$1.7 million) per megawatt. The pumped hydro projects would also be a boon for the grid. These 10 gigawatts of pumped storage will complement, and not replace, chemical storage. [<https://www.green-techmedia.com/articles/read/india-to-build-pumped-hydro-storage-for-solar#gs.1Vf1Nv0>].

Compressed Air Energy Storage (CAES)

CAES is another technology which is gaining lot of importance in recent years. Round trip efficiency of more than 70% has been realized in smaller systems. CAES offers the potential for small-scale, on-site energy storage solutions as well as larger installations that can provide immense energy reserves for the grid. CAES plants are similar to PHS in terms of their applications, output and storage capacity. But, instead of pumping water from a lower to an upper pond during periods of excess power, in a CAES plant, ambient air is compressed and stored under pressure. When electricity is required, the pressurized air is heated and expanded in an expansion turbine driving a generator for power production. Some of the variations of CAES are :

- Advanced Adiabatic Compressed Air Energy Storage (AA-CAES) is an evolution of traditional CAES, designed to deliver higher efficiencies. Operation is similar to traditional CAES in that energy is stored by compressing air with turbomachinery and storing in an underground cavern. The difference lies in the treatment of the heat of compression.
- Isothermal compressed air energy storage (CAES) is an emerging technology which attempts to overcome some of the limitations of traditional (diabatic or adiabatic) CAES.

There have been only very few demonstrations of this technology.

- 290 MW plant belonging to E.ON Kraftwerke, Huntorf, Germany, built in 1978, and
- 10 MW plant of AEC (Alabama Electric Corporation) in McIntosh, Alabama, USA, commissioned in 1991. AEC's plant recuperates heat from the compression process and stores the heat for the turbine stage of new power production. The storage cycle efficiencies are typically 40–50%.
- Huntorf uses a 0.3 million m³ underground cavern.
- An Isothermal Compressed Air Energy Storage System has been established by SustainX at New Hampshire to store four megawatt-hours worth of energy in transportable 40-foot long containers,

- Instead of storing the compressed air in caverns, Hydrostar developed in Canada stores compressed air in balloons which are submerged in sea. In Hydrostar's system, excess energy from solar or wind charges an air compressor. The compressed air is cooled before it shoots down a tube and out to massive balloons. Just like blowing up a balloon on land, the air fills up the balloons in the ocean, but because of the pressure of water pushing down, the air inside compresses. The deeper the balloons, the more air they can hold. [<https://www.engerati.com/energy-management/article/energy-storage/sea-eggs-promising-compressed-air-energy-storage>]. To release the energy, operators open an onshore valve and the overlying water forces the air out, which spins a turbine to generate power. Sitting under roughly 55m of water, Hydrostar's six test balloons measure 9m tall and 5m wide. They are made of a urethane-coated nylon, which is the same material used to haul shipwrecks from lake and sea floors – a fabric that can withstand a good deal of force from air deep underwater. Hydrostar's balloons hold a fairly small amount of energy. The generators are capped at roughly 1MW.
- A variation of the same concept is the Stored Energy in the Sea (StEnSEA) device developed by Fraunhofer Institute in Germany. It is a large concrete sphere – named a 'sea egg' – which is heavy enough to sit in deep water (600m to 800m) without anchors and generates energy when flooded. Each sphere is about 30m in diameter with 3m thick walls [<https://www.engerati.com/energy-management/article/energy-storage/sea-eggs-promising-compressed-air-energy-storage>].

In India, CAES technology is still to take off. Few laboratory studies have been reported.

Superconducting Magnetic Energy Storage (SMES)

Superconducting Magnetic Energy Storage (SMES) technology stores electricity from the grid within the magnetic field of a coil comprised of superconducting wire with near-zero loss of energy. A typical SMES consists of two parts – cryogenically cooled superconducting coil and power conditioning system – which are motionless and result in higher reliability than many other power storage devices. Ideally, once the superconducting coil is charged, the current will not decay and the magnetic energy can be stored indefinitely. [<http://www.superpower-inc.com/content/superconducting-magnetic-energy-storage-smes>]. Modular units can address both long term (hours) and short term (seconds) storage requirements to help load levelling on the grid being fed by variable renewable sources such as solar and wind. Exceeding roundtrip efficiency requirements at 85%, SMES can have both energy storage and dynamic compensation capabilities due to the nearly instantaneous dynamic response of the superconducting coil. SMES systems are highly efficient; the round-trip efficiency is greater than 95%. Due to the energy requirements of refrigeration and the high cost of superconducting wire, SMES is currently used for short duration energy storage. Therefore, SMES is most commonly devoted to improving power quality. If SMES were to be

used for utilities it would be a diurnal storage device, charged from base load power at night and meeting peak loads during the day.

The global market for superconducting magnetic energy storage demonstrates a highly competitive structure. Some of the key players in the market are Columbus Superconductors SpA, GE Corporation, American Superconductor Corporation, Sumitomo Electric Industries, Nexans SA, and SuperPower Inc. [<https://www.tmrresearch.com/superconducting-magnetic-energy-storage-market>]. SuperPower Inc., in partnership with ABB Inc., Brookhaven National Laboratory (BNL) and the Texas Center for Superconductivity (TcSUH) at the University of Houston is developing an advanced SMES device. This project is expected to demonstrate a 20 kW ultra-high field (UHF) SMES system with a capacity up to 2 MJ class; Field of up to 25 T at 4.2K, Capability of flexible and direct deployment in medium voltage distribution networks at 15-36 kV and 2G HTS wire with high critical currents

In India SMES technology development is not very popular. Modelling studies on use of SMES have been reported from Indian Universities. Scientists at BARC reported several years back, development of low temperature superconductor (Nb-Ti) which can find application in Superconducting Magnetic Energy Storage system (SMES).

Flywheel Energy Storage System (FESS) - A flywheel is a mechanical solution for storing electrical energy in the form of kinetic energy in a rotating mass. FESS is increasingly important to high power, relatively low energy applications. They are especially attractive for applications requiring frequent cycling given that they incur limited life reduction if used extensively (i.e., they can undergo many partial and full charge-discharge cycles with trivial wear per cycle.) Flywheels can be "charged" with AC or DC if designed to do so. Generators generate AC. Batteries can only be charged with DC (which means not alternating), and a consequence of that is that the power from generators has to be converted from AC to DC with a rectifier and then the batteries supply DC power to a device which converts it back to AC. There is a cost associated with the batteries and the rectifier and energy is lost in this process as well.

Currently, high-power flywheels are used in many aerospace and UPS applications. 2 kW / 6 kWh systems are being used in telecommunications applications. For utility-scale storage a 'flywheel farm' approach can be used to store megawatts of electricity for applications needing minutes of discharge duration. FESS may also be valuable as a subsystem in hybrid vehicles that stop and start frequently as a component of track-side or on-board regenerative braking systems.

Beacon Power, USA demonstrated in 2008 FESS for utility frequency regulation for power grid operations. The storage systems are designed to help utilities match supply with varying demand by storing excess power in arrays of 2,800-pound (1,300 kg) flywheels at off-peak times for use during peak demand. However this company is now reported to be bankrupt.

Few years back, two Indian companies in collaboration with partners in UK and France were offering flywheel solution for storing energy in UPS market.

- PCI LTD in technology partnership with Piller Germany GmbH which is a wholly owned subsidiary the global UK engineering group Langley Holdings plc.. PCI in India is involved in providing power protection systems. They offer Rotary UPS System ranging from 625 KVA to 50 MVA. However the present status is not known
- Several years back Numeric Power Systems Ltd. (Presently Swelect Energy System) had a business relationship with Active Power to distribute its Clean Source DC flywheel energy storage systems in India. The Clean Source DC acts as a replacement or supplement to batteries in uninterruptible power supply (UPS) systems, and is available in several power ratings ranging from 100 kW to 2000 kW. However the present status is not known

There are also reports of Indian automobile industries using flywheel in regenerative braking.

Super capacitors (Ultracapacitors) :

Conventional Electrochemical capacitors which stores electrical energy in the form charges on the electrodes have evolved into Supercapacitor or ultra-capacitor which use high surface area materials and also specific electrolytes to storage increased amount of energy. Typically, the supercapacitors are useful in storing very small amount of energy but discharge them at very high rate allowing them for use in applications which requires very high speed energy delivery. There are two types of ECs: those with 1) symmetric designs, where both positive and negative electrodes are made of the same high-surface-area carbon and 2) asymmetric designs with different materials for the two electrodes, one high-surface-area carbon and the other a higher capacity battery-like electrode. Symmetric ECs have specific energy values up to ~6 Wh/kg and higher power performance than asymmetric capacitors where designs having specific energy values approach 20 Wh/kg. There are other differences in the characteristics and performance of these two types leading to use in different applications.

Symmetric ECs have response times on the order of 1 second and are well-suited for short duration high-power applications related to both grid regulation and frequency regulation. Asymmetric ECs are better suited for grid energy storage applications that have long duration, for instance, charge-at-night/use-during-the-day storage (i.e., bulk energy storage). Some asymmetric EC products have been optimized for ~5 hour charge with ~5 hour discharge. Advantages of ECs in these applications include long cycle life, good efficiency, low life-cycle costs, and adequate energy density.

However it is to be noted that demonstration of super-capacitors in large capacity storage applications is still a long way. There have been demonstrations of supercapacitor powered electric buses in China, USA, Germany and other countries.

In India, super capacitor development is mainly focussed towards materials development. Supercapacitors of large capacity have been developed by some defence and space laboratories but have not reached commercial level. A company in Pune (Surya

Powerfarad Energy Limited) has developed supercapacitor for commercial purposes in recent times using home grown technology. These have been successfully demonstrated in many mobile applications.

Electrochemical Energy Storage:

Secondary batteries are already in use in UPS and inverter/ back-up power applications in small capacities. Of the six types of secondary batteries, (lead acid, NiCd/NiMH, Li-ion, metal air, sodium sulphur and sodium nickel chloride) [International Electrotechnical Commission White Paper Electrical Energy Storage- IEC WP-energy storage-LR-en, 2011] lead acid batteries have been used in storing wind and solar energies in 100s of kW level owing to its easy availability and low cost. The Na-S Battery has been demonstrated in storing wind energy especially in Japan. In the last few years Li-ion batteries are being projected as storage devices for large scale VRE applications. Two types of flow batteries [redox flow batteries, hybrid flow battery] have also been investigated for energy storage.

IRENA's, in their renewable energy roadmap (REmap 2030), has reported the potential of batteries in storage applications. This is based on the country-by-country analysis of electric vehicle sales of around 80 million vehicles by 2020, and the assumption that the discarded batteries of these vehicles would become available after 2028. The total available battery storage capacity available would be around 250 GW, conservatively assuming that 50% of these batteries would be used for second-life applications, and that only 10% would be available to support the integration of renewables. Considering a total installed VRE capacity of 2885 GW by 2030, REmap 2030 suggests that 5% (or 150 GW) of the VRE capacity would be supported by second-life batteries. Navigant Research estimates that around 20 gigawatt-hours (GWh) out of 50 GWh of advanced battery storage systems in the utility sector will be supporting the integration of renewables. (Jaffe, S., & Adamson, K. (2014), Advanced Batteries for Utility-Scale Energy Storage. Navigant Research. Boulder, CO. <https://www.navigantresearch.com/research/advanced-batteries-for-utility-scale-energy-storage>)]

Sodium Sulfur (NAS) Batteries

One of the earliest examples of rechargeable batteries that was demonstrated for energy storage is the Sodium Sulphur (NaS) batteries. These high temperature batteries have been deployed in MW level. The active materials in a Na/S battery are molten sulfur as the positive electrode and molten sodium as the negative and the electrolyte being sodium aluminate, a ceramic which has the ability to allow migration of the sodium ions from anode to cathode. During charging, this process is reversed. The battery must be kept hot to facilitate the process (independent heaters are part of the battery system). In general Na/S cells are highly efficient (typically 89%). Earlier models of NaS batteries operated at above 600°C limiting their application as suitable for continuous use. Improvements in electrolyte conductivity reduced the temperature of operation to ~350°C. Further breakthrough

research has reported operating these batteries at more comfortable 120°C.

NaS battery technology has been demonstrated at over 190 sites in Japan. More than 270 MW of stored energy suitable for 6 hours of daily peak shaving have been installed. The largest NaS installation is a 34-MW, 245-MWh unit for wind stabilization in Northern Japan. Several installations have also been reported in USA and South Korea.

Indian effort in development NaS batteries is not much except for some attempt to make low temperature electrolytes for use in NaS cells. The high temperature electrochemistry knowledge has to increase. Recent exploits in Solid Oxide Fuel Cells could pave way for interest in high temperature solid state batteries to increase.

Lithium Batteries:

Rechargeable batteries which use lithium (ion) as one of the electrodes are being extensively used in several consumer devices and in recent times in electric vehicle applications, UPS & others owing to several advantages/features such as high voltage per cell, high power and energy density, light weight etc. Variants such as Li-polymer batteries, Li-air batteries have also been reported. Advances in materials used in these batteries continue to improve their performance.

Li ion cells with lithiated metal oxide and carbon electrodes have high cell voltages (typically 3.6 V to 3.7 V) and correspondingly high energy density. These technologies have widely differing life and safety characteristics. Cells with lithium iron phosphate are inherently safer than their metal oxide/carbon counterparts but the voltage is lower (around 3.2 V), as is the energy density. Designs with lithiated metal oxide and lithium titanate electrodes have the lowest voltage (around 2.5 V) and low energy density but have much higher power capability and better safety. Li-ion batteries of few kilo watt capacity have been deployed in recent times in energy storage applications such as in residential systems with rooftop photovoltaic arrays. In the last one year there have been demonstration of Li-ion batteries as storage device in MW level solar and wind energy installations in Australia, USA, many countries in Europe, Japan, S Korea etc. The operation details and experience with these systems are slowly trickling out. Safety is a major concern for Li-ion batteries regardless of the electrochemistry involved. Availability of lithium is another major concern as the ores are controlled by few countries. Since electric mobility and portable electronics are a high volume markets, availability of Li batteries for large scale storage applications is doubtful. In addition, the cost of the batteries is also an area of concern.

In India a large number of laboratories are engaged in developing Li Ion batteries. However most of the work is restricted to material development and depend on imported materials. Although a large amount of money has been invested in developing these batteries, the results are rather disappointing. Assembly of batteries for vehicular, space and defence applications is being carried out in few national and strategic sector laboratories.

Many Indian automobile industries who are engaged in electric vehicle program have some programs on Li battery development although their demonstrations are depended on imported Li batteries. Li batteries for energy storage applications is being discussed. But cost is a major concern. No major battery industry is involved presently although there was a company engaged in Li battery production in the early 2000.

One of the success story is the development of Li ion batteries for space application by ISRO. Recently, ISRO has announced that they will transfer technology to BHEL for manufacturing of Li ion batteries for electric vehicle applications. In collaboration with foreign companies/ universities, some Indian companies are developing low cost Battery Management Systems (BMS) for Li battery application.

Redox Flow Batteries (RFB)

Other battery technologies that are being used for storage applications, albeit at low KW level include several types of flow batteries (Vanadium redox, Fe-Cr, Zn-Br, Zn-Cl). Unlike in other batteries where the energy is normally stores in the electrodes, in RFB the energy is stores in the electrolyte which contains the materials that undergo the oxidation /reduction reaction. The voltage developed by the RFB is specific to the chemical species involved in the reactions and the number of cells that are connected in series. The current developed by the battery is determined by the number of atoms or molecules of the active chemical species that are reacted within the cells as a function of time. In some sense RFB is similar to fuel cells.

RFB's can be classified into two types:

- true redox flow batteries, where all of the chemical species active in storing energy are fully dissolved in solution at all times; and
- hybrid redox flow batteries, where at least one chemical specie is plated as a solid in the electrochemical cells during charge.

Redox flow batteries are suitable for energy storage applications with power ratings from 10's of kW to 10's of MW and storage durations of 2 to 10 hours. Some of the disadvantages that are associated with RFBs are lower volumetric energy. especially in the high power, short duration applications and self discharge. This is due to the volume of electrolyte flow delivery and control components of the system, which is not used to store energy.

There have been some recent R&D activities on REDOX flow batteries in India. Once again the R&D is on materials rather than system development. It would take several years before they can reach high capacity levels. An Indian company offers an upto 5 kW redox flow battery solution for UPS applications using a NASA technology.

Chemical Storage :

Storing electrical energy in the form of chemicals is another subject of great importance. Under this category, Hydrogen is being considered as an ideal storage system in renewable energy

sector. Hydrogen and Electricity complement renewable energy sources particularly well, by presenting them to the end user in a convenient form and at a convenient time. Wind farms would become multi-purpose, decentralized producers of either electricity or hydrogen for fuel when the automotive industry enters mass production of hydrogen-fueled vehicles.

UNIDO has sponsored several projects on using hydrogen as an energy vector especially in Islands where different forms of energy can be coupled. Hydrogen generation from wind energy is considered to be one of the best options to address the variable nature of wind energy. The hydrogen thus generated could be used not only for generating power when needed using ICEs or fuel cells but also used in fuel cell powered electric vehicles. Offshore wind for hydrogen production has also been demonstrated. In addition to power- power programs, in recent times use of wind hydrogen to produce transport fuels is gaining importance especially in Europe where nearly 30 power to gas projects are under way. These projects include studies on provide link between power and gas grid, Blending hydrogen into Gas Grid which offers potentially high store capacities even at low blend share and use the hydrogen to convert biogas to methane or methanol.

Thermal Storage :

Thermal energy storage (TES) technologies allows to store the energy produced in the form of heat or cold for use at a different time. There are several TES technologies in the offing. TES technologies operate in the generation and end-use steps of the energy system and can be grouped by storage temperature: low, medium, high. Thermal storage technologies are well suited for an array of applications including seasonal storage on the supply-side and demand management services on the demand-side portion of the energy system [IEA-ETSAP, 2013- IEA-ETSAP (Energy Technology Systems Analysis Programme and IRENA (2013) "Thermal Energy Storage", Technology Brief E17, Bonn, Germany]. As heating and cooling requirements represent 45% of the total energy use in buildings in the western world, these demand-side services can represent significant value to the energy system [IEA, 2011- Technology Roadmap: Energy Efficient Buildings: Heating and Cooling Equipment, OECD/IEA, Paris, France].

Several approaches have been reported. Seasonal thermal energy storage (or STES) wherein the storage of heat or cold is for periods of up to several months. There are several types of Seasonal thermal energy storage (STES) technology, covering a range of applications from single small buildings to community district heating networks. Generally, efficiency increases and the specific construction cost decreases with size. UTES (underground thermal energy storage), in which the storage medium may be geological strata ranging from earth or sand to solid bedrock, or aquifers. UTES technologies include: ATES (aquifer thermal energy storage);BTES (borehole thermal energy storage);CTES (cavern or mine thermal energy storage) and Energy Pilings. Other

methods reported are Pit storages, Large-scale water storages, Horizontal heat exchangers and Earth-bermed buildings.

Energy from the solar thermal plant can be stored in the form of molten salts and can be used to generate steam to drive a turbine whenever required. Alternatively, a facility can use 'off-peak' electricity rates which are lower at night to produce ice, which can be incorporated into a building's cooling system to lower demand for energy during the day.

Today's R&D in thermal energy storage is primarily focused on reducing the costs of high-density storage, including thermochemical process and phase-change material (PCM) development [European Association for Storage of Energy [IEA-ETSAP, 2013- IEA-ETSAP (Energy Technology Systems Analysis Programme) and IRENA (2013), "Thermal Energy Storage", Technology Brief E17, Bonn, Germany].

Thermal energy storage for low-temperature (<10°C) applications

Cold-water storage tanks in commercial and industrial facilities are already installed around the world to supply cooling capacity. Due to the higher energy storage densities seen with PCMs compared to sensible heat storage, the United States and Japan have already installed significant amounts of thermal storage that uses ice for cooling applications. In the United States, an estimated 1 GW of ice storage has been deployed to reduce peak energy consumption in areas with high numbers of cooling-degree days [O'Donnell and Adamson, 2012, Thermal Storage for HVAC in Commercial buildings, District Cooling and Heating, Utility and Grid Support Applications, and High-Temperature Storage at CSP Facilities, Pike Research, New York, United States].

Beyond water, significant R&D activities have been dedicated to developing other PCMs for the transportation of temperature sensitive products. Thermochemical storage – where reversible chemical reactions are used to store cooling capacity in the form of chemical compounds – is currently a focus in thermal storage R&D projects due to its ability to achieve energy storage densities of 5 to 20 times greater than sensible storage.

Thermal energy storage for medium temperature (10°C-250°C) applications

Distributed thermal energy storage has been around for decades in countries such as New Zealand, Australia and France that use storage capabilities in electric hot water storage heaters. By allowing the heater system to be controlled by the local utility (or distribution company in cases with market liberalisation), the demand from these systems is used to manage local congestion and has reduced residential peak demand. In France, for example, thermal storage capabilities in electric water heaters are used to achieve a 5% annual peak reduction

Borehole and aquifer UTES systems have been successfully deployed on a commercial scale to provide heating capacity in the Netherlands, Norway and Canada. These systems utilise holes drilled deep into the ground to store and release energy for heating. Pit storage – where hot water is stored in a covered pit – is used throughout Denmark's district heating networks.

Thermochemical storage systems can be designed to discharge thermal energy at different temperatures, making them an appealing option for medium temperature thermal energy storage applications. As with low-temperature applications, this storage mechanism's relatively high energy density potential has prompted significant R&D efforts.

Thermal energy storage for high-temperature (>250°C) applications

The most well-known form of thermal energy storage for high-temperature applications is currently found in molten salts. This material is used to increase the dispatchability of power from CSP facilities by storing several hours of thermal energy for use in electricity generation [IEA (2010), Technology Roadmap: Concentrating Solar Power, OECD/IEA, Paris, France] However, these technologies will need to overcome containment vessel design and material stability challenges at very high temperatures before they can achieve widespread deployment. The 150 MW Andasol solar power station located in Spain is a commercial parabolic trough solar thermal power plant. It uses tanks of molten salt to store solar energy so that it can continue generating electricity even when the sun isn't shining.

Large-scale thermal storage technologies are competitive for meeting heating and cooling demand in many regions. Thermal energy storage systems appear well-positioned to reduce the amount of heat that is currently wasted in the energy system. This waste heat is an underutilised resource, in part because the quantity and quality of both heat resources and demand is not fully known.

Thermal energy storage can increase operational flexibility in CHP plants by enabling the decoupling of the heat demand of a connected district heating system and the requirements of the electricity system. Furthermore, the increased flexibility afforded by both thermal and electricity storage in CHP facilities could enable higher levels of participation in balancing power markets.

Indian Scenario:

Solar Thermal storage is high on the agenda of many Indian Industries and laboratories and several international collaboration programs are in place. Few such efforts are given below:

PLUSS® , an offshoot of Manas Research and Technology, is the first Indian company to indigenously develop and market the savE® brand of phase change materials in the year 2005 for Thermal Energy Storage.

"India One "Solar Thermal power plant set up by the World Renewal Spiritual Trust at Abu (1 MW) uses Thermal storage units which are used for generating power during night .

Solar Tunnel Drier with Thermal storage for drying of copra uses sand as Thermal storage media (Dr. Mahalingam College of Engineering and Technology, Pollachi, Institute of Road and Transport Technology, Erode Tamil Nadu, India.

Punjab University – Energy Research Centre working on Development of Storage Systems based on Reciprocal Salt pairs

for multiple applications; Development of an active heat exchanger for latent heat thermal energy storage; Development and Evaluation of Thermal Energy Storage materials; Evaluation of Seasonal Thermal Storage in Aquifers for Heating and Cooling

High Efficiency Solar Thermal Air-conditioning Systems – a collaborative project of

Thermax Limited and Solar Energy Centre: The project (100 KW cooling capacity) is being implemented by M/s Thermax Limited at Solar Energy Centre with an objective to integrate solar collectors, vapor absorption machine (VAM) and appropriate thermal storage system to achieve consistence performance of the system with coefficient of performance (COP) (1 : 1.7)

Cold Storage with Solar – Biomass Hybrid System: It is an APP project in partnership with TERI, Thermax Limited, SEC and CSIRO Australia with an objective to develop cold storage particularly in rural areas utilizing exhaust heat of biomass gasifier engine/solar schffler dish.

Energy Management in Building Sectors Through Thermal Storage- Capacity Reduction and Grid Stability - Anna University, Chennai

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 uninterruptible 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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