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A Review Article on Green Energy Forecasting

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Abstract

Looking at our environmental condition it has become necessary to increase the generation of electricity using green energy sources such as solar, wind, biomass, geothermal, waves of ocean, tides etc. Among these energy types wind energy and solar energy have the great potential for generation of electrical power but at the same time it is important to accurately forecast the green energy generation in advance as they are intermittent in nature, less reliable and location specific. In this paper the focus is given on different forecasting methods of wind energy and solar PV generation. An attempt has been made to bring and evaluate the common methods and the most suitable methods for forecasting of the wind and solar PV.

Keywords— *Green energy forecasting, Wind energy, Solar PV generation, Statistical method, learning method, Hybrid method, mean absolute percentage error.*

1. Introduction

Now a days global warming has become a big issue for our environmental condition. Greenhouse gases emitted by the thermal power plants are the primary reason to pollute our environment and create global warming. Mainly because of this reason, Governments of the world and India are focusing on green energy sources such as solar and wind power. The contribution of different RE sources in India is shown in Fig. 1.

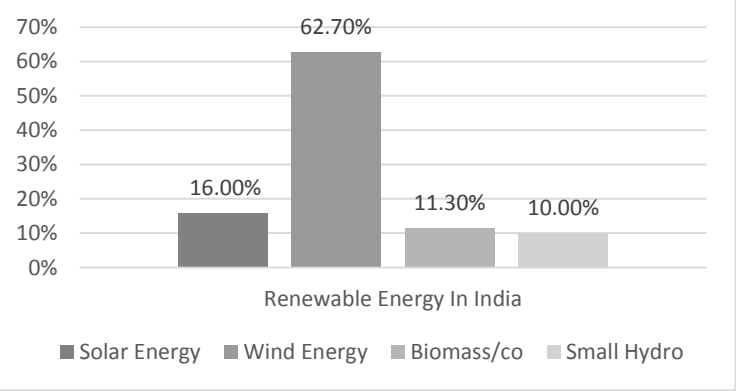

Figure 1. Position of Renewable Energy in India

Among all the renewable energy sources solar and wind are mostly utilized one [1]. Wind energy alone produces the 67% of the total renewable energy in India. Wind and solar photo

voltaic (SPV) power generations are main green energy sources. The electrical energy demand in India is increasing rapidly and it is expected to be 900 GW by the year2032 out of which the contribution of renewable energy is expected to grow to 183GW. Wind and solar PV power generations have certain disadvantages also as it depends on the locality as well as climatic conditions. Due to its intermittent nature, penetrations of wind and solar generation may add more variability to the grid as well as it may increase the demand for ancillary services. This needs a balancing between the actual production and forecasted one leading to increase in cost to the consumer.

In view of the above, Green energy forecasting is critical for grid operators to carry out operational planning studies and ensure that adequate resources are available for managing the variability and unpredictability of green energy output. The accurate forecasting of green energy will lead to correct forecasting of conventional power requirement and scheduling/ rescheduling of generation will be decided based on it. The accurate green energy forecast will further improve the forecasted price and help in formulating the more accurate bids by Generators and Distributors. This will improve overall efficiency of the power Grid and will make it more reliable and empowers the potential customers having sufficient installed capacity of green energy.

Many statistical and artificial Intelligence (AI) based models are used for forecasting of green energy. In this type of models a sequence of observed data pattern in a particular order is considered. Initially autoregressive (AR) models, the moving average (MA) models and integrated models (I) were used then after the combination of these models are used frequently [2]. AI based methods have shown promising results as they are able to handle fast changing and unforeseen situations.

In this paper a comprehensive study of various green energy forecasting methods have been presented along with evaluation criteria being used in green energy forecasting.

Section II discusses overview of green energy forecasting methods. The statistical approach of green energy forecasting is discussed in section III and learning method approach is presented in section IV. Section V presents the Hybrid forecasting methods. Section VI discusses the evaluation criteria.

2. Overview of Green Energy Forecasting Methods

Forecasting of green energy is needed to reduce the gap between demand and supply. Because of variant nature of wind speed, solar radiations and other variable parameters it is very difficult to predict it very accurately. Several methods are developed for getting good forecasting results of wind and solar energy. These forecasting methods are classified in many different ways. Classification of forecasting tools may be based on the methodology or time scale for forecasting of wind energy [3]-[4]. Common methods of green energy forecasting are statistical methods, learning methods, physical method, persistence model etc. statistical methods include seasonality, autoregressive moving average (ARMA), multiple regressions etc. Learning methods include neural network (NN), genetic algorithm (GA), fuzzy logic etc. Classification of forecasting models may be done on the basis of time scale, methods used, historical data based and locality based etc. Green energy forecasting methods according to the time scale is given as below.

- Ultra-short term: Few minutes to 1 hour
- Short-term: hour to several hours ahead
- Medium-term: several hours to 1 week ahead
- Long term: 1week to 1 year or more ahead

Forecasting methods are also classified based on the historical data as discussed below.

3. Statistical Methods

Conventional statistical methods generally used are Moving average (MA) model, autoregressive (AR) model, integrated (I) model ARMA, ARIMA etc [5]. The most frequently used model for time series is autoregressive process. The statistical methods are commonly used for wind power forecasting and solar PV forecasting. In statistical method we use data from time series of the last few years. The accuracy of this method depends upon the quantity of data available from the different sources. This method need less data series in comparison with learning method. Statistical methods are generally used for short time period. These are mainly of three types as given here.

i) Seasonality Analysis
ii) Regressions Analysis Model
iii) Non – Stationary Time Series

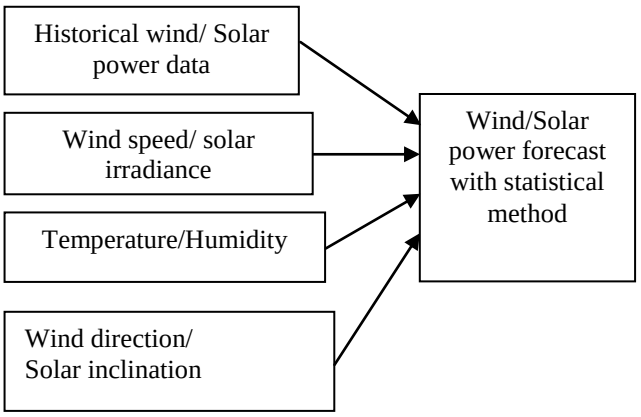

Figure 2. Statistical Approach for Green Energy Forecasting

Regression analysis model include linear regression model, multiple linear regression model, non-linear regression model, autoregressive model, moving average model, autoregressive moving average model. The statistical model of green energy is shown in fig. 2 with their respective input variables. The main disadvantage of statistical method is that the prediction error increases with increase of time [6]-[8].

4. Learning Methods

Learning methods need large number of observed data set for accurate forecasting. These methods are using artificial intelligence techniques and some of them are artificial neural network (ANN), Genetic algorithm (GA), Fuzzy Logic, particle swarm optimization (PSO) etc. Neural network tool is mostly used for load forecasting and price forecasting [9]. Now a day it is also used for wind energy forecasting and solar PV forecasting. Because of non-

linearity in wind speed and PV power irradiance a tool is required which can accommodate such behavior and forecast accurately. ANN is found to be most promising on this criteria and is used by many researchers. ANN is a technique used to map random input vector to the random output vector with no prior assumption of relation between them. It can learn from past data, relationship in historical results or recognize pattern and use them to forecast the future value. Over the conventional forecasting scheme ANN provide the great advantage of error tolerance, adaptability, self-learning and self-organizing.

Table 1. Comparison of Green Energy Forecasting Methods

Forecasting Techniques	Main Features
Numerical Weather Prediction	It is used for short duration, long and medium duration forecasting of wind power generation. Physical Approach- no requirement of training from historical data
ARMA/ARIMA	It is generally used for forecasting of wind and solar energy for short, medium and long term. Prediction of dependent variable by the knowledge of explanatory variable.
Probabilistic	Generally used for short, medium and long term forecasting. Prediction interval requires lower limit and upper limit.
Artificial Neural Network	It is commonly used for solar PV power forecasting and wind energy forecasting. No need of prior assumption. Pattern recognition methodology.
Genetic Algorithm	Very useful for combinational multiobjective problem. Weighting factor are required.
Fuzzy Logic	Less accuracy Gives good results in combination to other methods.
Hybrid Methods	NWP used in combination to NN gives accurate results for long and medium term forecasting. ANN and Fuzzy logic WT+FA+FF+SVM EMD+SVM for short term forecasting GA+ANN+PSO

It is found that ANN gives more accurate results for short and medium term forecasting rather than long term forecasting. Applications of ANN are feed forward, recurrent and multilayer perception. Some new techniques are spatial correlation and entropy based training

of model. Knowledge based methods such as fuzzy systems, expert systems, decision trees etc. are also used for green energy forecasting [10]. It is convenient to use fuzzy system with combination of other techniques such as neural network also known as neuro–fuzzy systems [11].

Numerical Weather Prediction (NWP) Models are at different levels from global NWP to the models for regional environment. In this method data of temperature, pressure, humidity and other variables can be collected from the meteorological department. With the above parameter the forecasted solar irradiance on horizontal plane or tilted plane should be taken as one of the inputs. Physical Method is generally used for long term forecasting. In this method forecasting is decided by the weather condition. Persistence Model is utilized to forecast the wind energy and solar P V forecasting. It is used to forecast one hour ahead. Sometimes it is favorable to use combination of any two methods to get better forecasting results. A climate dependent hybrid approach for one day before hourly prediction of PV output power is anticipated in [12]. A comparison of various green energy forecasting methods is presented in table 1.

5. Hybrid Approaches for Green Energy Sources

Many researchers use the combination of any two or three method to accurate forecast for the wind power forecast and solar PV generation forecast. These hybrid methods include a combination of dynamic clustering with linear regression. References [13]-[17] have discussed forecasting of green energy with hybrid methods including statistical hybrid forecast method. Genetic algorithm with adaptive particle swarm optimization algorithm has been applied for optimizing the parameters of wavelet neural network (WNN) model in wind energy forecasting [18]. This model subsequently examined the wind farm of eastern China. In reference [19], accurate localized short term weather prediction has been done taking into account for smart grid planning and control scenario. It is important to forecast the solar irradiation in different weather condition. Also solar forecasting is accurate when compared to the wind energy forecasting. Solar PV forecasting methods are based upon historical data of solar irradiance, technique used to forecast, time scale, etc. A detailed literature review has been carried out on classification and/or methodology of solar PV forecasting [20]-[23]. A weather based hybrid approach for one day ahead hourly prediction of PV output power is proposed in [24]. Some researchers use the combination a data filtering technique using wavelet transform (WT) and generalized regression neural network (GRNN) and for validation of WT+GRNN model results are compared by soft computing models (SCMs) as given in ref [25].Such classification shown in Fig 3.

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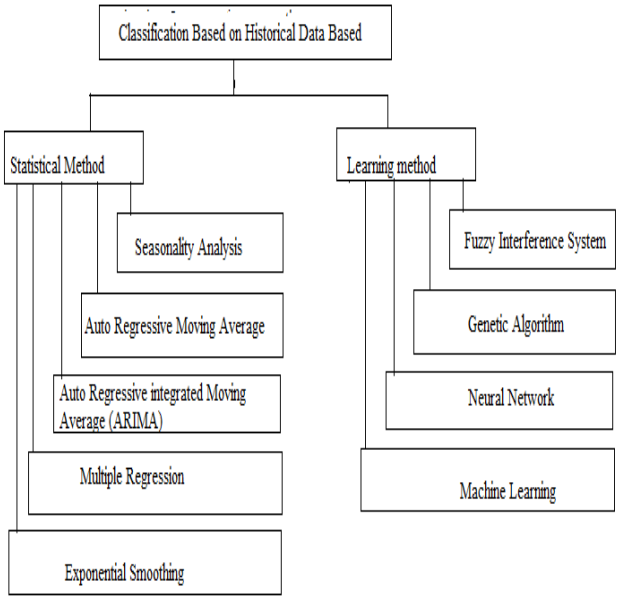

Figure 3. Classification of green energy forecasting methods

6. Evaluation Factors

Wind speed is intermittent in nature and solar radiations vary with season, time in a day and the daily weather condition, so it is important to evaluate the forecasting technique by means of a numerical value. Some of the evaluation methods used by researchers are described below from eq. 1 to 4. In all the equations A_i is the actual value and F_i is the forecasted value of i_{th} term and N is the number of iterations taken.

(i) The Mean Average Error (MAE)

$$MAE=1/N\sum_{i=1}^{N}(Ai - Fi) \quad (1)$$

(ii)The Mean Average Percentage Error (MAPE)

$$MAPE=1/N\sum_{i=1}^{N}\frac{(Ai-Fi)}{Ai}\times 100 \quad (2)$$

(iii) The Mean Square Error (MSE)

$$MSE=1/N\sum_{i=1}^{N}(Ai - Fi)^{2} \quad (3)$$

(iv) The Root Mean Square Error(RMSE)

$$RMSE=\sqrt{1/N\sum_{i=1}^{N}(Ai - Fi)^{2}} \quad (4)$$

7. Conclusions

In this paper, number of techniques to forecast the green energy are studied and presented including some of the hybrid methods. Different conventional as well as modern methods of forecasting methods used for green energy has been discussed and analyzed for their merits and demerits. The learning methods such as artificial neural network in combination with other artificial intelligence methods are having potential to provide more accurate results. These methods use weather conditions as well as historical power generation data for

forecasting. The detailed approach used by these tools has also been discussed. There are many types of evaluation criteria for checking the accuracy of these tools and same has been identified and presented in this paper.

References

[1] V.V. Sharma and H. Chawla, "Integrated renewable systems", 2nd International Conference on Power, Control and Embedded Systems, IEEE, **(2012)**.

[2] A.K. Rajeevan, P.V. Suri and U. Nair, "ARIMA modeling of wind speed for wind farm reliability studies", International Conference on Magnetics, Machines & Drives, IEEE, **(2014)**.

[3] A. Agrawal and K.S. Sandhu, "Comparative study of stochastic wind speed prediction models", IEEE, **(2014)**.

[4] S. Chai, X. Xu and L.L. Lai and K.P. Wang, "An overview of wind power forecasting methods", Proc. of the 2015 International Conference on Machine Learning and Cybernetics Gaungzhou, 12-15 July **(2015)**.

[5] M.G. De Giorji, P.M. Congedo and M. Malvoni, "Photovoltaic power forecasting using statistical method:impact of weather data", IET Science Measurement and technology, pp. 1-8, Jan. **(2014)**.

[6] D. Chauhan, M. Patil, Dr. P. Liu and Sharau Rao, "Statistical analysis of mismatch error in series and parallel conection of photovoltaic".

[7] S. Škuleti, V. Radulovi and I. Steševi, "Possibilities and limitation of measuring the energy of direct solar radiation", 4th International Conference on Power Engineering, Energy and Electrical Drives, Istanbul, Turkey, pp. 1789-1794, 13-17 May **(2013)**.

[8] K. Gairaa, F. Chellali, S. Benkaciali, Y. Messlem and K. Abdallah, "Daily global solar radiation over a desert area using NAR neural networks comparision with conventional methods", 4th International Conference on Renewable Energy Research and Applications Palermo, Italy, (ICRERA 2015), pp.567-571, 22-25 Nov. **(2015)**.

[9] H. Quan, D. Sriniwasan and A. Khosravi, "Short term load and wind forecasting using neural network based prediction intervals", IEEE Transaction of Neural Network and Learning Systems, IEEE, **(2013)**.

[10] S.M. Chen, Y. Chuan and J.S. Pan, "Fuzzy rules interpolation for sparse fuzzy rule based systems based on interval type-2 gausian fuzzy sets and genetic algorithm".

[11] A. Bara, G. Karutasu, C. Botezatu and A. Pîrjan, "Comparative analysis between wind and solar forecasting methods using artificial neural network", IEEE, **(2015)**.

[12] H.T. Yang, C.M. Huang, Y.C. Huang and Y.S. Pai, "A weather-based hybrid method for one day ahead hourly forecasting of PV power output", IEEE Transactions on Sustainable Energy, Vol. 5, No. 3, pp. 917-926, July **(2014)**.

[13] O.H. Mohammed, Y. Amirat, M. Benbouzid and T. Tang, "Hybrid generation system planning expansion forecast:A crtical state of the art review", IEEE, pp. 1668-1673, **(2013)**.

[14] J. Wang, F. Zhang, F. Liu and J. Ma, "Hybrid forecasting – based mining and genetic algorithm-adaptive particle swarm optimization: A case study of wind speed time series", IET Renewable Power Generation & The Institution of Engineering and Technology, pp. 1-12, **(2015)**

[15] D. Corne, M. Dissanayake, A. Peacock, S. Galloway and E. Owens, "Accurate localized short term weather prediction for renewable energy planning", IEEE, **(2014)**.

[16] M. Cococcioni, E. D'Andrea and B. Lazzerini, "24-hour ahead forecasting of energy production in solar pv systems", IEEE, **(2011)**.

[17] D. Al Hakeem, P. Mandal, A. Ul Haque, A. Yona, T. Senjyu and T.L. (Bill) Tseng, "A new streategy to quantify uncertainties of WAVELET_GRNN-PSO based solar PV power forecast using bootsrap confidence intervals", IEEE, **(2015)**.

[18]J. Wang, F. Zhang, F. Liu and J. Ma, "Hybrid forecasting – based mining and genetic algorithm-adaptive particle swarm optimization: A case study of wind speed time series", IET Renewable Power Generation & The Institution of Engineering and Technology, pp. 1-12, **(2015)**.

[19]D. Corne, M. Dissanayake, A. Peacock, S. Galloway and E. Owens, "Accurate localized short term weather prediction for renewable energy planning", IEEE, **(2014)**.

[20]M. Cococcioni, E. D'Andrea and B. Lazzerini, "24-hour ahead forecasting of energy production in solar pv systems", IEEE, **(2011)**.

[21]D. Al Hakeem, P. Mandal, A. Ul Haque, A. Yona, T. Senjyu and T.L. (Bill) Tseng, "A new streategy to quantify uncertainties of WAVELET_GRNN-PSO based solar PV power forecast using bootsrap confidence intervals", IEEE, **(2015)**.

[22]E.G. Kardakos, M.C. Alexiadis, S.I. Vagropoulos, C.K. Simoglou, P.N. Biskas and A.G. Bakirtzis, "Application of time series and artificial neural network models in the short term forecasting of PV power generation", EEE.

[23]S.H. Oudjana, A. Hellal and I.H. Mahamed, "Short term photovoltaic power generation forecasting using neural network", IEEE, **(2012)**.

[24]H.T. Yang, C.M. Huang, Y.C. Huang and Y.S. Pai, "A weather-based hybrid method for one day ahead hourly forecasting of PV power output", IEEE Transactions on Sustainable Energy, Vol. 5, No. 3, pp. 917-926, July **(2014)**.

[25]P. Mandal, A. Ul Haque, S.T.S. Madhira and D.I. Al-Hakeem, "Applying wavelets to predict solar PV output power using generalized regression neural network", IEEE, **(2013)**.

