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Survey on Sustainable Energy Resources Prediction using Different Technologies

Sumana Kuppannagari, Sree Devi E
Dept. Master of Computer Applications (MCA)
Sree Vidyanikethan Institute of Management, SVIM
Tirupati, India
sumana1819@gmail.com, sreedevi.mca15@gmail.com

Abstract **- Solar energy and the wind power are the environment friendly, sustainable sources of energy which are constantly being restored like sunlight and water. There are some non-renewable sources of energy available in the world like coal, Petroleum, natural gas etc. which can forms Fossil Fuels. In this world, it is important to predict the solar energy, in order to know how much the amount of energy can be consumed by different locations. Depending on different meteorological parameters like temperature, wind direction, velocity and humidity, wind power and solar energy forecasting can be done at regular intervals, so that it can balance the supply and demand of energy. In numerous applications in meteorology to understand phenomenon like humidity and rainfall, the statistical method has become a major tool and it is known as Time Series Analysis. Including time series analysis, regression analysis there are so many models like Autoregressive Integration Moving Average (ARIMA), Neural Network, Simple Moving Average (SMA) which are used to find the randomness of Solar Energy and wind power. Various Approaches has various disadvantages. This Paper can shows and can give a brief review on the theoretical forecasting methodologies and can provides the pros and cons of different methods. The study of Time Series Prediction of Solar Power is to know the advantage of using Exponential Smoothing (SES), Long-Short Term Memory (LSTM) and the suitability of Recurrent Neural Networks (RNN).**

Keywords- **Solar Energy, Prediction, SMA, Time Series, RNN, ARIMA, LSTM, Forecasting.**

I. INTRODUCTION

There are two categories of energy resources in the earth namely: Renewable and Non-renewable. The energy that can be restored or refill naturally at a short period of time like Solar Energy, Wind Energy, water etc comes under Sustainable resources of energy. The energy resources that are available very limited in the earth and there is no way to get that resources more during our lifetime after they were utilized, such resources like Petroleum, natural gas, coal etc. are called Non-Sustainable
Energy Resources. Solar Energy or the energy from the sun is collected by using Solar Collectors called Photovoltaic Panels, nothing but PV Panels. And this collected energy can be used in generating electricity, solar cooling, and to provide heat, light and in various industrial purposes. Wind power is the cheapest and the best sustainable energy resource which is used in generating electricity by using Wind Turbines. Meteorological Variables plays a vital role in forecasting the Energy generation. Here in forecasting the solar Energy, the main focus will be on the Photovoltaic (PV) Panels, along with meteorological parameters. The solar Energy can also depend on the Sunlight and the atmospheric conditions. Even though the Photovoltaic Power production is more and exploring day by day, Sunlight can be collected only when it is sunny. So the best alternative sustainable energy resource is wind power.
Along with the development of technologies, the need of various resources also has increased day by day. Wind power is the most optimum and cheapest energy source among all sustainable energy resources. It is also clean and environment friendly fuel source. With the increase of sustainable power, power systems are penetrated in most of the regions.
It is important to forecast the sustainable power in advance, so that we can get the effective and reliable power system operation and control.
In our country the growth of renewable energy capacity has increasing day by day. To represent the capacity growth graphically, in various regions [China, US, EU, India, Japan, Brazil and Africa] from 2011-2016 and 2017-2022 a bar graph is plotted in the source World Economic. Forum, which gives the importance of Sustainable energy.
In the world our country [India] is the fourth largest energy producer after China, US, and Russia. So, in India, the sustainable energy will become doubled by 2022. When compared to European Union (EU), the growth of sustainable energy between now and 2022 will increases.

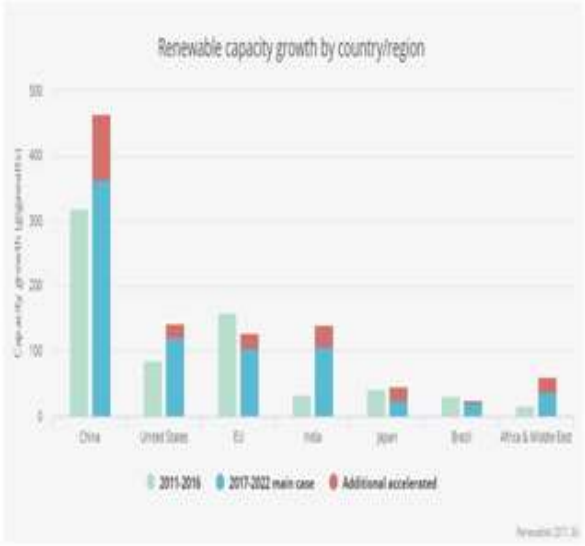

Fig.1. Sustainable capacity growth by country/region.

The graph presents in Fig.1 shows the region wise sustainable energy capacity growth [Source: World Economic Forum] [1]. Here the bar graph is developed for the sustainable energy capacity growth in country wise by getting the source from world economic forum. It is very clear from the above plot that China has more sustainable energy growth by 2022 considering over 40% of total global clean energy mix. In the world our country [India] is the fourth largest energy producer after China, US, and Russia. So, in India, the sustainable energy will become doubled by 2022 [1]. When compared to European Union (EU), the growth of sustainable energy between now and 2022 will increases. From the above Fig: 1, it shows that in India 18.9 % of power consumption will be produced by the 175GW sustainable energy in 2022.

The Sun energy has the highest potential among all other sustainable energy resources in our country. Whereas the wind power is clean Fuel source, which doesn't pollute air and is completely free.

II. OVERVIEW OF ENERGY FORECASTING

In supply and demand management in various organizations, Energy forecasting plays a vital role. So, it is very important to predict the future energy consumption in order to utilize the refilling energy properly.

There are different techniques and methods to predict the future energy consumption accurately. Energy forecasting can be done in any of the three ranges: Short term forecasting, Medium term forecasting and Long term forecasting. And some efficient production of forecasting methods are introduced in order to overcome the stochastic behavior of wind and solar resources, which can creates numerous problems [3]. In this paper different energy forecasting methods have been reviewed including their pros and cons. The different methods for forecasting the energy, can mainly divided into three methods: A. Physical Methods, B. Statistical Methods and C. Machine Learning Methods

1. Physical Methods

Physical methods input weather data (e.g., temperature, pressure, surface, obstacles and roughness) and the numerical weather prediction (NWP) are the two categories in this method. These methods based on NWP. Also by using physical data (temperature, pressure, cloud cover, humidity etc) and some cloud observations (satellite images) forecasting can be done. The Cloud information like the particular position of the cloud can get by performing the image processing on the sky images that are taken sequentially in time. Also, to identify the particular position of the cloud, the cloud motion should be captured by using the resolution satellite.

- **Numerical Weather Prediction (NWP):**

In NWP, the future condition of weather is forecasted, based on the weather or atmospheric conditions. So by using the atmospheric conditions, NWP can apply a number of mathematical techniques to forecast the energy. To predict the future condition of the weather, firstly NWP can take the parameter observations of weather and then it can model these data values with the help of various computer models.

For these computer models the input will be the present atmospheric observations, so that, it can produce the output for different atmospheric parameters like humidity, precipitation, temperature etc. And the entire process is known as Data assimilation process, which is used for prediction.

NWP is suitable only for smaller datasets because it is time consuming process. So, the main drawback in this method is that NWP produces the results after a taking a long time to overcome this drawback, there are some other methods are available to predict the energy accurately.

2. Statistical Methods

Statistical Methods is one of the methods to forecast the energy by using one or more models. Statistical methods also include regression analysis and its various subcategories. It can develop the relation between the past observations of weather and climate parameters as well as past and forecast values of atmospheric parameters and wind and solar energy measurements. This method consists of two models: linear and non-linear models. There are various statistical methods are available to predict the energy consumption. They are Simple Moving Average (SMA), Multiple Regressions, Auto Regressive Moving Average (ARMV), Auto Regressive Integrated Moving Average (ARIMA), Box-Jenkins and Exponential Smoothing (ES).

- **Simple Moving Average (SMA):**

SMA is used to calculate the trend in atmospheric parameters. Both the linear and non-linear trends are also be analysed by using SMA. So, based on patterns SMA can determine the trend whether it may be uptrend or downtrend and also it can smooth out the noise (valleys).

- **Auto Regressive Integrated Moving Average (ARIMA):**

ARIMA is the statistical Method to perform the short-term forecast. ARIMA can forecast the hour ahead values by using sequence of analysis. ARIMA is based on the past values and can function on balanced and lengthy series. ARIMA can consider the data set and parameters refer to the AR, integrated and MA.
Auto regression (AR): AR is a time series model to predict the output. The output depends on the earlier time steps (inputs).
Integrated (I): It can produce the time series stationary by comparing of raw observations in a sequential manner.
Moving Average (MV): It is used to disentangle (loosen) the noise (peaks).

- **Exponential Smoothing (ES):**

In time series analysis of weather parameters, ES model is favourable method to produce a smoothed time series. Like the above models (SMA, ARIMA) ES model is also used for short term predictions. When examine to the time series past observations, the present observations have more useful information. So, the recent observations should be given the higher weights and the earlier observations should be given the lower weights. ES model has proved as a favourable model than SMA by defeating the problem of weighted schema, which is not achievable in SMA.
To determine the operating feature of exponential smoothing, it is must to select the smoothing constant. The main drawback of this model is that it is suitable only for short term prediction and for non-seasonal patterns with relatively zero trend [4].

III. MACHINE LEARNING METHODS

The alternative methods to the statistical methods for time series prediction are the Machine Learning Methods. By using this Machine learning methods we can perform more accurate prediction with better performance. Machine learning methods are of various types as described below:

1. **Artificial Neural Network (ANN):**

In statistical methods it is not simple to detect the trends and patterns, whereas it is achieved with ANN. So, the Artificial Neural Network is the best alternative for Statistical methods to overcome many difficulties like classification, clustering, estimation, recognition etc. The time series forecasting by using the statistical methods is applicable for only linear and is not for non-linear. So, applying for both linear and non-linear is achieved by using ANN. The union of ANN and ARIMA can enhance the predicting accuracy in time series forecasting [5]. ANN is the best learning method needed for real world applications such as credit scoring for loan approval, electricity price forecasting [6] etc.
ANN is mainly needed for non-linear system modeling. It has a number of neurons that are interconnected. ANN is mainly developed for the purpose of long-term predictions with more accuracy.

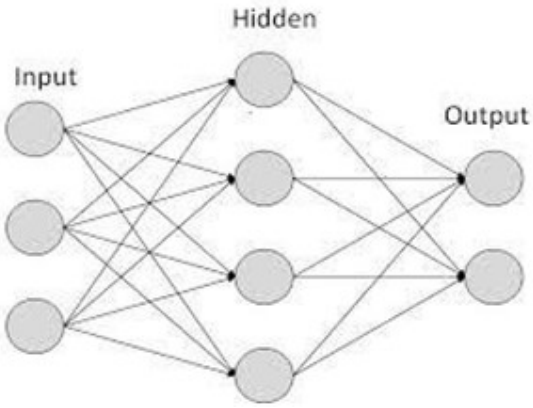

Fig.2.Representational view of simple ANN architecture.

As shown in the above Fig.2. ANN has a number of nodes, nothing but 'Neurons'. These neurons are combined with the help of links and weights and they interact with each other as shown in Fig: 2. ANN can build the strong relationships between the input and output values. ANN method consists of three building blocks. They are: Network Topology, Adjustments of weights or Learning, Activation Functions.

1. **LSTM Recurrent Neural Network for time sequence forecasting:**

ANN (feed forward) can allows the signals move from input to output, i.e., in only one direction. So that, there are no feedback loops in feed forward and is used only in pattern recognition. Whereas RNN (feed backward) forms loop in the network and permits the signals to travel in both directions. This can privilege them to store the data in memory over time. RNN is frequently changes its state up to it enhances to an equilibrium point. The main drawback of the RNN is vanishing gradient problem. So, to overcome this drawback of RNN, the extension to the RNN was introduced and is known as LSTM which uses special units along with standard units.

LSTM has many interconnected memory blocks. Deep Learning is highly preferable to the time series domains and it can produce the accurate results. By using memory cells LSTM can easily resolves the problems.

Time series predicting is one of the complex types of predictive modeling problems. The time sequence analysis can adds the difficulties depending on the series of input variables. To control sequence dependencies RNN was developed and it is the strongest model of Neural Network. RNN based LSTM network is essential to deal with large data set in machine learning. The outstanding training algorithm for LSTM network is Un-truncated BPTT algorithm.

An LSTM network consists of interconnected memory blocks in the form of layers. Each and every memory block has gates. And these can be used to control the output and the state of the block. The latest sequences are stored in the memory. The input time sequence data is operated first and then it examines whether they have to activate or not by using the activation units in each and every gate inside a block. Each block consists of three blocks as shown in the Fig.3.

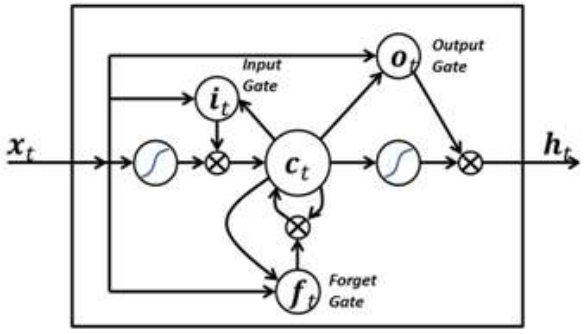

Fig.3. LSTM with input, output, forgets gates.

The three blocks of LSTM are: 1. Input Gate, 2. Output Gate, 3. Forget Gate.

1. **Forget Gate:** The first step in LSTM can be done by this block. The forget gate is needed to choose what data or information has to be sent away from the cell state.

2. **Input Gate:** This block is essential to decide which input values have to update in memory state and also needed to make the choice on which the latest data wants to store in the cell state.

3. **Output Gate:** The sigmoid functions will select any one of the bit of the cell state as output. So, the output Gate is entirely depends on the cell state.

IV. CONCLUSION

Standardized survey of different energy prediction techniques for wind and solar are reviewed in this paper. Different time series analysis methods are utilized in various research works for solar energy, wind energy and weather prediction. This work briefs about different prediction methods such as physical methods (NWP), statistical methods (SMA, ARMA, ARIMA, ES) and learning methods (RNN, LSTM). This study gives an analysis on forecasting sustainable energies of wind and solar. Three kinds of forecasting methods and their advantages and disadvantages were also discussed in this review. It is very critical to measure the performance of various methods using various scales. Predicting the solar and wind energy by using physical methods which is based on NWP can uses the meteorological parameters like humidity, temperature pressure etc. Whereas statistical methods can predicts the future by using historical data. When compared to other models, it is easy and inexpensive to construct the statistical models. Both physical and statistical methods are suitable only for short term predictions. This is the main disadvantage of these two models. If the prediction time increases, then prediction errors will increases in these models. This type of complex and non linear problems of solar and wind energy prediction will be solved by ANN method. In training process ANN method can extracts dependencies between the variables. ANN can calculate the error at the output and distributes backwards throughout the network layers, as ANN has back propagation technique. It is noticed that ANN method is best for short term predictions with accurate results. RNN can take the previous state information along with current input to produce an output, as it contains feedback connections. This study mainly focused on LSTM method for prediction. RNN has long sequence dependencies issues and this will be overcome by using LSTM. LSTM have to make a decision that which information has to add or remove in the unit state and this architecture stores the information over longer periods. The complex relationships in data can be learned by using Deep learning models. Therefore it is clear that for long term prediction, short term prediction as well as for medium term prediction, LSTM network is the best method for accurate results. Prediction levels are completely depends on spatial scale with respect to grid control. Due to spatial averaging, when prediction is done on larger areas it leads to lower uncertainties, whereas if the prediction is on local level, then it leads to larger uncertainties.

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AUTHOR PROFILE

Sumana Kuppannagari

Ms. K. Sumana pursuing MCA (Master of Computer Applications) from Sree Vidyanikethan Institute of Management, Tirupati. B.sc. in Computer science from S.V University Tirupati. Main survey interest includes prediction on cloud computing platforms and in Big Data Analytics.