International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 06, June-2019

IMPACT ANALYSIS OF SOLAR POWER GENERATION ON SMART GRID USING BIG DATA

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Abstract*: A Smart grid is an electrical grid with a variety of operational and energy measures including smart meters, Renewable energy resources equipped with modern technologies to describe the increasing demand on the quality of the power supply. It is relatively easy to manage the grids when the input is consistent and predictable such as thermal and hydropower plants. The reliability of the smart grids is very challenging especially when a significant percentage of the source is from renewable energy sources, such as solar and wind. The output of those renewable energy resources is very dynamic and unpredictable which effects the grid reliability. In this paper, the data is collected from the solar power plants and by running this data on the software the impact of renewable energy source i.e., solar on the reliability of the smart grids is analyzed by load modeling and prediction using big data technologies.

Keywords: Demand Forecasting, Solar Penetration, R programming, and Tableau software

1. INTRODUCTION:

The power generation from conventional energy sources is constant but the power generation from renewable energy sources i.e., from solar and wind varies according to the weather condition. Due to the variation of power generation from renewable energy sources, there will be an effect on grid reliability. One may get the 100% grid reliability when there is a matching of generation and the demand curves, i.e., power generated should meet the demand without any surplus or deficit.

For determining the grid reliability there is a need to forecast the demand. According to the demand the power generation is done. By load forecasting one may know how much amount of generation is needed to meet the demand. So, a load modeling is necessary for load forecasting. For a long time, the focus of load forecasting depended on the selection of algorithms and predictive models, including artificial intelligence algorithms such as support vector machine [1], neural network [2-5], evidence theory [3] and including prediction methods such as grey model method [4]. These forecasting methods are simple and easy to operate, but the effect is not ideal when solving the non-linear power load forecasting problem. By using multiple regression in R programming [7], the load forecasting is done for non- linear power loads. The portion of power provided by renewable energy sources to meet the demand gives the penetration of renewable energy sources.

In this paper, it is proposed to plot and analyze the demand patterns using tableau software and to predict the demand using multiple regression in R programming. In this paper, solar power penetration is proposed to be determined using the demand and generation data in R programming.

In section 2, the proposed methodology and steps for load forecasting is described. In section 3, demand patterns are plotted using tableau software for load modeling. In section 4, penetration of renewable energy sources, Results and analysis obtained for penetration is also discussed. In section 5, Load forecasting is done using multiple regression in R programming. Further the load forecasting results obtained using big data technologies are also presented in this section.

2. PROPOSED METHODOLOGY:

Load forecasting is done by plotting and analyzing the demand patterns from collected data using Tableau software and by applying multiple regression to set of data in R programming.

2.1 MULTIPLE REGRESSION:

Multiple regression is a statistical method used to determine the relationship between a dependent variable and one or more independent variables.

The general equation for Multiple regression is as follows:

$$Y = a + b_1 x_1 + b_2 x_2 + \dots + b_k x_k \quad \text{.... (1)}$$

For load forecasting the multiple regression equation is as follows:

$$D = a + b_1 t + b_2 w \quad \text{.... (2)}$$

where D = Demand
a = intercept

b_1 = temperature coefficient
t= temperature
b_2= week day coefficient
w = week day

Here D represents the Demand to be forecasted i.e., dependent on input variables temperature(t) and week day(w). By applying multiple regression to the collected data in R programming the coefficients obtained are

a=6029.65 b_1=73.2130 b_2=0.5946

$$D = 6029.65+73.21t+0.5946w \quad ....(3)$$

The steps for load forecasting are as shown in Fig. 1

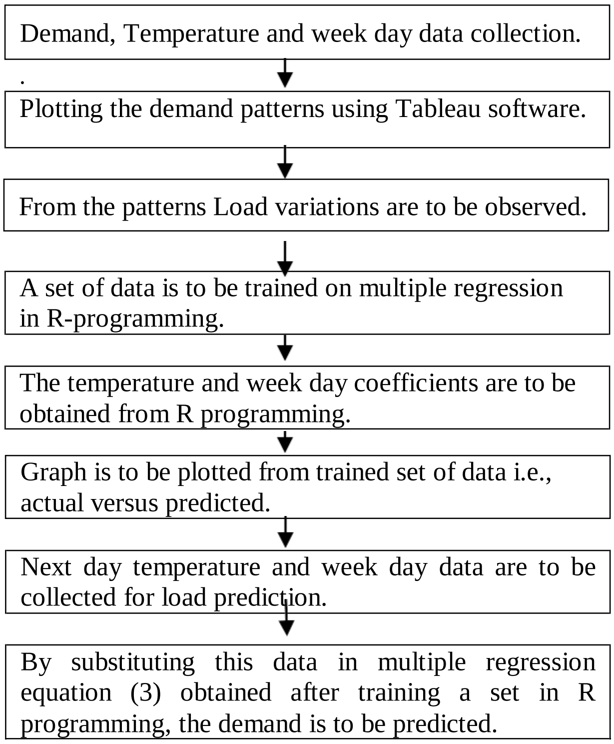

Fig.1. Steps for load forecasting

3. LOAD MODELING:

To forecast the load the demand data is to be collected and the load patterns are observed daily, weekly and monthly. The demand data for 24 August 2018 is collected and the demand curve is drawn by using tableau software.

3.1 DAILY GENERATION VERSUS DEMAND CURVE:

In Fig.1 the daily generation versus load characteristics are plotted.

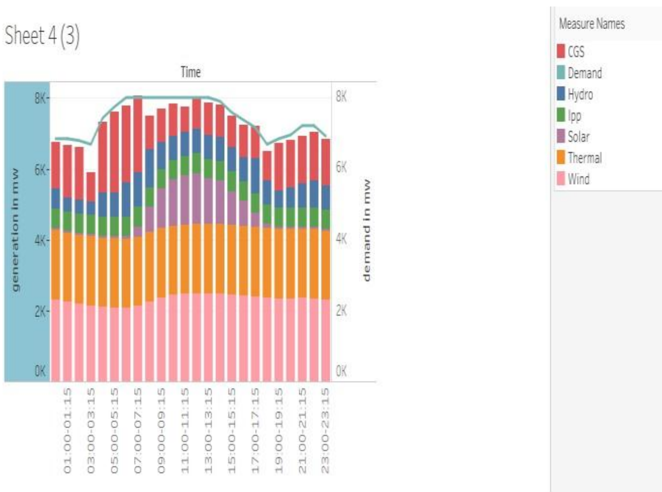

Fig.2. Daily generation versus demand curve

From the graph, the Maximum demand is 7942 MW, the minimum demand is 6477 MW and the average demand is 7064 MW. The variation for maximum demand and the minimum demand is 18%. The variation for maximum demand and the average demand is 11%. The generation from all power plants i.e., thermal, hydro, wind, central generating stations, and independent power producer are meeting the minimum demand at 6 p.m. During day time the demand increases. So, in order to meet the maximum demand the solar power generation is used. But from 12 a.m. to 7 a.m. and 6:15 p.m. to 12 a.m. almost there is no solar power generation. By using conventional energy sources also the generation does not meet the demand. To meet the demand there should be an increase in generation from any of the conventional sources, using thermal and hydel plants for generation takes a long time so one may go for the generation of power that meets the demand in less time i.e. by using central generating stations or independent power producer. The power generation from this source takes less time i.e. in 10-15 minutes.

3.2 GENERATION VERSUS LOAD CURVE:

In Fig.3, the power supply position from renewable energy sources i.e., from solar and wind is shown. The maximum demand is 7942 MW and the amount of solar power generation meeting the demand is 1437 MW i.e., 18% similarly from the wind there is 2487 MW i.e., 31.3%.The percentage of renewable energy sources meeting the demand is 49.8% during the maximum demand. The minimum demand is 6634 MW and the amount of power supplied from solar and wind power generation is 53 MW and 2137 MW.

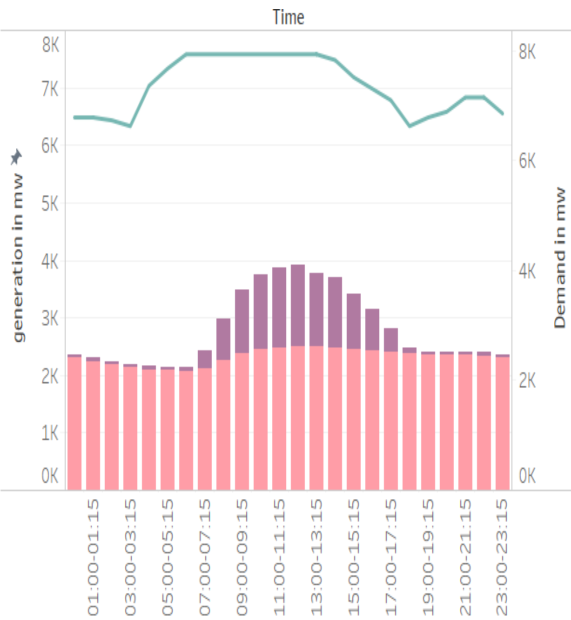

Fig.3. Generation versus load curve

The percentage of renewable energy sources meeting the demand is 33% during minimum demand.

3.3 DAILY LOAD CURVE:

In Fig.4, daily load curve is obtained from the collected data using Tableau software. The maximum demand is observed from 6 a.m. to 1 p.m. and the minimum demand is seen from 12 a.m. to 3 a.m. and also at 6 p.m. The demand is increased from 3 a.m. to 6 a.m. i.e., from 6634 MW to 7942 MW and from 6 a.m. to 1 p.m. The demand is maximum i.e., 7492 MW. From 1 p.m. to 6 p.m. the demand is decreased, again at night the demand rises to 7157 MW at 10 p.m. From this one may say the less demand is seen

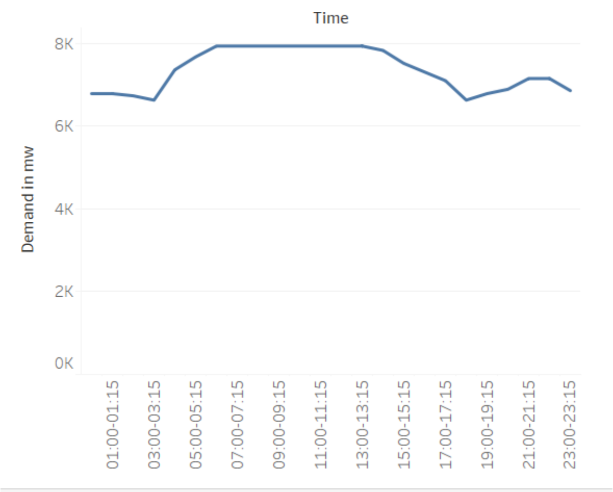

Fig.4. Daily load curve

in morning times and more demand is seen in morning times and more demand is seen during afternoon times.

3.4 MONTHLY PEAK DEMAND CURVE FOR THE YEAR 2018:

In Fig.5, the monthly peak demand curve has been obtained using Tableau software, from the collected data.

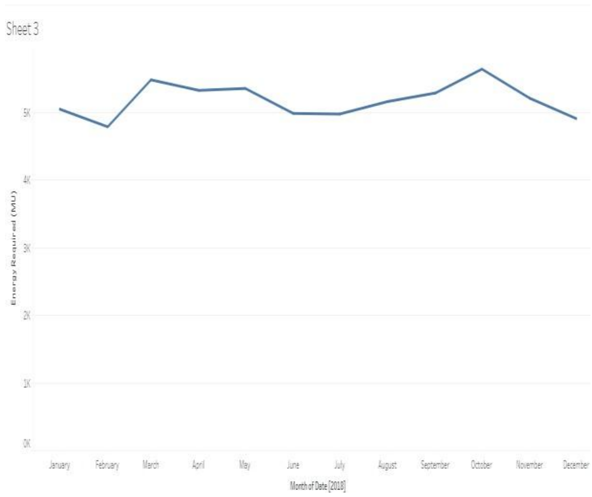

Fig.5.Monthly Peak Demand Curve

From the fig. 5 it is observed that the highest peak demand is seen in month of October i.e., 5633 MW and the least peak demand is seen in the month of February i.e., 4781 MW. The demand from January to February is decreased and Feb to March the demand is increased linearly i.e., 5475 MW near to the highest peak demand. The demand in March April and May is nearly same i.e., 5319 MW. From June to October the demand is increased slightly and October to December it is decreased.

3.5 WEEKLY LOAD CURVE:

In Fig.6, the weekly load curve has been shown.

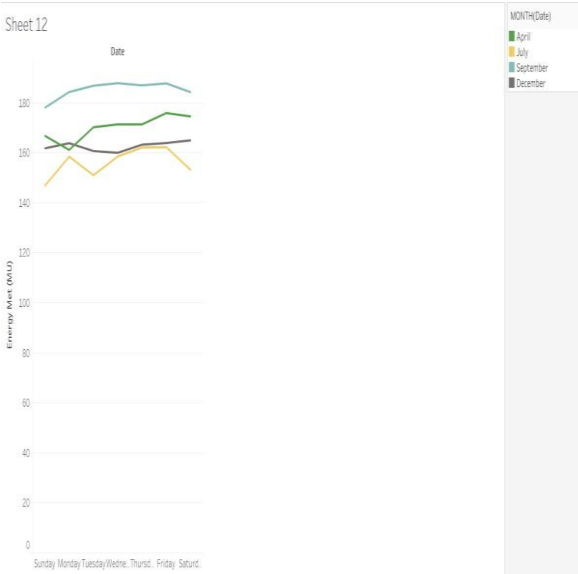

Fig.6.Weekly load curve

For the weekly load curve, the demand data for 4 months (April, July, September, December) is collected from 2nd to 8th date i.e., 1st week. From this graph, one may observe the demand is seen maximum during the April month. On Sundays and Saturdays the demand is very less compared to weekday's i.e., 146.8 MU and 153.11 MU. On weekdays the demand is more due to heavy usage of power for commercial and industrial purpose i.e.,
162.09 MU.

3.6 SEASONAL LOAD CURVE:

In Fig.7, the seasonal load curve is shown. From Fig. 7, it is observed that the maximum demand is seen during summer season i.e., it varies from 8685 MW to 9517 MW and in spring the demand is alternating daily and it is increasing from 8551 MW to 9293 MW. During the winter season, the demand is minimum i.e., 6561 MW when compared to autumn, spring and summer seasons. On 17th December 2018 the demand during four seasons i.e., winter, autumn, spring, and summer is 6561 MW, 8037 MW, 9050 MW, 9557 MW respectively.

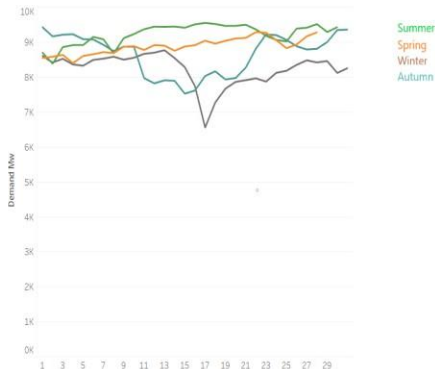

Fig.7.Seasonal load curve

3.7 SECTOR WISE DEMAND CURVE FOR 2018:

For the sector-wise demand curve, the demand data per month per sector type is collected for the year 2018 and is as shown in Fig.8. From the curve it is observed that the percentage of demand required by different sectors in the year 2018 is as follows. From the Fig.8, it is observed that the peak demand is seen in month of October i.e., 5633 MW and the least peak demand is seen in the month of February i.e., 4781 MW. The demand from January to February is decreased and Feb to march the demand is increased linearly i.e., 5475 MW near to the highest peak demand. The demand in March, April and May is nearly same i.e., 5319 MW. From June to October the demand is increased slightly and October to December it is decreased.

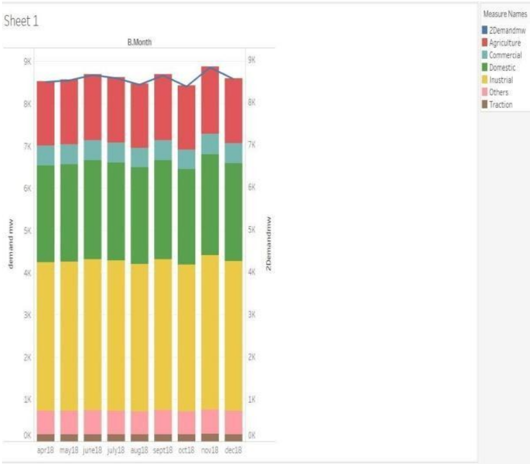

Fig.8.Sector wise Load curve

Industry-41.48% Domestic-27.12% Agriculture-18.08%Commercial-5.51% Traction-1.27% Others-6.54%

4. PENETRATION OF SOLAR POWER:

From the generation versus load curve, During day time the maximum demand is 7942MW and the generation of power from solar is 1437MW and from the wind, it is 2487MW.

The maximum penetration of the solar is given by the equation as follows

$S/(S+O)=D/(D+N)$ . . . (4)

where S=Solar power generation in MW

O=Power generation from other sources

D=Day Demand

N=Night Demand

$S/(S+O)=1/(1+(N/D))$ . . . (5)

For the calculation of solar penetration, the demand data for a different set of days is collected, based on the demand i.e. during day time and night time the solar penetration changes.

4.1 SAMPLE CALCULATIONS:

From the data collected on June 30, the maximum demand during day time is 6671 MW and the maximum demand during the night time is 1096 MW.

N/D=1096/6671=0.164

Percentage of solar Penetration = 11.164*100

= 85.88%

From the data collected on December 30, the maximum demand during day time is 8400 MW and the maximum demand during the night time is 6034 MW.

N/D=6034/8400=0.718

Percentage of solar penetration = 11.718*100

= 58.19%

Similarly, the maximum demand observed during daytime and night time on Feb. 15 is7446MW and 3000 MW.

N/D=3000/7446=0.4029

Percentage of solar penetration =11.402*100

= 71.28%

From the sample calculations, the graph is plotted as shown in Fig.9, between the percentage penetration of solar and N/D ratio. From the graph, if the demand is known then one can predict the percentage penetration of solar.

4.2 RESULT:

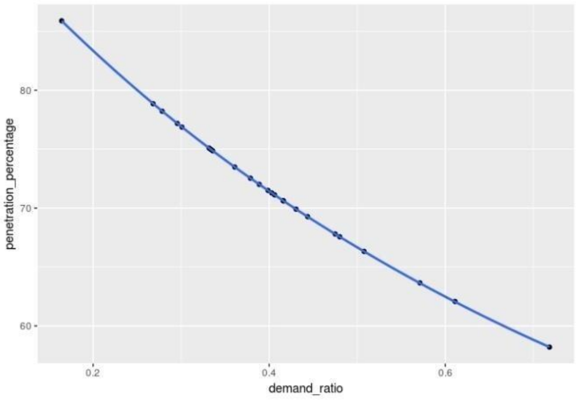

Fig.9. Solar penetration versus demand

5. LOAD FORECASTING:

To forecast the demand, yearly data is collected from the data collected. Demand patterns are observed by using tableau software, as temperature and weekdays as input variables, the future demand is predicted by using the multiple regression model and R Programming.

The yearly demand data, temperature data and week day's data are collected and these sets of data are trained on multiple regression in R programming. The actual and the curve obtained from the trained set is shown in the Fig.10.

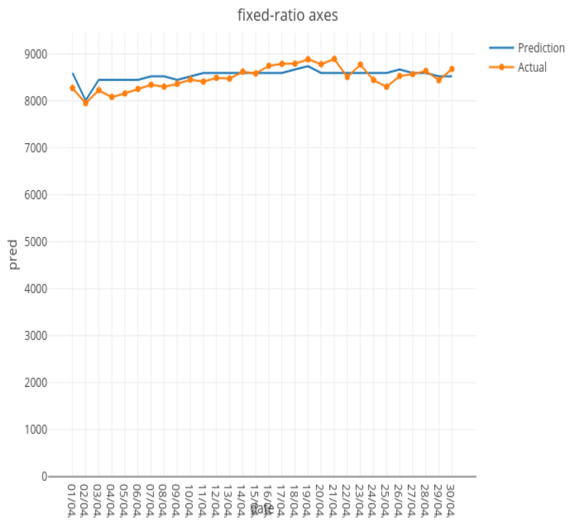

Fig 10. Actual curve versus trained set curve

5.1 PREDICTION:

For the prediction of demand the next day temperature samples and week, day data is collected by running this data on multiple regression in R programming the future demand is predicted.

5.2 SAMPLE CALCULATION:

For load forecasting the multiple regression equation is as follows:
D = 6029.65+73.21t+0.5946w .... (6)

for t=35 and w=1

Demand D=6029.65+73.21*35+1=8592.7

for t=27 and w=0

Demand D=6029.65+73.21*21+0=8006.4

5.3 RESULT:

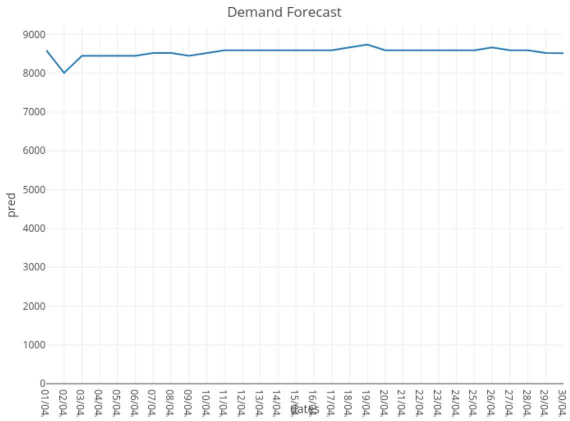

Fig.11. Predicted demand curve

6. CONCLUSION: The main aim of this paper is to improve the reliability of the grid. In this paper demand patterns are observed and plotted by using tableau software, Load forecasting is done by using multiple regression in R programming and penetration of solar power is determined. By load forecasting how much amount of generation is needed to meet the demand is determined which helps in improving the grid reliability.

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