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BIG DATA MODELING OF THE OUTPUT OF SOLAR ENERGY FOR SMART GRID RELIABILITY

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Abstract: ***A Smart Grid is an electricity grid that improves the power generation, distribution of power, and electricity consumption through the introduction of IT on the electricity grid. All this will cause vast data that will have to face by the energy companies. By using Big Data technologies, suitable solutions for utilities is offered, but it is critical to decide to use particular Big Data technology.***

The reliability of Smart Grid depends on the characteristics of both the demand (load) and the generation. The power generation by the conventional sources, such as thermal power plants is relatively stable and easily estimated. However, the power generation by renewable energy sources, such as solar and wind, is very dynamic and difficult to predict as it depends on the weather conditions. It's very challenging to have a reliable smart grid under these unpredictable dynamic power generation, especially when the share of the power generated by solar increases. For a long time solar radiation predictions are done using MATLAB, the prediction of solar power using Big Data is a new methodology.

In this paper using Big Data, Solar power is predicted with solar radiation as input variable. The Generation Patterns are observed in Tableau. Modeled and trained the historical data by using R programming language. The power generated by the solar plant, can be predicted using Regression Model and results obtained are presented and analyzed.

Key Words: BIG-DATA, Smart Grid, R programming and Tableau.

1. Introduction:

The Power generation from Solar is increasing rapidly because of less cost and pollution free. Hourly solar radiation data is mostly not available in solar plants and weather stations, where available is normally daily average global horizontal [6, 7]. Solar radiation data is more significant due to its adaptability in many applications like in building planning, agriculture, health centers, power plants, analysis etc. [10]. From the above models, solar radiation is predicted [5] but in this paper solar power forecasting is to be done using linear regression [3].The Consumption of power on these days is more. So it is very important to forecast the power. Due to the variation of power generation from renewable energy sources there will be an effect on the reliability [3, 9] of the grid.

For determining the grid reliability there is a need to forecast the power. To forecast the power a new methodology using big data of the solar power is to be analyzed and to correlate the actual power with solar Radiation.

In this paper, it is proposed to plot and analyze the generation patterns using tableau software [2] and to predict the generation power by applying linear regression [1] techniques by developing R- programming. The aim is to predict the solar power forecast using solar radiation. Solar Power can be forecasted by applying linear Regression technique [4] using Big Data. Forecast radiation data can be collected from the weather report [8], with solar radiation as input by using linear regression output power is to be forecasted.

In section 2, the proposed methodology i.e., linear regression concept is discussed. In section 3, Generation forecasting is done using linear regression in R programming, algorithm and case study is presented. In case study Collection of data, Generation patterns are plotted using tableau software for generation modeling is presented and Further, the generation forecasting results and analysis are obtained using big data technologies.

2. Proposed Methodology:

Generation forecasting is done by plotting and analyzing the generation patterns from the collected data using tableau software and by applying linear regression to set of data in R programming. Generation data is to be collected on minute to minute basis and patterns like power versus time, power versus radiation, monthly power variations; seasonal wise variations are to be plotted using tableau software.

2.1 Linear Regression:

Regression models can be either a linear or non-linear. A linear model assumes the relationship between variables is a straight line relationship. While a nonlinear model assumes the relationship between variables are having represented by curved lines.

The relationship between the dependent and independent variable is

$$y = a + b\,x \qquad \text{......... (1)}$$

Where x = input variable i.e. solar radiation

y = output response i.e. solar power

a = intercept

b= slope

$$a = ((\sum y)\ (\sum x^2) - (\sum x)(\sum xy))\ /\ (n(\sum x^2)(\sum y^2))$$

$$b = (n\ (\sum xy) - (\sum y)(\sum x))\ /\ (\ n(\sum x^2)(\sum y^2))$$

By applying linear regression to the collected data in R programming the coefficients obtained are

a=100.649, b=4.303

$$Y = 100.649+4.303x \qquad \text{.... . . (2)}$$

3. PREDCTION OF GENERATION:

3.1 Algorithm:

Step1: Data collection for power forecasting
Solar power plant data for the year 2018 is collected from Perivale village, Anantapur. Minute to Minute data is to be collected upto four months.

Step2: Generation patterns
From the data collected the graphs are to be plotted viz., daily generation curve, monthly peak generation curve, and seasonal generation curve, and to be plotted using the Tableau software.

Step3: Data Analysis
From the generation patterns how the power varies in a particular interval of time is to be observed.

Step4: For four months data is to be taken and it is to be trained on Linear Regression by using R programming.

Step5: The graph is to be plotted from the trained set of data then how accurately the actual Power curve and the predicted curve are matched is to be observed.

Step6: For solar power prediction, the Future radiation data taken as input variables is collected and the Generation Solar Power is to be predicted.

The sequence of steps of the proposed methodologies predicting the generation using big data is shown in Fig. 1.

Power Generation Data and Radiation Data are collected from solar power plant

↓

Daily and Monthly generation patterns are observed using Tableau

↓

Data modeling using linear regression

↓

Use linear regression technique in R programming

↓

The historical data is trained in R programming to predict the solar power

↓

Solar radiation is taken as input variable using linear regression solar power is predicted

Fig 1. Steps for generation forecasting

3.2 Case Study

For solar power forecasting minute to minute generation and radiation data for a year 2018 is collected. Generation patterns are plotted and analyzed using Tableau software. Solar power is to be forecasted by using linear regression in R programming.

3.2.1 Data collection:

In table 1. Monthly and hourly data is collected from Pervalli village, Anantapur. Installed capacity of the solar plant is 5MW**.**

Table 1. Monthly data in hourly basis

Time	January 1	January 2	January 3	feb1 tot p	feb2 total	feb3 tot p	April 1 tot	April 2 tot	April 3 tot	July powe	July powe	July powe	1-Aug	2-Aug	3-Aug
0:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:00	65	42	21	49	49	38	350	204	277	305	247	491	154	221	852
8:00	1278	1038	1217	1616	1546	1585	1835	1303	1925	735	727	821	812	1690	1956
9:00	2676	2392	2592	3112	3063	2926	2812	2397	2946	1799	1201	2329	1310	3812	3871
10:00	3226	2823	3120	3542	3531	3511	3335	3109	3500	2617	2896	2413	2284	3411	3292
11:00	3345	3148	3301	3672	3636	3826	3510	3460	3587	2146	4258	2333	2902	2632	2900
12:00	3554	3139	3297	3791	3740	3798	3578	3416	3722	3669	3808	1283	2234	3883	4513
13:00	3425	3367	3334	3835	3739	3832	3502	3498	3682	2152	2087	1472	4508	3434	4507
14:00	3363	2879	3517	3732	3679	3776	3452	0	3553	2798	1896	1993	1968	3669	0
15:00	3131	1194	3122	3603	3540	3649	0	2737	2012	0	1709	451	2753	3625	4143
16:00	2628	736	2281	3005	3079	3308	2597	1727	2917	1402	1362	79	2015	3719	2615
17:00	930	502	526	1543	1667	2207	1575	0	1689	509	1290	0	2320	2434	852
18:00	0	0	0	78	77	230	166	184	213	453	361	0	254	294	123
19:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20:00	0	0	0	0	0	0	0	0	0	0	0		0	0	0
21:00	0	0	0	0	0	0	0	0	0	0	0		0	0	0
22:00	0	0	0	0	0	0	0	0	0	0	0		0	0	0
23:00	0	0	0	0	0	0	0	0	0	0	0		0	0	0

The historical data of Solar Radiation, weather data and Power from the solar plant is to be collected. Minute to minute data can be collected seasonal wise. As the size of the data is very large minute to minute data is converted to hourly. This data can be observed by the Tableau [3] the graphs are to be drawn which is presented in section 3.2.2, from the graphs, it is observed how the power varies in daily and seasonal wise.

3.2.2 Generation Models:

Using historical data the generation patterns are observed. These patterns are observed by using Tableau (Software tool). A minute to minute data can be taken and the graphs are plotted.

A. Power versus Time
B. Radiation versus Power
C. Monthly power variations
D. Seasonal Wise Power Variations

A. Power versus Time:

In Fig.2, shown the power versus time characteristics**.** It is observed that the maximum power generated is 4.444 kW at the time 12 p.m.

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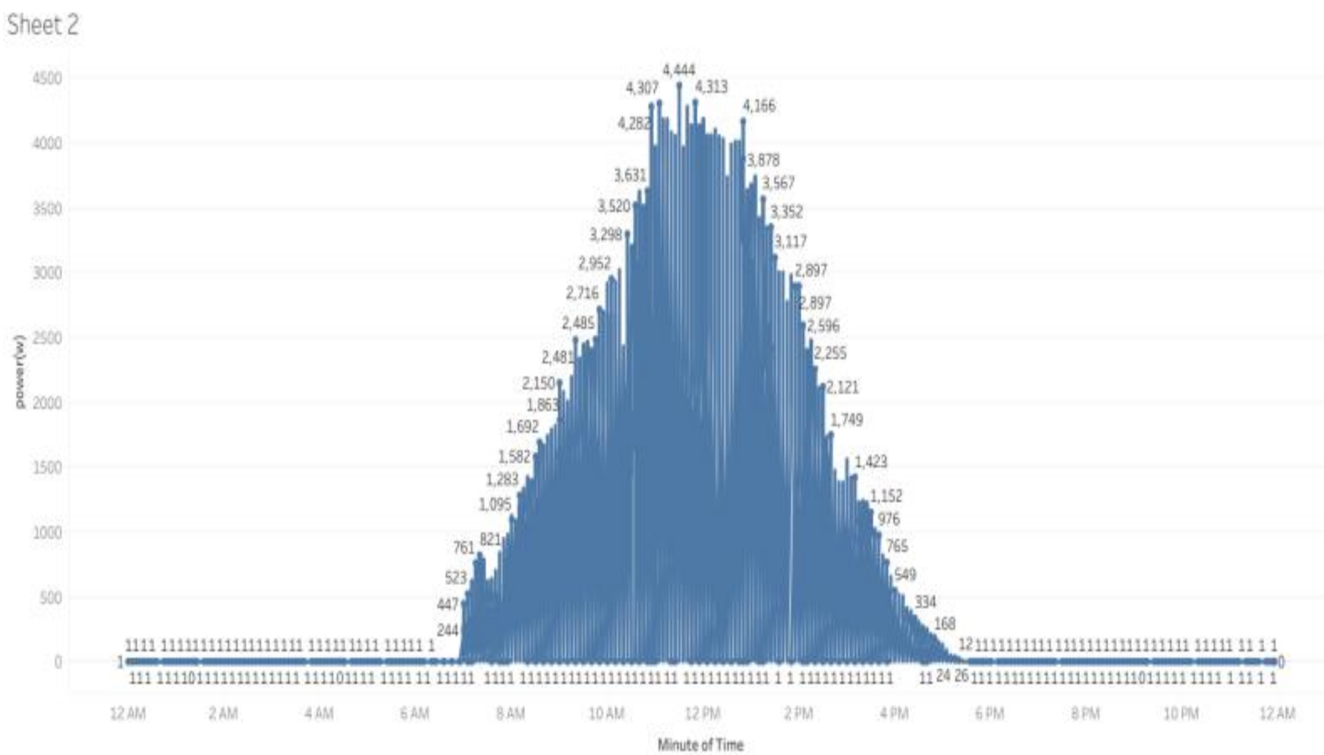

Fig.2 Graphical representation of Power versus Time

Power increases up to 12 p.m. and decreases gradually after 12 p.m. Daily maximum output power occurred during the period from 12:00 p.m. to 14:00 p.m., there is no output at night.

B. Power versus Radiation:

In fig.3 and fig.4, Power versus Radiation generated during the months of January and August 2018 are shown.

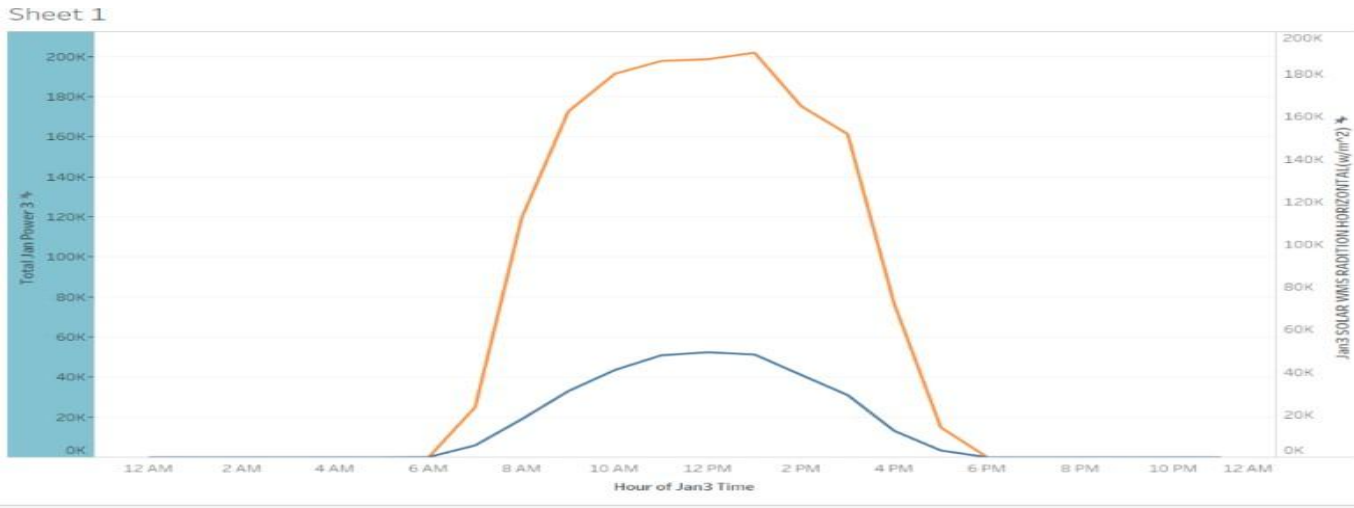

Fig.3 Power versus Radiation in January month 2018

The generation of power depends on the Radiation. The generation of power in the month of January starts at 6 A.M, as the solar power slightly increases at midafternoon the power generation is high. After it slightly decreases to 6 P.M shown in fig.2, similarly in the month of August as it is monsoon season solar radiation changes more compare to the January solar radiation.

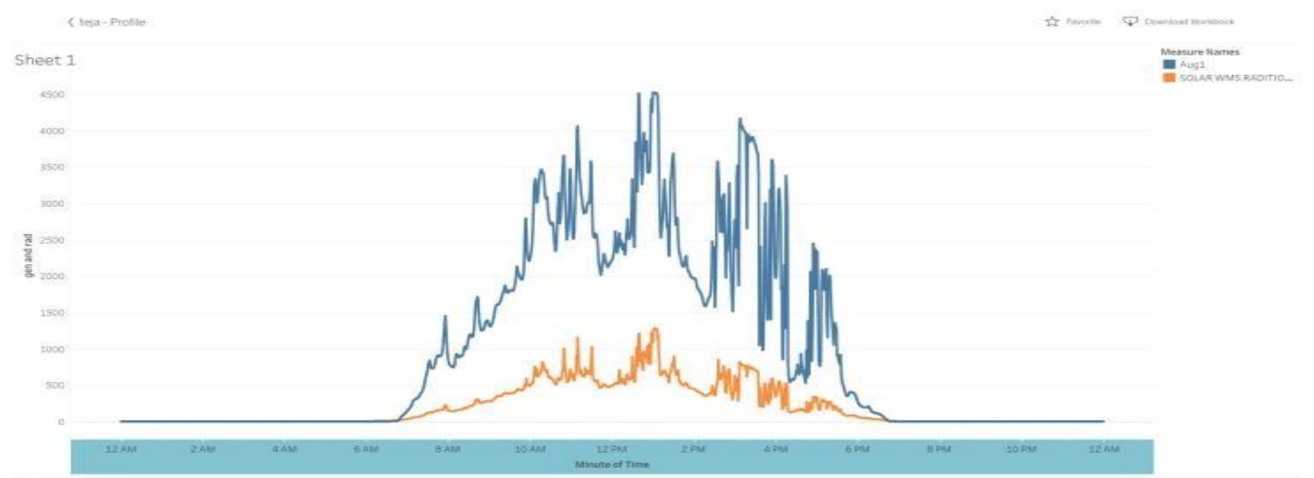

Fig.4 Power versus Radiation in August month 2018

C. Monthly power variations:

In Fig.5 shows two different months i.e. January and April 2018.

Fig.5 Graphical representation of monthly power

In the month of January, generation starts early compared to the April month. After mid-afternoon the generation graph has ups and downs, because of distribution substations are designed for the unidirectional flow of power from the transmission system to the distribution system.

Reverse power flows or reduced power flows will impact relay operations and protection coordination (due to static settings), potentially leading to equipment damage or unsafe conditions during faults. Due to reverse power flow the meter shows zero value, but slightly generation is present. Radiation depends on Weather conditions. As Weather changes radiation also changes then the power generation varies. It can say that weather is one of the reasons of power variation.

D. Seasonal wise power variation:

In fig.6, April, February, July, August graphs are observed. In the month of April more power is generated compare to other months because of more radiation. In the month of july and august more power change are occurred due to variation of radiation in monsoon season. In the month of february less variations are present because of the winter season radiation is slightly varied.

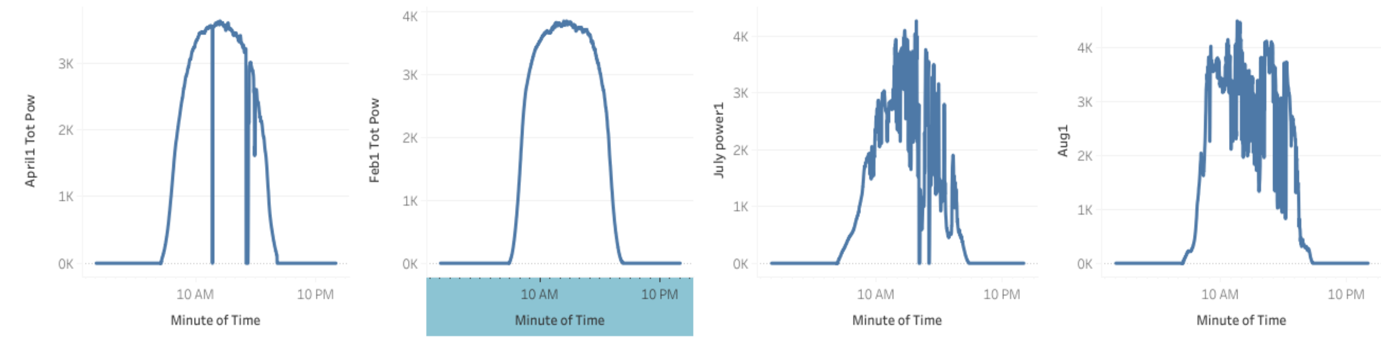

Fig. 6 Graphical Representation of different months

On every month there is a variation of power due to weather conditions. In fig.7, shown the average output power of the photovoltaic power station is which affected by seasonal changes. In January output power is low at starting as compare to another months, increasing each month to reach its peak in May, and then decreasing each month and in December reaching its minimum value. The fact that output power is higher in summer and autumn and lower in spring and winter is consistent with the distribution of radiation intensity in the area. Photovoltaic power station output was limited to the hours of 6:00 a.m. to 6:00 p.m. every day. Maximum output power is occurred daily during the period from 12:00 to 14:00 and there is no power output at night.

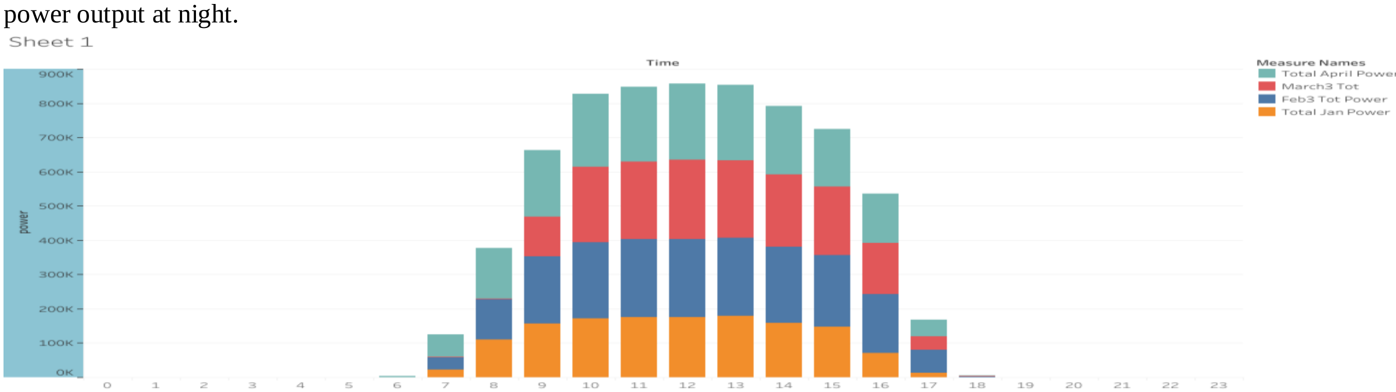

Fig.7: Graphical representation of seasonal wise

3.2.3 Sample Calculations:

For generation forecasting the linear regression equation is as follows:

From equation 1

$$y = a + b x$$

From equation 2

y = 100.649 +4.303x
For Radiation x=68

Forecast power y = 100.649+4.303*68 =393.2

For x = 115
Forecast power y = 100.649+4.303*115 =595.4

4. Results and Analysis:

In Fig.7, Power versus Radiation with outliers is plotted. These outliers are not considered. If outliers are present, Then the Graph does not show clearly. To remove the outliers, how the Power varies with radiation is shown in Fig.8.

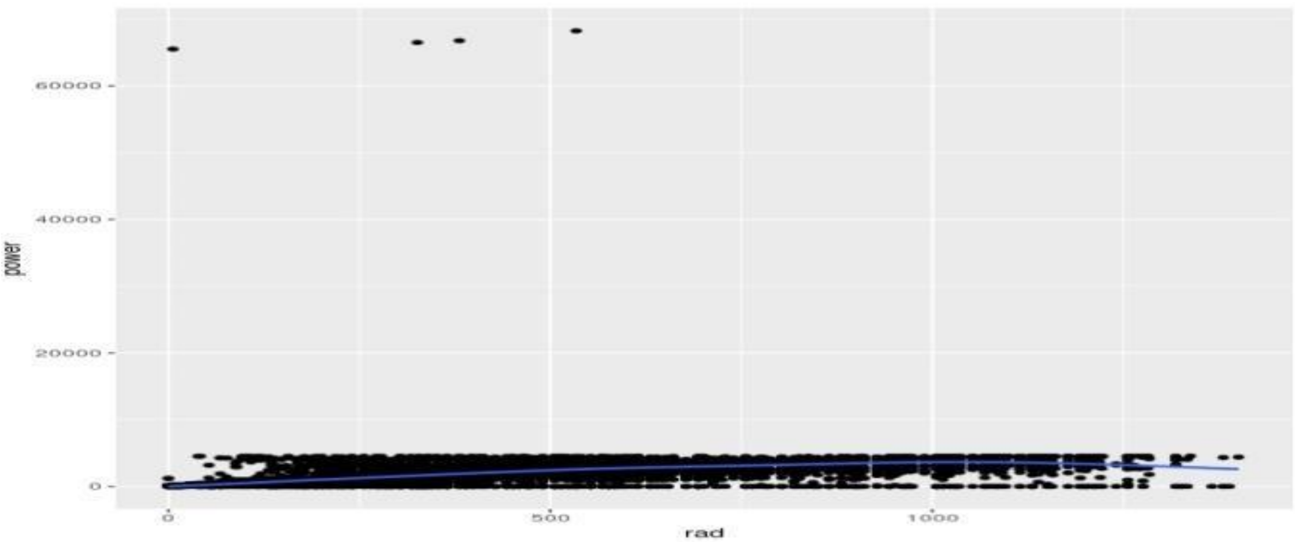

Fig. 8 power versus radiation with outliers

In Fig.9, graph is correlated positively, i.e., radiation increases power increases.

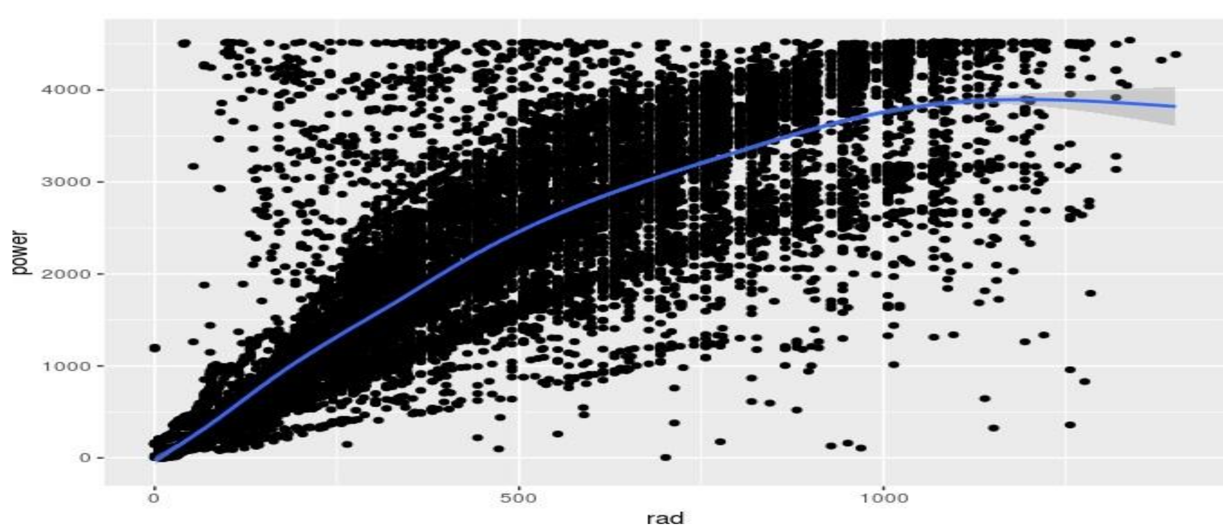

Fig.9. Power versus Radiation without outliers

In table 2, Time taken in minutes, forecast radiation (w/m^2), actual power (KW), predicted power (KW) are tabulated. The actual power and predicted power values are plotted as shown in fig.9.

Table.2. Actual power versus Prediction power.

1	Time(minutes)	Radiation(w/m²)	Actual power(w)	Prediction power(w)
2	6:59:00	68	275	393.2415042
3	7:00:00	68	288	393.2415042
4	7:13:00	100	478	530.9319251
5	7:14:00	100	493	530.9319251
6	7:15:00	104	510	548.1432277
7	7:16:00	105	526	552.4460534
8	7:17:00	107	541	561.0517047
9	7:18:00	109	554	569.657356
10	7:19:00	115	559	595.4743099
11	7:20:00	115	573	595.4743099
12	7:21:00	115	577	595.4743099
13	7:22:00	115	584	595.4743099
14	7:23:00	115	587	595.4743099
15	7:24:00	115	595	595.4743099
16	7:25:00	116	616	599.7771356
17	7:26:00	119	628	612.6856125
18	7:27:00	119	636	612.6856125
19	7:28:00	110	582	573.9601816
20	7:29:00	131	663	664.3195203
21	7:30:00	131	696	664.3195203
22	7:31:00	123	662	629.8969151
23	7:32:00	135	734	681.530823
24	7:33:00	139	748	698.7421256
25	7:34:00	143	792	715.9534282

In fig.9. Actual power and predicted power with radiation is plotted. From the weather station, the future forecast radiation data is taken, to predict the power generation.

The Forecast power and actual power results are matched as shown n fig.9.

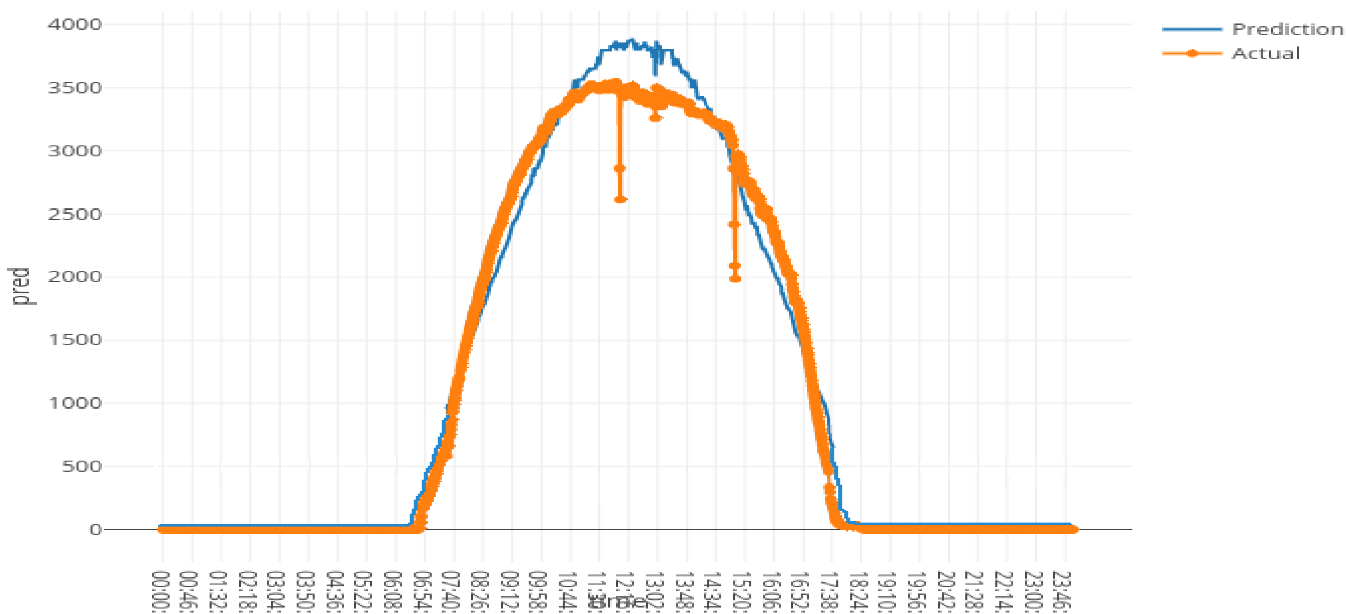

Fig. 10 Actual power and Prediction power versus Radiation.

From Fig.10 shows a graph is plotted from the historical data of solar plant. A Blue color line represents the average line for the data of radiation versus power.

Blue curve shows the predicted solar power generation curve and orange color shows the actual power curve.

5. CONCLUSIONS:

In this paper, Big data monthly wise and seasonal wise solar power minute to minute variations are observed using tableau from actual data. The solar power of actual generated verses predicted power generation graphs are developed. Solar energy depends on Radiation and Radiation depends on the weather condition. The results of solar energy actual data and solar prediction data are accurately predicted by using R programming. The prediction will match when a clear sky is present in otherwise it is difficult to find a cloudy sky at that more deviations are present. Solar power is forecasted with radiation as input variable. The main aim of this paper is to predict solar energy by using a linear regression method.

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