Impact of Trend and Seasonality in Forecasting of 5 MW PV Plant Generation using Single Exponential Smoothing Method

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ABSTRACT
In 21st century forecasting of solar power generation is an important issue due to grid integration. In these days power shading and heavy load is a major problem in front of conventional power generation sources so grid integration is plays an important role to fill the gap in between demand and supply of power generation. So solar power and conventional power are basic sources of grid integration. Solar power is playing a key role in grid integration. In this work, Solar power generation forecasting is carried out based on the data collected from a 5MW Gujarat Power Cooperation limited solar photovoltaic power plant which is installed in Charanka, Gujarat. In this paper we discussed about the single exponential smoothing for solar power forecasting problem and impact of trend and seasonality on modelling of power generation forecasting.

General Terms
Forecasting, Exponential Smoothing

Keywords
Solar Power, Forecasting, Single Exponential Smoothing

1. INTRODUCTION
Solar photovoltaic power output is an important power source in renewable energy. It helps in integrated grid operations, planning, and maintenance. Six months solar power generation data from March 2015 to August 2015 has taken for study. Generation of plant varies with solar radiation and ambient temperature. It is found in the data that solar radiation and ambient temperature changes according to time. Compared to conventional power, solar power is very difficult to dispatch due to uncertainty and dynamic behavior of solar radiation. Geographically, Charanka Solar Park is situated in western region of the India in the state of Gujarat. Gujarat Power Corporation Limited has taken initiative for sustainable progress in solar power generation by establishing 5 MW capacity Solar Power Plant at Gujarat Solar Park, village Charanka, District Patan in Gujarat. As a developing country India needs a better energy management and environmental security. It is the biggest challenge for any developing country.

The impact of trend and seasonality on 5 MW plant generation forecasting using single exponential smoothing is discussed here in this paper. This paper builds on impact analysis of trend and seasonality on solar power generation.

2. DATABASE DESCRIPTION
2.1 Solar photovoltaic plants
A peculiarity of Gujarat is extreme climatic conditions which are categorized by very hot and dry summer and cold and chilly winters. In Figure. 1 and Figure. 2 shows 5MW grid-connected multi crystalline photovoltaic power plant which has being developed in approx. 2,024 hectare of government waste land and has capacity to generate 7.75 million units of electricity generation in favorable conditions. Corporation has used the state of the art technology considering the Indian conditions. The project is fully commissioned and operational. The plant is located at Latitude 23054'20.24"N and Longitude 71011'54.29"E.

Fig. 1 Aerial View of 5 MW Gujarat Power Cooperation Limited Solar Photovoltaic Power Plant

2.2 System Specification
Solar PV array (high efficiency poly / multi crystalline -Si SPV Module) - The plant consist of 21,277 no. of 235 Wp

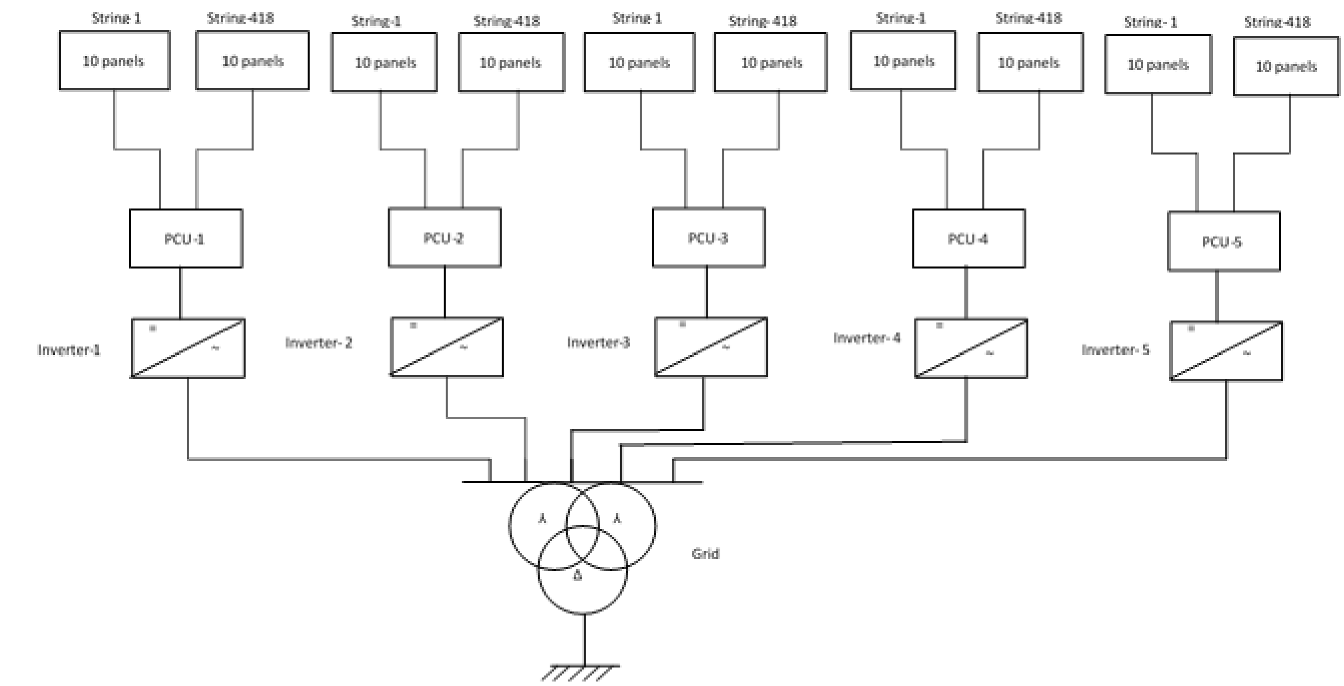


Fig. 2 Schematic block diagram of the considered PV plant (5 MW GPCL solar PV plant)

Poly / multi crystalline-Si from "C-Sun" Solar PV modules. Details of solar photovoltaic panel shown in Table.1 Power conditioning unit with transformers-The basic function of power conditioning unit is to convert DC electricity generated by solar modules into AC electricity which is then fed into the grid. The plant comprises of 5 numbers of power conditioning

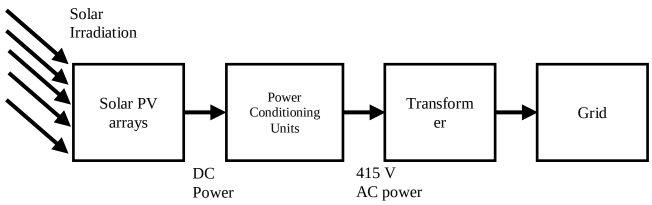
Unit and 5 Inverter of 1000 MVA inverter from “Bonfiglioli".

Table 1 C-Sun 235 Wp Solar panel specification

Particulars	**Specifications**
Power (W)	235
Tolerance	3%
Max. Power Voltage (V)	29.5
Max. Power Current (A)	7.97
Open Circuit Voltage (V_{oc})	38.8
Short Circuit Current (I_{sc})	8.59
Temperature Coefficient of Power (%/OC)	-0.408%/k
Maximum system voltage (V_{dc})	1000
Length (mm)	1640
Width (mm)	990
Height (mm)	50
Weight (kgs)	19.8
Max. Power Current (A)	7.97
Open Circuit Voltage (V_{oc})	38.8

2.3 Online data acquisition system

In this solar power plant, data acquisition using ground based measurement approach for measuring the solar resource parameters and meteorological data. Solar photovoltaic plant generation is online monitored at the both DC and AC side using data acquisition system controlled by sunny sensor web box. RS232/RS485 peripheral interface is used for data communication and stored in the computer system using with a data acquisition system (SCADA). Converted DC power is directly fed in to 11 kV grid of GPCL via a 415V/11 kV transformer. Schematic diagram of step by step process of solar irradiation to power generation is shown in (Figure. 3)



for solar power plant.

Fig. 3 Schematic Diagram of 5 MW GPCL SPV Power Plant

Data acquisition system monitored generation for six month. Figure. 4 shows the plant generation for six months (March-August 2015) as consider for data analysis on the basis of peak months in a year.

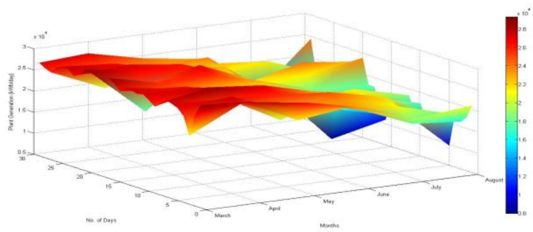


Fig. 4 Solar Power Plant Generation

2.4 Data normalization

Data normalization is most important part of the data analysis. Data normalization process can help in managing the data in same magnitude. If one parameter has a value of hundred and other parameter has a value in one, then it could be a problem in training of data in neural network. In this paper data scaled in the range of .1 to .9 to avoid convergence problems using equation. 1.

If

$$X = Actual\ data$$

$$X_{max} = \max(X)$$
$$X_{min} = \min(X)$$

$$Y = 0.1 + (X - X_{min}) * \left(\frac{0.8}{X_{max} - X_{min}}\right) \dots \dots \dots (1)$$

3. METHODOLOGY

In this paper solar power generation data is use which is highly non-linear and non-stationary in nature. Solar power generation is dependent on global horizontal irradiation (GHI). Because of GHI, Solar power generation had cycle variation and little trend in a nature because simple exponential smoothing method when there is no trend and seasonality so trend and seasonality based decomposition is included in this study.

3.1 Development of simple exponential smoothing

Suppose a measured solar power generation data expressed by:

$$E_1, E_2, E_3, E_4, \dots \dots \dots \dots \dots \dots \dots, E_n$$

Simple exponential smoothing equation is explained by Equation. (2) and explained in [1].

$$\hat{E}_{i+1} = \alpha . E_i + (1-\alpha)\hat{E}_i \quad (2)$$

Let

E_i = $Measured\ data\ for\ interval\ i$

$\hat{E}_i$ = $Forecasted\ data\ for\ interval\ i$

$\hat{E}_{i+1}$ = $Forecasted\ data\ for\ internal\ i+1$

α = $Smoothing\ constant$

Here $\hat{E}_{i+1}$ is dependent on the historical value of E_i with a α and $\hat{E}_i$ with a weight of $(1-\alpha)$. Because here $\hat{E}_i$ is not available so it is assume that $\hat{E}_i = E_i$ and use initial smoothed value [2-3]. The range of α is 0 < α <1.

3.1.1 Selection of α

Due to quickness at which the older responses are smoothed is a function of the value of $\boldsymbol{\alpha}$. When is $\boldsymbol{\alpha}$ close to 0, smoothing is low and when $\boldsymbol{\alpha}$ close to 1 then smoothing is very fast [2-3]. Here $\boldsymbol{\alpha}$ = [.5 .7 .9]

So after consider the $\hat{E}_i = E_i$ then Equation (2) can re-written as Equation. (3).

$$\hat{E}_{i+1} - \hat{E}_i = \alpha . (E_i - \hat{E}_i) \quad (3)$$

Here $(E_i - \hat{E}_i) = \varepsilon_i$ is residual so forecasted value is:

$$\hat{E}_{i+1} = \hat{E}_i + \alpha . \varepsilon_i \quad (4)$$

So

General form equation for simple exponential smoothing is given in Equation. (5) Which is explained in [4-5].

$$\hat{E}_{i+1} = \alpha . E_i + (1-\alpha)\left[\alpha . E_{i-1} + (1-\alpha)\hat{E}_{i-1}\right] = \alpha . E_i + \alpha(1-\alpha)E_{i-1} + (1-\alpha)^2\hat{E}_{i-1},$$

$$\hat{E}_{i+1} = \alpha . E_i + \alpha(1-\alpha)E_{i-1} + (1-\alpha)^2\hat{E}_{i-2} + (1-\alpha)^3\hat{E}_{i-3},$$

$$\hat{E}_{i+1} = \alpha \sum_{j=0}^{i-1} (1-\alpha)^j . E_{i-j} \quad (5)$$

4. RESULTS

In this paper historical data of 5MW GPCL solar photovoltaic power plant generation is used for forecasting. The available data is having trend and seasonality, since it depends upon solar radiation and time. Hence, de-trending and de-seasonality is performed on the data to obtain decomposed time series which is shown in Fig 5(a) -5(f). Single exponential smoothing is performed on this data to forecast the power plant generation. Here, forecasted generation are computed with a value of $\boldsymbol{\alpha}$ = [.5 .7 .9] shown in Figs. 6(a) – 6(f) and it is observed that with the higher value of smoothing factor forecasting accuracy value is much compared to lower values. RMSE (root mean square error) and R2 for evolution of forecasting accuracy which are given in Equation (6-7). According to Table. (2), it is observed that after using de-trend & de-seasonal power generation in singe exponential smoothing model results are much better compared to actual forecast.

$$R^2 = 1 - \frac{Var(\hat{I} - I)}{Var(I)} \quad (6)$$

The Root-Mean Squared Error (RMSE) which is a measure of the average spread of the errors:

$$RMSE = \sqrt{\frac{1}{N}\sum_{t=1}^{N}\left(\hat{I}_t - I_t\right)^2} \quad (7)$$

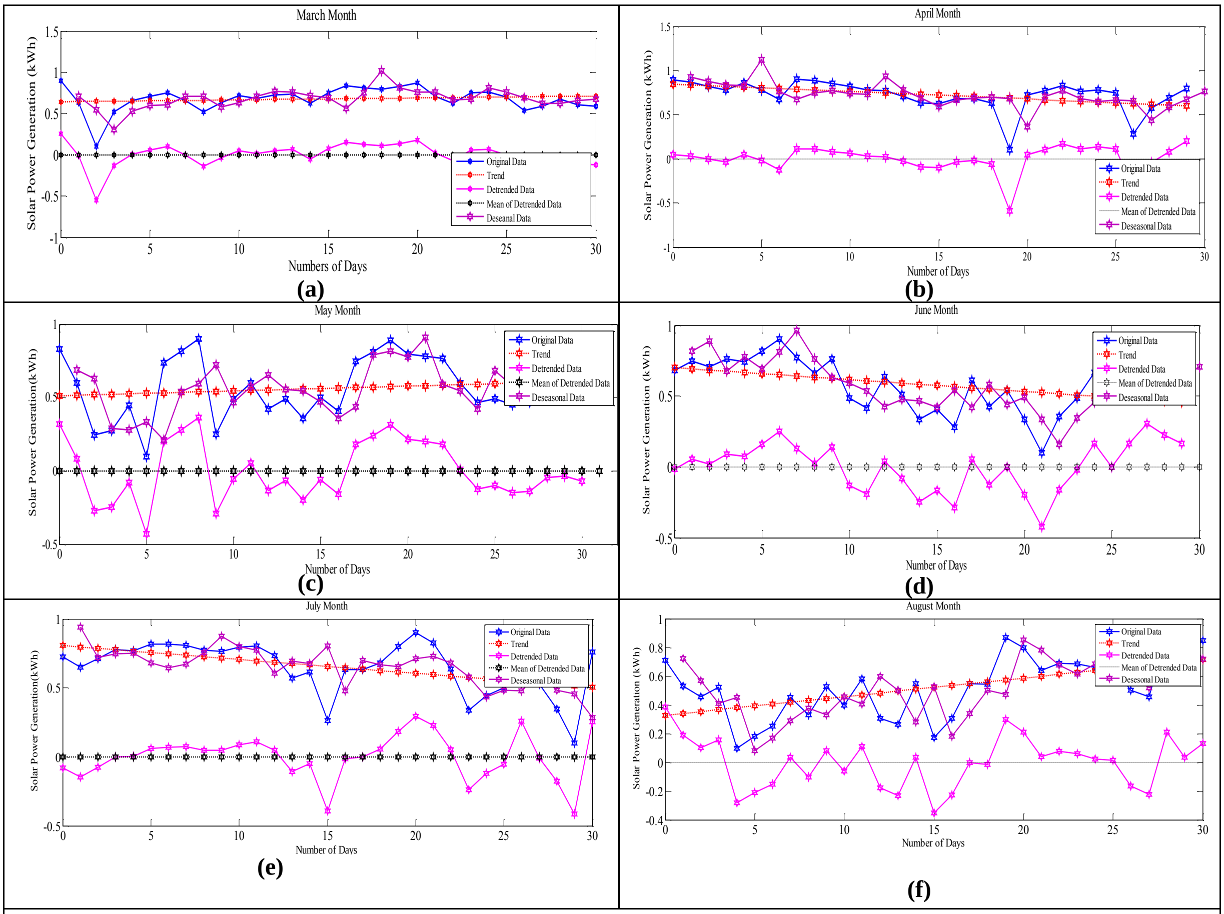


Fig. 5(a) - Fig. 5(f) Six month Actual plant generation versus trend and seasonal based decomposition values

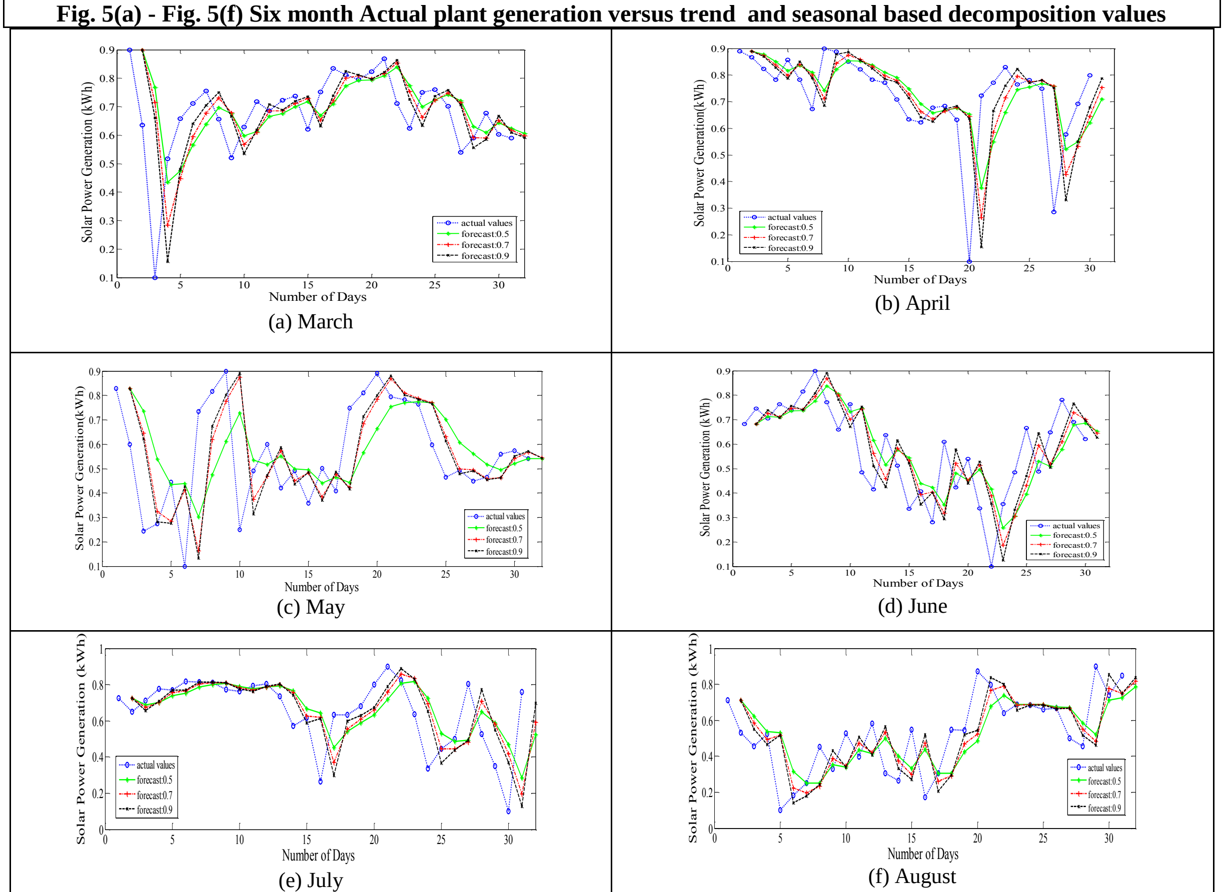


Fig. 6(a) - Fig. 6(f) Plot for Actual Values and Forecast Values using α = 0.5, α = 0.7 and α = 0.9

Table 2 Error metrics for forecasting accuracy using given value of α.

Months	Single Exponential Smoothing					
With Trend						
	RMSE			R^2		
D.F.	α=.5	α=.7	α=.9	α=.5	α=.7	α=.9
March	0.1589	0.1573	0.1893	0.7012	0.8945	0.9881
April	0.1741	0.1806	0.1893	0.7367	0.8981	0.9836
May	0.2183	0.2159	0.2211	0.7211	0.9014	0.9876
June	0.1475	0.1482	0.1533	0.8453	0.9438	0.9913
July	0.1864	0.1904	0.1954	0.7593	0.9096	0.9854
August	0.1819	0.1821	0.1898	0.8173	0.9341	0.9921
Without Trend						
	RMSE			R^2		
D.F.	α=.5	α=.7	α=.9	α=.5	α=.7	α=.9
March	0.1592	0.1575	0.1571	0.6931	0.8919	0.9881
April	0.1738	0.1805	0.1893	0.6762	0.8742	0.9846
May	0.2188	0.2162	0.2202	0.7129	0.8991	0.9884
June	0.148	0.1484	0.1589	0.8159	0.9333	0.9921
July	0.1841	0.1905	0.1957	0.6879	0.8822	0.9862
August	0.1821	0.1823	0.1899	0.7363	0.9049	0.9885
Without Seasonality						
	RMSE			R^2		
D.F.	α=.5	α=.7	α=.9	α=.5	α=.7	α=.9
March	0.1163	0.1159	0.1159	0.7653	0.9161	0.9907
April	0.1308	0.1369	0.1439	0.786	0.9156	0.9897
May	0.1645	0.1594	0.1586	0.7554	0.9173	0.9949
June	0.1475	0.1482	0.1533	0.8453	0.9438	0.9933
July	0.1099	0.1095	0.1126	0.8508	0.9467	0.9937
August	0.1694	0.1664	0.1711	0.8258	0.9395	0.9929

5. CONCLUSION

In the last, when using single exponential smoothing model for forecasting, it is very important to know the characteristic of time series data then it will help in better forecasting results. When seasonality and trend is considered, after the seasonality reduced to non-seasonal models. Here single exponential smoothing models show that, trend and seasonality based decompositions increase the accuracy of forecasting of solar power generation.

6. ACKNOWLEDGEMENTS

The authors would like to acknowledge the Gujarat Power Cooperation Limited, Gujarat for providing Photovoltaic generation data and Central power Research Institute, and Bangalore for financial support.

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