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Single exponential smoothing approach for 5 MW solar power plant generation forecasting

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In 21st century forecasting of solar power generation is an important issue due to grid integration. 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.

Keyword: *Solar power, forecasting, exponential smoothing.*

1.0 INTRODUCTION

Solar photovoltaic power output is an important power source in renewable energy. It helps in integrated grid operations, planning, and maintenance. In this paper we consider six months for study of solar power generation, from March, 2015 to August, 2015. 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.

DATABASE DESCRIPTION

1.1 Solar photovoltaic plant

A peculiarity of Gujarat is extreme climatic conditions which are categorized by very hot and dry summer and cold and chilly winters. Figure 1 shown 5 MW grid-connected Multi crystalline photovoltaic power plant 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.

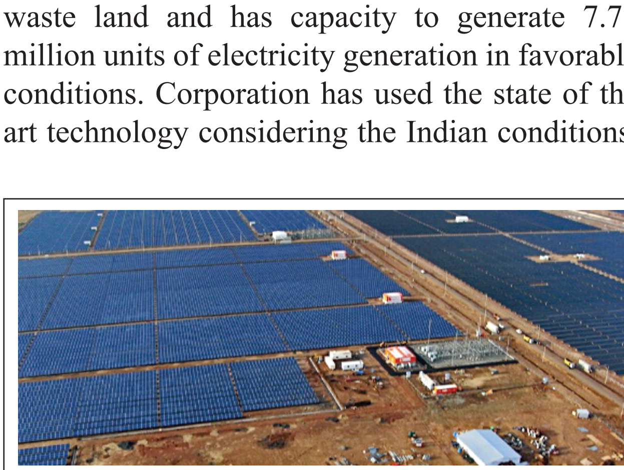

FIG. 1 5MW GRID-CONNECTED MULTI CRYSTALLINE PHOTOVOLTAIC POWER PLANT

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The project is fully commissioned and operational. The plant is located at Latitude $23^0 54' 20.24''$N and Longitude $71^0 11' 54.29''$E.

1.2 Specifications

Solar PV array (high efficiency poly/multi crystalline -Si SPV Module) - The plant consist of 21,277 no. of 235 W_p poly/multi crystalline-Si from "C-Sun" Solar PV modules.

1.3 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. RS 232 / RS 485 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 415 V/11 kV transformer. The schematic diagram of the solar power plant is shown in Figure 2.

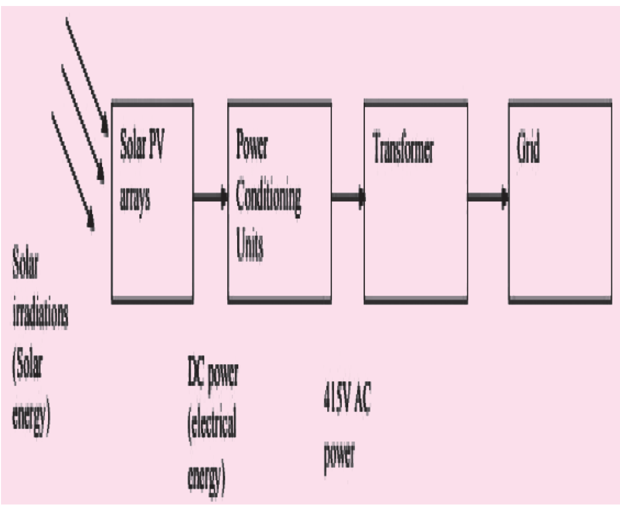

FIG. 2 SCHEMATIC DIAGRAM OF 5 MW GPCL SPV POWER PLANT.

Data acquisition system monitored generation for six month. Figure 3 shows the plant generation for six months (March-August 2015) as consider for data analysis on the basis of peak months in a year.

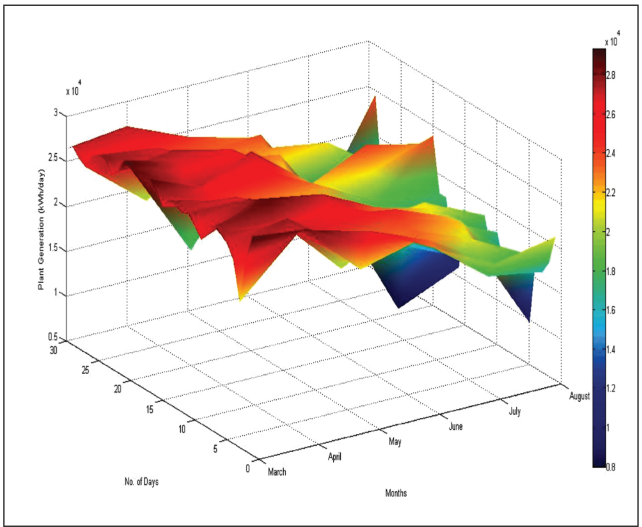

FIG. 3 SOLAR POWER PLANT GENERATION.

1.4 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 scaledin the range of .1 to .9 to avoid convergence problems using equation. 1.

If

$$X = Column\ Vecot\ of\ particular\ parameter(Actual\ data)$$
$$X_{max} = \max(X)$$
$$X_{min} = \min(X)$$
$$Y = 0.1 + (X - X_{min}) * \left(\frac{0.8}{X_{max} - X_{min}}\right) \quad ....(1)$$

2.0 METHODOLOGY

In this paper solar power generation data is use which is highly non-linear and non-stationary in nature. Solar power generation is highly 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 we have done trend and seasonality based decomposition of PV plant generation.

2.2 Development of Simple exponential smoothing:

Suppose a measured solar power generation data expressed by:

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

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

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

Let

E_i = Measured power generation data for interval i
$\hat{E}_i$ = Forecasted power generartion for interval i
$\hat{E}_{i+1}$ = Forecasted pwoer generation for internal i + 1
α = Smoothing constant

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

The range of α is 0 < α <1.

2.2.1 Selection of α

As we know that the quickness at which the older responses are smoothed is a function of the value of **α**. When is **α** close to 0, smoothing is low and when **α** close to 1 then smoothing is very fast. Here we are taking **α** = [.5 .7 .9]

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

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

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

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

So

General form equation for simple exponential smoothing is given in Equation. (5)Which is explained in[2].

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

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

3.0 RESULTS

In this paper historical data of 5 MW GPCL solar photovoltaic power plant generation is used for forecasting. Single exponential smoothing is performed on this data to forecast the power plant generation. Here, forecasted generation are computed with a value of = [.5 .7 .9] shown in Figures 4(a) – 4(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 R^2 for evolution of forecasting accuracy which are given in Equation (6-7). According to Table. (1), it is observed that after using de-trend and de-seasonal power generation in singe exponential smoothing model results are much better compared to actual forecast.

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

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

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

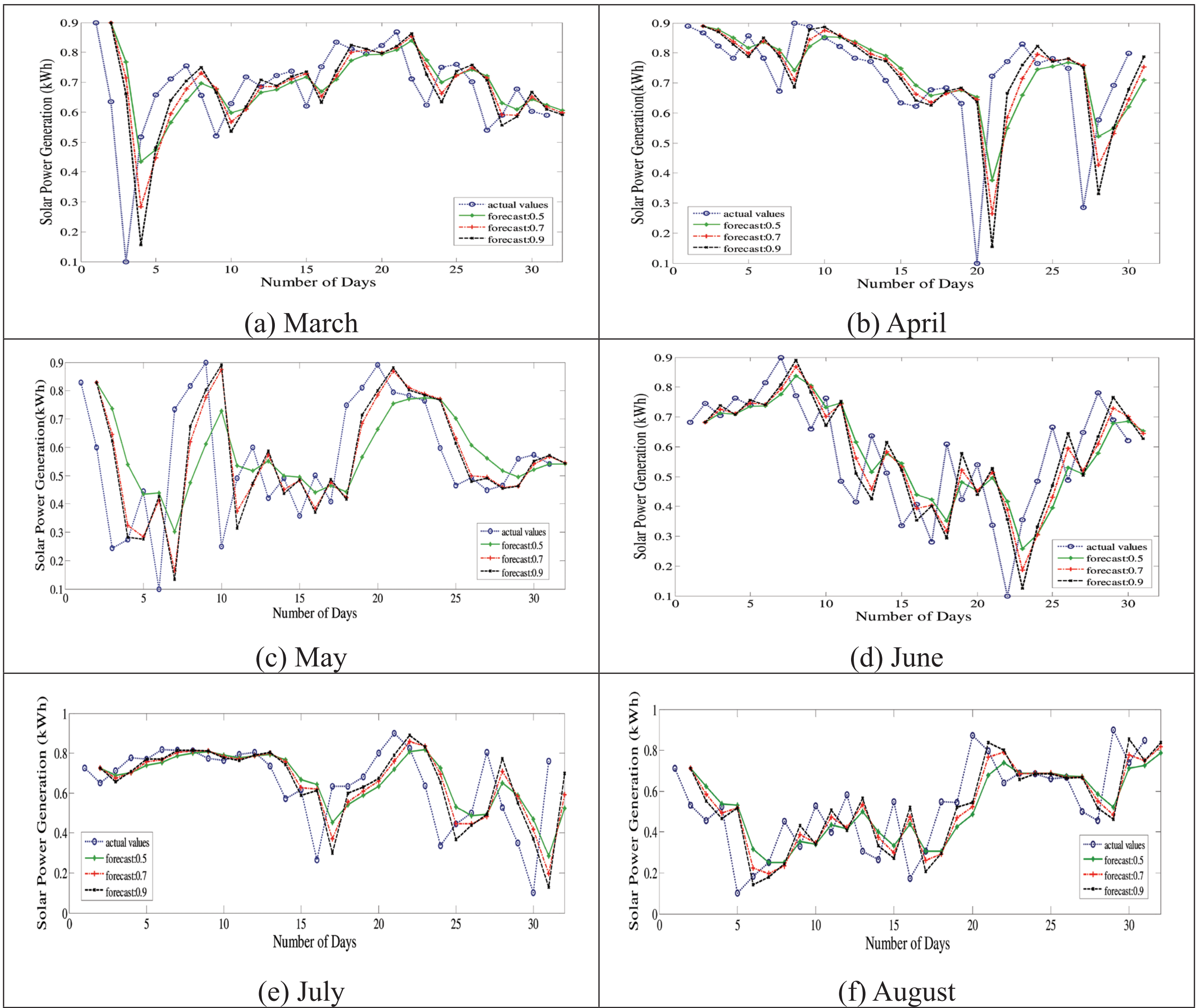

FIG. 4 A) - FIG. 4 (F) PLOT FOR ACTUAL VALUES AND FORECAST VALUES USING α = 0.5, α = 0.7 AND α = 0.9 .

TABLE 1						
ERROR METRICS FOR FORECASTING ACCURACY USING GIVEN VALUE OF A.						
Months	**Single Exponential Smoothing**					
	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

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