

# SHORT-TERM FORECASTING OF ELECTRIC ENERGY GENERATION FOR A PHOTOVOLTAIC SYSTEM

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**Abstract.** This article presents a short-term forecast of electric energy output of a photovoltaic (PV) system towards Tomsk city, Russia climate variations (module temperature and solar irradiance). The system is located at Institute of Non-destructive Testing, Tomsk Polytechnic University. The obtained results show good agreement between actual data and prediction values.

## 1 Introduction

The renewable technologies provide a feasible alternative of generating electricity which inexhaustible, clean and can be used in a decentralized way. Considering the geographical position and climatic characteristic of Tomsk Oblast, Russia, there is a good potential of renewable energy development in PV systems [1]. The prediction and optimization of electrical performance of PV system provides essential references values on maintaining the actual load stability as well as the system design considerations of GCPV system.

The analysis of difference models showed that: the time series data of PV power generation output have chaotic characteristics, so they can be predicted. PV power generation prediction generally includes solar irradiance forecast, temperature forecast and model output statistics [1], and the key is solar irradiance forecast. According to the range of forecast time, solar power generation prediction can be divided into short-term forecast (1 hour–10 days), medium-term forecast (11–30 days), long-term prediction (1–5 years), and the most useful prediction is short-term prediction.

All the PV power generation prediction models include two stages: data collection; and data processing. The role of data collection is to provide input information for the prediction model. As for PV power prediction, the most important information are meteorological parameters and historical PV power output data. The meteorological parameters come from measuring device (such as weather sensors, etc.) and weather forecast information. Recently, there are few methods that involve in PV system outputs prediction. For example by employing Artificial Neural Network (ANN) which utilizes the solar radiation, ambient temperature and module temperature as it inputs whereas voltage and current are predicted as outputs. Besides, the evolutionary programming (EP) algorithm schemes is implemented

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for adjusting the optimal value of the fill factor in order to achieve more accurate outputs of PV systems.

In this paper we demonstrate the necessity of short-term time series prediction of generated power using mathematical approach based on fundamental equations.

## 2 Theoretical aspects of forecasting of PV electric energy

### 2.1 About photovoltaic system

The tested PV system is located at Institute of Non-destructive Testing, Tomsk Polytechnic University, Tomsk, Russia. The station includes 3 kW solar battery and 2 kW wind-driven electric plant [2]. The station is shown in Figure 1.

The station consists of:

- solar generator ARPS-250 (10 elements);
- wind generator 1000 W (2 elements);
- voltage transducer =48/~220V, 50Hz.

Specification:

- generator capacity, no more than 5 kW;
- output voltage ~220 V, 50 Hz;
- surface area of the PV modules, no more than 230 m<sup>2</sup>;
- effective area of the station, no more than 300 m<sup>2</sup>;
- height of wind generator tower 6 m.

Operating conditions:

- temperature, from -50 to 50° C.



Fig. 1. Wind - solar station at Tomsk, Russia.

### 2.2 Statistical model of PV power output

The PV array power generates the DC component output, so the PV inverter performs the conversion of the variable DC output of the PV modules into a utility frequency AC current that can be fed into the commercial electrical grid or used by a local, off-grid electrical network. Therefore, the conversion efficiency of the PV inverter will affect the AC component of output power [3]. The maximum power output of the PV system can be expressed by

$$P_S = \eta_{IN} \times P_A = \eta_{IN} \times FF_A \times V_A \times I_A = \eta_{IN} \times M_P \times M_S \times P_M$$

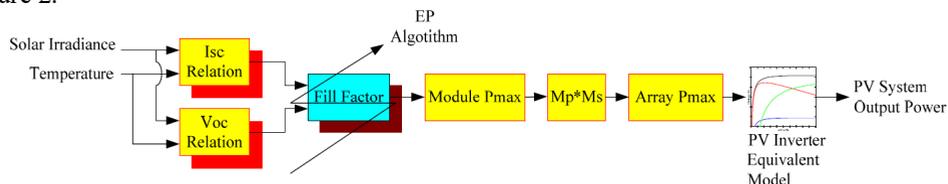
where,

$\eta_{INV}$  is PV inverter efficiency;

$P_A$  and  $P_M$  are the PV array and PV module power output, respectively;

$I_A$  and  $V_A$  are the PV array current and voltage, respectively;

The structure of EP based on the output power of photovoltaic system is shown in the Figure 2.



**Fig. 2.** Structure of EP based on the output power of photovoltaic system model.

### 2.3 The solar irradiation model

To calculate the sun’s position in the sky at any location and time, two angles should be known: Azimuth angle and the Altitude angle. Also the sunrise and sunset times will help determining the start and end points of azimuth angle. In this paper we follow the convention of azimuth angle starting from zero degree at North Pole. Accordingly east, south and west poles are at 90°, 180° and 270°, respectively.

Azimuth angle (Figure 3) depends on latitude and time of year. The following equation is used to find the angle at any location [4].

$$\gamma = \frac{1}{2} \cos^{-1} \left[ \frac{\sin \delta \cdot \cos \phi - \sin \phi \cdot \cos \delta \cdot \cos H}{\cos \alpha} \right]$$

where,

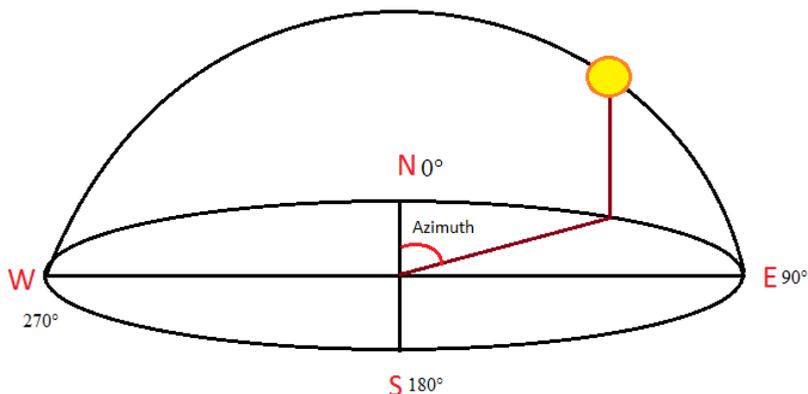
$H = H = 15 \times (LST - 12)$  hour angle;

$LST$  – local solar time;

$\delta$  – declination angle;

$\phi$  – latitude of the place;

$\alpha$  – Elevation angle.



**Fig. 3.** Azimuth Angle.

In order to point the dependence of extraterrestrial solar radiation by the time of the year, the following equation were used [5]:

$$G_{on} = G_{sc} \cdot \left( 1 + 0.033 \cdot \cos \frac{360 \cdot n}{365} \right)$$

where,

$G_{on}$  is the extraterrestrial radiation measured on the plane normal to the radiation on the  $n$ -th day of the year;

$G_{sc}$  is the solar constant,  $G_{sc} = 1367 \text{ W/m}^2$ ;

$n$  is the day of the year.

### 2.4 Temperature forecasting value

The detailed values of temperature forecasts over a 10 day period are provided by varies websites, in this paper we get the values from website wunderground.com by using python and packages Beautiful Soup 4 and Requests (Figure 4). The received values are organized with an array.

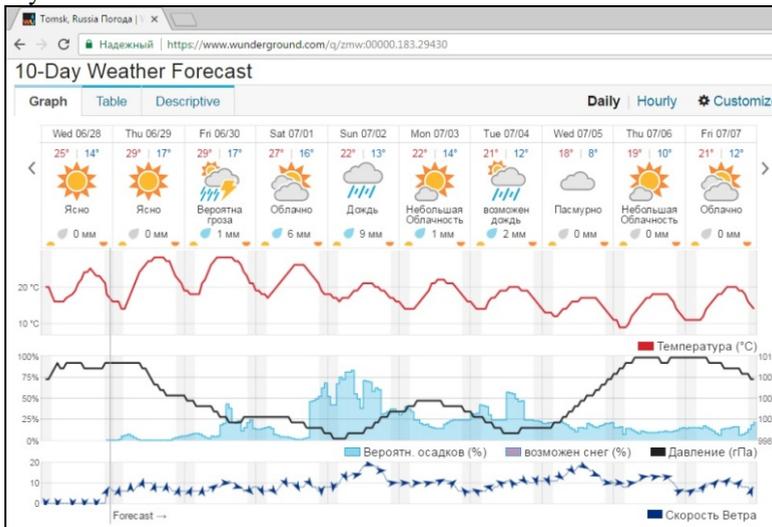


Fig. 4. Example screenshot of 10-day temperature forecast.

### 3 Results and discussion

Software solarEnergy was created on the basis of the MATLAB 2012b. The main window screenshot is shown in Figure 5. The size of PV panel and daily average consumption are set in the field “Real size of panel” and “Daily average consumption” of the software. Plots of prediction value of output and balance are shown in the plot area (Figure 6).

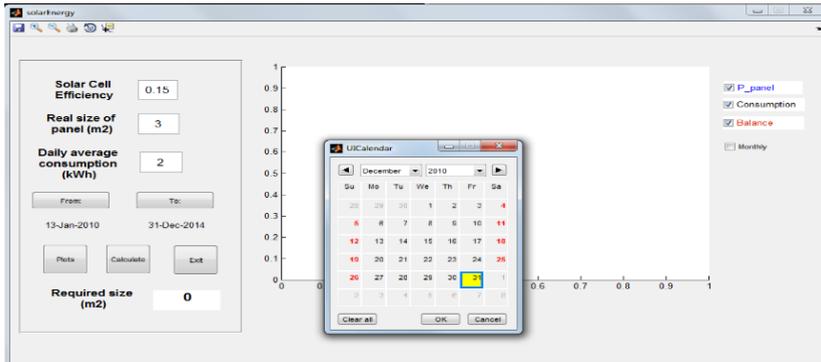


Fig. 5. SolarEnergy main window.

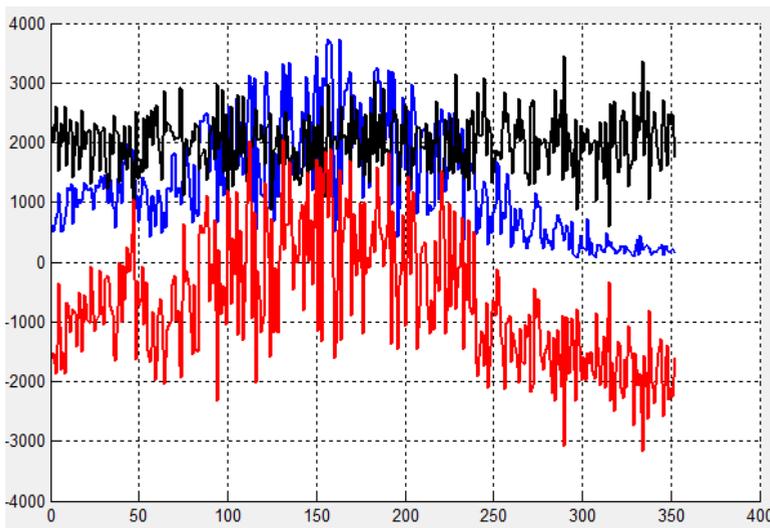


Fig. 6. Example of plot of power output and balance.

## 4 Conclusion

The performance of grid connected PV system is primarily influenced by the solar irradiance and module temperature. This paper demonstrated the prediction on PV system outputs based on mathematical approach for the PV system, which is located at Tomsk Oblast, Russia. The proposed approach provides an effective method for prediction and feasible in time under the same accuracy. Based on the results, it shows a good correlation between actual and predicted of electrical performance on grid connected PV system. In the future we plan to continue the research, including prediction using neural network and machine learning methods to improve accuracy and range of forecasting, as well as design applications to wind farms and other renewable power sources.

## References

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