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Short-term forecast of generation of electric energy in photovoltaic systems

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ABSTRACT

The paper presents the use of classical statistical methods and methods based on neural modeling in short-term forecasting of electric energy from photovoltaic conversion. A detailed analysis of the input data measured in central Poland (Poznań, 52°25′ N, 16°56′ E) showed that some variables like air pressure and the length of the day are statistically insignificant. The values of kurtosis, skewness and results of applied tests, to check the normality of the distribution of dependent variable in the form of daily electricity production, indicate that the linear regression models should not be the only method in forecast process. The result of neural modeling using implemented network designer is RBF 6: 6-5-1: 1 model with quality test approximately 93% and the RMS error of 0.02%. The input parameters necessary for the operation of proposed ANN model are: number of sunny hours, length of the day, air pressure, maximum air temperature, daily insolation and cloudiness.

1. Introduction

The intensive development of photovoltaics can be observed over the last 10 years in Poland as well as in the whole world [1,19]. In 2014 the total power of photovoltaic installations in the world exceeded 175 GW. According to the report prepared by European Photovoltaic Industry Association, the countries in which photovoltaics expanded rapidly are: Germany, China, Japan and the USA. The level of investment in the sector of conventional energetic is modest.

The total electric power in photovoltaic systems installed in 2015 equalled 59 GW. IHS consulting company estimated that in years 2016–2019 additional 272.4 GW of power stemming from the above mentioned systems is to contribute to exponential increase of the generative potential. Fig. 1 illustrates the current and forecasted increase in the aggregate power installed in the world PV systems from 2007 to 2016.

The rapid development of photovoltaics can be noticed on the Asian market, where the participation of China in the volume of new powers till the end of 2017 is forecasted to exceed 70 GW in relation to the currently installed 20 GW [24,30]. Germany have exceeded the level of 38 GW which contributed to accomplishing the energetics plan 2 years earlier than planned. The remaining countries, which exert a vital influence on the development of the photovoltaic branch are Italy (18.3 GW), France (5.6 GW) and Spain (5.4 GW), which does not achieve essential increase in installed power since reaching the network quota in 2013 [11]. Photovoltaic energy plants have major influence on the increase in power in the world energy system [8]. Currently the biggest investment is a solar farm in San Luis County (USA, California). The plant generates maximum 550 MW [28]. In terms of maximum installed power American photovoltaic farm called Desert Sunlight (Riverside County, California) equals the previously mentioned one and has been built from thin-layer modules of cadmium telluride. The facility using monoaxial tracking systems, enabling the change of the spatial position of silicon modules against the vertical axis, is the American project Solar Star (Rosamond, California), generating the maximum electric power of 597 MW. The project was completed in the end of 2015. The systems concentrating solar radiation can contribute to further increase in power. The systems can focus the solar radiation from considerable area in the small surface of photovoltaic cells – most frequently using a system of lenses or speculums [20]. Another method bases on luminescent radiation hubs applying a particular amount of the total radiation spectrum for photovoltaic conversion. In several cases solutions of this type are utilized in big photovoltaic installations [18]. The dynamic growth of alternative technologies generating electric energy must intercorrelate with conventional sources, which enables the compensation of production outage, depending on the weather.

Not only the technology of production of solar cells and the configuration of their work and the volume of installed power but also the method of settlement of produced electric energy have impact on the economic application of photovoltaic installations [10,12,22,4,9]. Nowadays is observed the participation of the pro-consumer in energy market. Supporting of dispersed energetics and introducing feed-in-tariff rates it is possible to improve the situation on the market of

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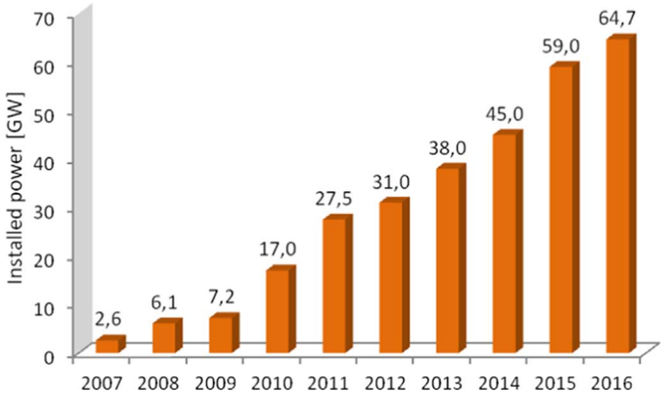

Fig. 1. Increase in aggregate power stemming from installed photovoltaic systems in years 2007 – 2016 [29].

renewable energy. Only by taking the above mentioned steps the long-term stability of purchase prices of electric energy generated in microinstallations might be stabilized. The investment of the so-called committed provider and owner of the microinstallation is supposed to be subsidized or be given soft credits. In order to estimate the economics of applying photovoltaic modules of various production technology in particular climates, it is of utmost importance to determine the amount of electric energy generated by the photovoltaic system against the total financial and energetic outlay.

Energy providers in Europe base on the numeric models (for example Global Forecasting System) complimented by local measurements in order to enhance the accuracy of the forecast. It will become crucial to forecast the electric energy from diverse generating sources to guarantee the stability of providing energy in short and long time horizons.

The generated power depends on the availability of solar resources. The power is defined by numerous external factors, namely: insolation (the sum of momentary density of solar power radiation on the given surface during the established period of time) as well as the number of sunny hours. The second parameter depends also on the geographic position of the measurement point – the photovoltaic installation, which is related to the length of the day during the particular seasons. Fig. 2 bases on data from 2004 to 2010 and presents the distribution of average insolation in Poland.

Among the independent (clarifying) variables, exerting a potential influence on analyzed dependent variable (clarified), there are also ones which have a decisive impact on the amount of generated electric energy. A crucial parameter is the temperature of installed photovoltaic modules. The value of temperature influences the I - V characteristics as well as the position of the maximum power point [5].

Fig. 3. Physical realization of analyzed fixed photovoltaic unit.

Statistical and neural modeling analyses are the basic methods of assessment and forecasting of electric energy production in photovoltaic systems. Artificial Neural Networks (ANN) are widely applied tools, for instance in engineering, agronomic areas as well as issues connected with ecoenergetics [13–17,2,21,23,25–27,3,6,7].

The analysis conducted by means of multiple regression presents the relation between numerous defining variables and the criterion variable in form of the electric energy. The analyzed photovoltaic system with a maximum power of 0.25 kW was installed on a specially prepared construction. The inclination angle was constant during the year.

Fixed photovoltaic unit consists of polycrystalline module installed with calculated annually - optimal elevation angle β = 37° in south direction (azimuth angle γ = 180°).

Specially prepared construction in accordance with calculated elevation angle for a photovoltaic module is shown in Fig. 3.

Table 1 presents the parameters of the photovoltaic modules and microinverters used in the analyses. The fixed construction is installed on the roof of the Faculty of Electrical Engineering Poznan University of Technology building.

The analysis comprises the possibility of embracing neural model-

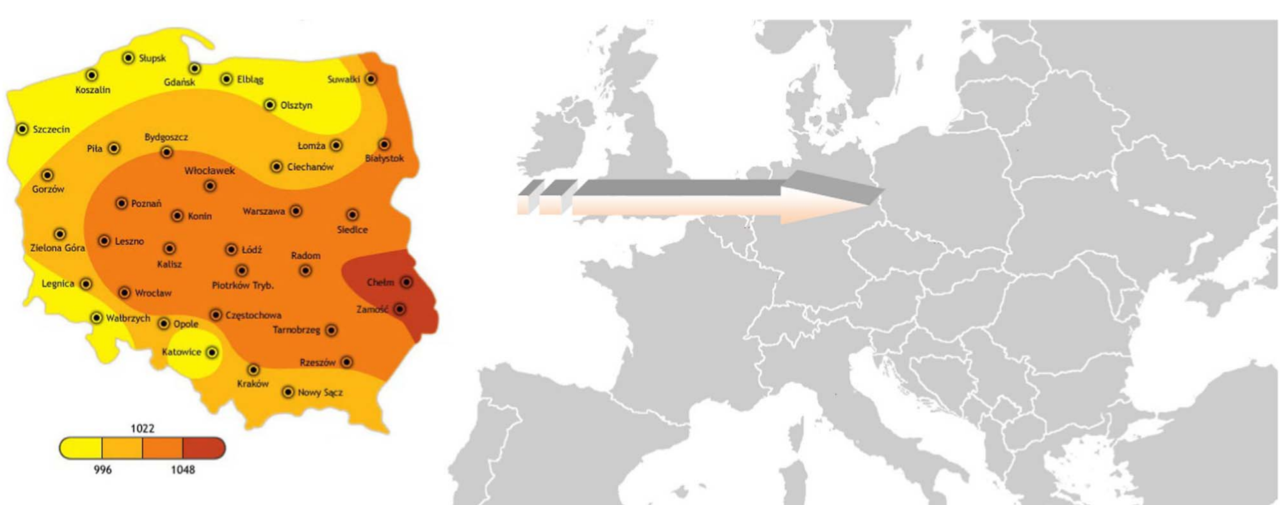

Fig. 2. Average insolation in Poland [own data basing on [31].