Analysis and modeling of load parameters of wind power station

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Abstract. The method and the load parameters dynamics simulation algorithm fed to the input of the energy-dynamic wind power station modes management system have been developed. Based on the real data analysis, we obtained dependencies of the management system input data changes for the specific time intervals. Input load parameters were simulated using the developed method. We have obtained data for the neural network training with the justification of changes in active wind power composition. The results are shown in a load parameters table as input management system data and estimated load charts. The results are important for the wind power station management system simulation as they provide higher reliability and accuracy of the results.

Key words: wind power station (WPS), load curve, management system, input load parameters simulation.

INTRODUCTION

Modern industrial WPSs consist of a large number of different types of electrical wind turbines (EWT), and their operation modes are determined by the balance of generated and consumed electricity. These conditions, on both sides, are determined by the random processes, which significantly complicates the energy-dynamic processes control algorithm [12, 15]. This problem becomes particularly relevant in case of WPS operation simultaneously with the electrical distribution network, that is, when it is necessary to ensure implementation of a complex load schedule based on active capacity or other mode parameters [11]. The possibility of power generation by a wind turbine depends on many factors, the most important of which are wind power and the technical condition of the EWT. [1, 9, 18] The capacity of modern WPSs is so high that objective of generating the necessary amount of energy in some periods of time does not require the operation of all existing EWT [20]. So nowadays, an urgent task is to increase the efficiency of certain electrical wind turbines operation within a farm wind [2] in order to increase the period of their operation, optimization of electric-dynamic modes [10]. To study and implement these modes within certain time intervals, required composition of wind turbines is formed. In [3] this issue is addressed by developing each wind turbine usability coefficient at a given time, which makes it possible to substantiate and change the WPS structure. However, the analysis of the energy-dynamic processes management implementation results suggests that one of the possible methods of improving its effectiveness is a preliminary study of the load parameters for specific time intervals in order to enable the situations classification to make a decision on the change in the active composition of wind power station [4, 14, 17].

Therefore, the load parameters dynamics study, development of methods for its simulation to improve the efficiency of wind power station energy-dynamic modes management is a ***critical scientific task.***

The design and operation of electrical systems provides for three types of electric load, reactive load power Q, active load power P and current I. The curve which reflects the change in load over time is called load demand. The load at a given time means its true value determined using measuring devices with low inertia. The value of consumed active and reactive power depends on parameters such as the number, determined power and operation modes of different types of receivers. Power consumption can vary widely throughout the day. The total electrical load that determines the mode of power station operation is changing continuously [5]. This fact is usually reflected using load curves, i.e. charts of electrical unit capacity change over time, which can be smooth, zigzag or stepped curves built in the Cartesian coordinate system, where the vertical axis reflects power, and the horizontal axis - the time during which its change is considered. Load curve which characterizes the change in capacity for one day is called a daily curve [5, 6].

The value of the load for different groups of consumers may differ, but the load curves share some general quantitative estimates – they include the largest and the smallest value of load capacity at a certain time interval. To analyze the data on the capacity use, daily curves for the two typical periods of consumers operation

– in summer and winter – are used. Hence, the highest and the lowest load are distinguished for these periods.

OBJECTIVE

The objective of this work is a preliminary study, extrapolation and simulation of the load parameters dynamics which are fed to the management system input to improve the efficiency of methods and means used to determine a plurality of used electrical wind turbines (EWT) by increasing the reliability of input data.

THE MAIN MATERIAL

The task of obtaining reliable load parameters at the wind power station management system input is very important because to verify the algorithms for analysis, simulation, forecasting, dynamic determination of wind power station composition used in the system developing, it is necessary to submit data with high reliability. At the first step, it is necessary to create and fill a database with the real control input load values which can be obtained from the real daily load curve for the basic consumer groups for the regime days of June and December from the company which provides services to the electricity consumers.

In order to obtain universal data, data on the load dynamics at the administrative unit level - the region rather than at the level of the building, street, district or city were used because at the high level of integration, load curves for different regions will have a high degree of similarity which will allow taking into account the typical change in the load parameters.

Based on the data obtained in [7], we are building region power grid daily load change curves (Figure 1), where —— the load parameters change throughout the day in June 16; - - - the load parameters change throughout the day in December 15; -·-·- the load parameters change throughout the day in June 15; -··- the load parameters change throughout the day in December 21; ······ the load parameters change throughout the day in June 21; —— the load parameters change throughout the day in December 20.

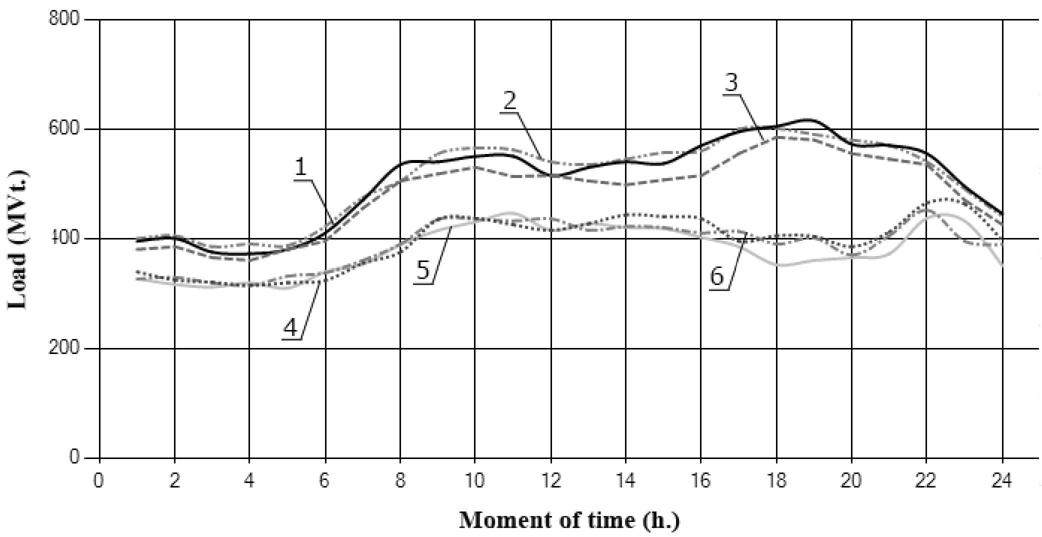

Fig.1. Daily grid load curve in the summer and winter periods

On the vertical axis, you can see load (MW) at time t (h) which is shown on the horizontal axis. The figure shows six curves, curves 1, 2, 3 characterize the load parameters change throughout the day for winter the period while curves 4, 5, 6 show the change throughout the day in the summer period for three consecutive years.

Algorithm and software which allows us to obtain the data change interval and visually display the result in the form of a load curve have been developed [13] for the analysis of input load parameters. Algorithm for determining the load used for the software development can be presented using a block diagram (Figure 2) [19].

The first step is to determine the maximum and minimum capacity in each control point. Mathematically, this step can be represented as follows:

$$P_{\max}(t_j) = \max(P_i(t_j)), \quad (1)$$

$$P_{\min}(t_j) = \min(P_i(t_j)), \quad (2)$$

where: $P_{\max}(t_j), P_{\min}(t_j)$ – the maximum and minimum capacity in t_j time respectively, $j = [0,23]$;

$(P_i(t_j))$ – value of the i-th capacity measurement in t_j time period; $i = [0, n]$ - the number of measurements.

Since the reference data are provided accurate to an hour, it is necessary to extrapolate the maximum and minimum values to improve the reliability of the resulting data.

Discretisation is specified by the software user. Mathematically, extrapolating process [8, 16] can be represented as follows:

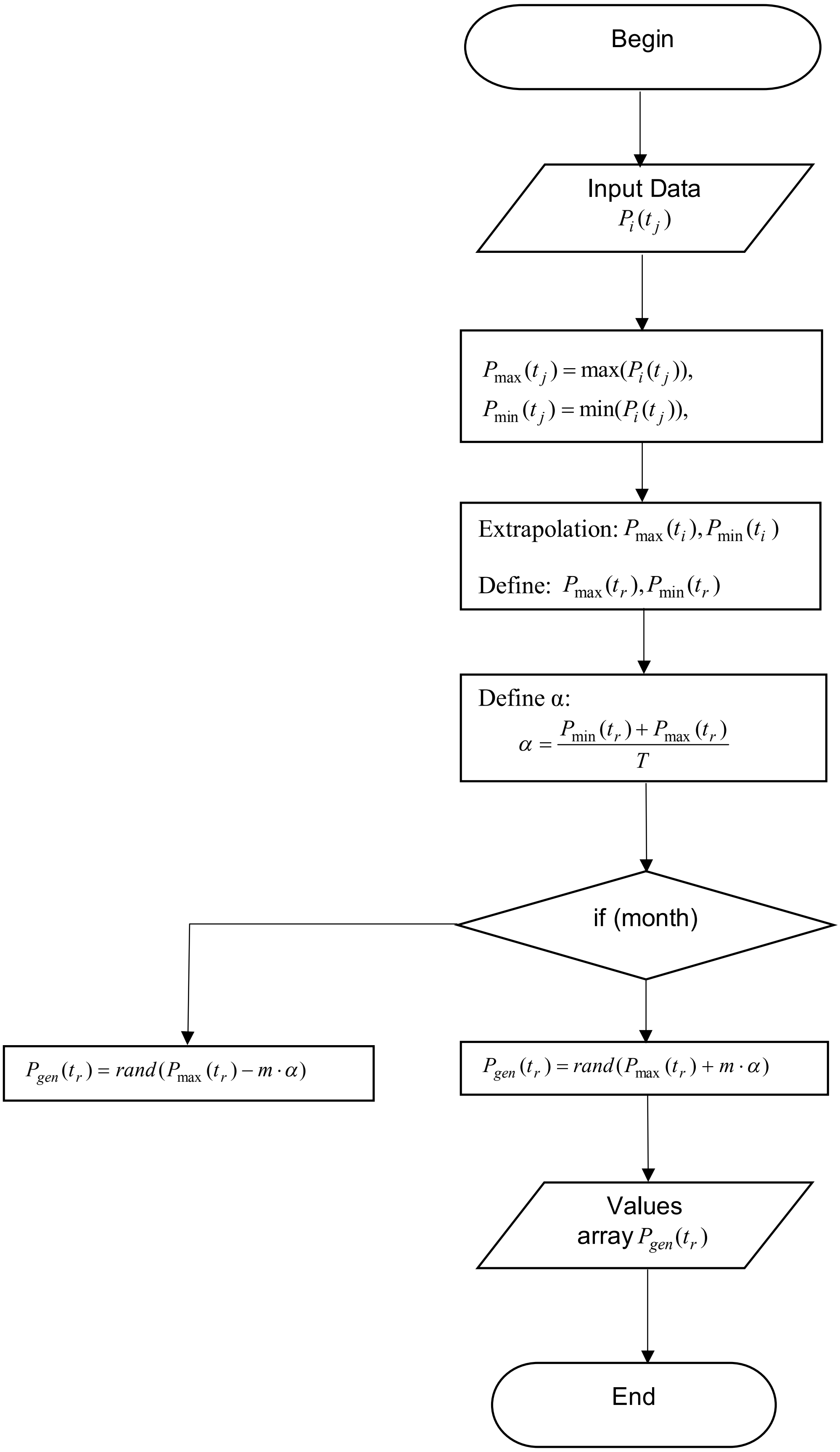

Fig. 2. Block diagram of the algorithm for the wind turbine management system input load analysis

$$P_{\max}(t_r) = \frac{P_{\max}(t_j) + P_{\max}(t_{j+1})}{K} \cdot r, \quad (3)$$

$$P_{\min}(t_r) = \frac{P_{\min}(t_j) + P_{\min}(t_{j+1})}{K} \cdot r, \quad (4)$$

$$r = k \cdot \Delta \quad (5)$$

where: $P_{\max}(t_r)$, $P_{\min}(t_r)$ is the maximum and minimum capacity at the r-th second of time,

r is moment of time for which $P_{\max}(t_r)$, $P_{\min}(t_r)$ is determined,

k is experiment number K= 3600,

Δ is generating discretisation (set by the user).

The next step is to determine the values of the input capacity for experiments in a special range of values. Since the system load parameters are directly proportional to the length of the daylight, which is clearly confirmed experimentally by analyzing measurements of extreme values of instant capacity, to enhance the results reliability, it has been proposed to narrow the range of the spread of values by introducing the correction coefficient α.

The mathematical description of the process is as follows:

$$\alpha = \frac{P_{\min}(t_r) + P_{\max}(t_r)}{T}, \quad (6)$$

where: α is corrective coefficient determined as an average between the maximum and minimum values of capacity, at the T = 6 intervals, i.e. every six months.

$$P_{gen}(t_r) = rand(P_{\max}(t_r) - m \cdot \alpha) \quad (7)$$

or

$$P_{gen}(t_r) = rand(P_{\min}(t_r) + m \cdot \alpha) \quad (8)$$

where: $P_{gen}(t_r)$ is the determined capacity in t_r time period in the adjusted range,

$m = [1,12]$ is serial number of months in the year.

The results of the algorithm operation can be viewed in tabular and graphical mode.

Figure 3 shows the load parameters dynamics curve for 24 hours with a step of 300 seconds.

Figure 4 shows the load parameters dynamics curve over a period of 7 days with a step of 500 seconds.

Figure 5 shows the load parameters dynamics curve for a period of 12 months with a step of 3600 seconds.

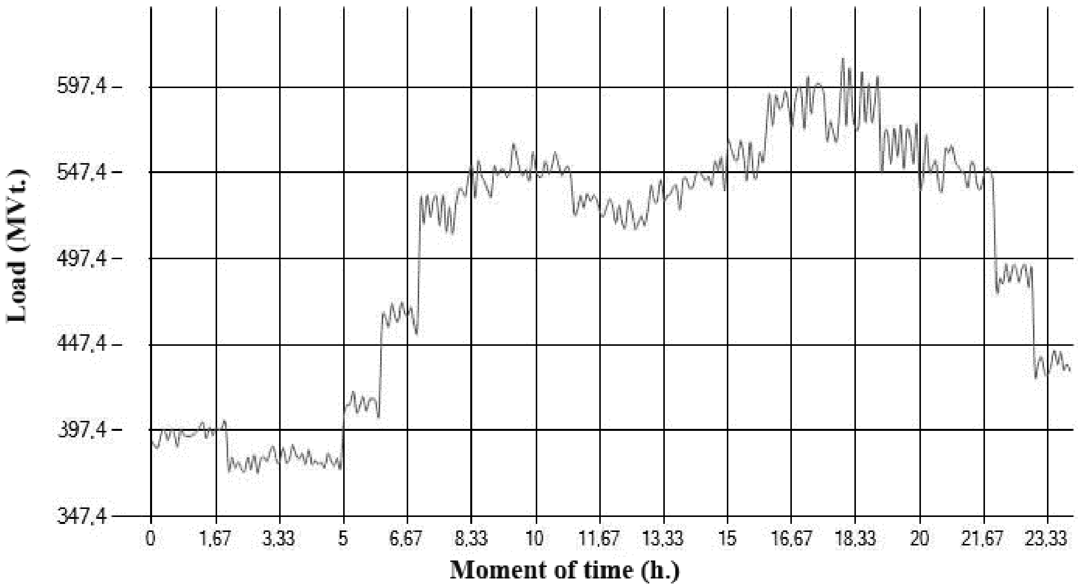

Fig. 3. Load parameters dynamics for 24 hours with the generation interval of 300s

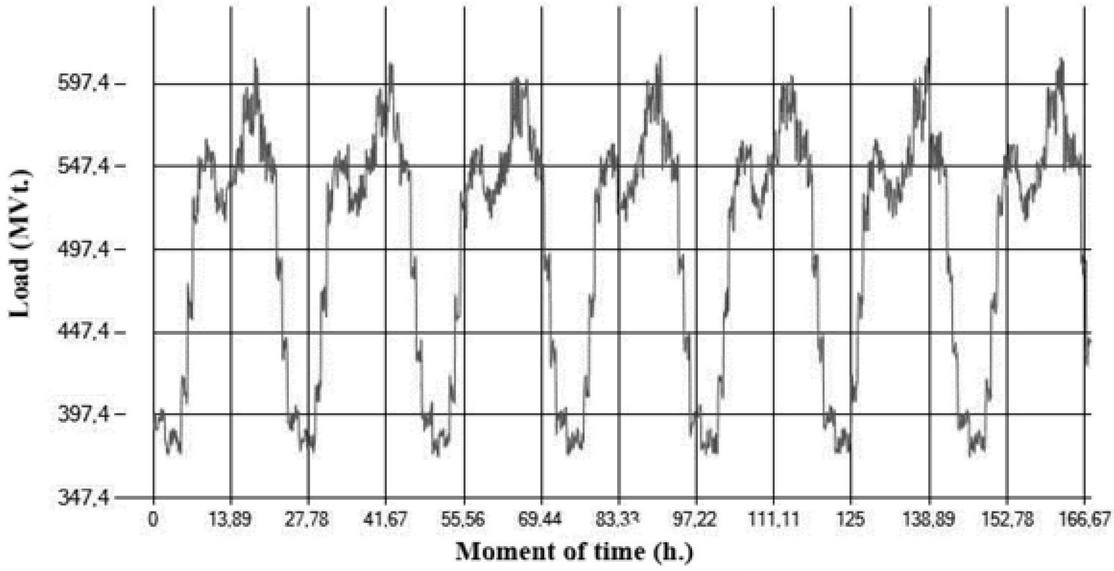

Fig. 4. Load parameters dynamics for 7 days with the generation interval of 500s.

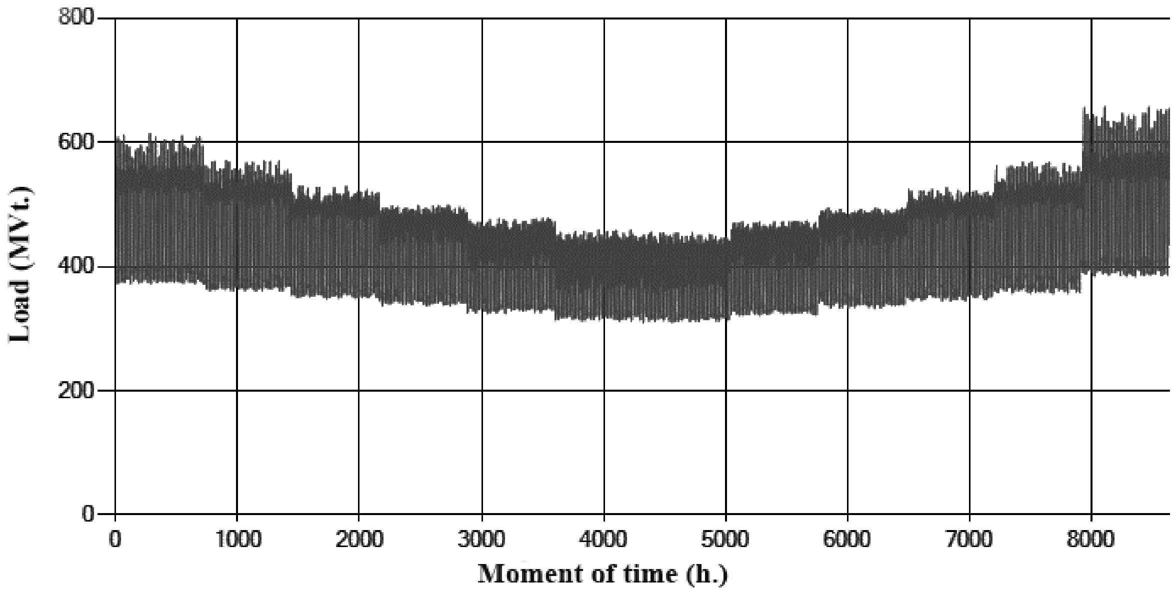

Fig. 5. Load parameters dynamics for 360 days with the generation interval of 3600s.

CONCLUSIONS

Algorithm and software which allows us to determine the real input data change intervals and visually display the result as a load curve have been developed for the analysis of the input parameters of the active power management by WPS. The input values dynamics dependencies for the typical time intervals based on the real data analysis have been obtained [21, 22].

The input load parameters were determined with one second discretisation using the algorithm which can be used to teach the neural networks when justifying active wind power station composition. The specified range of data provides a more detailed description of the input load parameters curve and increases the results reliability.

The results are presented in a table of input load parameters as input data of the management system and calculated load curves. The results are important for the wind power station management system simulation as they provide higher reliability and accuracy of the results.

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