Simulation of a wind power generator operation as a part of an electrotechnical complex

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Abstract. Authors presented mathematical model of 5 kW wind generator. Parameters of wind generator, including armature inductance, stator phase resistance flux linkage by magnets and parameters of rectifier, were calculated in accordance with experimental data. Verification of those parameters was conducted.

1. Introduction
Wind-driven power units have achieved wide distribution across the globe. By the beginning of 2017 the total installed power capacity of all wind power generators amounted to 539 GW [1]. Use of the wind turbine for solving the problems of ensuring energy security for enterprises from the mineral resources sector [2, 3]. The design of wind-driven power units is varied multiply, but the common thing for all of them is the presence of an electric generating unit. In many instances this unit is a permanent magnet synchronous machine [4]. Simulation of this type of units is necessary to determine the most optimal operation mode. Many scientific papers are devoted to this subject matter [5–8]. However, the parameters of the generator vary due to the influence of the environment, insulation aging, property loss of permanent magnets, and for some other reasons. In this paper, the model parameters of the electric generator of the wind-driven power unit are determined and their testing for reliability is carried out using a real wind power generator.

2. Methodology
2.1. Structure of the computer model, according to the MatLAB mathematical computing system
To derive operating energetic characteristics of the wind power complex, in a form of dependences between the voltage applied to the load and the rotation velocity of the wind-wheel (of generator) under different load impedances, a computer model, according to the MatLAB mathematical computing system, the SimuLink software package, was created, as shown in Figure 1. The virtual model has apparent advantages [9]. This model allows one to determine different dependencies within wider ranges and for all values of the variable parameters of the model, compared to the actual physical model.
The model consists of several basic units: a permanent magnet synchronous machine (PMSM), a three-phase diode rectifier (bridge), load. Also, the model comprises an ammeter in the rectifier circuit and in the generator’s phase circuit, voltmeters are installed on the load and in a three-phase circuit. All measuring devices are connected via the RMS unit, which specifies the root-mean-square voltage and current. In addition, a small program to control the virtual model has been written.

The model operation comprises the following steps:
– the wind speed setting;
– computation, using theoretical formulas, of the corresponding speed of the wind power generator’s shaft;
– starting the simulation modeling with subsequent determination of steady-state load and generator parameters.

The program controlling the model has repeatedly started it on change in the wind-wheel speed value. Thus, sets of characteristics were obtained under different load values and the wind-wheel speed.

2.2. Structure of the testing bench for physical simulation of the wind power generator operation
The testing bench is represented in Figure 2. The operation of the wind-wheel was simulated using a three-phase asynchronous motor (1) with the following nominal parameters: 7.5 kW, 50 Hz, 380 V, 1450 rpm, 87.6%, 0.87. The asynchronous motor (1) was controlled by a frequency converter (2) with a nominal rated power of 15 kW. On the testing bench, as well as in the real wind-driven power unit, a direct momentum transfer between the motor and the generator was used. A three-phase permanent magnet synchronous machine with the following nominal parameters: 4 kW, 100 Hz, 400 rpm was used as the generator (3). The testing bench includes a three-phase diode rectifier (4) and a load unit in a form of active resistances (5) with dissipated thermal power up to 6 kW, as well as measuring equipment (6) [10, 11].
2.3. *Comparison of simulation results on the computer and the experiments*

By achieving the identity of the physical and virtual simulation results, the model parameters presented below were obtained. Also, the results of comparison between the model operation and the actual testing bench are given in Figure 3.

The convergence of computer and simulation modeling results makes at least 95%.

![Figure 2](image1.png)

*Figure 2.* Testing bench for physical simulation of the wind power generator operation.

![Figure 3](image2.png)

*Figure 3.* The measured values of linear voltage are shown with blue color, the values obtained by simulation – with red one.
PMSM parameters obtained are as follows: Armature inductance (5.2e-3 H); Stator phase resistance Rs (0.06 Ohms); Flux linkage established by magnets (0.19292 V.s.) Parameters of the power uncontrolled rectifier are as follows: Snubber resistance Rs (1e5 Ohms); Ron (1e-3 Ohms). Load parameters varied during the experiments.

PMSM model parameters were determined based on the results of the set of experiments carried out on the testing bench. The model parameters verification was conducted based on the additional set of experiments.

3. Conclusions
As the result, parameters of the real permanent magnet wind power generator were determined during the study. Also these parameters were confirmed while conducting real experiments on the presented testing bench. This model can further be used to solve the tasks on optimizing the operation modes of wind-driven powers units.

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