ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 8, Issue 2 , February 2021

Effect of Wind Speed on the Power of a Hybrid Wind Power Plant at Different Nominal Battery Voltages

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ABSTRACT: The use of renewable energy sources is one of the priorities to meet the ever-increasing needs. Electricity supply based on hybrid wind power plants gain significance due to their relatively simple design. The use of such installations requires a deep study of the operating modes associated with changes in weather conditions. The article examines the operation of a wind farm at various rated battery voltages for guaranteed power supply and builds a model for maximizing the energy efficiency of a system with variable wind flows.

KEYWORDS: Combined installations, wind power plant, computer simulation, aerodynamic characteristics, generator, rechargeable battery, wind speed, MatLab Simulink.

I.INTRODUCTION

Today, the use of autonomous wind power plants is one of the most environmentally neutral and relatively low-cost ways of electricity supply. But, like any energy source, it is poorly researched and has its own nuances. Such a nuance of hybrid wind power plants is their autonomous operation, since wind energy cannot be a permanent source.
The duration of the autonomous operation of a wind power plant (WPP) in conditions of complete calm or insufficient power generation of the WPP in comparison with the power of the consumed load with a large capacity of buffer storage batteries. The increase in batteries leads to a significant increase in capital costs, which reduces the economic feasibility of using wind energy. Therefore, to ensure a guaranteed power supply to consumers, hybrid electrical complexes (ETC) are used, including wind turbines, intermediate combined DC energy storage devices (batteries and super capacitors), and generator sets operating on hydrocarbon fuel, the most common of which are diesel generator stations (DES).

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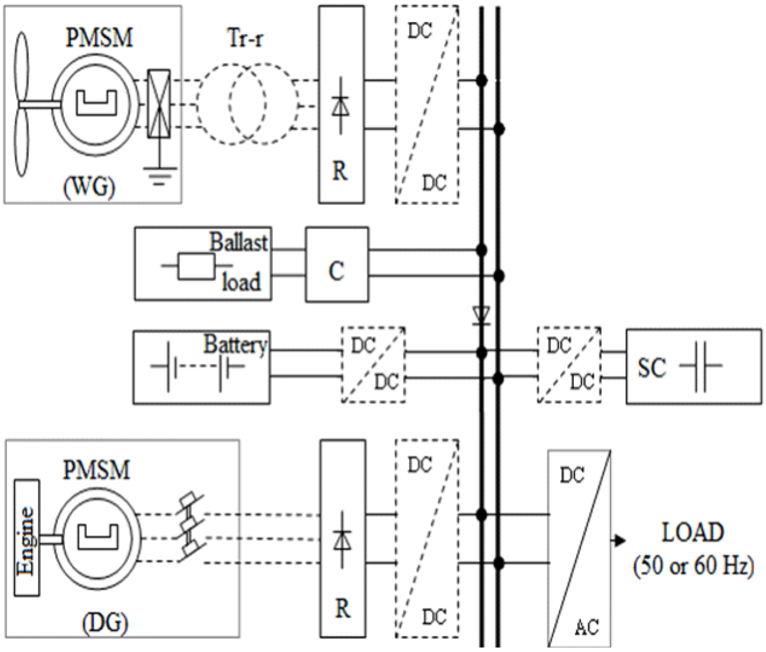

Figure 1 - Generalized diagram of an autonomous ETC with a hybrid wind turbine: **WG**-Windgenerator, **Tr-r**-Transformer, **DG**-Diesel generator, **PMSM**-Synchronic generator with permanent magnets, **R-** Rectifier, **SC**-Super condenser, **DC/DC**-dc converter, **DC/AC** – invertor.

Figure 1 shows the proposed structure of such an autonomous ETC with a hybrid wind turbine, while other generating sets based on renewable energy sources (photovoltaic, geothermal, bio- and hydropower) can be included in this complex.

The use of diesel-generator stations allows to provide power supply to consumers when the wind flow is insufficient. In turn, the use of the same diesel generator station, leads to the use of carbon fuel, which affects the efficiency of the complex, through the cost of 1 kWh of electricity. This is especially noticeable under variable operating conditions of the wind generator [1]. In such conditions, an urgent task is the optimal choice of elements of the electrical complex, namely wind turbines and batteries. To solve this problem, it is necessary to consider the statistical and dynamic modes of operation of a wind power plant for charging batteries. The ultimate goal of solving this problem is to identify the relationship between the characteristics of the wind generator and the battery with the efficiency of the system.

To solve the set tasks in the MatLabSimPowerSystems environment, simulation computer modeling of a hybrid wind turbine from the electrical complex of guaranteed power supply was carried out. Modeling of the system operation was carried out for a wind turbine with a synchronous generator on permanent magnets with a rated power of 5 kW at a design wind speed of 12 m / s, with a wind wheel having a typical aerodynamic characteristic (rated speed - Znom).

For computer simulation of the dependence of the torque on the frequency of the wind turbine at given wind speeds in the Simulink graphical programming environment based on MATLAB, the formulas were applied (1) – (3) [2].

There is a relationship between the coefficient of use of wind energy Cp and the value of the relative torque developed by the wind wheel, which is determined by the expression:

$$C_p = \overline{M} \cdot Z, \qquad (1)$$

where C_p is the coefficient of wind energy use; $\overline{M}$- relative torque developed by the wind wheel; Z - speed of the wind turbine.

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For practicality, the abstract aerodynamic characteristic of the wind wheel by the moment was approximated by a polynomial of the 6th degree:

$$\bar{M} = a_6Z^6 + a_5Z^5 + a_4Z^4 + a_3Z^3 + a_2Z^2 + a_1Z + a_0. \quad (2)$$

The coefficients of expression (2) corresponding to the typical aerodynamic characteristic of a three-bladed wind wheels are

a_6=13,6•10^{-6}; a_5=49,9•10^{-5};
a_4=69,1•10^{-4}; a_3=44,5•10^{-3};
a_2=0,125;a_1=0,093; a_0=0,025

The transition from the relative aerodynamic moment of the wind turbine to the torque developed by the wind turbine is carried out according to the formula:

$$M_w = \frac{1}{2}\bar{M}\pi R^3 \rho V^2, \quad (3)$$

where M_w is the wind turbine power, N • m;V - wind speed, m / s; R is the radius of the wind wheel, m; ρ - air density, kg / m3 (under normal conditions 1.225 kg / m3).

In the process of studying the characteristic dependences, graphs of changes in the speed of rotation and the electromagnetic moment of the generator, the power at the generator output, the power at the load, and the battery charge current were recorded with a change in the wind speed for batteries of various nominal voltages. Recording of oscillograms was carried out at a voltage of 24 V (0.154 r.u.) to 120 V (0.769 r.u.) with a step of 12 V.

The data obtained depending on the power of the wind turbine from the wind speed is at steady-state for different nominal voltages of the battery built power characteristics of wind turbines in p.u, is shown in Figure 2.

The battery voltage is measured in p.u. and is determined by the expression U * = Ufact / Uxx.r., where the amplitude of the linear open-circuit voltage of the generator Uxx.r. = 156 V at the rated speed is taken as the base value.

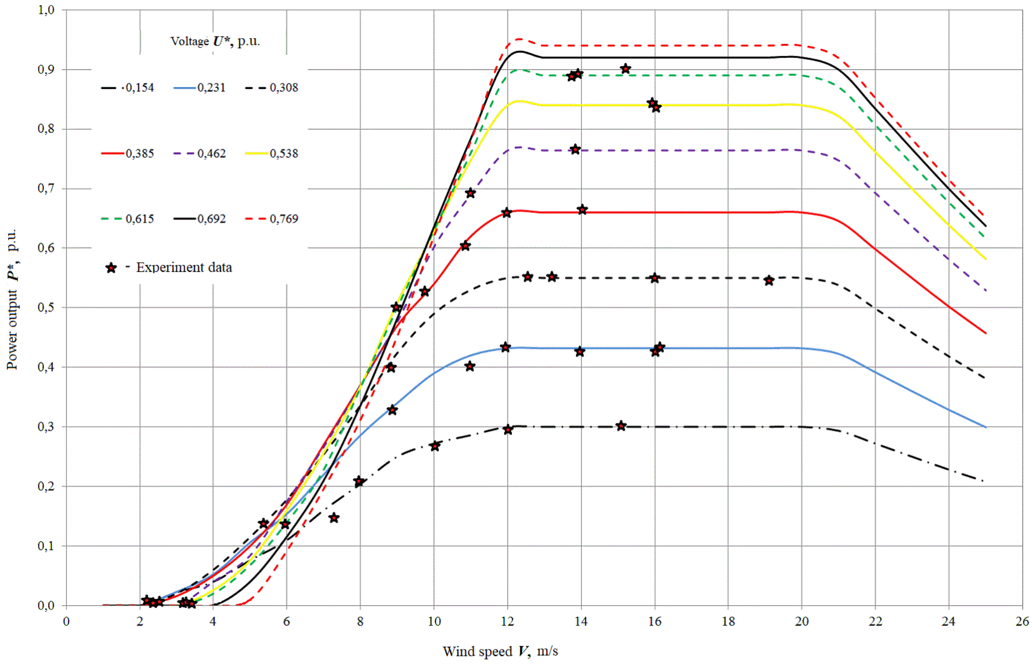

Figure 2 - Energy characteristics of wind turbines taking into account the variation of the nominal voltage of the storage batteries, obtained as a result of modeling (lines) and experiment (stars)

The graph shows that with the choice of a larger nominal battery voltage (U *), the maximum power of the wind turbine (P *), transmitted to the load, increases at the rated (calculated) wind speed for this wind turbine, which is a positive moment. At the same time, the operating speed of the wind power plant increases, which leads to a decrease in energy efficiency, mainly in areas with weak wind flows. Thus, from the given graph, it is possibleto choose the voltage level of the battery, or in the case of using a diesel generator station, the amount of energy generated by it, which will allow you to ensure maximum electricity generation by the wind power plant at the site of the ETC installation.

The correctness of the developed computer model was checked on an autonomous ETK with a hybrid wind turbine " Breeze 5000».

The wind speed was recorded using the Vetromer-1 anemorumbometer. The data on the power supplied by the wind turbine to the load (to charge the batteries) was obtained using the Fluke 43B power quality analyzer.

Figure 2 also shows experimental data on the dependence of power on the wind flow velocity at different rated voltages of the battery. The convergence of the results of computer simulation with the data obtained during the experiment was no worse than ninety percent.

Based on studies of the effect of wind speed on the power of the wind turbine at different nominal battery capacity, a dependence was found, which can determine the minimum nominal voltage at which the power and efficiency of the wind turbine will be maximum.

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