Stabilization of the Rotor Speed of an Asynchronous Generator of a Wind Power Plant

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Abstract. Alternative energy sources play a significant part in the development of modern electric power, agriculture and forestry. In accordance with the decree of the Government of the Russian Federation of 08.01.2009 1-p “On the main directions of state policy in the field of improving the energy efficiency of the electric power industry based on the use of renewable energy sources for the period up to 2035”, currently, due to the high level of environmental pollution, the use of electricity obtained using alternative sources is relevant. Since alternative energy sources are renewable, there is no need for additional raw materials that are needed to generate energy. Alternative sources of electricity are widely used for consumers who are located in a remote area from power lines and have the need to obtain not only single-phase, but also three-phase electrical energy. For the implementation of power supply to these consumers, a wind turbine is considered, which allows for long-term uninterrupted three-phase power supply. The main difference of this wind turbine is a device for stabilizing the rotor speed of an asynchronous generator, which is a combined synchronous machine with a common inductor.

1. Introduction

The use of wind power plants is one of the ways to provide electricity to domestic and industrial consumers who are remote from centralized power supply lines [1–3].

Wind is a variable quantity and has a pulsed nature, so for a stable power supply to consumers, it is necessary to use systems for converting wind energy into a stable torque and then using an electric generator into electricity [4, 5].

Recently, an asynchronous machine with a short-circuited rotor has been used as an electric generator for a wind power plant. An asynchronous generator with a short-circuited rotor is sensitive to changes in the angular velocity of the rotor, as a result of which there is a need to stabilize the rotor speed.

The creation of a stable torque on the rotor of an asynchronous generator is possible from the drive of an electric motor powered, for example, by the energy stored in the battery. To provide the electric motor with energy, it is necessary to first store the electric power in the battery. For these purposes, it is possible to use a synchronous generator [6–10].

2. Research methods

Thus, the following scheme of an autonomous power supply system is proposed, shown in figure 1.
Figure 1. Wind turbine for autonomous power supply: 1–wind wheel, 2–shaft, 3–armature No. 1 with windings, 4–armature No. 2 with windings, 5–control unit, 6–charger, 7–accumulator batteries, 8–collector-brush assembly, 9–neodymium magnets, 10–inductor, 11–asynchronous generator with a short-circuited rotor, 12–consumer.

The wind turbine consists of a wind turbine, the torque from which is transmitted to the anchor No. 1 of the synchronous machine, on which the windings are located, the synchronous machine has a common inductor with permanent neodymium magnets located on it, and the inductor is rigidly fixed relative to the body of the synchronous machine and does not change its spatial position. The armature no. 2 with the windings located on it is connected to the short-circuited rotor of the asynchronous generator. The generated energy is transmitted by an asynchronous generator to consumers of electrical energy.

The armature No. 1 of the synchronous machine operates in the generator mode, while the generated electricity on the armature windings is supplied through the control unit and the charger to the battery.

The anchor No. 2 of the synchronous machine operates in the motor mode, using the energy stored in the battery. The torque from the armature no. 2 is transmitted to the rotor of the asynchronous generator, and depending on the voltage level in the phases of the asynchronous generator, the torque transmitted from the armature no. 2 can be changed by changing the current and voltage supplied to the armature winding no. 2. This solution allows you to stabilize the voltage at the phases of the asynchronous generator when the load power changes.

The synchronous machine operates in generator mode when the armature 1 begins to rotate, and the armature 2 operates in motor mode when the voltage from the batteries is applied to it.

The use of a common inductor of a synchronous machine with two anchors makes it possible to increase the value of the magnetic induction vector in the armature windings by using permanent neodymium magnets of increased length. Also, this solution allows you to avoid using two separate electric machines, such as a synchronous generator and a synchronous motor.

The armature windings are made of copper and are located at a minimum distance from the neodymium magnets, to obtain maximum magnetic induction. 12 windings are arranged symmetrically relative to neodymium magnets, the number of turns in each winding is 55, and the length is 3.37 meters. The synchronous machine is three-phase, contains 12 windings on the armature No. 1 and No. 2, on the common inductor of the arrangement of 14 permanent magnets.

The distribution of the magnetic flux of the synchronous machine is shown in figure 2.
The power of a synchronous machine is determined from the expression

$$P = \sqrt{3} U I \eta \cos \varphi$$

(1)

where

- $U$ – armature voltage No. 1, V;
- $I$ – current of armature windings No. 1, A;
- $\eta$ – efficiency factor;
- $\cos \varphi$ – the power factor of the synchronous machine.

The voltage induced by the armature windings No. 1 operating in the generator mode can be determined from the expression:

$$U = \frac{\sqrt{3} \pi n B L V R_{cr} R}{30 (R_{cr} + r)}$$

(2)

Where

- $n$ – number of revolutions of the synchronous machine armature;
- $L$ – armature winding wire length, m;
- $R_{cr}$ – internal resistance of the armature windings, ohms;
- $r$ – load resistance, ohms;
- $R$ – radius of the synchronous machine armature, m;
- $V$ – linear speed of the anchor, m.

As an energy storage device, helium storage batteries are used. The plates of the helium batteries are made of lead, which are filled with silica gel, in which an electrolyte based on sulfuric acid is embedded. Lead plates are located in a thick porous mass, the charge transfer occurs through oxygen ions, which combine with hydrogen ions and turn into water, the water does not evaporate, but remains in the silica gel balls.
Let's build a mathematical model of an autonomous power supply system. In order to form a mathematical algorithm, it is necessary to study the relationships between the elements and the modes of operation that are presented in figure 3.

The equation of the balance of torques of the electromechanical circuit, according to Figure 3, has the form:

\[ M_{\text{wk}} - M_1 = 0 \] (3)

\[ M_2 - M_g = 0 \] (4)

Where \( M_{\text{wk}} \) – wind turbine shaft torque, N m\(^{-1}\);

\( M_1 \) – armature resistance moment No. 1, N m\(^{-1}\);

\( M_2 \) – torque at anchor No. 2, N m\(^{-1}\);

\( M_g \) – the moment of resistance of the rotor of the asynchronous generator, N m\(^{-1}\).

From expression (3), it can be seen that the torque is transmitted to the wind wheel to the anchor No. 1 of the synchronous machine, part of which operates in the generator mode, without directly entering the rotor of the asynchronous generator. The energy generated by the anchor No. 1 accumulates in the battery and then goes to the anchor No. 2, operating in the motor mode, the torque from which goes to the rotor of the asynchronous generator (expression 4).

Thus, using a buffer element, which is used as a combined synchronous machine, the voltage is stabilized at the phases of the asynchronous generator with a variable wind load and a change in the power of electricity consumers.

3. Conclusion

1. The use of a combined synchronous machine having two anchors with windings located on them allows you to accumulate electricity due to the operation of the armature No. 1 in the generator mode in the battery, use the accumulated electricity to provide the necessary torque on the rotor of the asynchronous generator due to the operation of the armature No. 2 of the synchronous machine in the motor mode.
2. The use of 12 armature windings and 14 permanent neodymium magnets on the inductor allows you to organize a three-phase synchronous machine system.
3. The introduction of a common inductor with permanent neodymium magnets located on it allows you to combine two electric machines in one device, such as a synchronous generator and a
synchronous motor, to increase the power of the synchronous machine by using permanent magnets of increased length.

4. The use of an asynchronous generator with a short-circuited rotor allows for the power supply of single-phase and three-phase consumers of electrical energy with a voltage of 380/220 V.

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