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Features of Automation of Operation of Solar Collectors and Wind Turbines

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Abstract: A major problem in the use of renewable energy sources is to increase the energy efficiency of their operation. Automation and selection of the optimal process flow diagram allow increasing this energy efficiency. The article examines the features of automation of a solar collector with forced circulation of the coolant and various types of wind turbines along the channel for converting wind energy into electricity. It is concluded that in the event of an increase in the production of electrical energy due to distributed generation (wind energy, solar energy) in the power system, it is necessary to provide for appropriate measures to compensate for the randomly generated electrical power that changes.

Keywords: wind generator, solar collector, automation, energy efficiency, solar collector.

Introduction. There is great potential for the development of renewable energy in the Republic of Uzbekistan. In particular, solar and wind energy are promising sources. Solar collectors with forced circulation of the coolant are necessary to increase the efficiency of collecting solar energy. However, as in other cases, increasing the energy efficiency of these systems involves automating their operation. In this context, studies have shown that the automation of solar collectors with forced circulation of the coolant can increase the collection of solar energy by 20%. In addition, the automation of various types of wind turbines can also increase the productivity of a wind power plant by up to 30%. For this, it is necessary to develop complex control systems that can optimize the operation of the equipment in real time, taking into account changing weather conditions .

A solar collector operating in a cyclic mode accumulates the thermal potential of the coolant gradually depending on the intensity of solar radiation. When a certain temperature of the coolant is reached, a circulation pump is switched on from the upper part of the solar collector , and the coolant is pumped into the storage tank. In conventional automation schemes, it is proposed to switch on the pump as a certain, pre -set, difference in the temperature of the coolant in the upper part of the solar collector and inside the storage tank is exceeded. However, when there is no excess of the temperature difference, the pump does not work. In our opinion, it is necessary to change this adjustable temperature difference depending on the intensity of solar radiation.

Method and Result. As is known, the solar collector along the temperature channel of the coolant input-output is an aperiodic link of the first order with a transfer function:

$$W(p) = \frac{X_{input}}{X_{output}} = \frac{k_1}{T_1 \cdot p + 1},$$

here is $k_1 = \frac{1}{(A - A_{losses})}$ −the gain coefficient, which depends on A - the intensity of solar radiation and A_{loss} - the amount of heat loss in the solar collector .

$T_1 = \frac{(c_m + c_{water})}{(A - A_{losses})}$ −time constant of a solar collector , depending on the heat capacity of the solar collector material , heat capacity of c_m −the solar collector material.

The transient characteristics of the solar collector along the temperature channel of the coolant input-output are shown in Figure 1 .

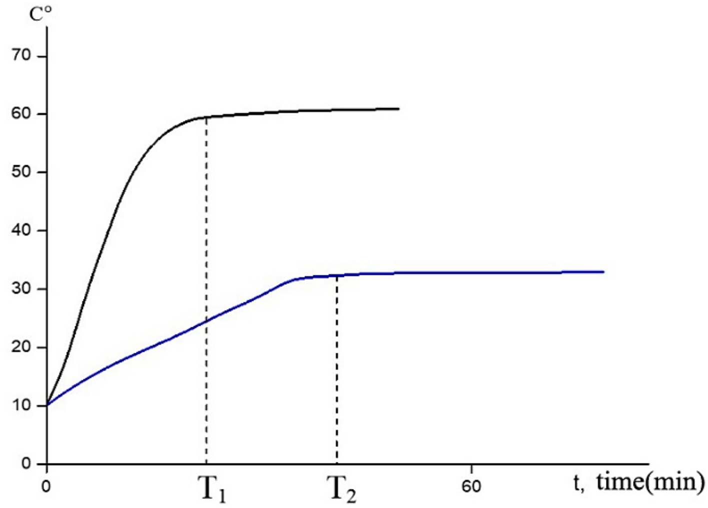

Figure 1. Characteristics of the solar collector.

The interdependence of heating time on the intensity of solar radiation is shown in Figure 2 .

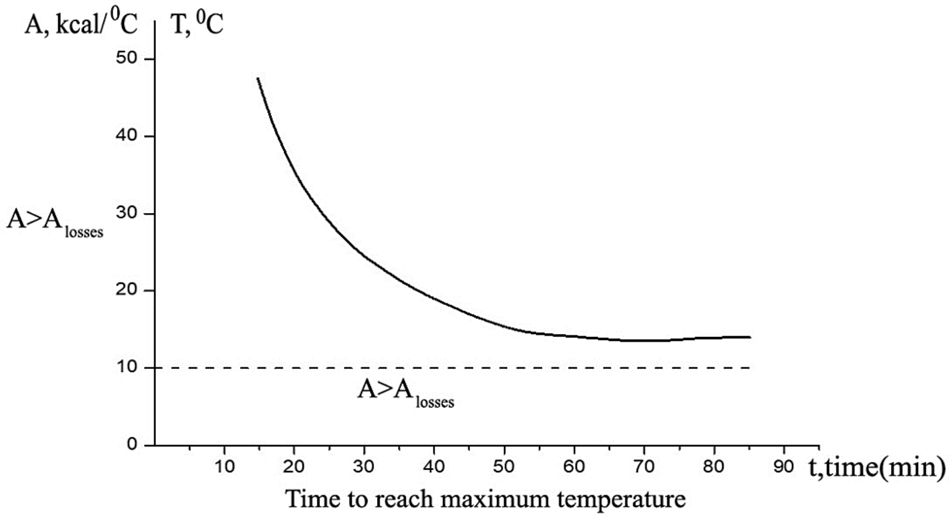

Figure 2. Heating time from solar radiation.

To implement such a control characteristic, it is proposed to use a light sensor together with a temperature sensor.

To improve the energy efficiency of wind turbines, let us consider the main types of losses that occur when converting wind energy into electrical energy. First, these are losses associated with the inefficiency of the wind wheel, i.e. losses when converting wind flow energy into mechanical rotation energy.

Next, these are losses of mechanical energy in the gearbox, losses of electrical energy during its conversion, etc.

Currently, there are various wind turbine concepts on the market that use different technologies to convert wind energy into electricity. Let's look at these technologies in terms of their reliability, complexity and energy efficiency.

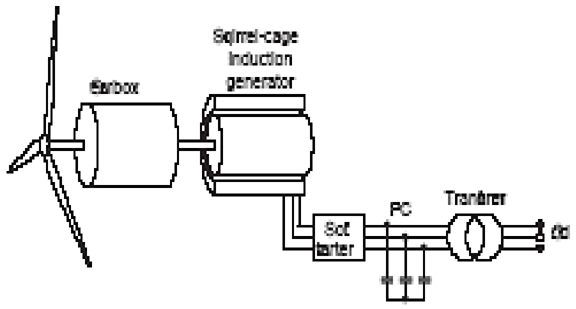

Figure 3. A wind turbine operating at a constant speed.

Fig. 3 shows a system of the type "turbine-reducer-asynchronous generator-electric network". Here the asynchronous generator is presented as an electric machine with a "squirrel cage" rotor. Since the asynchronous machine is connected to the network via a transformer, a soft starter (Soft) is installed to limit the currents and torque during start-up. starter).

After the soft starter, there is a set of compensating capacitors, which are necessary for reactive power compensation, i.e. to generate this power on site, without consuming it from the network. As a result , losses in the network are significantly reduced. The network transformer is necessary to increase the generated voltage to the voltage of the supply or distribution transmission line.

Variable slip wind generator. Figure 4 shows a wind turbine where the resistance in the rotor circuit can be controlled dynamically, synchronously with wind gusts. During a gust, the resistance in the rotor circuit increases , which allows for an increase in slip (in absolute value); the angular velocity increases insignificantly and the energy is absorbed by inertia. After the gust, the resistance in the rotor circuit decreases, which leads to a decrease in slip and energy transfer to the power grid over a longer period of time.

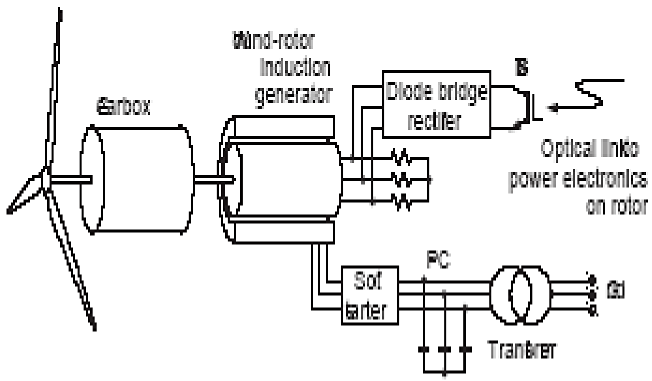

Figure 4. Variable slip wind generator

The variable slip concept ensures high quality electrical power at high wind speeds without generating any detectable high frequency harmonics. The variable slip concept does not increase power output, but reduces the loads in the wind turbine transmission in the event of sudden wind speed fluctuations.

AMDP wind generator. DFI - doubly fed induction machine. Figure 5 shows a simplified diagram of a wind turbine connected to a doubly fed induction generator. An insulated gate bipolar transistor (IGBT) converter connected to the rotor of the voltage source is connected to an IGBT converter connected to the main line via a DC link containing a capacitor. Both converters can control the transfer of active and reactive power in either direction.

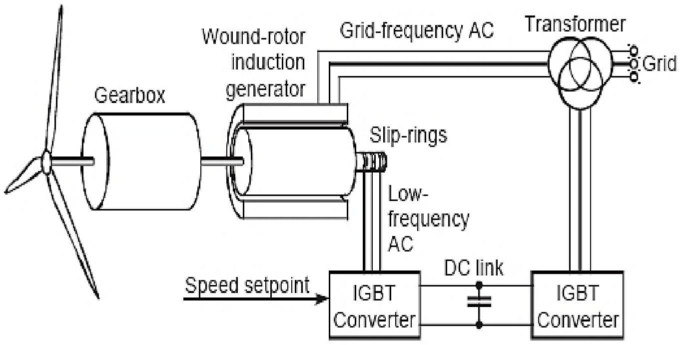

Figure 5. AMDP wind generator

The converter connected to the rotor is controlled by the speed of the wind turbines, so that energy extraction is maximized. The generator is controlled based on the vector control principle, which offers excellent transient characteristics, allowing the asynchronous generator to have a low lag time. This increases the possibility of extracting energy from wind gusts and reduces mechanical overloads in the transmission.

The function of the main line-connected converter, in most circuits, is to transfer the required active power from the DC circuit to the power system or vice versa. This is accomplished through a voltage control circuit that ensures that the DC voltage is maintained at a fixed level.

Both converters are controlled via a pulse width modulator, which ensures a minimum of high-frequency harmonics in the network.

Wind generator with full converter. The configuration shown in Fig. 6 uses two full converters. Full means that any power (active or reactive) goes through the converters. The converters allow standard squirrel cage induction machines to operate at variable frequency and therefore from 0 to 100% variable speed.

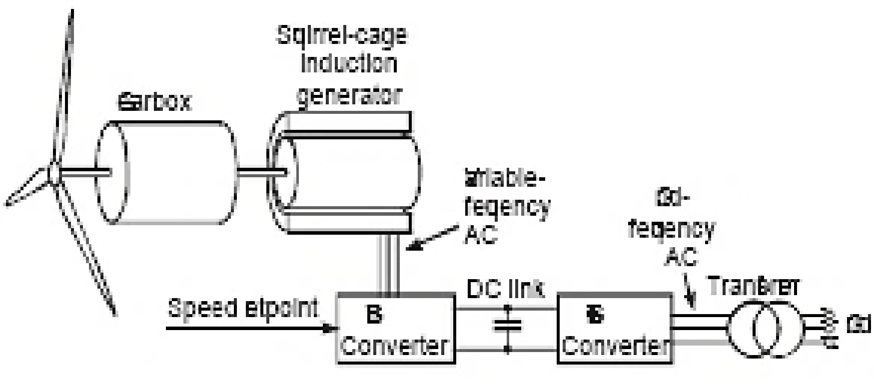

Figure 6. Wind generator with a full converter

The active power from the asynchronous generator is rectified by the converter on the machine side and fed into the DC circuit. The converter on the power system side acts as an inverter, taking power from the DC circuit and feeding it into the power system.

The converters implemented in this circuit are standard industrial drives, typically used for variable speed motors . They are reliable and affordable. The main disadvantage of the configuration is that it requires two expensive IGBT converters rated for the full power of the wind turbine.

Driveless (gearless) wind generator. The use of a synchronous generator via a full converter eliminates the gearbox from the transmission scheme. The first factor for the development of gearless wind turbines is that the rating of any electrical machine is roughly proportional to the volume of its rotor. The gearbox in a typical 1 MW wind turbine has a gear ratio of about 80. Eliminating the gearbox increases the torque and, therefore, the volume of the generator rotor required by about the same amount.

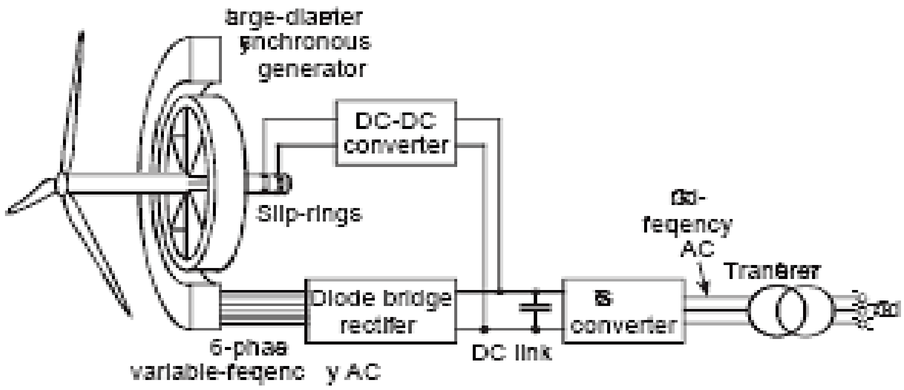

Figure 7. Wind generator without drive (gearless).

As shown in Fig. 7, the converter on the machine side can be a simple diode rectifier, which is typical for small wind turbines. The converter on the grid side is an IGBT inverter , which is based on the need to transmit active power unidirectionally - to the grid, but at the same time, it is able to transmit reactive power both to the grid and from the grid.

As follows from the above, currently wind power uses different types of generators. The main ones are asynchronous and synchronous. When asynchronous wind turbine generators operate together with synchronous generators, traditionally used in thermal power plants, there are some peculiarities.

The first feature is that an asynchronous generator requires a magnetizing reactive current, i.e. reactive power, to operate. The amount of this consumed power is proportional to the magnetizing current and can reach up to 45% of the asynchronous generator's power. In order to prevent the consumption of this power from the network and the associated electrical losses, traditional circuits use reactive power compensation by installing static capacitor banks. These banks are installed in close proximity to the wind turbine.

The second feature is that the design of wind turbines provides for a mode of their shutdown when the wind speed exceeds the permissible value or decreases below the permissible value. Usually, the highest permissible speed is about 25 m/s and is dictated by the conditions of the mechanical strength of the wind wheel blades and the wind turbine tower, and the lowest, 2.5-3 m/ s, is dictated by the lack of power to turn the wind wheel rotor and the rotor of the asynchronous generator associated with it. What does such a shutdown mean for the electrical network? Only one loss of part of the generated power.

The greatest danger to the electric grid is the shutdown of some wind turbine generators operating at maximum load. This lack of power must be immediately compensated by other generators. If this does not happen, then an imbalance of the generated active power in the power system will arise, the risk of a decrease in the frequency of the generated electric current and, as a consequence, a partial disconnection of electricity consumers from the grid.

This problem may arise during a storm situation, i.e. the movement of an extended wind front at high speed. This may result in the shutdown of a large number of wind generators. To compensate for the resulting imbalance of power, the energy system will need immediate input of additional generating capacity.

Conclusion. Obviously, this problem can also arise when using photovoltaic systems without storage to generate electric energy into the grid. Thus, it can be concluded that in the case of an increase in the production of electric energy due to distributed generation (wind energy, solar energy) in the power system, it is necessary to provide for appropriate measures to compensate for the randomly changing generated electric power.

The increase in electricity generation from renewable sources such as solar and wind energy does require the implementation of control and compensation systems to stabilize the power grid. This may include the use of battery systems, demand management, and the integration of flexible generators and modern forecasting technologies to eliminate mismatches between generation and energy consumption.

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