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Analysis of the Main Parameters of Electrical Generator which Works Efficiently in Low-Speed Wind and Water Flows in Various Climate Conditions

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ABSTRACT: This article analyses high-efficiency generators using low-speed wind and water currents. In wind and water currents, reducer structures are used to reduce low speed to high speed, which leads to high cost of low speed wind and micro hydro. Reducer devices lead to a decrease in energy efficiency.
In small-power wind and water currents, it has been confirmed that the use of multi-pole axial and radial current synchronous generators can give good results. We used axial and radial current synchronous generators. The virtual model for the analysis of generators was analysed in Ansys Maxwell, the program used the electromagnetic field for the analysis of electric machines.

I. INTRODUCTION

Currently, there is a strong crisis in the energy sector around the world. As the main factors for the emergence of such a situation, it is possible to mention the increase in the number of the population and the standard of living, and the expansion of various industries and service sectors. Especially the instability observed around the world at the moment leads to changes in power sources in the energy network in the regions. As of September 2022, gas supplies from Russia to the European Union have decreased by 80 percent compared to previous years. Increased demand for thermal energy in the winter months has led to the restart of thermal power plants using compressed gas and coal. But these energy sources pollute the air, causing a sharp increase in the demand for alternative energy sources in the countries of the region. According to the information provided by the International Energy Agency, in 2023, investments in projects based on renewable energy sources with a capacity of more than 500 GW have been made. This is the highest ever. The share of energy produced on the basis of renewable energy sources and nuclear energy reached 40% of the total energy production. Among investment projects based on renewable energy sources, solar energy is leading. For example, two-thirds of the renewable energy projects planned to be built around the world in 2023 will be solar energy.

By 2028, electricity generation from renewable energy sources is expected to reach about 14,400 TWh, an increase of about 70% compared to 2022. In the next five years, several milestones are expected to be reached in the production of electricity from renewable energy sources [1].

II. MATERIALS AND METHODS

In Uzbekistan, the estimated share of electricity production using water flow energy is 13% of the total energy. But now, since most of the high-potential water resources have been exploited, the main attention is focused on the low-pressure potential water resources. Therefore, in the near future, the use of micro-hydroelectric power plants is considered a promising project.

Installed capacity of hydroelectric power stations around the world.
1.1 - table

Rating	Location area	Installed Power (MW)
1	China	391,000
2	Japan	46 643
3	Vietnam	17333
4	Australia	8162
5	Laos	8108
6	Indonesia	6602
7	South Korea	6541
8	Malaysia	6275
9	New Zealand	5354
10	North Korea	5010
11	Taiwan	4696

Two on hydroelectric power plants in Central Asia country: the hydropower potential of Kyrgyzstan and the Republic of Tajikistan is considered high, their energy density corresponds to 2227 kW / km - 5322 kW / km, respectively [2] developed by Nova Energy Systems and ITDG in 1986, based on the Darrius Turbine an energy device capable of supplying 0.5 kW at a flow rate of 1 m/s was effectively used in irrigation systems [3]. Using generators designed for high-speed water currents to produce electricity has been observed to kill off some fish and plant species. It has been suggested that the use of low-speed multi-pole generators can be a good solution to this problem. In an experiment with a generator that can operate at 0.3 m/s-1 m/s underwater, more than 300 fish survived 96% showing the advantage of using these generators [4].

Classification of hydroelectric power stations by capacity.

1.2 – table.

Pico	5 kW
Micro	5 kW-100 kW
Small	101 kW-2000 kW
Mini	2001 kW - 25000 kW
Very powerful	25,000 kW high power hydroelectric power plants

In micro hydropower plants, the low speed generator installation construction is simple, resulting in lower capital and maintenance costs. It is noted that it is effective to use a generator with a power of 6 kW and a rotation speed of 1500 rpm in a micro-hydro generator with a height of 6 m and a speed of 0.16 / s.m^3[5].Open water scientific research on the use of low-pressure water flows in irrigation canals was carried out. The feasibility of installing the proposed turbine in different areas of the bottom of the channel has been determined. The proposed system is simulated in Ansys Fluent 16.0 software at water flow speeds of 0.6-1 m/s. [6].

III. TAKE ADVANTAGE OF LOW-SPEED WIND CURRENTS

Large-scale wind energy that is widely used today on devices the speed of the generator is changed to 1000-3000 rpm through a reducer [7].But in low-speed wind currents, when gear units are used, the starting torque increases, and this leads to a decrease in the efficiency of wind energy use. In such cases, the use of multi-pole permanent magnet electric generators is of great importance [8]. Electric generators of different designs for horizontal and vertical axis turbines operating efficiently in low-speed wind flows were analyzed. In the analysis of generators, the lack of use of reducers was considered as the main factor. Because not using a reducer in the system increases the reliability of the overall system. In such systems, the probability of device failure is low. In addition, reducing the use of reducers leads to a reduction in overall system weight, noise, various vibrations, and capital and service costs. Reducing the weight of the power

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generation system is an urgent issue for large-capacity and high-altitude wind turbines. Because the increase in the weight of the power generation system requires an increase in the strength of the materials used for the tower. The higher the height of the tower, the better its vibration, high wind resistance, and corrosion resistance [9].

IV. MULTIPOLE AXIAL AND RADIAL FLOW SYNCHRONOUS GENERATOR WORKING IN LOW SPEED WIND AND WATER FLOWS

In low-speed wind turbines, this type of generator, which uses an axial-flow multipole synchronous generator without a reduction gear, is rated as high in energy density and efficiency. It is emphasized that if this axial-flow synchronous generator is used, there is no need to build a reducer and it is possible to reduce the mass of this turbine. The voltage of the two-rotor axial generator is 79 V-150 V, and the frequency of 50 Hz is 333 rpm as a result of movement at 219-402 rpm. /min was recorded [10]. The energy density of two-stator and three-rotor axial-flow generators, and 283.6 W/kg and 195.3 W/kg, respectively, were recorded for two-rotor and one-stator axial flow generators. However, the need for a large amount of magnets in the preparation of this type of generator has led to an increase in the price of the generator [11]. Multi-pole radial current synchronous generators are widely used in low-speed water currents; this type of generator uses a reducer arrangement. The speed of 214.3 rpm generated 10 kW of energy [12]. Radial flow synchronous generators are used in Kaplan type turbines with water flow height of 2-60 m, capacity of 2-200000 kW, rotation speed of 450 rpm. In the literature, the possibility of using a synchronous generator with a radial flow in wind and water currents is confirmed, it is cheaper compared to an axial flow, and the generator with a total mass of 35.55 kg, a rotation speed of 300 rpm and a power of 4016.6 W is observed to have an efficiency of 90.28%. permanent magnets are installed in the rotor, which is designed to resemble a motor [13]. In some research studies, a new design of radial current generators consisting of three rotors was used, the generator had two stators, 12 windings were arranged in the rotors, and a total of 450 windings produced a magnetic flux of 0.89 MT [14].

V. THE OBTAINED RESULTS OF EXPERIMENTAL STUDIES

In Bukhara Institute of Engineering and Technology, some research work is being done to improve the construction of a generator that works efficiently in low-speed wind and water currents. When we study the results of the research, it is mentioned in the proverbs that the efficiency of the generator increases if the rotor and stator of the generator are moved against each other at low speeds, for example, axial flow Axial flux generator with two rotors and one stator, the efficiency of the generator increases by 1.4% when one rotor and stator move against each other in the generator 22.6% increased efficiency [15]. In low-speed wind and water currents, axial and radial flow synchronous generator due to moving the rotor and stator against each other at the relative rotation speed of the generator it was concluded that a double reversal of poles occurs. Based on this, the expressions for determining the nominal speed relative to the standard generator were determined as follows.

$$S_n = S_{rotor} - S_{stator} \quad (1)$$

S_n – nominal speed of the generator, rpm
S_{rotor} - rotor rotation speed, rpm
S_{stator} - stator rotation speed, rpm

If the generator rotor is moving and the stator is at rest

$$S_n = S_{rotor} \quad (2)$$

If the stator and rotor move in the opposite direction relative to each other, then the nominal speed of the generator will be reflected as below.

$$S_n = S_{rotor} + S_{stator} \quad (3)$$

As a result of moving the rotor and stator of the axial and radial current synchronous generators in opposite directions with equal speeds, it was observed that the rotation speed of the generators increased by 2 times and the frequency of the generators increased by 2 times.

Design parameters of an electric generator with axial and radial flow.
1.3 – table.

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Axial flow constructive dimensions of the generator.		Structural dimensions of the radial current generator.	
The total mass of the counter current generator.	11.11 kg	Radial current generator total mass	8.835 kg
Stator mass.	4.19 kg	Stator mass	4.7 kg
Rotor mass.	6.92 kg	Rotor mass	4.135 kg
Stator diameter.	390 mm	Stator diameter	260 mm
Rotor diameter.	260 mm	Rotor diameter	285 mm
Stator and rotor thickness.	25 mm	Stator and rotor thickness	25 mm
Power.	500 W	Power	1000 W

The 2016 interpretation of the ANSYS Maxwell program was used to design the rotor and stator counter-movement of the generator.

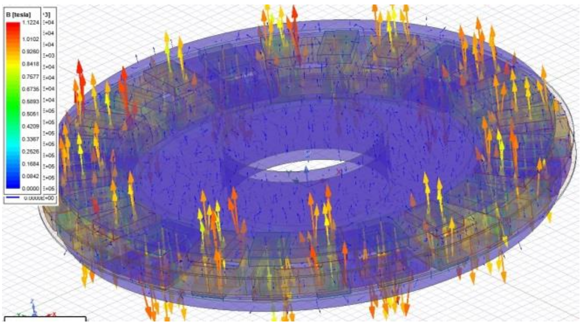

Fig. 1. View of force vectors in the stator of an axial-flow two-rotor electric generator

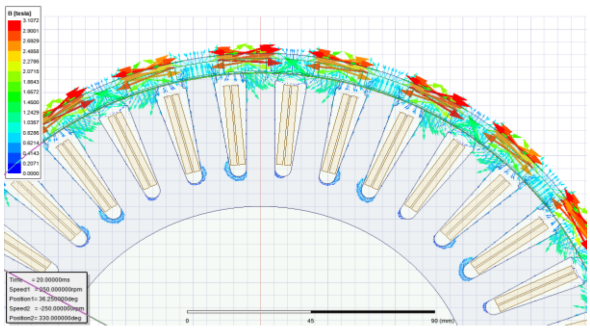

Fig. 2. Direction of force vectors in the stator of a radial current electric generator

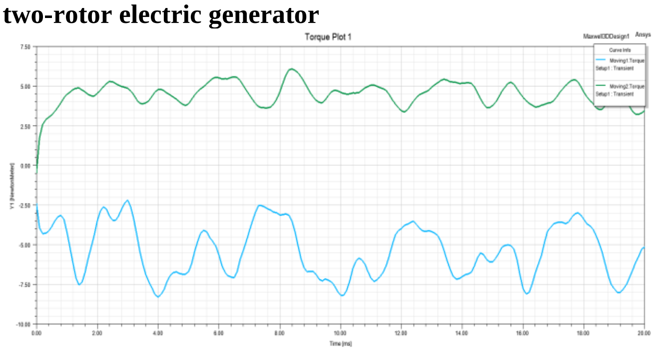

Fig. 3. Mechanical power expended to counter-rotate the stator and rotor of an axial flow generator

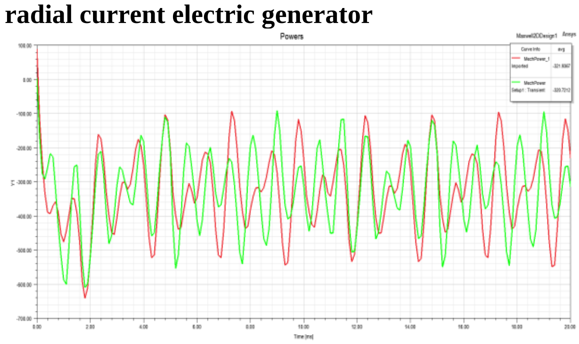

Fig. 4. Mechanical power expended to counter-rotate the stator and rotor of a radial flow generator

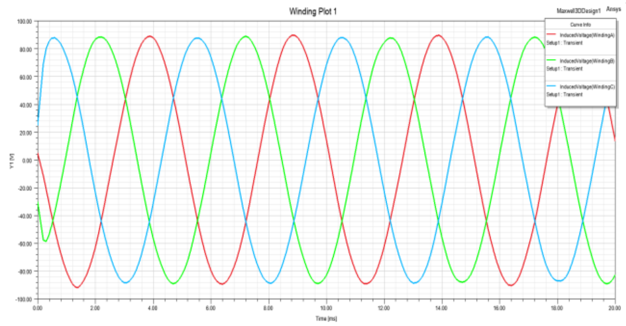

Fig. 5. EMF generated in the stator of an axial flow generator.

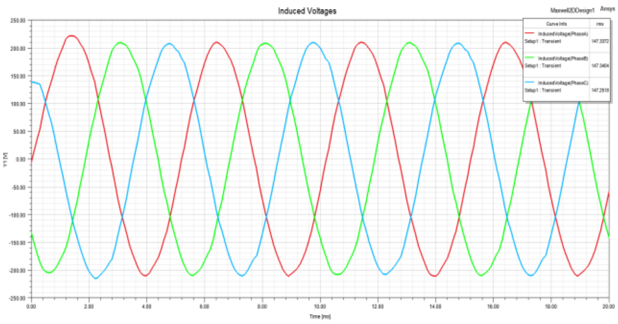

Fig. 6. EMF formed in the stator of a radial current generator.

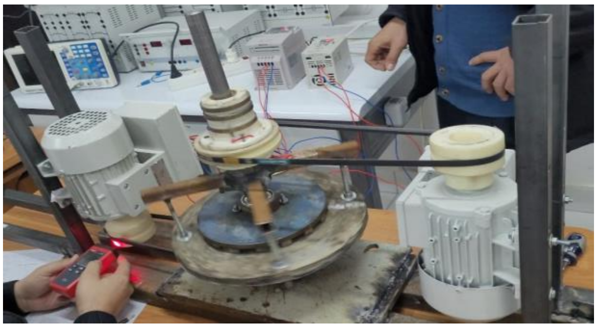

Fig. 7. Axial flow synchronous generator rotor and stator moved against each other.

Figure 8. Radial current synchronous generator rotor and stator moved oppositely

In order to move the rotor and stator opposite to each other, a separate motor was installed on the stator, and the rotor and stator were moved opposite to each other through two frequency converters.

Output results of axial and radial flow synchronous generators when the rotor and stator move opposite to each other
1.4 – table.

Stator and rotor moved opposite to each other with equal speed (rpm)	88	126	152	201	250
Axial current generator output voltage (V)	31	42	53	70	87
Radial current generator output voltage (V)	30	46	56	75	92
Axial current generator output frequency (Hz)	16	23	28	38	47
Radial current generator output frequency (Hz)	43	64	82	108	134

Analysis of a radial flow generator. The mass of the stator of the electric generator selected for the radial current generator is 13% more, and the rotor diameter is naturally 9% more. due to unequal masses and differences in diameter, the moments of rotation and inertia are different. Power to the stator is consumed by 28% at low rotation speeds, and by 12-13% at high rotations (at speeds close to the nominal speed).

Axial flux generator analysis. Based on the analysis of the experimental results, the rotor mass of the generator is 65% greater than the stator mass, and the stator diameter is 50% greater than the rotor diameter. Due to unequal masses and differences in diameter, rotation and moments of inertia, the power required to rotate them is also different. Based on the analysis of the results of the experiment, despite the fact that the mass of the rotor is 65% larger, due to the large diameter of the stator, the power to the stator is 42% more at low rotation speeds, and 33% more at high rotations (speeds close to the nominal speed). Conclusion from the results of the experiment To do this, if it is necessary to ensure the same rotational speeds of the stator and rotor during the generation of mechanical energy into electrical energy, it is necessary to choose a turbine with a larger working surface for the stator will be.

In order to determine the selection of a turbine with a larger working surface by how many percent of the turbine, we enter an indicator called ksh - shape coefficient. This coefficient is appropriate at high speeds, that is, at speeds close to the nominal speed of the generator. Because of the low rotational speeds, a lot of energy is used to start the generator from rest.

When comparing the results of axial current and radial current synchronous generators, the efficiency of the axial current generator is higher, but the output voltage of the radial current generator has shown good results and is considered cheap. The results of the experiment are continued.

VI. CONCLUSION

1. The use of high-efficiency generator axial and radial flow generators for low-speed energy flows can give good results. These generators are multi-pole and do not require the construction of a reducer.
2. 70% of the climate of Uzbekistan has low-speed energy flows, we need to produce low-cost generators with high efficiency in low-speed energy production in accordance with the climatic conditions of Uzbekistan.
3. Taking into account the low cost of electricity in our republic, it is important to use relatively cheap generators and other electrical devices in order to reduce the payback period of the system.
4. Based on the results of the experiments, when moving the rotor and stator opposite to each other, the stator of the axial current generator is lighter than the rotor, but a lot of energy was consumed from the rotor to rotate the stator. In the radial current generator, the stator mass is larger than the rotor, but a lot of energy is collected to rotate the stator, because the experimental results are not completed, the rotor and stator are opposed by one mechanism. movement can work well.

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