Ministry of Education and Science of Ukraine
Ternopil Ivan Puluj National Technical University

Faculty of Applied Information Technologies and Electrical Engineering
(full name of faculty)
Electrical Engineering
(full name of department)

QUALIFYING PAPER

For the degree of

bachelor
(degree name)

topic: DESIGN OF A VERTICAL-AXIS WIND TURBINE FOR INDIVIDUAL POWER SUPPLY

Submitted by: fourth year student 4 , group IEE-43
specialty
141 Electrical Engineering
(code and name of specialty)

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Ternopil
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« 01 » 01 2024

ASSIGNMENT
FOR QUALIFYING PAPER

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specialty 141 Electrical Power Engineering, Electrical Engineering and Electromechanics
(code and name of the specialty)
student *Ekome Daniel Ifeanyi*
(surname, name, patronymic)

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Paper supervisor *Koval Vadym Petrovich, Ph.D., Assistant professor*
(surname, name, patronymic, scientific degree, academic rank)
Approved by university order as of «*28*» *12* 2023 № *4/7-1212*
2. Student's paper submission deadline 27.01.2024
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4. Paper contents (list of issues to be developed)
1. Analysis of the scheme and structural elements of wind turbines with a vertical axis of rotation
2. Analysis of wind turbine operation problems
3. Speed calculation
4. Generator Calculation, Basic Parameters and Manufacturing
5. Charge Controller Diagram

5. List of graphic material (with exact number of required drawings, slides)
1. Wind turbine with a vertical rotor axis of rotation
2. Simplified diagram of an electric generator with a rotor on permanent magnets of radial (cylindrical) type
3. General view of the wind receiver developed by the wind turbine
4. Dependence of the wind energy utilization factor on speed
5. Appearance of the generator
6. Cross-sectional model of the generator of a low-speed wind turbine

6. Advisors of paper chapters

Chapter	Advisor's surname, initials and position	Signature, date	
		assignment was given by	assignment was received by
Labour occupational safety	*Ph.D., Assistant professor Okipnij I.B.*		
and security in emergency			
situations			

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1	Preparation of the «ANALYTICAL SECTION»	01.01.24 – 05.01.24	
2	Preparation of the «CALCULATION AND RESEARCH	05.01.24 – 12.01.24	
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3	Preparation of the «PROJECT DESIGNING SECTION»	12.01.24 – 20.01.24	
4	Preparation of the «LABOUR OCCUPATIONAL	20.01.24 – 22.01.24	
	SAFETY AND SECURITY IN EMERGENCY		
	SITUATIONS»		
5	Preparation of introduction, conclusions,	22.01.24 – 24.01.24	
	Content and summary.		
6	Preparation, execution and printing graphic material of	24.01.24 – 26.01.24	
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7	Getting feedback and review of thesis	26.01.24 – 27.01.24	
	And drafting a report for the defense.		

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ABSTRACT

Bachelor's thesis. Ternopil National Technical University named after Ivan Pulyuy. Faculty of Applied Information Technologies and Electrical Engineering.

Department of Electrical Engineering, IEE-43 group. - T.: TNTU, 2024.

The qualifying work of the bachelor was performed on the basis of the task on the topic: " Design of a vertical-axis wind turbine for individual power supply".

Wind energy is considered one of the most important sources of renewable energy in the world, because it contributes to reducing the negative effects on the environment. The most important types of wind turbines are horizontal and vertical axis wind turbines. This work presents the full details of design for vertical axis wind turbine (VAWT) and how to find the optimal values of necessary factors. Additionally, the results shed light on the efficiency and performance of the VAWT under different working conditions. It was taken into consideration the variety of surrounding environmental conditions (such as density and viscosity of fluid, number of elements of the blade, etc.) to simulate the working of vertical wind turbines under different working conditions. Furthermore, the effect of the design factors was investigated such as the number and size of the blades on the behavior and performance of VAWT

Keywords: vertical axis wind turbine; power generation; aerodynamic analysis

CONTENT

INTRODUCTION

One of the priority areas of energy development in the XXI century. There is a comprehensive use of renewable energy sources, which have huge resources, which will reduce the negative impact of energy on the environment, increase energy and environmental security. The need for widespread use of RES is determined by the rapid growth in the need for electricity, which is projected to increase 2 times by 2030 and 4 times by 2050 compared to 2000; depletion of explored reserves of fossil fuels in the foreseeable future; crisis state of the environment due to pollution with nitrogen and sulfur oxides, carbon dioxide, dusty particles from fuel combustion, radioactive and thermal pollution.

Wind energy is produced from the kinetic energy of the wind, the origin of which is associated with the energy of the Sun. Humans began using wind as an energy source hundred and thousands of years ago. Windmills and sailing vessels serve as the best example. Modern wind turbines convert wind energy into electricity. Electricity generated in this way does not cost much more than the energy produced in thermal power plants. The annual capacity of installed wind farms in Europe is 400 MW. More than 10 of Europe's largest banks are investing in the wind energy industry. More than 20 large European private investors are financing wind energy.

All this indicates the relevance of this work.

The aim of the work is to study the processes of converting wind energy into electricity at low wind speeds and to design a vertical-axis wind power plant.

To achieve this goal, you need to solve the following tasks:

- after analysing, determine the type of wind turbine suitable for the use of low-speed wind flow.

- to determine the most common causes of wind turbine failures by analysis.

- calculate the main parameters of the wind turbine, - Finalise the battery charge controller circuit.

1 ANALYTICAL SECTION

1.1 Features of wind energy and overview of existing wind turbine designs

The cause of winds is the absorption of solar radiation by the earth's atmosphere, which leads to the expansion of air and the appearance of convection currents. On a global scale, these thermal phenomena are superimposed on the effect of the Earth's rotation, which causes the appearance of wind directions.

Wind energy has been used in mechanical installations (mills, water pumps) for several centuries. Since 1930, various designs of wind turbines have been intensively developed.

The experience of using wind turbines has shown that structurally it should consist of a wind turbine, an engine room, and a support.

VD converts the energy of the wind flow into mechanical energy, which is further used to drive machines, or is transformed into electrical or heat. VDs used as a drive for a wind turbine electric generator are divided into 2 types: rotary (IDR) and propeller (VDP) type.

During operation, the plane of rotation of the VDP should be set perpendicular to the direction of the wind, and 2 options for the working position are possible - leeward (behind the support) and windward (in front of the support).

Structurally, high-power wind turbines can be mono-wind-driven and poly-wind-driven.

It is most expedient to place the engine room for wind turbines with VDP of any capacity at the top of the support. To protect it from the effects of atmospheric elements, it must have a cylindrical shell.

The engine room of the wind turbine should include: an electric generator; an overrunning clutch that disconnects the VD shaft from the multiplier input shaft to prevent fan mode; electric, mechanical or hydraulic brake; a multiplier with a variable or constant gear ratio for a high speed of rotation of the VD to the level determined by the characteristics of the electric generator; clutch connecting the output shaft of the multiplier and the shaft of the electric generator; electromechanical or hydraulic drive of the blade angle; information and control units of the automatic control system;

electromechanical or hydraulic drive of the angle of orientation to the direction of wind flow for wind turbines with VDP; Auxiliary equipment is required.

Traditionally, wind turbines have three blades, but can be 2, 4, 6, etc., for a given wind wheel diameter, as the number of blades increases, the wind utilization rate increases. The increase in this coefficient in the transition from 1 to 2 blades is 10%, and in the transition from 2 to 3 blades – 5%. As the number of blades increases, their cost increases and the structure of the bushing becomes more complicated.

The main characteristics of the blade design are the cut profile and shape, material and manufacturing method. Sections of blades with a wing profile are usually used to achieve a high ratio of lift to drag, and therefore a high coefficient of use of wind energy. [1] The blade materials are different – wood, aluminium, steel, fibreglass, etc. Tree – spruce, beech. Wooden blades are often reinforced with the use of aluminium, steel, copper. The angle of installation of the blades for small wind turbines is variable. The angle of the blades provides protection against exceeding the maximum speed and power regulation. For small wind turbines, blades with a fixed angle are used in cases where an increase in the maximum speed of rotation can be prevented by other means.

Horizontal-propeller-type wind turbines require an orientation mechanism to guide the wind turbine rotor according to changes in wind direction. The simplest system is when the windpipe rotates behind the tower.

Disadvantages of this system:

- the blades pass through the wind flow behind the tower, which leads to an increase in cyclic loads on the blade.
- Under the influence of the mass of the pipe and the wind pressure, a bending moment is created, acting on the top of the support structure. If the rotor is installed in front of the turret, the means of orientation to the wind are necessary - a tail shovel and a Wind-rose (in case of a storm).

The wind turbine should have 2 generators for more efficient conversion of wind flow energy (for low and high HE speeds).

The VD must have 2 brakes – mechanical, actuated by the control system, and aerodynamic. The wind turbine must have remote control for the distribution and transmission of electricity. When designing wind turbines, the calculation of the support structure is important, since its height can reach 100 m – steel grating, steel with cable guys, steel tubular, reinforced concrete supports.

– The disadvantage of wind turbines is the unevenness of the wind flow.

– The advantage is that wind energy is the cleanest.

1.2. Analysis of the scheme and structural elements of wind turbines with a vertical axis of rotation

A vertical-axis rotor has several advantages over a horizontal-axial rotor:

– independence of functioning from the direction of propagation of the wind flow eliminates the need to install additional mechanisms for orientation to the wind;

– the presence of a vertical shaft that allows placing electromechanical equipment at the base of the wind turbine, which reduces the requirements for the strength and rigidity of the support and does not limit the weight and size of the equipment.

– convenience of mechanical maintenance and repair;

– uniform geometric increase in the scale of the vertical-axis rotor, which has little effect on the strength characteristics.

– the ability to mount blades at several points;

– relatively simple blade manufacturing.

As disadvantages of the vertical-axis fig. 1.1 The following should be noted by wind turbines:

– a much greater susceptibility to fatigue failure, due to the self-oscillating processes that often occur;

– pulsation of torque leads to pulsations of power and other parameters of generators.

– as shown by the latest test results of wind turbines of the Darier type and

H-rotor with a capacity of 5 MW, the main weakness is the heel bearing of the main shaft of the wind turbine.

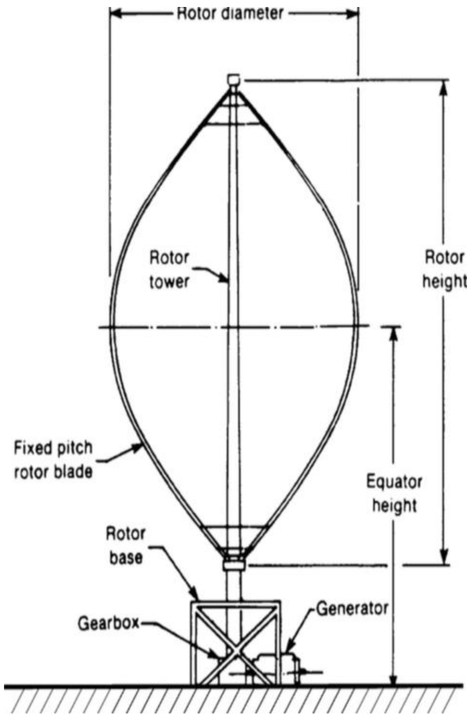


Figure 1.1 - Wind turbine with a vertical rotor axis of rotation

It is because of its destruction that attempts to build powerful wind turbines with a vertical axis have been stopped, although the development of low-power wind turbines is successfully continuing.

In general, the following main types of rotors with a vertical axis are used in practice for a wind turbine as an active surface that absorbs the energy of the wind flow:

- Darier rotor;
- Savonius rotor;
- orthogonal rotor (Evans rotor);
- a rotor of the carousel type, in which the non-working blades are either covered with a screen or go edge-on against the wind (Masgrove rotor).

The operation of a wind turbine with a vertical-axis rotor, as well as that of a wind turbine with a horizontal-axial rotor, is influenced, albeit to a lesser extent, by the aerodynamic shadow of the support and the mutual dimming of the blades.

Darier rotor (Fig. 1.2). In the rotor design of the French engineer (Darrieus), the torque is generated by the lifting force.

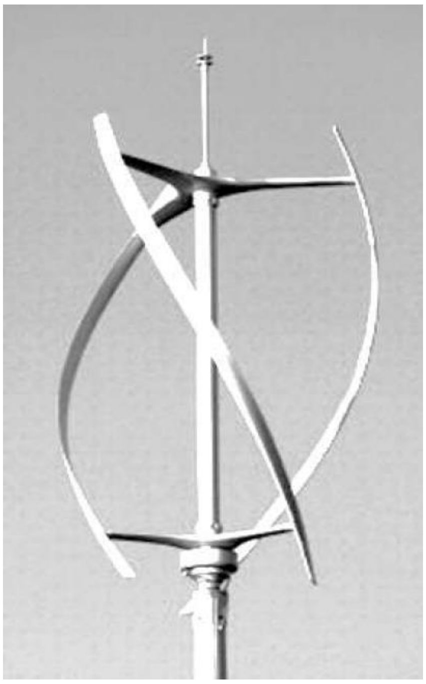


Figure 1.2 - Darier rotor

The rotor consists of two or three thin, curved blades with an aerodynamic profile. Lift is maximum when the blade crosses the incoming airflow and minimum when the blade moves parallel to the flow. Thus, in one revolution, the blade is subjected to the maximum and minimum torque twice, which is the cause of most fatigue failures.

Darier's rotor cannot start rotating on its own, so either a generator in engine mode or a special engine is used to start it. The need to have an independent power source for start-up significantly reduces the possibility of spreading this type of wind turbine.

Savonius rotor (Fig. 1.3). This wind wheel is also rotated by the force of resistance. Its blades are simple and cheap. The author's first wind wheel (1922) invented by the Finnish engineer Savonius (SI Savonius) was generally a barrel cut into two parts, planted on an axle. The torque is created due to the difference in the moments of resistance given to the air flow by the concave and convex wind blades relative to it.

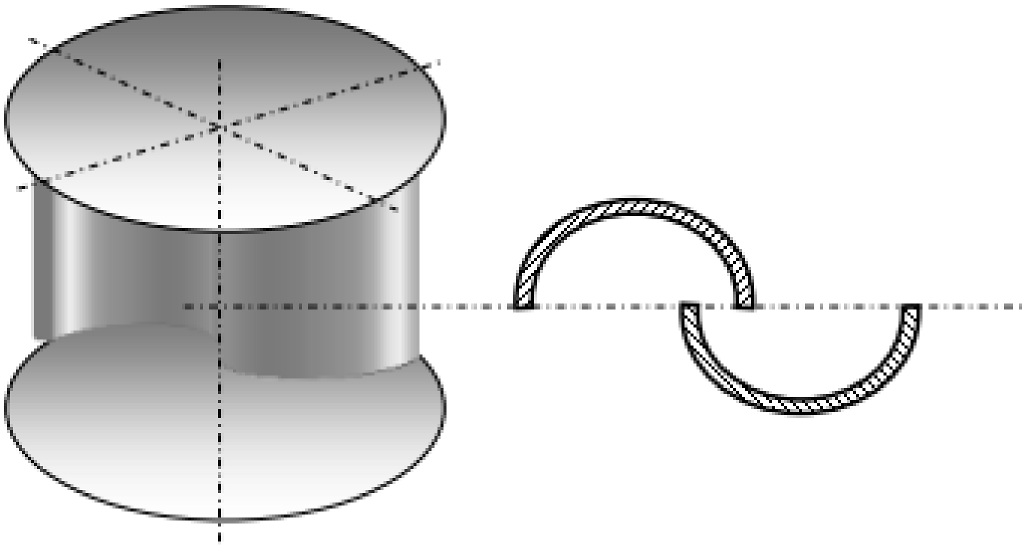


Figure 1.3 - Savonius rotor

The wind wheel has a large geometric filling, and therefore a greater initial torque, which is necessary for water-lifting mechanisms.

Evans rotor or H-rotor (Fig. 1.4). The torque is also generated by the lifting force of two vertically arranged blades with an air foil. To start it, spinning is also required, and to stop, a 90∘ rotation of the blades around the vertical axis is used.

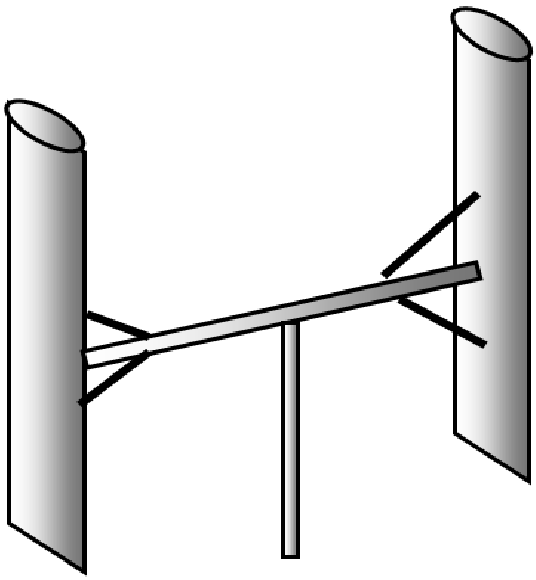
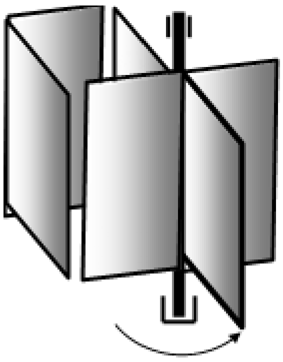


Figure 1.4 - Evans rotor

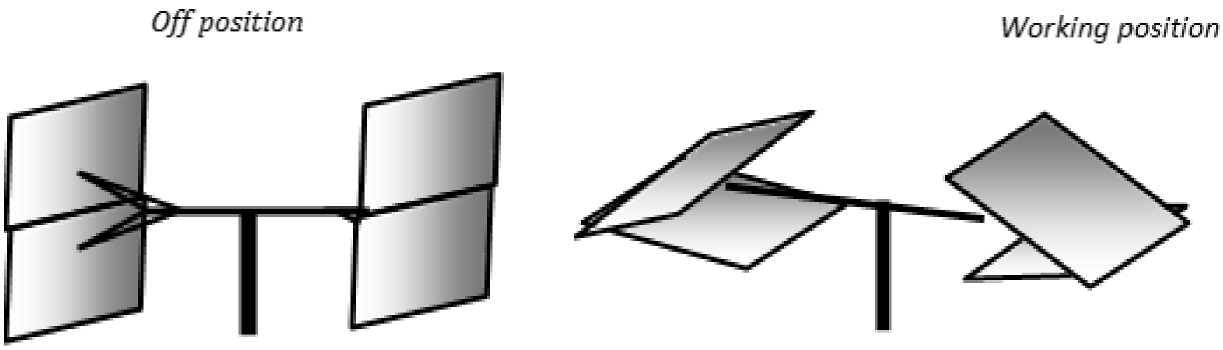
The rotor is of the carousel type and the Masgrove rotor (Fig. 1.5). Torque is also generated by lift. In the first case, to create a torque, half of the rotor (non-working blades) are covered by a screen (flap).

Half of the rotor (non-working blades) is covered by a screen (flap). In the second case (Masgrove's rotor), the two rotor blades, which have an aerodynamic profile, are located vertically at the initial starting moment. As the wind speed increases, the blades begin to fold, reducing lift by reducing the area captured.

And at the maximum design wind speed, the wind wheel stops when the blades are fully assembled. Like the Darier rotor, this rotor must be given an initial rotation.



(a)



b)

Figure 1.5 - Diagram of a carousel-type rotor: a) with a screen; b) with a folding blade.

In addition to the main types of rotors with a vertical axis, various modifications and combinations are used. As an example, in Fig. Figure 1.6 shows a general view of a variant of a technically more advanced wind turbine rotor.

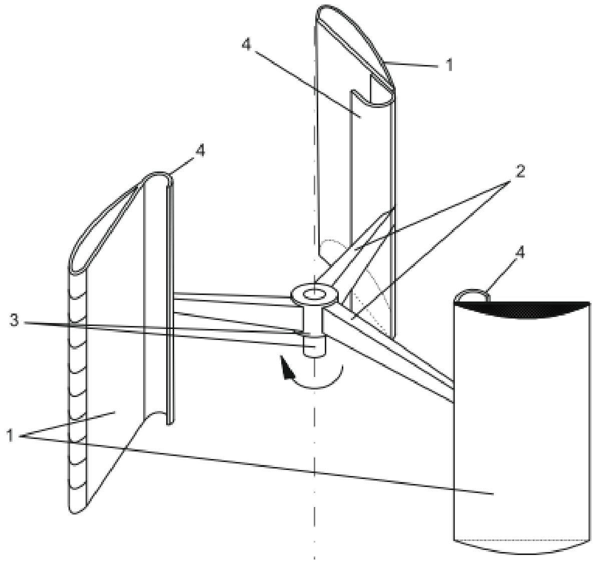


Figure 1.6 - General view of a three-bladed wind turbine

The wind turbine contains three blades 1 with an asymmetrical airplane wing type air foil, mounted on horizontal load-bearing brackets 2. The latter are fixed on a vertical shaft 3. At the same time, the aerodynamic profiles of the blade 1, located in the horizontal plane of the wind wheel, are installed at the required design angle of installation β, e.g. 60°. From the tail sections of the blade profile 1, a stream descends along the entire length of the blade. Flaps 4 are installed in this place, made in the form of half-cylinders and are a continuation of the wing-shaped profile 1. In this case, the convex side of the flaps 4 are oriented in the direction opposite to the entrance part of the air foil.

A wind turbine works as follows. The wind at speed v, interacting with the blades 1, exerts pressure on them and rotates the shaft 3 of the wind turbine with the calculated angular velocity. In this case, two forces arise and act simultaneously – the lifting force on the aerodynamic profile 1 and the dynamic pressure force of the inner surface of the profile 1 on the flaps 4.

The combined value of these two forces creates the moment of rotation of the wind turbine relative to the shaft 3. At the same time, the wind flow at speed v enters the confusor channel between adjacent blades 1, accelerates to a higher speed and its dynamic pressure is triggered by the flaps 4 with the reaction of turning the flow towards the entrance, which ensures a quick start of the wind turbine and increases the torque of rotation of the impeller. Therefore, the main advantage of the proposed wind turbine is the design of blades 1 in the form of three-dimensional structures in combination with rigid flaps 4.

This ensures a minimum of dangerous bending stresses that arise during its operation, increases the aerodynamic quality of the wind turbine, and in general ensures reliable operation of the wind turbine with improved and strength characteristics.

For a vertical-axis wind turbine, in general, a drive with a shaft located at right angles allows you to install electromechanical equipment on a horizontal plane, which makes it easy to move and replace individual devices. In addition, the presence of two axes ensures the compactness of the installation, as it avoids unnecessary support height and simplifies any modifications to the transmission coupling system and the electric generator. However, these benefits are less significant for vertical-axis wind turbines of medium and high power.

Since the starting aerodynamic moment of a vertical-axis wind turbine of the orthogonal type (Darier rotor, Evans rotor) is very small, an electric motor or a Savonius rotor can be used to start it.

The starting electric drive is an effective device for starting wind turbines, however, its use leads either to the complication of the automatic control system or to the use of manual start. The use of the Savonius rotor, which has maximum power at low circumferential speeds, can significantly simplify the starting process.

1.3 Analysis of Permanent Magnet Generator Configurations

Non-contact synchronous generators with permanent magnets (SGPM) have a simple electrical circuit, do not consume energy for excitation and have increased efficiency, are characterised by high reliability of operation, and are less sensitive to the action of the armature reaction than conventional machines. Their disadvantages are associated with low regulating properties due to the fact that the working flow of permanent magnets cannot be changed within wide limits. However, in many cases, this feature is not decisive and does not prevent their widespread use.

Most of the SGPMs in use today have a magnetic system with rotating permanent magnets. Therefore, magnetic systems differ from each other mainly in the design of the rotor (inductor). The SGPM stator has almost the same design as in classic AC machines, usually it contains a cylindrical magnetic core made of sheets of electrical steel, on the inner surface of which there are grooves for placing the armature winding. Unlike conventional synchronous machines, the working gap between the stator and the rotor in the SGPM is chosen as minimal, based on technological capabilities. The design of the rotor is largely determined by the magnetic and technological properties of the material.

At low wind speeds, generators with low rotational speeds should be used for wind turbines. In this case, the system often does not have a gearbox and the axle is directly connected to the axis of the electric generator. In this case, there is a problem of obtaining a sufficiently high output voltage and electrical power. One of the ways to solve this problem is a multi-pole electric generator with a rotor of a sufficiently large diameter. In this case, the rotor of the electric generator can be made using permanent magnets. An electric generator with a permanent magnet rotor does not have a collector and brushes, which can significantly increase its reliability and operating time without maintenance and repair.

An electric generator with a permanent magnet rotor can be built according to different schemes, differing from each other in the common arrangement of windings and magnets. Magnets with alternating polarity are located on the rotor of the generator. Windings with alternating winding direction are located on the stator of the generator. If the rotor and stator are coaxial discs, then this type of oscillator is called axial or disc disk.

If the rotor and stator are coaxial coaxial cylinders, then this type of generator is called radial or cylindrical rice. 1.87. In a radial generator, the rotor can be internal or external to the stator.

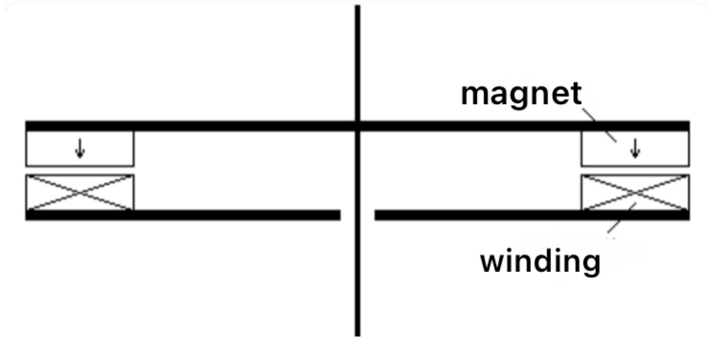


Figure 1.7 - Simplified diagram of an electric generator with a rotor on permanent magnets of axial (disk) type

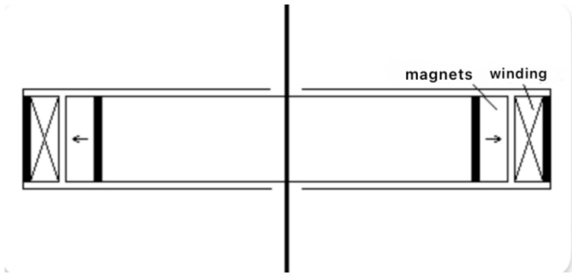


Figure 1.8 - Simplified diagram of an electric generator with a rotor on permanent magnets of radial (cylindrical) type

1.4 Conclusions to the chapter

- After analysing the existing designs of wind turbines, we will choose a vertically axial Savonius rotor. Since it is the design of this type that has the maximum shear moment, which will allow, in accordance with the purpose of work, to use the energy of a low-speed wind flow.
- On the basis of the considered structural diagrams of the systems for generating and using electricity, we combine the connection diagram of the wind turbine with a rectifier and the circuit equipped with a battery.
- After analysing the configurations of permanent magnet generators, we can conclude that the most efficient and easiest to perform is the design of an axial generator.

2 DESIGN SECTION

2.1 Analysis of wind turbine operation problems

Wind provides a very diffuse energy resource. Nature did not collect the winds in individual deposits like fossil fuels and did not blow the winds along the riverbeds like rivers. Each moving air mass is scattered over large areas. Diffusion and low concentration are also characteristic of solar energy, but it is even worse with wind. Its main parameters - speed and direction - change much faster and within wider limits quite unpredictably.

Thus, there are two main challenges in the design of wind turbines.

Firstly, taking into account the dispersion of the wind, they tend to remove its kinetic energy from the maximum area. For wind turbines of conventional design (wind wheel on the horizontal axis) - this is the area of the circle that the blades describe when rotating. Such an area is called the swept area (OP). Under these conditions, they tend to increase the diameter of the wheel (the length of the blades). There are known projects of giant wind turbines with a wind wheel diameter of up to 120 m. But for such dimensions, powerful winds are no longer desirable from the safety conditions of wind turbine use. At the same time, when calculating strength, it is necessary to pay attention even to unlikely hurricane gusts and further complicate and increase the weight of the bulky structure.

Secondly, even more important is the need to achieve uniformity, constancy of the wind flow on the blades. After all, the quality of electricity produced by a wind turbine is determined by the stability of the torque and angular velocity on the shaft of its generator. But if the first problem is somehow solved, then the second is even more difficult. It is necessary to install a fundamentally new design. Simple mathematical studies will help to find approaches to it. Consider what are the main parameters on which the energy efficiency of wind turbines depends. As is known, the kinetic energy of a body moving with a velocity V of mass m is determined by the formula $W = mV^2/2$.

When it comes to airflow, V is, of course, its velocity. To determine the mass m of the airflow, it is necessary to take into account the volume of air that passes through the OP per unit time, i.e. m = ρ·S·V, where ρ is the density of the air; S=OP; V is the same wind speed.

Then the initial expression to define the energy will be

$$W = \frac{\rho \cdot S}{2} \cdot V^3 \qquad (2.1)$$

It is the amount of energy per unit of time, that is, power. Even a superficial analysis of the above formula shows that the wind power is linearly dependent on the area S, and cubic on the wind speed V.

Simple considerations suggest that with an increase in the OP by 2 times, the capacity of the wind turbine can be increased (approximately also by 2 times), and with an increase in wind speed by 2 times, the power of the wind turbine can increase by 8 times (excluding production costs). That is, a 2-fold increase in wind speed is 4 times more effective than a 2-fold increase in the OP plane.

Thus, in order to increase the efficiency of wind turbines, it is necessary to look for ways and approaches to increase the speed V of the air flow.

The search for ways to improve the efficiency of wind power equipment is relevant in the context of limited traditional energy resources and growing problems of environmental pollution. The use of renewable energy sources opens up prospects in solving such problems and at the same time raises a whole range of research, design, production and operational issues of use. Only a successful and comprehensive solution to such problems will allow us to hope for a significant contribution of wind energy to the overall energy balance of the country.

Highly efficient and cost-effective wind turbines can only be units that have good aerodynamics combined with sufficient simplicity and high reliability. The creation of such wind turbines should be based on in-depth scientific research that allows the production of modern units in accordance with their designs and production technology.

At the same time, ensuring the high aerodynamic qualities of the rotor, as the main unit of any wind turbine, is one of the most important tasks.

It should be noted that the theory of wind energy calculation is currently underdeveloped. Existing models and approaches make it possible to mainly perform evaluation calculations of the aerodynamic characteristics of wind turbines with a horizontal axis of rotation.

When converting wind energy, the wind flow meets blades on its way and gives energy to the wind wheel.

Due to aerodynamic losses, the wind wheel uses only part of the power of the wind flow. At the same time, due to the constant change in instantaneous wind speeds, the energy of the wind flow changes within significant limits, and as a result, the power created by the wind wheel changes.

The structure of the wind flow, over the period of observation time, is characterised by a number of values:

1) average wind speed;

2) wind gustiness;

3) wind variability;

4) duration of dips - rises in wind speed above or below the average.

Average wind speed is defined as the arithmetic mean value that is obtained from a series of instantaneous wind speeds, measured at regular intervals, over a specified period of time:

$$V_{avr} = \frac{\sum_{i=1}^{n} V_i}{n}, \qquad (2.2)$$

where Vavr- average wind speed,V_i– the value of the instantaneous wind speed,n– the number of instant measurements.

Wind gustiness is the magnitude of the deviation of the instantaneous value of the wind speed from the mean value.

Wind gustiness characterises the depth of dips – rises in wind speed and is determined by the marginal Ggy mean Gser and the most probable (RMS) Gser.sq. Values:

$$G_{gr} = V_{gy} - V_{avr}\,, \tag{2.3}$$

where Vgy is the highest or lowest value of the instantaneous wind speed during the observation time.

$$\left.\begin{aligned} G_{\text{сер}} &= \frac{\sum_{i=1}^{n}(V_i - V_{\text{сер}})}{n} \\ G_{\text{сер.кв.}} &= \sqrt{\frac{\sum_{i=1}^{n}(V_i - V_{\text{сер}})^2}{n}} \end{aligned}\right\} \tag{2.4}$$

Wind variability is the rate of change in wind flow and is determined by the largest δnaib and intermediate δavrValue:

$$\delta_{naib} = \frac{V_{\max} - V_{\min}}{\Delta t}$$

, where Δt is the duration of the interval between instantaneous measurements.

$$\delta_{avr} = \frac{\sum_{i=1}^{n}\dfrac{V_{\text{in}} - V_i}{\Delta t_i}}{n} \tag{2.5}$$

The durations of dips and rises in wind speed are determined by the values of the intervals (Δτ) during which the wind speed has values greater or smaller than the average wind speed observed over the period of time.

The structure of the wind depends to a large extent on the height above the earth's surface. The presence of obstacles on the surface of the earth and the friction of the lower layers relative to the earth's surface reduces the speed of the air flow. The gustiness of the air flow when decreasing in altitude, on the contrary, increases. O.L.

Laichtman proposed the following formula for changing the average wind speed depending on the height of elevation above the earth's surface:

$$V = V_1 \frac{\ln \frac{h}{h_0}}{\ln \frac{h_1}{h_0}}, \tag{2.6}$$

where V – wind speed at altitude h, V1- known wind speed close to the ground at altitude h1; h0 is the altitude at which the wind speed at the measurement point is zero. Magnitude h0 depends on the unevenness of the earth's surface (for snow cover h0= 0.5 cm, for low grass surfaces h0 = 3.2 cm, with taller vegetation h0=5÷7 cm, h0=20 cm).

The latter formula is suitable for open, flat terrain at an altitude of 10m to 100m in the adiabatic state of the atmosphere. Under inversion conditions, satisfactory results are obtained only up to 10-15 m in summer, and up to 50 m in winter. The above formula (2.6) cannot be used to determine average wind speeds if the longest time interval is less than a 10-minute interval. To carry out wind energy calculations for extended time intervals (day, month, year), it is necessary to know the wind energy cadastre.

The wind energy cadastre is a system of numerical characteristics, on the basis of which it is possible to judge the production and frequency of operation of a wind unit. The main characteristics that are included in the wind energy cadastre include:

1) average wind speeds over a long period of time;

2) recurrence of average wind speeds;

3) characteristics of daily and annual wind speeds;

4) duration of wind periods and periods of calm.

Data on average wind speeds over a long period of time (month, year) are based on observations of the existing network of weather stations. On the basis of records of wind speeds, which are carried out by weather stations regularly, several times during the day, tables of average daily, average monthly and average annual wind speeds for a long-term period are compiled. The recurrence of wind speeds is the arithmetic sum of the time intervals during which, at a certain point at different times, the same average wind speed was observed.

For most regions of Ukraine, the wind has the highest speed during the day, the lowest at night. During the year, the average monthly wind speed for most regions of Ukraine is characterised by a minimum in the summer months and a maximum in winter. In spring and autumn, wind speeds are slightly higher than the average annual wind speed.

2.2 Analysis of power generation conditions

Using wind turbines to generate electricity is the most efficient way to utilize wind energy. The efficiency of converting mechanical energy into electrical energy in an electric generator is usually 95%, and the loss of electrical energy during transmission does not exceed 10%. The requirements for the frequency and voltage of the generated electricity depend on the characteristics of the consumers of this energy. These requirements are strict when operating wind turbines within a single energy system and are quite mild when using wind turbine energy, for example, in lighting and heating installations.

The main points to be considered when choosing schemes related to the conversion of wind energy into electrical energy are: the type of electricity (alternating voltage of alternating or constant frequency or constant voltage) generated, the speed of rotation of the wind turbine (constant, close to constant or alternating), the nature of the use of electrical energy (the use of batteries or accumulation by other methods, the supply of electricity to the AC network), that is produced.

Direct generation of direct current is now carried out practically only at small wind turbines with a capacity of no more than 10-20 kW. In this case, Ω_p a constant speed of the wind turbine is not required, and batteries are usually used.

Accumulation of wind energy in the form of heat for the purpose of its further use on site can be carried out by using an alternating voltage wind turbine with a variable frequency, or a constant voltage wind turbine in combination with an electric thermal storage device.

Obviously, the speed of the wind turbine in this case does not have to be constant. It is also possible to use rectifiers to obtain a constant voltage, which can be used directly or after its inversion into an alternating voltage of constant frequency.

Large-scale production of electrical energy through the use of wind energy should be produced in the form of alternating voltage of constant frequency in order to be able to supply electricity to the networks of existing power systems.

Another approach that has recently attracted attention is to enable the wind turbine to rotate at a variable optimal frequency, adjusted according to changes in wind speed and with the use of generating systems that provide, under these conditions, a constant frequency alternating voltage at which electricity can be supplied to existing power systems. Methods for obtaining an alternating voltage of constant frequency at a variable speed of rotation of the drive shaft are reduced to two large groups: differential and non-differential.

The first ones are implemented in circuits with synchronous generators with the help of mechanical devices that provide a constant speed of rotation of generators (gearboxes with variable gear ratio, devices with hydraulic power transmission), as well as with the help of electrical devices that compensate for the change in speed of rotation by supplying the excitation winding with a voltage with a sliding frequency equal to the difference between the speed of rotation of the generator rotor and the voltage frequency of the power system, on which the generator works.

Non-differential methods can be implemented through static arrangements of frequency change according to the conversion scheme AC voltage – DC voltage – AC voltage by using rotating devices – collector alternating current generators, cycloconverters and frequency converters, converters with amplitude frequency modulation. In the latter case, high-frequency or low-frequency modulation can be used.

According to the type of current, electromechanical energy converters for wind turbines are divided into AC and DC machines. AC machines are divided into synchronous and asynchronous, as well as AC collector machines.

In synchronous machines, the angular velocity of rotation of the rotor and the Ω_p angular velocity of rotation of the magnetic field of the stator are Ω_1 equal to each other. The frequency of the EMF and currents generated in the stator is determined by the rotational speed of the rotor n and the number of pairs of poles p of its excitation winding:

$$f = \frac{p \cdot n}{60}. \tag{2.7}$$

In asynchronous machines, the angular velocities are $\Omega_p \, \Omega_1$not equal to each other, while in the generator mode of operation$\Omega_p > \Omega_1$. The frequency of the generated EMF and current in the asynchronous generator and its slippage s are determined by the expressions:

$$f_1 = \frac{p \cdot n}{60}(1 - s), \tag{2.8}$$

$$s = \frac{\Omega_p - \Omega_1}{\Omega_p}. \tag{2.9}$$

Commutator machines differ from synchronous and asynchronous machines in that they have a mechanical frequency and phase number converter – a collector that is connected to the stator or rotor winding. DC machines also have a collector on the rotor, which acts as a mechanical rectifier in generators.

The rotor of an AC electric machine may not have excitation windings. In such machines, the excitation magnetic field is created by permanent magnets, and they are called permanent magnet generators.

The pronounced designs of the poles on the stator and rotor belong to inductor or parametric machines, in which the conversion of energy is carried out by means of a periodic change in the magnetic resistance of the air gap. The design of inductor machines is very diverse. They can have two stators with an excitation winding placed between them and two rotors, or one stator and a rotor with pronounced, so-called claw-like poles, while the excitation winding is located either on the rotor or in the end parts of the stator.

Most of these types of electrical machines – synchronous, asynchronous, permanent magnet, inductor – are widely used as generators in wind turbines. End-cut generators, in which the stator and rotor are made in the form of discs and in which the energy conversion is carried out in the air gap between these discs, also have a future.

2.3 Materials for making wind turbine blades

Friction against the surface of the airflow blade results in significant losses, which are proportional to the square of the linear velocity of movement of the points on the surface of the blade. The greater the current radius of the blade, the greater this velocity. At significant radii of the blade, its speeds are very high, so the roughness of the blades surfaces greatly affects the power of the wind turbine in a wide range of speeds. For this reason, the quality of the surface finish of the rotor blades should be as high as possible.

The material of the blades must be strong, lightweight, wear-resistant in adverse climatic conditions and be well processed to create parts of the blades of the required shape and roughness.

Even though aluminium and steel blades are the most acceptable to ensure strength and rigidity, they have several significant disadvantages:

– during the manufacture, bad, from the point of view of aerodynamics, surfaces are obtained, and additional processing costs are required to improve them.

– the need to ensure corrosion resistance;

– with a small number of products, the manufacture of molds and matrices is unreasonably time-consuming and expensive.

– during operation, they create significant interference with radio and television signals.

– Significant mass of blades.

World experience in the creation of wind turbines has shown that stainless steel, aluminium and its alloys, wood, plastic reinforced with high-strength chemical Fibre can be used for the manufacture of blades.

The wood can be used for the manufacture of one-piece blades for low-power wind turbines and in the form of a plywood coating for medium- and high-power horizontal-axial wind turbine blades. However, despite the fact that wood allows you to get a smoothly finished surface, it does not tolerate bending loads and flutter, and is also vulnerable to weathering.

The disadvantages inherent in the above materials are successfully eliminated when using plastics reinforced with chemical Fibers.

The problems of corrosion and erosion are solved practically through the use of any fibreglass-reinforced plastics. The requirements for strength and rigidity are solved by the use of plastics and epoxy resins reinforced with carbon Fibre. Such blades are not only much superior to aluminium ones in terms of strength and weight characteristics, but also do not affect radio and television signals.

In addition, fibreglass blades are characterised by high precision manufacturing and a very smooth surface. At the same time, a constant quality of material processing along the entire length of the blade is achieved, which is crucial for the operational parameters of the wind turbine.

Blades for wind turbines of medium and high power, made of plastic reinforced with chemical fibre, must be equipped with appropriate lightning protection, which is an aluminium mesh laid over the entire surface, supplemented by conductors on the leading and trailing edges of the blade.

2.4. Supports for vertical-axis wind turbines

For low-power wind turbines, the following can be used as a support:

– central tubular trunk with cable guys, which is attached to the foundation by means of a bolted connection;

– A rotating lattice barrel made in the form of a welded structure with cable guys.

The lattice barrel, in comparison with the previous design, has equal strength, has an advantage in terms of weight, but has a large diameter, which leads to an increase in the zone of aerodynamic shadow.

The main advantages of the support structure with cable braces are:

– ease of achieving the required structural rigidity;

– reduction of bending moments acting on the barrel, simplicity of design;

– The location of the rotating barrel mass close to the axis of rotation increases the rigidity of the structure and minimizes dynamic stresses due to rotation.

In high-power vertical-axis wind turbines, the same types of supports can be used as for horizontal-axial wind turbines.

In general, for wind turbines with a horizontal and vertical axis at low static and dynamic loads (low-power wind turbines – up to 20 kW), supports with braces are used.

With the relatively low cost of steel truss supports, they require the use of increased safety measures during operation and repair (the presence of an open ladder). Tubular ones have increased aesthetic and energy-dynamic parameters (a staircase or elevator is located in the middle of the support), but they are expensive.

Wind turbine supports should not generate infrasound vibrations (negative impact on biological objects) and vibration. Reinforced concrete supports dampen vibration well but require the rotor to be positioned in working order in the windward position. In the leeward position of the rotor location, vibration and infrasound can also occur when using steel supports.

Vibration characteristics and characteristics for the strength of the support as a whole are also determined by the quality of the foundation. The depth of its embedding is not less than the depth of soil freezing (in Ukraine it is no more than 1.1 m). Foundations must meet the following basic requirements:

– have sufficient strength to static and dynamic loads;

– do not give subsidence (in order not to cause distortion of the structure, it is necessary to place the center of the entire mass of the wind turbine and the foundation on the same vertical).

When calculating the foundation and the support structure, the wind gust speed of about 60 m/s should be taken as a basis.

2.5 Chapter Conclusions

The initial value of the design wind speed for the developed low-speed wind turbine of 3-4 m/s was selected

To achieve a higher quality of the electricity generated, a design is required that will ensure a uniform rotation speed of the generator.

After reviewing the requirements for the materials from which the blades are made, the above advantages and disadvantages, it was decided to make blades from high-density polyethylene, since this material is quite durable, weather-resistant and lightweight.

3 CALCULATION SECTION

3.1 Speed calculation

Speed is one of the characteristics that determines the efficiency of the wind wheel. Let's consider two extreme modes, the ineffectiveness of which is clear at a qualitative level. The first is when the blades of the wind wheel are located so frequently, or the wind wheel rotates so fast that each blade rotates in a turbulent flow perturbed by the previous blades. As a result, the wind wheel "grinds" the air and the return from it is minimal. The second extreme case is when the blades are so sparsely spaced, or the wheel rotates so slowly, that a significant portion of the flow passes through the cross-section of the wind turbine in Figure 3.1 without interacting with its blades.

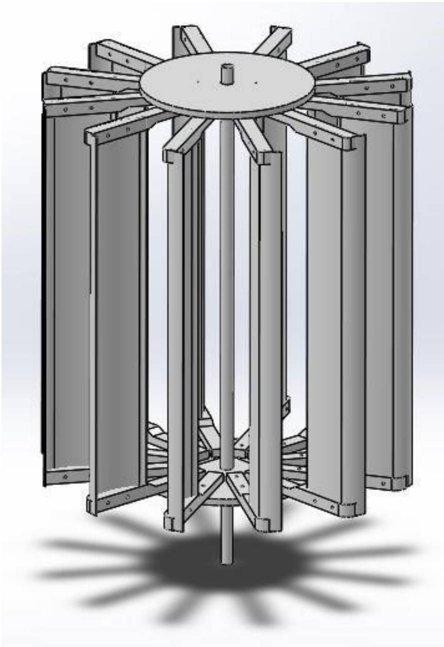


Figure 3.1 - General view of the wind receiver developed by the wind turbine made in the Solid Works program.

It follows that in order to achieve maximum efficiency, the speed of a wind wheel with a certain number of blades must somehow correspond to the speed of the wind. Let us consider the ratios that determine this correspondence.

The efficiency of the wind wheel is determined by the ratio of two characteristic time intervals:

Δtp - for which the blade moves a distance equal to the distance between the blades;

Δ tв - during which the disturbance of the air flow created by the blades will move a distance equal to its length.

The time interval Δt depends on the size and profile of the blades and varies in inverse proportion to the wind speed.

The time span Δtp for an N-bladed wind wheel rotating with angular velocity ω is equal to:

$$\Delta t_{П} = \frac{2\pi}{N\omega} = \frac{2 \cdot 3{,}14}{12 \cdot 13{,}95} = 0{,}0375\, s. \qquad (3.1)$$

Angular velocity is calculated using the formula:

$$\omega = \frac{2\pi n}{60} = \frac{2 \cdot 3{,}14 \cdot 133{,}3}{60} = 13{,}95\ rad\ /\ s, \qquad (3.2)$$

where n is the speed of rotation of the wind wheel, rpm.

The period of existence of the disturbance created by the blade in the plane of the wind wheel is approximately equal to:

$$\Delta t_{B} \approx \frac{d}{v_0} \approx \frac{0{,}15}{4} \approx 0{,}0375\ s, \qquad (3.3)$$

where: v0 is the velocity of the incoming air flow; d is the characteristic length of the area of air flow perturbed by the blade.

It is obvious that the efficiency of the use of airflow energy will be maximizes if Δtв = Δtp, or taking into account (3.1) and (3.3) we have:

$$\frac{2\pi}{N\omega} = \frac{d}{v_0}, \text{or } \frac{N\omega}{v_0} = \frac{2\pi}{d}. \qquad (3.4)$$

To perform the calculations, we use the data from Table 3.1.

Table 3.1 - Table of initial data for performing calculations

Denomination	Numeric value
N	12 pcs.
ω	13.95 (rad/s)
d	0,15
V0	4 (m/s2)
R	0.3 (m)

The speed factor is equal to the ratio of the speed of the end of the blade to the wind speed, or:

$$Z=\frac{R\omega}{v_0}=\frac{0,3\cdot 13,95}{4}=1,04. \tag{3.5}$$

Given the radius of the wind turbine R, we obtain a condition that determines the maximum efficiency of its operation

$$\frac{N\omega R}{v_0}=\frac{2\pi R}{d} \quad \text{or} \quad \frac{\omega R}{v_0}=\frac{2\pi R}{dN}.$$

Expression for calculating speed:

$$Z=\frac{2\pi R}{dN}. \tag{3.6}$$

The length of the perturbed blade of Fig. 3.2 of the area can be represented by which of the radius of the wind wheel by expressing this dependence by the coefficient " k ", $d \approx kR.$ Then the formula for optimal speed is:

$$Z_0=\frac{2\pi}{kN}. \tag{3.7}$$

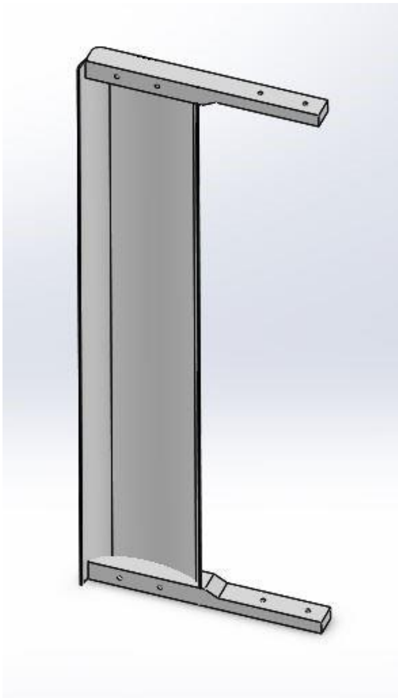
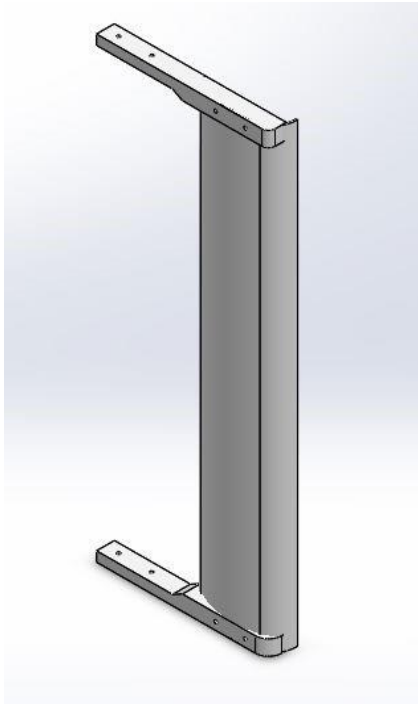
a)  b) 

Figure 3.2 - Blade with fastener (a- front side, b- reverse side)

It is known from practice that is $k = \frac{1}{2}$.equal to: Then the optimal speed

Equals:

$$Z_0 = \frac{4\pi}{N} = \frac{4 \cdot 3{,}14}{12} = 1{,}04. \quad (3.8)$$

Expressions (3.7) and (3.8) are not entirely accurate due to approximations, but they provide a good orientation for choosing the speed of rotation of the wind wheel.

Fig. 3.3 shows the dependencies of the wind energy utilisation coefficient cp on the speed of the wind turbine Z, for different wind wheels.

The condition for the maximum possible "removal" of wind energy is to maintain cp in the zone of the highest value, that is, it is necessary to ensure a more or less constant speed value. According to (3.5), when the wind speed (v0) decreases, it is necessary to reduce the number of revolutions of the wind wheel (ω) and vice versa.

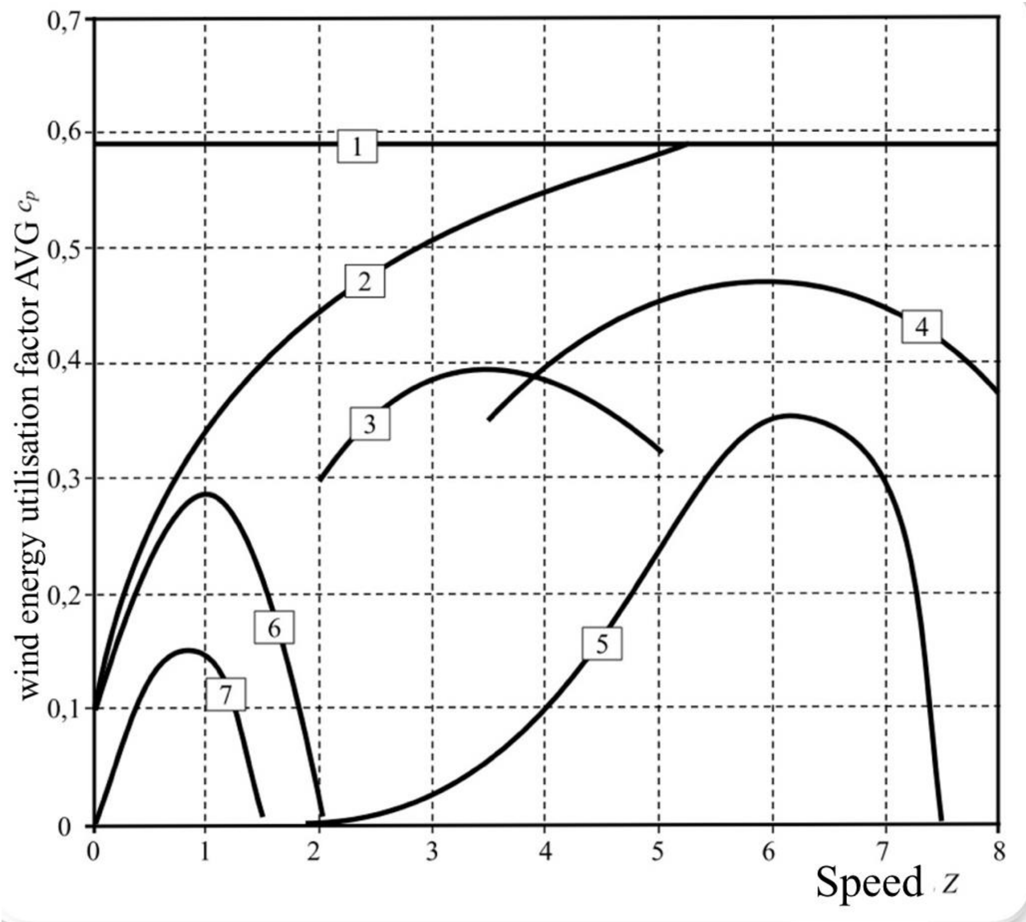


Figure 3.3 - Dependence of the wind energy utilisation factor on speed:

1 – Betz-Zhukovsky criterion; 2 – Glauert's criterion (ideal propeller); 3 – three-bladed wind wheel; 4 – two-bladed wind wheel; 5 – wind turbines with Darier and Masgrove rotors; 6 – multi-bladed wind wheel; 7 – wind turbines with a Savonius-type rotor.

That is why most modern wind turbines prefer wind wheels with variable rotational speed in a fairly wide range. Wind turbine Enercon E82 (power 2000 kW, rotor diameter 82 m) The speed range of the wind wheel is 6... 19.9 m/s, i.e. the maximum is 3 times greater than the minimum, and the Enercon E112 (power - 4500 kW, rotor diameter - 114 m) the speed range of the wind wheel was: 8... 13 m/s. Speaking about the condition of constancy of speed in specific designs, the wind turbine is carried out by maintaining the constancy of the angle φ equal to the sum of the angles: the angle of attack (α) and the angle of installation of the blade (angle of jamming) – γ. The angle of attack is the angle between the wind speed vector relative to the blade and the chord of the blade section. And the angle of installation of the blade is the angle between the chord of the blade section and the vector, perpendicular to the velocity vector in the plane of the wind wheel. Along with the Betz-Zhukovsky criterion, Glauert investigated the ideal propeller and deduced the relationship between the maximum value of cp and the speed, presented in Fig. 3.3. The dependencies presented in this figure allow us to unambiguously judge the capabilities of wind turbines of different designs in the use of wind energy.

The speed of the wind turbine is its most important parameter, which determines the main design solutions for the wind turbine. It depends on three main quantities: the diameter of the wind wheel, the speed of rotation of the wind wheel and the speed of the wind.

Thus, vertical-axis wind turbines of the Savonius type have a maximum cp value of 15%, which is less than the Betz-Zhukovsky criterion. Wind energy efficiency considerations work in the range of increasing wind speed from starting to nominal. When the wind speed exceeds the nominal value, the power limitation factor comes into play and the wind wheel is forcibly put into the cp reduction mode. The characteristic of the wind turbine is presented in the form of a straight line parallel to the axis of the abscissa, that is, the power of the wind turbine remains constant, although the wind speed increases.

3.2 Generator Calculation, Basic Parameters and Manufacturing

The main parameter of the alternator is the voltage, and knowing the voltage, all other parameters can be calculated, such as the charging current of the battery, and the power of the alternator Fig. 3.4 Overall.

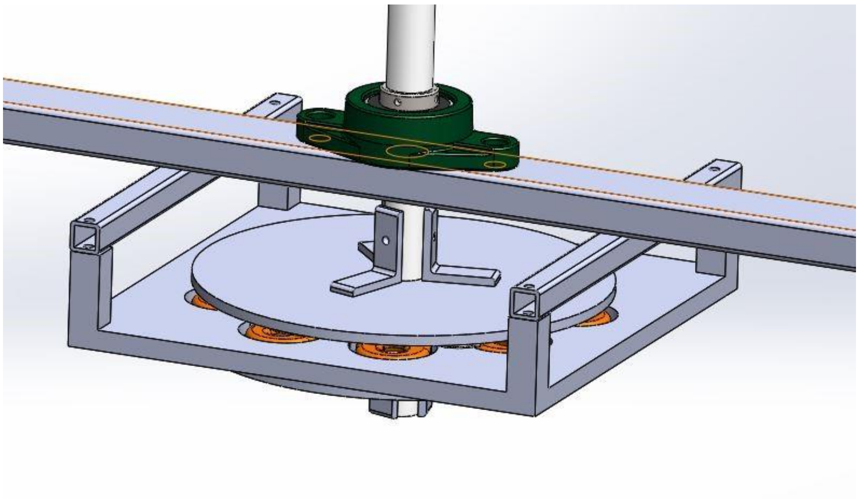


Figure 3.4 - Appearance of the generator made in Solid Works

A generator is usually built to charge batteries. The voltage at the output of the generator depends on the number of turns in the coils, on the magnetic induction of the magnets, and on the rate at which the magnetic field changes. So, the faster the magnets move past the coils of Fig. 3.5 the higher the voltage [18].

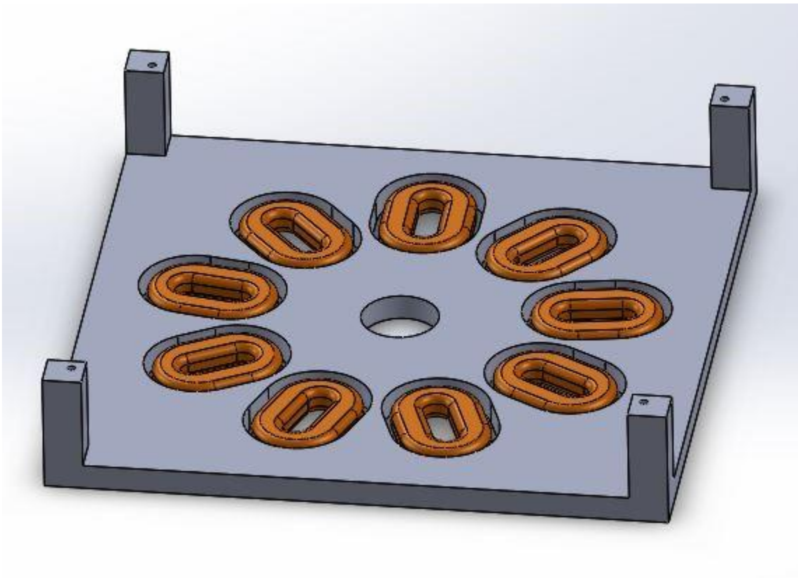
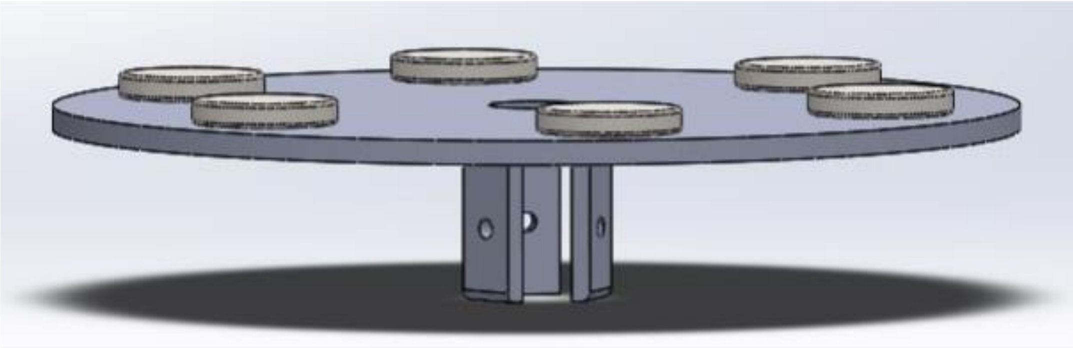
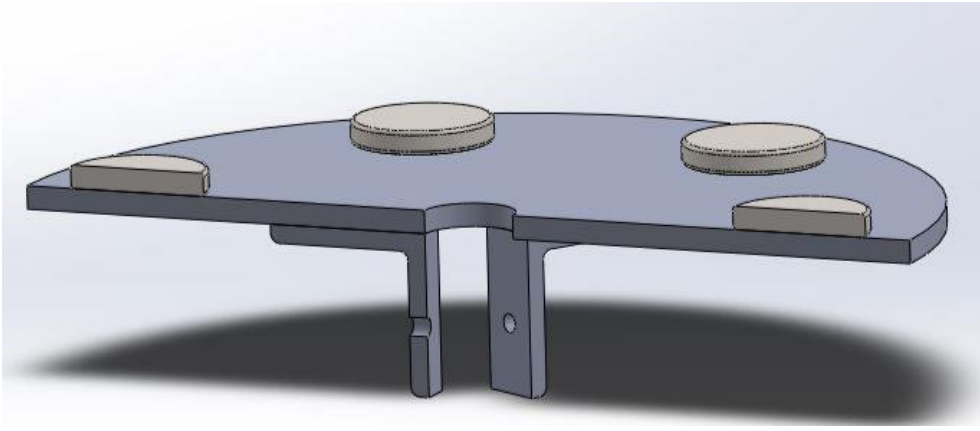


Figure 3.5 - Stator model made in Solid Works

Magnetic Induction of Neodymium Magnets Fig. 3.6 is about 1 T, and its value will be inversely proportional to the distance, that is, the farther from the magnet, the lower the magnetic induction.



(a)



b)

Figure 3.6 - Rotor model (a- general view, b- sectional view)

To calculate the voltage of the generator, we use the formula

$$E = B \cdot V \cdot L, B, \tag{3.9}$$

where E is the voltage of the generator, V; B - magnetic induction of magnets, T; V is the speed of magnets, m/s; L is the active length of the conductor, m.

For an induction of 1 T, it is necessary that the distance between the magnets does not exceed 10 mm. Taking into account the clearance, for the safe operation of the generator, the thickness of the coil should be 8mm.

The active length of a conductor is the length of the copper wire that is exposed to magnets. For disk axial generators in Figure 3.7, the length of the active conductor is equal to the dimensions of the magnet. In this case, this length will be. $l = 30мм$

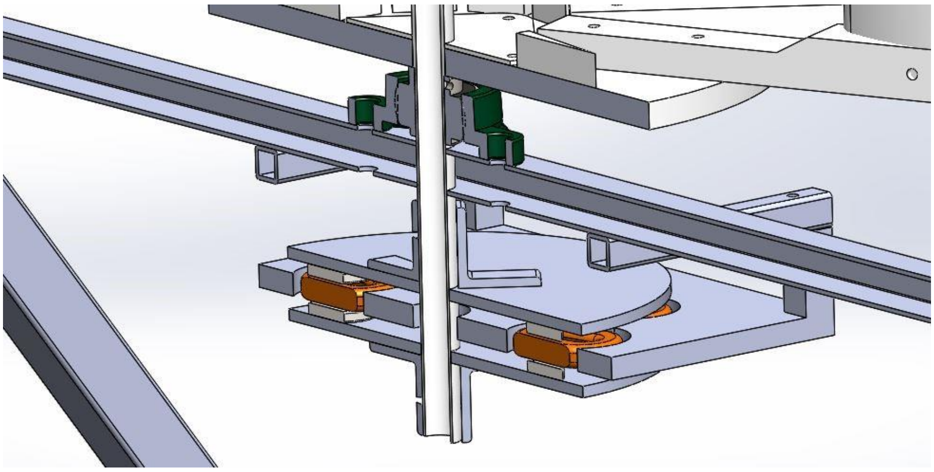


Fig 3.7 - Cross-sectional model of the generator of a low-speed wind turbine made in the Solid Works program

The speed of magnets is calculated using the formula

$$V = \frac{D_{pom} \cdot 3{,}14}{t} = \frac{0{,}17 \cdot 3{,}14}{1} = 0{,}53\ m/s. \quad (3.10)$$

That is, with the number of turns $n_{вит} = 160$ in one coil, the length of the active conductor is:

$$L_{kot} = L_{akt} \cdot n_{coil} = 0{,}03 \cdot 160 = 4{,}8\ m. \quad (3.11)$$

Given the number of coils in the phase, we have

$$L_{faz} = L_{kot} \cdot n_{kot} = 4{,}8 \cdot 3 = 14{,}4\ m. \quad (3.12)$$

For three-phase generators, the ratio of the number of magnets to the coils is 2/3, due to this, an even load distribution and a significant reduction in vibration are achieved.

By substituting the values of all quantities into the formula at a rotational speed of 60 rpm. With the connection of phases into a triangle, we get

$$E = 1 \cdot 0{,}53 \cdot 14{,}4 = 7{,}632\ V \quad (3.13)$$

At 120 rpm, the voltage will be 15.2 V, which means that this rotational speed will be enough to charge the battery. If you connect the phases into a star, the voltage will increase by 1.7 times, this will make it possible to charge already at 90 rpm.

So, by connecting the generator with a star, we get 15.2 ·√3 = 25.8 V. For the charging current, we will have the following expression

$$I = \frac{U_{xx} - U_{ак}}{R_{ф}} = \frac{25,8 - 13}{3,82} = 3,35\,A.$$

3.3 Practical tests of the developed wind turbine

Having made a prototype of a low-speed wind turbine, measurements of the initial values and graphs of their change were carried out.

Consequently, the oscillograms of the output alternating voltage in the no-load mode of Fig. 3.8 and Fig. 3.9 when connecting the stator coils into a star. To do this, with the help of a household fan, a wind flow was simulated, the speed of which was 2.3-2.5 m/s, while the wind turbine rotated at a speed of 34 rpm.

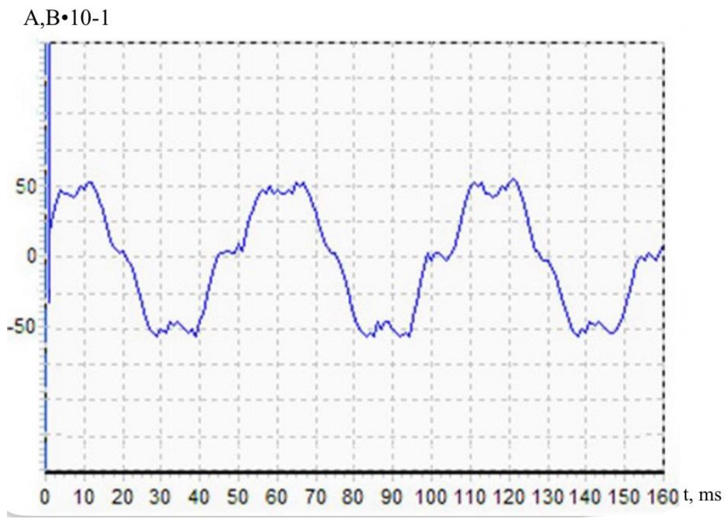


Figure 3.8 - Graph of the change in the output alternating voltage of the generator over time (200ms)

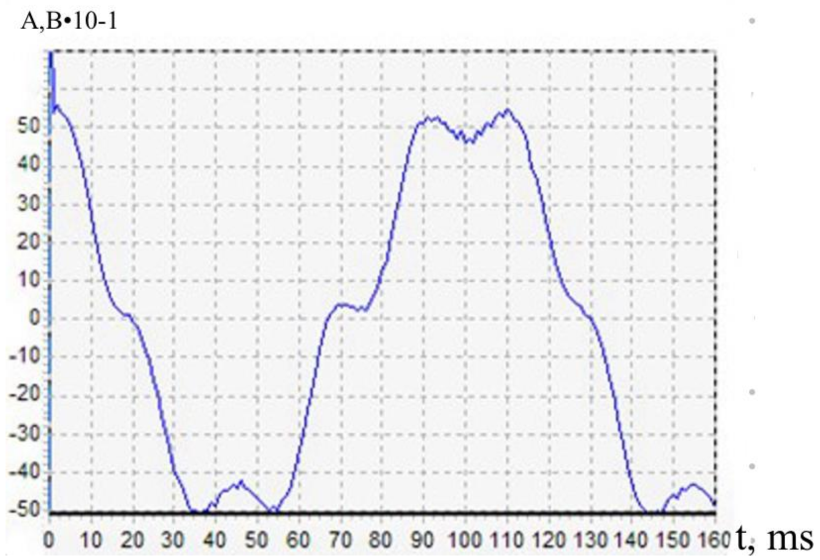


Figure 3.9 - Graph of the change in the output alternating voltage of the generator over time (50ms)

After that, a three-phase diode bridge was manufactured and installed according to the Larionov scheme of Fig. 3.10.

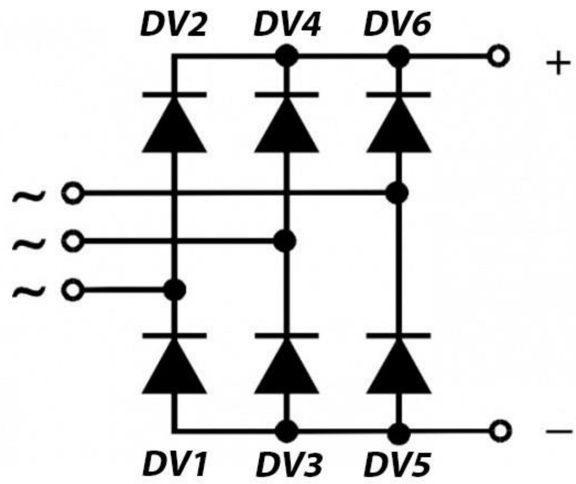


Figure 3.10 - Diagram of a three-phase bridge rectifier

In the circuit of a three-phase bridge rectifier, the six diodes in the circuit are combined into two groups: anode (VD1, VD3, VD5) and cathode (VD2, VD4, VD6). The coils of the generator can be connected by a "star" or "triangle". All diodes work in pairs: one from the anode group and one from the cathode. In the cathode group, the current is conducted by the diode whose anodic voltage is greater, and in the anode group - the one whose anode voltage is greater. which has the greatest negative potential at the cathode. The change of pairs of diodes occurs after 1/6 of the period. The current flows through the load in one direction.

The positive half-waves of the sine wave are rectified by the diodes of the cathode group, since this voltage direction is conductive for them. Negative half-waves are rectified by diodes of the anode group.

As a result, the sum of the rectified stresses of the anode and cathode groups is applied to the load. The instantaneous voltage values represent the phase voltage difference, i.e. the linear voltage of the alternating coil phases, so U0 is greater than the line voltage of the transformer. Graphs of voltages and currents of the bridge three-phase circuit of the rectifier are shown in Fig.3.11.

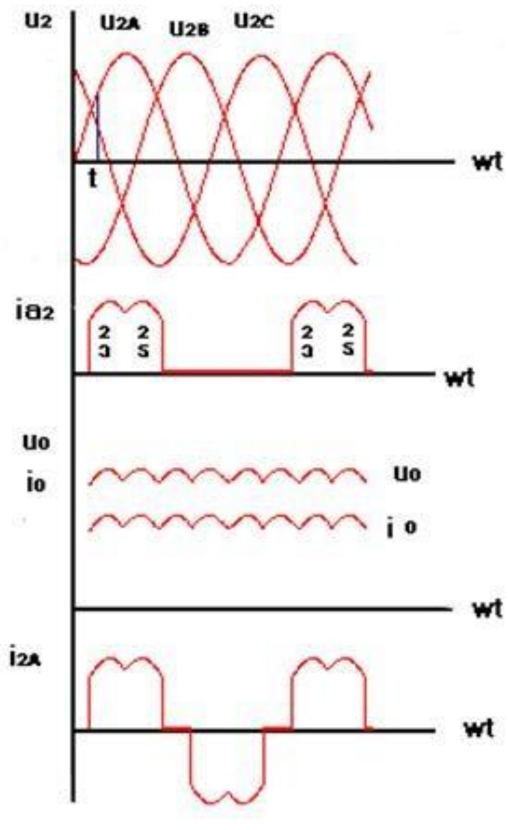


Figure 3.11 - Graphs of voltages and currents of a bridge three-phase rectifier circuit

After connecting the rectifier, the following waveforms of the rectified voltage in no-load mode were obtained: Fig. 3.12 and Fig. 3.13.

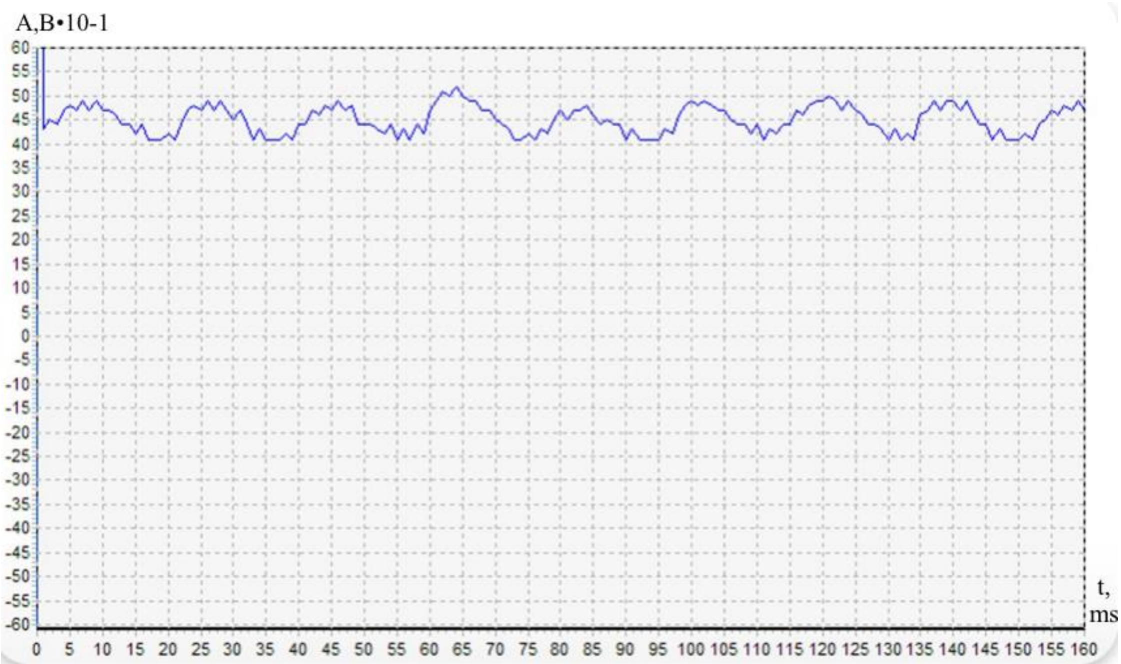


Figure 3.12 - Graph of the change in the output rectified voltage of the generator over time (200ms)

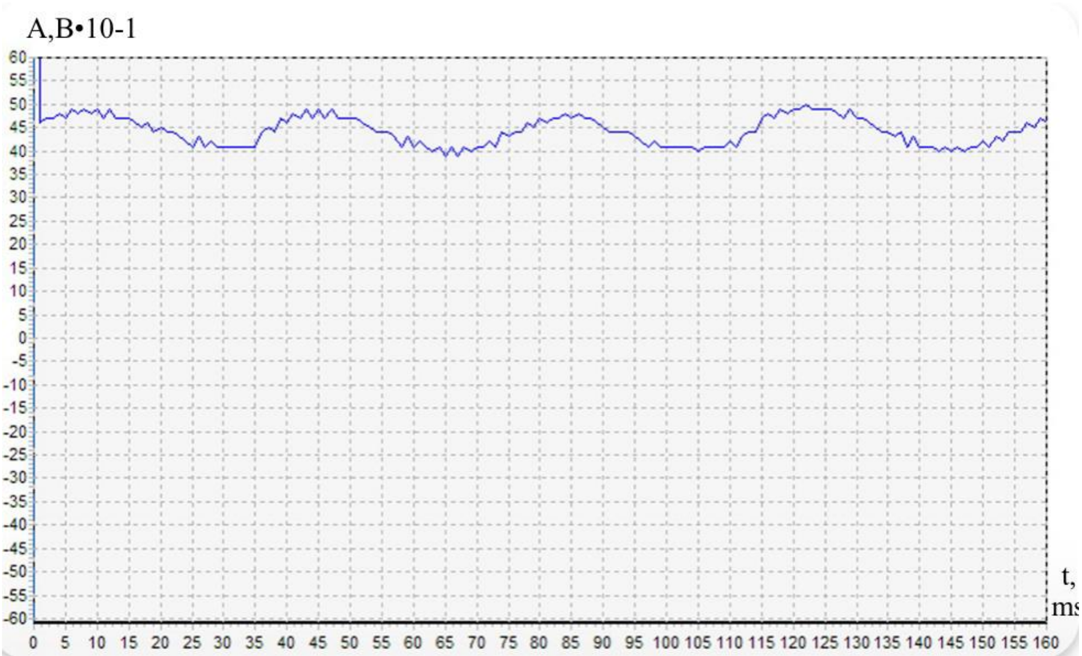


Figure 3.13 - Graph of the change in the output rectified voltage of the generator over time (50ms)

Let's calculate the ripple coefficient:

$$K_P = \frac{U_{\max} - U_{\min}}{U_{avr}}, \qquad (3.15)$$

$$K_P = \frac{5-3,85}{4,4} = 0,26.$$

3.4 Charge Controller Diagram

The purpose of the controller of the selected configuration makes it possible to ensure that the battery is charged within the established limits. The electrical diagram of the controller is shown in Fig. 3.14.

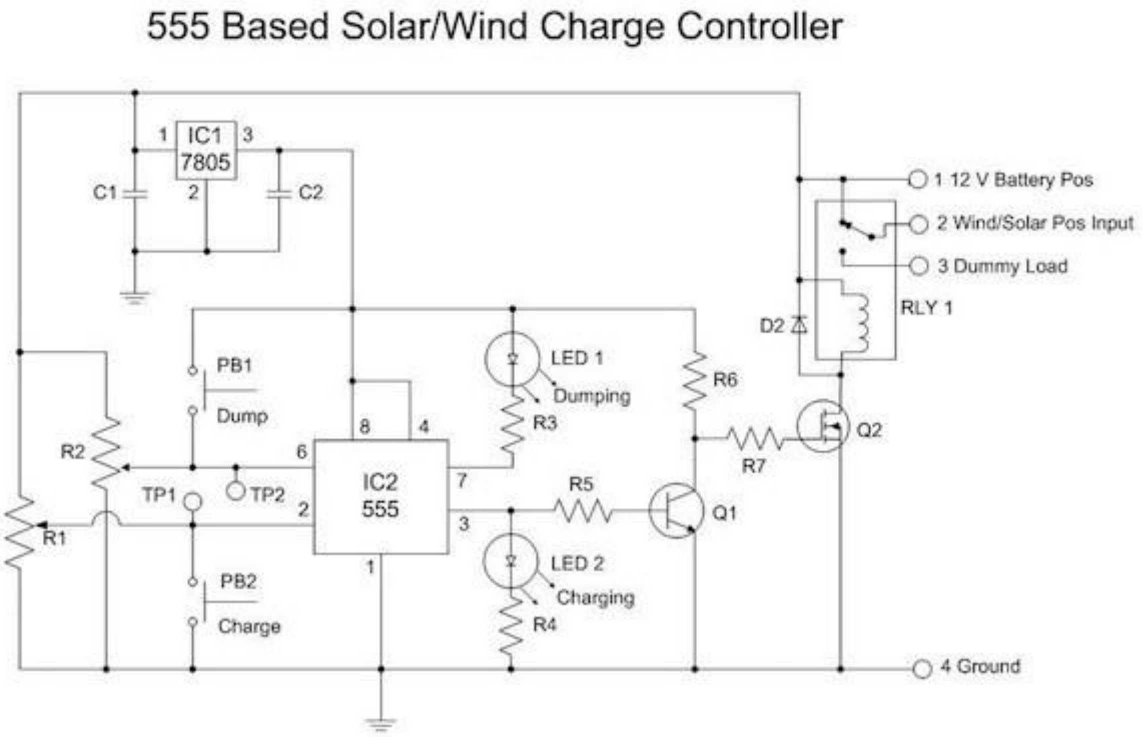


Figure 3.14 - Battery charge controller diagram

The list of elements of the controller circuit is given in tab. 3.2.

According to the electrical diagram, a layout of the printed circuit board was developed in the program Sprint Layout 6.0 Fig. 3.15.

Sprint Layout 6 is a PCB development environment. A huge number of electronic components have been added to this version, which will make the development of the board easier and more convenient compared to previous versions of Sprint-Layout.

Table 3.2 - List of elements of the controller circuit

Denomination	Description
IC1	7805 5V
IC2	NE555
PB1, PB2	Non-latching button
LED1	Green LED
LED2	Yellow LED
RLY1	30 A Relay
D1	1N4001
R1, R2	10 KΩ potentiometer
R3, R4, R5	1 room
R6	330 Ω
R7	100 ohms
Q1	2N2222
Q2	IRF540
C1	0.33μF 35V
C2	0.1μF 35V

Distinctive features:

- The software package contains 1355 electronic components (macros).

- All components are grouped.

- The program is adapted to Windows Vista, 7.

The signal transmitted from the generator rectifier is switched using the RLY1 relay, which is controlled by a threshold circuit with a Q2 field-effect transistor switch. To adjust the correct operation of the circuit at control points TP1 and TP2 using two multi-rotation resistances R1 and R2. Stabilization of the voltage of the circuit in Fig. 3.16 is performed by an integral regulator 7805 (K142EH5A).

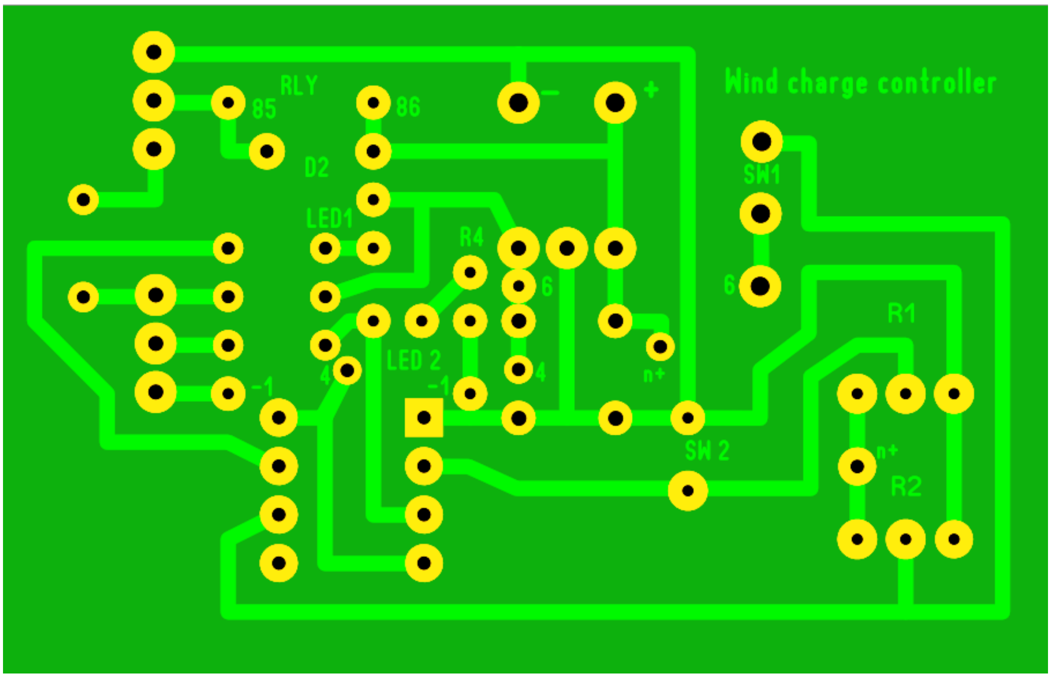


Figure 3.15 - Layout of the charge controller PCB.

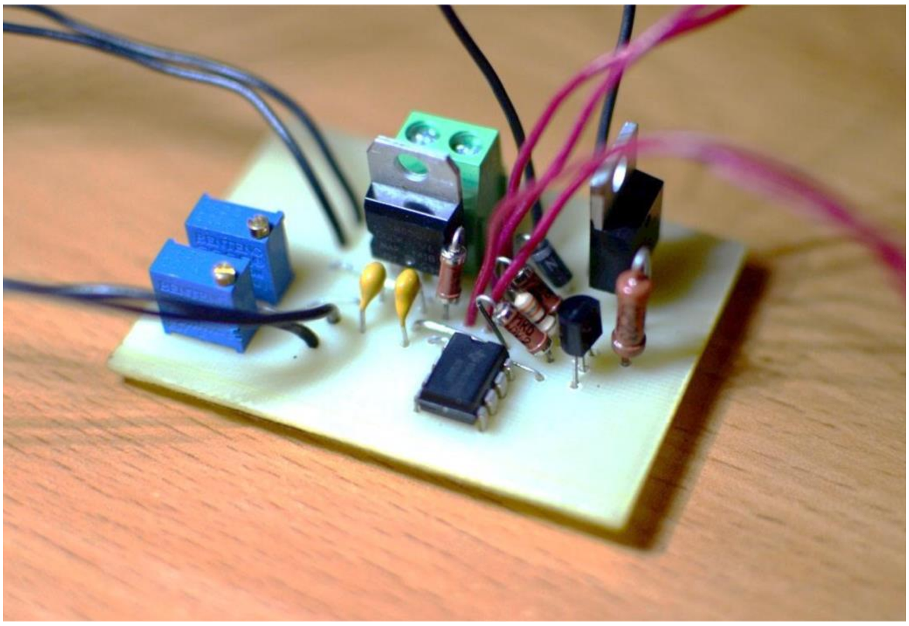


Figure 3.16 - Photo of the manufactured controller.

3.5 Conclusion to the section

1 Based on the analysis of the conditions, operating modes of the wind turbine and basic calculations, the vertical-axial structure of the wind turbine with the number of

blades of 12 was selected. This makes it possible to use the maximum percentage of wind energy for the selected design.

2 A three-phase axial alternating current generator for operation at low speeds of 30-180 rpm was calculated. The developed design consists of 9 coils and 12 magnets placed on two metal discs with a thickness of 5 mm.

3 To be able to change the type of connection, the beginnings and ends of the generator's stator phases are displayed on the terminal block.

4 As a result of tests in the laboratory at a rotational speed of 32 rpm. obtained the ripple coefficient KP=0.26 of the DC voltage rectified by a three-phase diode bridge according to the Larionov scheme.

LABOUR OCCUPATIONAL SAFETY AND SECURITY IN EMERGENCY SITUATIONS

4.1 Help with electric shock

Electric shock occurs because of contact between a person and an electrical energy source. Electrical energy flows through a portion of the body causing a shock. Exposure to electrical energy may result in no injury at all or may result in devastating damage or death. Electricity requires a complete path (circuit) to continuously flow. This is why the shock received from static electricity is only a momentary jolt: the flow of electrons is necessarily brief when static charges are equalized between two objects. Shocks of self-limited duration like this are rarely hazardous.

Without two contact points on the body for current to enter and exit, respectively, there is no hazard of shock. This is why birds can safely rest on high-voltage power lines without getting shocked (Fig 6.1): they contact the circuit at only one point.

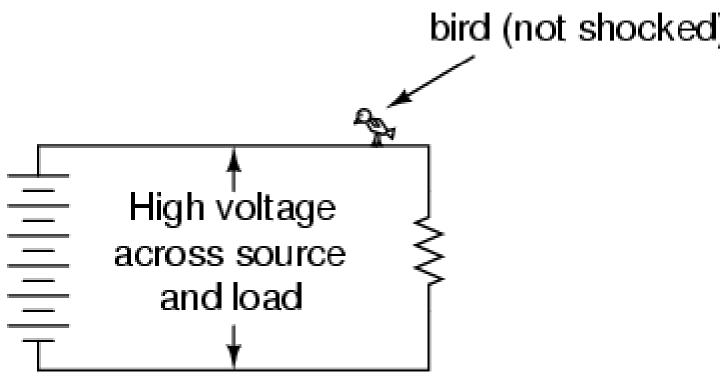


Figure 4.1 - High voltage across source and load

For electrons to flow through a conductor, there must be available voltage to excite them. Voltage is always relative between two points. There is no such thing as voltage “on” or “at” a single point in the circuit, and so for example the bird contacting a single point in the above circuit has no voltage applied across its body to establish a current through it. Even though they rest on two feet, both feet are touching the same wire, making them electrically common. Electrically speaking, both of the bird’s feet touch the same point, hence there is no voltage between them to motivate current through the bird's body.

This might lend one to believe that it's impossible to be shocked by electricity by only touching a single wire. Like the birds, if we're sure to touch only one wire at a time, we'll be safe, right? Unfortunately, this is not correct. Unlike birds, people are usually standing on the ground when they contact a "live" wire. Many times, one side of a power system will be intentionally connected to earth ground, and so the person touching a single wire is making contact between two points in the circuit (the wire and earth ground):

The ground symbol is that set of three horizontal bars of decreasing width located at the lower left of the circuit shown, and at the foot of the person being shocked. In real life the power system ground consists of some kind of metallic conductor buried deep in the ground for making maximum contact with the earth.

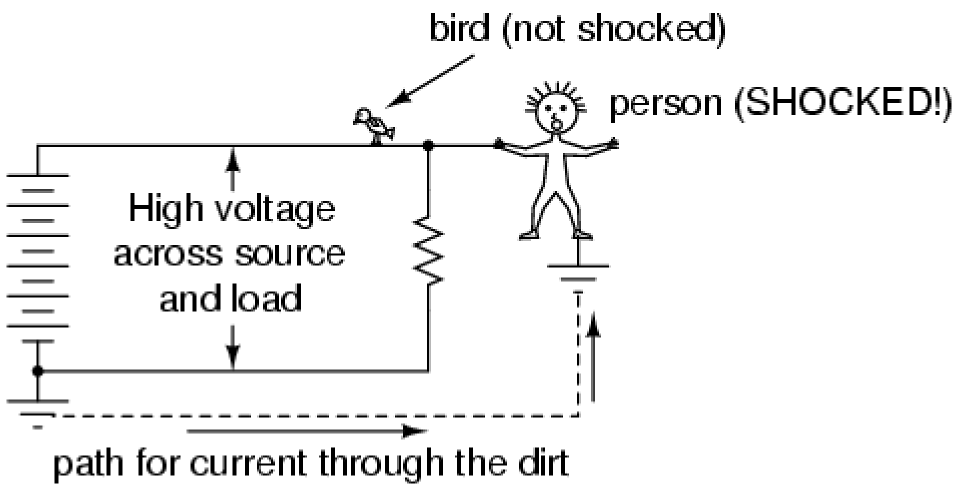


Figure 4.2 - High voltage across source and load

That conductor is electrically connected to an appropriate connection point on the circuit with thick wire. The victim's ground connection is through their feet, which are touching the earth.

4.1.1 Causes of electric shock

Extension cords. These cords are found in every home and office and in smart meters. They are the source of many electrical shocks and burns. What causes this electric shock are damaged insulation on electrical cords.

Electric Outlets. Unfortunately, most electric outlets are located where young children easily can reach them. This is a drawback in the height and construction of these outlets as a result electric shock is inevitable According to the United States Consumer Product Safety Commission (CPSC), about 4000 people are treated in hospital emergency rooms each year due to injuries relating to electric outlets. If there are young children at home, it's recommended to use sliding outlet covers.

- Accessible live parts of the energy meter.
- The association of current transformer secondary.
- Single component fault.
- Electrical spacings over-surface and through-air.
- Endurance of load control switch or the lack thereof.

4.1.2 Effects of electric shock

Burns are usually most severe at the points of contact with the electrical source and the ground. The hands, heels, and head are common points of contact.In addition to burns, other injuries are possible if the person has been thrown clear of the electrical source by forceful muscular contraction.

Pain in a hand or foot or a deformity of a part of the body may indicate a possible broken bone resulting from the electric shock causing violent muscle contraction.

4.1.3 Electric Shock Treatment

In cases of severe electric shock, it would be advisable to call the health care emergency line. There are two methods of approaching the treatment of electric shock.

Self-Care at Home

Brief low-voltage shocks that do not result in any symptoms or burns of the skin do not require care. For any high-voltage shock, or for any shock resulting in burns, seek care at a hospital's emergency department. A doctor should evaluate electric cord burns to the mouth of a child.

Medical Treatment

Treatment depends on the severity of the burns, or the nature of other injuries found.

Burns are treated according to severity:

- Minor burns may be treated with topical antibiotic ointment and dressings.
- More severe burns may require surgery to clean the wounds or even skin grafting.
- Severe burns on the arms, legs, or hands may require surgery to remove damaged muscle or even amputation

Other injuries may require treatment:

- Eye injuries may require examination and treatment by an ophthalmologist, an eye specialist.
- Broken bones require splinting, casting, or surgery to stabilise the bones.
- Internal injuries may require observation or surgery.

4.2 The primary fire extinguishing means

Electric meter fires, when they occur, can put utility customers, workers and company reputation in jeopardy. News coverage of these events at times struggles to determine what caused the problems. Yet much is known on safe installations. A body of knowledge has emerged around socket safety: what to do before, during and after installing advanced meters.

Hot sockets are a very serious and very prominent concern for the metering industry. Meter socket safety issues, including fires, are nothing new. Due to the rise in AMI deployments throughout the world and more readily accessible information, the number of reported hot socket incidents is on the rise. There has been significant debate both inside and outside the industry about the root cause of these events. Are they caused by the new meters' being installed? Perhaps a defective meter socket is to blame?

Could it be that the meter was improperly installed? Some have suggested environmental factors such as vibration are to blame.

It is not merely a matter of looking at ways to avoid trouble, either. When utilities remove old meters, they create an opportunity to inspect equipment that may have been covered up for years, perhaps even decades. By detecting signs of deterioration or damage at the meter site and acting to make repairs, utilities can proactively ensure the safety of their networks for years. Too often, the industry has not recognized this moment as a once-in-a-generation chance to act.

While the causes of meter fires can be many and complex, a body of knowledge has emerged to reduce risk and enhance both the customer experience and the utility business case. Yet many utilities are not aware of the range of solutions available.

4.2.1 Causes of fire

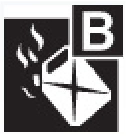
To prevent hot socket issues, one first must understand what causes these incidents. Several features or sources can cause hot sockets, but among the most prevalent are:

- Mechanical breakdown of components.
- Excessive moisture.
- Environmental contaminants.
- Frequent meter change outs (resulting in loss of jaw tension);
- Excessive electrical load (overload or short circuit);
- Loose or melted conductors.
- Vandalism;
- Ground settling; and
- Storm damage.

Becoming informed and establishing methods to address hot socket issues is paramount for manufacturers and utilities. Developing a process that proactively identifies and mitigates problem sites is crucial in getting in front of hot socket issues.

When issues with hot socket arises and there is fire afterwards, we must know how to deal with it primarily before it escalates, or the fire service arrives. The primary way of putting out the fire is with the use of fire extinguishers. All fire extinguishers are not made equal, there are several classes of fire extinguishers. Each class identifies the type of fuel involved and allows appropriate fire extinguisher media to be identified.

Table 4.1 - Fire Extinguisher Classes

Class Icon	Nameof Class.	Type of Fire/ Fuel involved
	Class A Fires	**Freely Burning Materials** i.e.: Wood, Paper, Straw, Textiles, Coal etc.
	Class B Fires	**Flammable Liquids** i.e.: Petrol, Diesel, Oils, Paraffin etc.
	Class C Fires	**Flammable Gases** i.e.: Methane, Propane, Hydrogen, Natural Gas etc.
	Class D Fires	**Flammable Metals** i.e.: Magnesium, Aluminium, Lithium etc.
	Class F Fires	**Combustible Cooking Media** i.e.: Cooking Oil, Fats, Grease etc.
	Electrical Fires	**Electrical Appliances** i.e.: Computers, Stereos, Fuse boxes etc.

Fire extinguishers are manufactured with a red body and have a band of a second colour covering between 5-10% of the surface relating to the extinguisher's contents. Each different type of extinguisher agent has a corresponding colour making identification easier for the user.

GENERAL CONCLUSION

1. To ensure the maximum shear moment, the vertical-axial design of the wind turbine of the Savonius rotor type was chosen.

2. In order to reduce vibrations and achieve smoother rotation, a three-phase axial generator is manufactured, the design of which consists of 9 coils and 12 neodymium magnets with a thickness of 5 mm placed on two metal discs with a thickness of 5 mm.

3. The parameters of the wind receiver $\Delta t_{р}$ = 0.0375 s and $\Delta t_{в}$ = 0.0375 s) are calculated, which indicates the efficiency of the installation. Since the time it takes for a blade to move to the position of another is equal to the time it takes for the flow perturbed by the blade to move a distance equal to the length of the perturbed flow. The speed of the wind turbine with the number of blades of 12 pcs was also calculated. Z=1,04.

4. An experimental sample of the PRO installation in the laboratory at a rotation speed of 32 rpm was studied. obtained the ripple coefficient KP=0.26 of the DC voltage rectified by a three-phase diode bridge according to the Larionov scheme.

5. In the existing charge controller circuit, the relay for switching the wind turbine and battery has been replaced with a more powerful one, in order to avoid its failure in hurricane wind gusts.

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