COMPARISON OF SYNCHRONOUS GENERATORS FOR AUTONOMOUS GASOLINE INSTALLATION SYSTEM

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Introduction. Generating power through the use of biomass represents the cost-effective and cleanest way to provide renewable electricity in biomass potential regions with high levels of biomass resources and its processing activity. Furthermore, use of this resource helps become more energy independent and use of a locally derived fuel provides employment and direct economic benefit to local communities.

Biomass is used for facility heating, electric power generation, and combined heat and power. The term biomass encompasses a large variety of materials, including wood from various sources, agricultural residues, and animal and human waste.

Biomass can be converted into electric power through several methods. The most common is direct combustion of biomass material, such as agricultural waste or woody materials. Other options include gasification, pyrolysis, and anaerobic digestion. Gasification produces a synthesis gas with usable energy content by heating the biomass with less oxygen than needed for complete combustion. Pyrolysis yields bio-oil by rapidly heating the biomass in the absence of oxygen. Anaerobic digestion produces a renewable natural gas when organic matter is decomposed by bacteria in the absence of oxygen [1-3].

Direct combustion systems feed a biomass feedstock into a combustor or furnace, where the biomass is burned with excess air to heat water in a boiler to create steam. Instead of direct combustion, some developing technologies gasify the biomass to produce a combustible gas, and others produce pyrolysis oils that can be used to replace liquid fuels. Boiler fuel can include wood chips, pellets, sawdust, or bio-oil. Steam from the boiler is then expanded through a steam turbine, which spins to run a generator and produce electricity.

The biggest problems with biomass-fired plants are in handling and pre-processing the fuel. This is the case with both small grate-fired plants and large suspension-fired plants. Drying the biomass before combusting or gasifying it improves the overall process efficiency, but may not be economically viable in many cases.

The relevance of the work lies in the evaluation of the effectiveness of replacing a traditional synchronous generator with electromagnetic excitation by a generator with permanent magnets, which is used in an autonomous gasoline installation.

The peculiarity of the comparison is that the geometric dimensions of the studied generator remain unchanged.

Replacements concern only the rotor of the generator under study - instead of the excitation winding, a rotor with permanent magnets is mounted.

Such a technical solution will improve the reliability of the autonomous installation, reduce losses and increase efficiency.

Results. In this work a two-dimensional and graphic models was developed of the designed generator in two-dimensional system automated design and drawing of AutoCAD. Three-dimensional graphic the model is a three-dimensional digital image of the required object, non-negative part of the technical documentation, as well as the basis for creating a prototype object.

A two-dimensional mathematical field model of the generator was also developed. Creating a two-dimensional graphical model is necessary for the future mathematical modeling of the designed generator in COMSOL Multiphysics software package.

On the fig. 1 shown traditional synchronous generator construction with electromagnetic excitation, which is basic for permanent magnet generator construction.

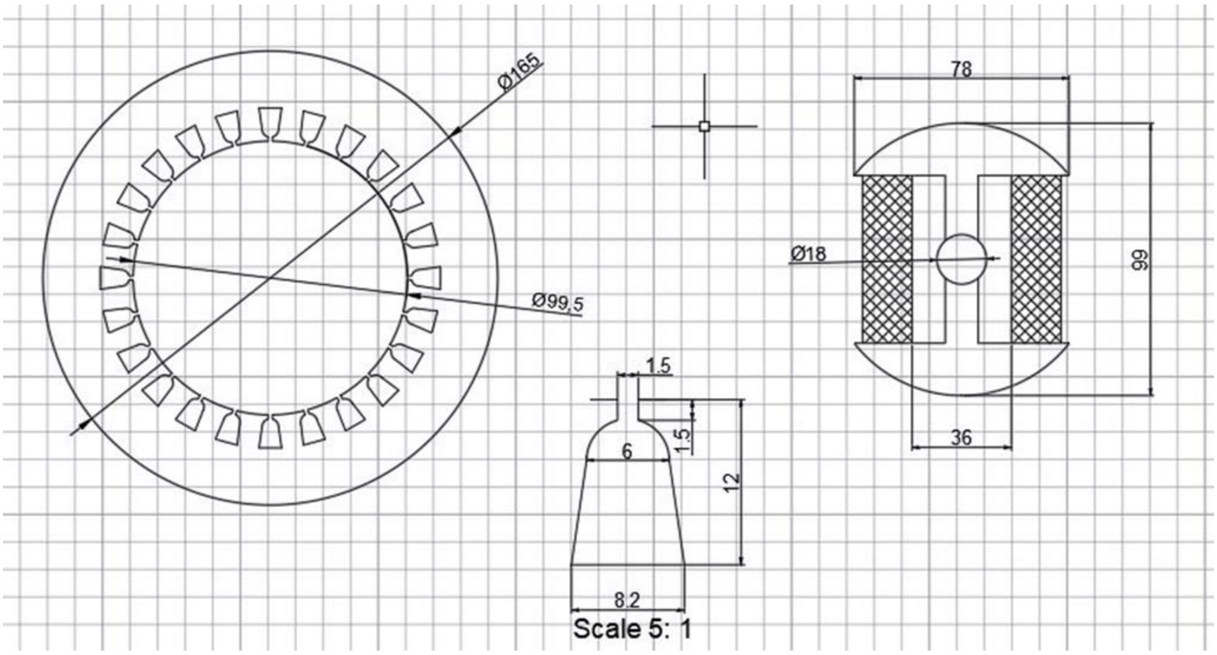

Figure 1 – Traditional generator construction 2-dimensional model prototype

In the drawing, the middle line of the air gap was additionally constructed for further calculation of the moment and the grooves of the stator were made closed to make a limited area for marking the phase of the motor in it. The dimensions for the construction of the engine drawing.

It is important when building a model is the coincidence of different types of lines. This should be achieved by using bindings to characteristic points of lines, such as endpoint, middle, quadrant, tangent, and the use of parameterization – parallelism, perpendicularity, coincidence, and so on. When creating an array of elements, it is necessary to avoid approximate size values, instead use integrated computational tools or other construction methods.

The construction of geometry is carried out in stages according to the obtained geometric dimensions shown in Table 1.

Table 1 – The main parameters and initial data used for modeling the generator are given in table

Number of slots	24
Axial generator length	102 mm
Number of poles	2
Number of turns	141
Inner rotor diameter	99 mm
Number of magnets	2
Generator type:	Synchronous with PM;
Number of phases:	3
Supply voltage:	220 V
Winding resistance:	1,34 Om
Current consumed:	3,86 A
Type of magnets	N50 NdFeBr

The two-dimensional circle-field mathematical model of aA permanent magnet synchronous generator(PMSG) is considered in the work. The expediency of developing a circuit-field model is that the electrical and electromagnetic phenomena in this type of motor are interconnected, and the motor power supply is pulsed. The voltages of the motor windings are a function of time and change periodically according to a certain law. It is impossible to realize the relationship between electrical and magnetic phenomena using classical field calculation. This can only be implemented using a circle-field model.

This model is multiphysical, it takes into account the mutual influence of electrical parameters on the magnetic and vice versa. It is possible to implement such a model using the program for multiphysical calculations COMSOLMultiphysics.

The paper uses a built-in interface for modeling electric machines that support rotor rotation with a given frequency.

Equation of three-dimensional electromagnetic field, relative to the vector magnetic potential A [4]:

$$\nabla x\left(\frac{\nabla xA - B_r}{\mu}\right) = J_e \tag{1}$$

where B_r is the final induction of the permanent magnet; J_e – current densities in the rotor winding; μ – magnetic permeability.

The differential equation in partial derivatives is formulated within the calculation area, which reflects the design of the generator. This area includes the structural elements of the generator.

The calculation area is limited by the outer boundaries of the creation model.

To obtain an unambiguous solution at the boundaries of the calculation area, the boundary conditions of the first kind are set [5]:

$$A\ (x,y,t)|G1=0,\ \{x,y\}\ \epsilon G1, \tag{2}$$

this means accepting the assumption of the absence of magnetic fluxes passing through the selected boundary of the calculation area.

The theoretical basis for mathematical modeling of electromagnetic fields is the field equations formed by Maxwell. Maxwell's equations establish the relationship between vector field functions, characteristics of field sources and physical parameters of material environments. In the modern form of writing, these equations are as follows:

$$\begin{aligned} & rotH = J \\ & rotE = -\partial B / \partial t \\ & divB = 0 \\ & divD = \rho \\ & B = \mu H, D = \varepsilon E \\ & J = \gamma E + \partial D / \partial t + \gamma (v \times B) + \gamma E_e + \rho v_r + rot(D \times v) \end{aligned} \qquad (3)$$

In the given system the following are marked: field functions – vectors of intensity of magnetic H and electric E of fields, vector of magnetic induction B and vector of electric displacement D; coefficients that characterize the physical properties of material media – magnetic permeability μ, electrical conductivity γ, dielectric conductivity ε; density of electric charges ρ. Expression (2) allows to find the current density J, due to the sum of terms of different physical nature. The term γ·E causes the induced current density in the conductive medium; term (∂D)⁄∂t – dielectric displacement current density; the term γ(v×B) determines the "convective component" of the current density, which is due to the motion of the conductive medium with velocity v relative to the magnetic field with induction B. Appendix J_e=γ·E determines the current density, which is caused by third-party EMF; the term $\rho \cdot v_r$ characterizes the density of currents moving free charges, and the term rot(D×v) is the "convective component" of the current density, which is due to the motion of the polarized dielectric.

Results. Electromagnetic field and magnetic vector potential distribution of basic and permanent magnets synchronous generator with electromagnetic excitation shown on fig. 2.

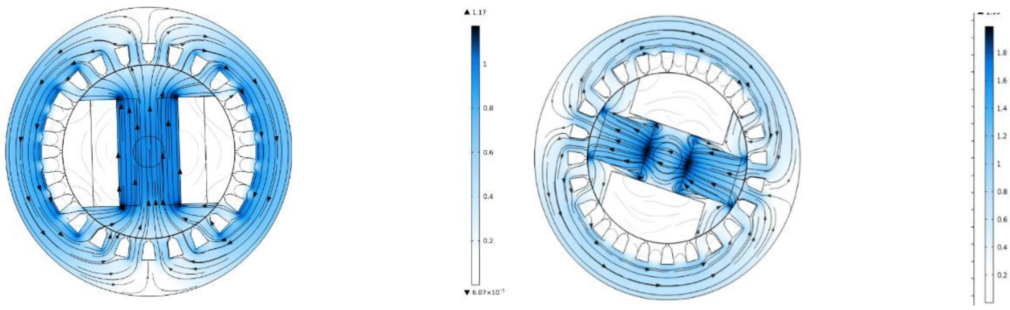

Figure 2 – The of the average value of magnetic induction and vector potential distribution

The maximum value of induction in acute areas reaches 1,99 T in the teeth; in the air gap from 0,4 to 1 T. The highest magnetic flux density is observed in the corners of the teeth and magnets – this is due to the influence of edge effects. It is also clear that at the moment two of the three phases of the motor are active, which confirms the theoretical calculations regarding the nature of the voltage coming from the semiconductor converter.

Instantaneous value of induced voltage and current in stator winding of permanent magnet synchronous generator shown on fig. 3.

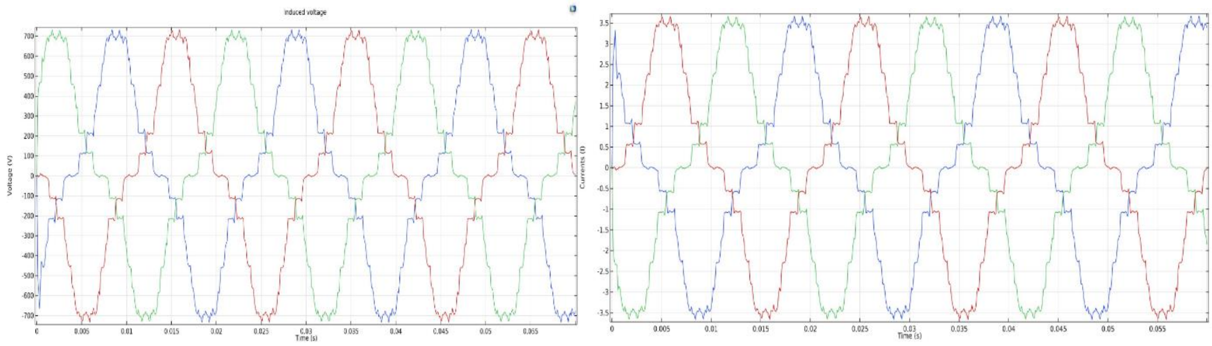

Figure 3 – Induced parameters in stator winding of permanent magnet synchronous generator

Permanent magnet synchronous generators have some advantages comparison to the traditional synchronous generator construction.

Conclusions. The main advantages, as the obtain results show, of using permanent magnet synchronous generators are:

1. Absence of sliding contact (loss on contact, limited resource, can work in an aggressive environment (no oxidation)), increased reliability in humid tropics.

2. There is no traditional excitation system. The main field of excitation is created by permanent magnets. Stabilization of the mode can be provided by control capacitor systems, the specific cost of which is currently several times less than the specific cost of the machine.

3. Due to the absence of the need for the initial excitation current (no-load EMF is provided by the action of permanent magnets), the efficiency of the generator can be increased by 5-3%, depending on the power of the machine. The greatest gain is achieved in generators for individual or small group use with a capacity of up to 100 kW.

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