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Investigation of the Rotor Core and Poles Double-Rotor Hydro Generator for Micro Hydro Power Plants

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Abstract

This paper explores the rotor core and pole double-rotor hydro generator for micro hydropower plants. To assemble the rotor core double-rotor hydro generator used forged multifaceted steel sheets thickness of 1-2 mm without insulation coating, where the number of faces of the core will match to the number of poles double-rotor hydro generator. Investigated the creation of EMF double-rotor hydro generator in one conductor. When calculating, EMF double-rotor hydro generator. Guides phase-shifted by the same angle α, and describe a circle. The induced EMF in them is equal in value but opposite in direction. Therefore, the EMF coiled twice EMF one conductor. Hydro generator designed with different number of poles, sometimes quite large. We studied double-rotor hydro pole is clearly synchronous generator with two poles. All along the bore north and south poles of the stator pole 2p double-rotor hydro generator has a p-wave magnetic field. Therefore, we can distinguish two pole divisions as one period of the magnetic field and treat them as some elementary machine –one period. Circle real model double-rotor hydro generator attributed the electrical angle of 360 (electrical degrees) or 2π.Each geometric degrees double-rotor hydro generator corresponds to p electrical degrees elementary machine. For double-rotor hydro generator which is a low-power not exceeding 1,000 V and a capacity of less than 100 kW is used in designing a single-layer winding, which is to operate in a safe and cost-effective

Keywords: rotor core, double-rotor hydro generator, permanent magnets, micro hydro power plant

1. Introduction

Axial flow machine with permanent magnets is an alternative to radial flow for the production of electricity from wind and water. High torque operates at low wind speeds, (PMS) 1.. In accordance with the resulting characteristics provide a good efficiency and reliability. Machine dimensions and weight can be reduced. Development of optimal design of the device should produce the maximum ratio of torque to weight ratio and the efficiency of the device 2.. For variable speed wind double-rotor Modifications synchronous generators using Nd-Fe-B, take great interests 5.. Rare earth elements such as Nd-Fe-B, manufactured permanent magnet generators of any size and shape of 6. and 7.. Magnetic load on the rotor disk is significantly higher 8.. The main components of the design with AFPM machine is crystal torque ripple and 9., 10. and 11.. Wave of torque created by change in the distribution field and armature magnet motive force, while the interaction between the stator slots and PMS produces cogging torque when the rotor rides along the electrode gap. Ripple can lead to undesirable changes in the rate, vibration and acoustic noise 12.. In order to reduce the cogging torque ripple to PMSGs used a number of methods 13. and 14.. Transient solution can be found, for determining the EMF flow of torque energy15., 16. and 17..

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2. Methods

Model of the proposed micro-hydro power plant. Us essentially new design of micro hydroelectric power station with double-rotor the hydro generator is offered. The principle of work of micro hydroelectric power station with double-rotor the hydro generator essentially does not differ from micro hydroelectric power station, only in one hydraulic stream two driving wheels which are located vertically on work one axis one after another and rotating, thus every which way rather to each other fig. 3.

Installation as follows works. Installation consists of two independent vertical driving wheels 10 and 11, located one over another. Each driving wheel has the shaft of rotation 3 and 4. On external a floor to a shaft 4 with the help radials - the basic bearing 5 the tank - a float 2 fastens. It is not placed double-rotor the generator 1. In the middle of a hollow external shaft 4 it is established radials - the basic bearing 6 on which internal ring takes place an internal integral shaft 3 bottom driving wheels. Each driving wheel consists from: the top and bottom rim 7, blades 9 and before a wing 8. Two turbines are divided among themselves by a dividing plane 12 and protected by a metal grid 13. At installation immersing on water installation work is carried out as follows: the water stream arrives on turbines and they start to rotate every which way at the expense of various installations of blades and before a wing. The bottom driving wheel it is connected to a rotor of the generator by means of an internal shaft and rotates clockwise. The top driving wheel it is connected with stator the generator by means of an external shaft and rotates counter-clockwise. Thus rotation of a rotor and stator is carried out rather each other in the opposite sides that provides increase in frequency of crossing with a magnetic field of an electric winding of the hydro generator.

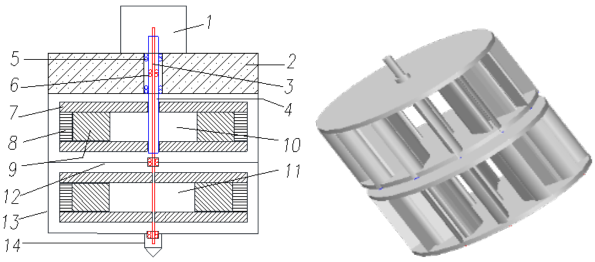

Fig. 1. The Circuit diagrammed double-rotor micro hydroelectric power station and model double-rotor turbines

Such technical decision allows to avoid presence of the animator for increase in frequency of rotation of a rotor as in the classical generator. Moreover there is a possibility to simplify a design such double-rotor the hydro generator and to lower it mass dimensions the sizes.

Works installation follows. Initially, a single stream of water on the pressure pipe supplied to the supply chute turbine chamber 1. The flow around the turbine chamber around the perimeter, is directed at a certain angle on the blades of the first turbine wheel 2 and rotate it to one side. After the turbine impeller 2 more hydraulic flow at a predetermined angle is directed to the blades of the second turbine wheel 3 which rotates in the opposite direction by reversing the structure of the blade of the turbine impeller 3. Moreover, the turbine 2 and 3 are arranged in succession in a single feed pipe. The turbine 2 and the turbine 3 are connected respectively to the rotor and the stator of the generator via a shaft, wherein the shaft is located inside a turbine shaft another turbine. Thus, the turbine converts the hydraulic energy of water flow into rotational energy of shaft generator (rotor) 4 and 5 (the stator). Wherein rotation of the rotor and stator is carried out with respect to each other in opposite that provides an increase in the frequency of the magnetic field crossing winding electricity hydro generator. After passing through the turbine exhaust stream flows through the suction tube 6.

Double-rotor hydro has a comb-like structure of the pole pieces with concentric air gap, where the total length of the packet with wide pole pieces $l'_{\omega\Sigma}$ is defined by the ratio of the received

$$l'_{\omega\sum} = l_n(l_{\omega\Sigma} / l_n) \quad (1)$$

In synchronous machines with an eccentric carried by an air gap beneath the pole pieces, the pole is manufactured from sheet steel with a thickness of 1-2 mm, without the insulating cover and attach to the core (rotor core) with the projections T-shaped or dovetail. Known recommendation also applies to double-rotor hydraulic generator, and to build hydro-generator rotor core double-rotor use embossed multi-faceted steel sheets thickness of 1-2 mm without insulation coating, where the number of faces of the core will correspond to the number of poles double-rotor hydro generator.

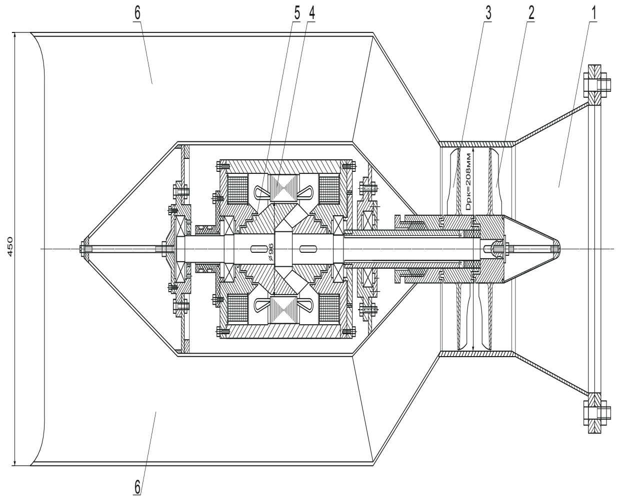

Fig. 2. Diagram of micro hydropower plants with rotary hydro generator
1. Turbine, 2. First runner; 3. The second impeller;
4. The double-rotor hydraulic generator ; 5. Double-rotor stator; 6. The suction tube

Fig.3. Micro hydropower plants chamber

Length laminated core pole accept as (mm):

$$l_n = l_1 + (10 \div 15) \quad (2)$$

In double-rotor hydro generator value of h is less than 280 mm, therefore the length of the rotor core axis assumed to be the length of the core pole, $l_2 = l_n$,

The width of the arc of the pole tip (mm)

$$b_{\text{H}.n} = \alpha\tau \quad (3)$$

Radius outlines eccentric pole piece at the air gap (mm)

$$R_{H.n} = D_1 / \left[2 + 8D_1(\delta'' - \delta') / b^2_{H.n}\right] \quad (4)$$

The width of the pole tip (mm) defined by the chord

$$b'_{H.n} = 2R_{H.n}\sin\left[0{,}5b_{H.n} / (R_{H.n})\right] \quad (5)$$

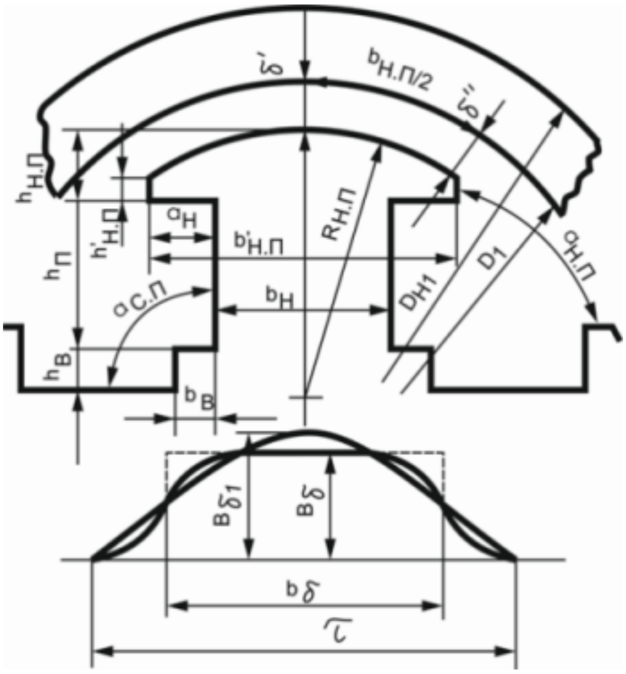

Fig. 4. Pole with eccentric air gap

The height of the pole piece along the axis of the pole for machines with eccentric gap (Figure 1) (mm) 18,19,20..

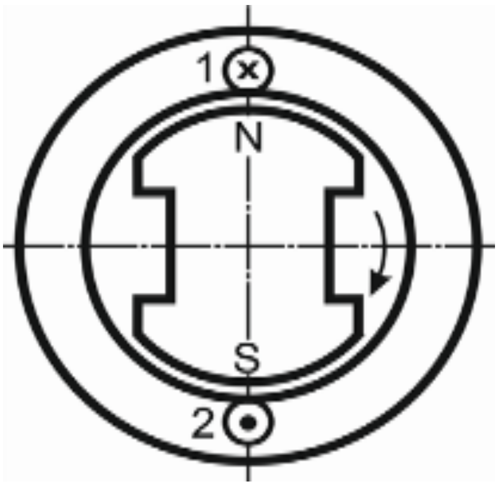

Fig. 5. Two hydro pole

$$h_{H.n} = h'_{H.n} + R_{H.n} - \sqrt{R^2_{H.n} - (0{,}5b'_{H.n})^2}. \quad (6)$$

In determining $h_{H.n}$ for double-rotor hydro generator with a comb structure of the pole pieces in place, $b'_{H.n}$ should be substituted b'_{ω}. The study shows that the height of the pole piece at the edges can be selected within $h'_{\text{H}.n}$ =2÷20 mm for structural reasons, but it should be borne in mind that with increasing $h_{H.n}$ increased scattering poles and transient inductive reactance x'_d and this can lead to deterioration of dynamic stability.

Hydro-designed with different number of poles, sometimes quite large. We studied double-rotor hydro pole is clearly synchronous generator with two poles. All along the bore north and south poles of the stator pole 2p double-rotor hydro generator has a p-wave magnetic field.

Therefore, we can distinguish two pole divisions as one period of the magnetic field and treat them as some elementary machine – one period. Circle real model double-rotor hydro generator attributed the electrical angle of 360 (electrical degrees) or 2π. Each geometric degrees double-rotor hydro generator corresponds to p electrical degrees elementary machine. Therefore, in future studies, we consider the circumference angles hydro as bipolar synchronous machine (generator) (Figure EMF induced in the conductor in one double-rotor hydro generator. We investigate the conductors create EMF BG. Consider the inner surface of the stator of hydraulic generator in the unfolded state (Figure 3).

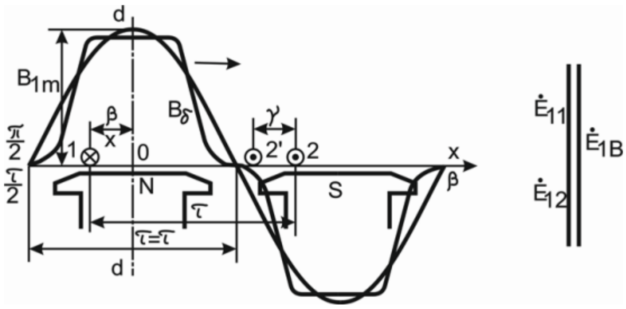

Fig. 6. A wave of induction and generation of emf in a conductor and coil

Magnetic induction Bδ distributed along the surface of the pole and moves with the poles (Figure 3 as well.) The curve of the induction period is 2 τ (τ - pole pitch of the stator bore). This wave is moving relative to the stationary conductor with a constant velocity v and it induces EMF e = Bδlv; value at any time is proportional induction Bδ near the stator bore as lv = const. Here I - the length of the stator core. Therefore, the variation of EMF of in time e (t) follows the law of variation of induction along the stator bore Bδ and EMF of curve e (t) contains the same time harmonic, which are available in a space curve Bδ (x)18,19, 20..

Figure 3 shows the decomposition of the magnetic induction curve Bδ (x) for the first cosine amplitude B1m. Obviously, the pole pitch of the first harmonic coincides with the actual pole pitch:

$$\tau = \pi D/2p \quad (7)$$

Conductors 1 and 2, double-rotor hydro generator located on the same diameter, shifted pole pitch (Figure 4). The induced EMF of in them are equal in value but opposite in direction. Therefore, EMF of coil $e_{в}$twice a conductor EMF of $e_{пр}$

This is true for both the Instant $e_{в}$= $e_{пр}$, and for operating $E_{1в} = 2E_{1пр} = \pi\sqrt{2f\Phi_1}$EMF values.

Also, Figure 4b shows a vector diagram of the EMF induced in the coil with a diametrical pitch. As seen in the chart that E_11 = - E _12 and should:

$$E_{1в} = E_{11} - E_{12} = E_{11} - (-E_{11}) = 2E_{11} \quad (8)$$

If there are a number of coil turns ω_k, its EMF of

$$E_{1к} = \omega_к E_{1в} = \pi\sqrt{2f\omega_к\Phi_1} = 4{,}44f\omega_к\Phi_1 \quad (9)$$

EMF of distributed winding.

To make better use of volume double-rotor hydro generator windings can be made from multiple coils.

For example in Figure 4, a generator is shown with three coils with a diametrical pitch. In each of the first harmonic coils induces EMF of $E_{\kappa 1} = \pi\sqrt{2f\omega_k \Phi_1}$

These EMF of phase shifted by the same angle α, which is shifted on the plane of the coils. EMF of coil group composed of geometrically in Figure 4b. Since these values are equal to EMF of and they are shifted in phase by the same angle α, then the EMF of around the polygon ABCD can be circumscribed 20.

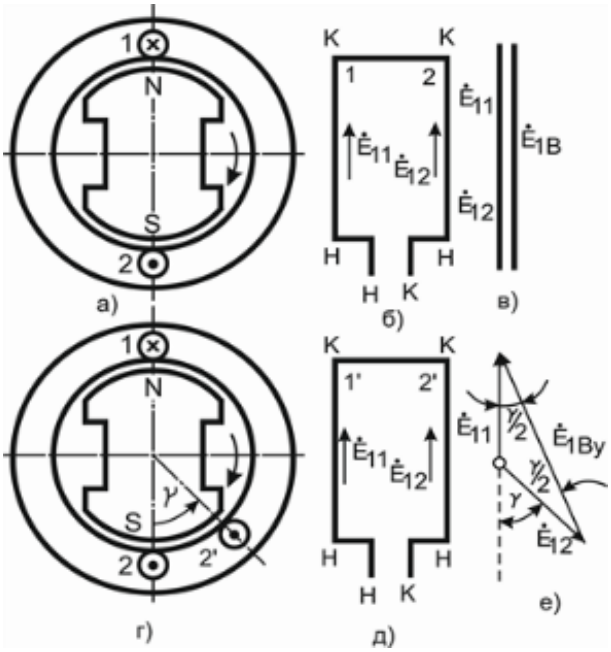

Fig. 7. EMF of coil-flow and a shorter step

AOS central angle subtended by any of the EMF of vector is equal to α. (∠ ABC = π-α. Therefore, the arcs ~ CDA = 2π-2α, and ABC ~ = 2α, ∠ AOC = 2α. Since AB = BC, ∠ AOB = 0, ∠ AOC = 2α).

Assume that one group has q coils. EMF of group denoted E_rp1.

Figure 4, b that:

$$E_{\kappa 1} = 2R\sin\left(\frac{\alpha}{2}\right);$$

$$E_{rp1} = 2R\sin\left(\frac{q\alpha}{2}\right).$$

Therefore

$$E_{\kappa 1} : E_{rp1} = \frac{\sin q\alpha}{2} : \frac{\sin\alpha}{2} \quad (10)$$

We introduce the distribution coefficient for the first harmonic EMF of k_p1 and write in standard form:

$$E_{rp1} = qE_{\kappa 1}k_{p1} \quad (11)$$

Comparing equations 9 and 10, we find

$$k_{p1} = \frac{\sin\left(\frac{q\alpha}{2}\right)}{q\sin\left(\frac{\alpha}{2}\right)} \quad (12)$$

Figure 4, b is visible geometric meaning of the distribution coefficient:

$$k_{p1} \frac{\overline{AD}}{\overline{AB}+\overline{BC}+\overline{CD}}. \quad (13)$$

The distribution coefficient is the ratio of the sum of the closing chord chords, inscribed in the circle group of coils. For the higher harmonics of order v angles α v increases in time and the distribution coefficient:

$$k_{pv} = \frac{\sin\left(\frac{qv\alpha}{2}\right)}{q\sin\left(\frac{v\alpha}{2}\right)}. \quad (14)$$

In this case, to choose the right number of coils in the group of q and the angle α, can significantly reduce some of the higher harmonics of EMF.

If the winding occupies slots double-rotor hydraulic generator, then q is the number of slots per one phase at one pole, or more briefly the number of slots per pole and phase:

$$q = \frac{Z}{2pm}. \quad (15)$$

where Z - the number of slots, m - the number of phases.

Claw harmonic EMF of Bevel slots.

In connection with the gear structure of the rotor magnetic flux density wave B_δ near the surface of the stator bore is not smooth form shown in Figure 2.10, a, a more complex (Figure 2.12 a). In a traveling wave induction failures occur, to maintain its position in front of the stator slots. Therefore, according to the law $e = -\omega_k = \frac{d\Phi}{dt}$ 18, 19..

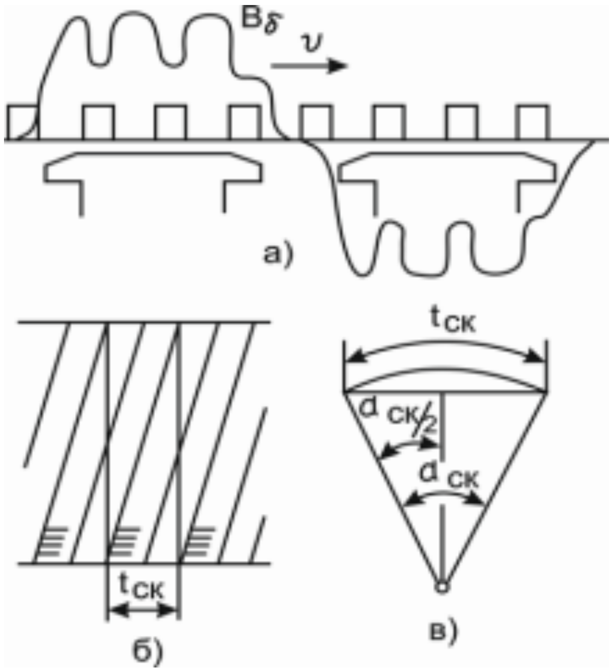

Fig. 8. A wave induction in the toothed surface (a) and slant grooves (b, c)

To reduce claw EMF slots Mow, one tooth division (Figure 5b). At the same time somewhat reduced EMF of rotor and stator, which takes into account the coefficient of the bevel:

$$k_{\text{ск}1} = \frac{2\sin\left(\frac{\alpha_{\text{ск}}}{2}\right)}{\alpha_{\text{ск}}} \quad (16)$$

$$\alpha_{ск} = p2t_{ск}/D. \quad (17)$$

where_t_{ck}- the size of the bevel in units of length.

For v-th harmonic:

$$k_{скv} = \frac{2\sin(v\alpha_{ск})}{v\alpha_{ск}} \quad (18)$$

In this case, the concept of slant grooves has meaning only in relation to the flow of mutual induction, the interaction with the stator and rotor windings birotornogo hydro generator.

The number of turns in the phase winding is defined as follows:

$$\omega_1 = Nn_1pq_1/a_1 \quad (19)$$

Where in N'_{n1} prior to the number of effective conductors of the groove, which is defined as follows:

$$N_1 = \omega_1 a_1 /(pq_1 \quad (20)$$

parallel branches birotornogo hydro generator windings have the same number of turns, and the side coils - located in a magnetic field under the same conditions. At a small valueN_{nI}This caused difficulties with the location of the wires in the slot increases the value a1 allows respectively increase N_{nI} However, the resulting N_{nI}we can round up to the nearest whole number N_{nI} 20..

In this case, a1 = 1, K, it must be equal to the number of winding layers i.e. in a single-layer winding, it is 1, and for use of hydraulic generator birotornogo monolayer winding.

3. Results

The most important characteristic is the synchronous hydro generator rotor speed, which allows you to get the necessary speed standard values. As can be seen from the formula 1, an increase in hydro-generator rotor speed n reduces the number of pole pairs p.

$$p = 60 \cdot f / n \quad (21)$$

To increase the hydro-generator rotor speed must increase flow or pressure hydraulic flow in the supply of the micro hydro generator. However, increasing the hydraulic parameters of micro hydro generator is not always possible and expedient.

In the case of hydro-generator, as seen from (1), requires fewer pairs of poles than the conventional hydroelectric generators because at a certain value of rotor speed can be obtained by hydro-generator stator speed in the opposite direction with the same values (Fig. 4). In this case the rotation of the rotor and stator of hydraulic, as already indicated above, is carried out with respect to each other in the opposite side. This leads to an increase in the frequency of crossing the magnetic field of electric generator windings. This principle of doubling the speed will hydro generator.

Produced analysis and study of electromagnetic calculation hydro generator including a selection of the main dimensions of the stator and rotor hydro generator show that the number of winding turns w_0, the inner diameter of the stator core hydro generator D_ (0) is almost two times less than traditional hydro generator w_1, D_1. These results can be achieved only in the case of the hydroelectric principle, which generally leads to a reduction in the geometric and mass-dimensions hydro generator.

$$w_0 = \frac{N_{п1} \cdot p \cdot q_1}{a_1} = 180 \quad (22)$$

$$D_0 = 6 + 0.69 \cdot D_{H1} = 90.18 \text{ mm} \quad (23)$$

$$w_1 = \frac{N_{п1} \cdot p \cdot q_1}{a_1} = 594 \quad (24)$$

$$D_1 = 6 + 0.69 \cdot D_{H1} = 126.75 \text{ mm}. \quad (25)$$

where- w_0- the number of windings hydro generator; p = 1 - number of pole pairs hydro generator; $N_{п1}$=60, the number of effective-conductors in the slot hydro generator; q_1=3, the number of slots hydro generator; a_1 =1, the number of parallel branches in the stator winding hydro generator; D_0-inner diameter of the stator core hydro generator; D_{H1}= 122 mm -the outer diameter of the stator core hydro generator; w_1 the number of windings of traditional hydro-generator; p = 2, the number of pole pairs of the traditional hydro-generator; $N_{п1}$-99-effective amount of conductors in the groove of traditional hydro-generator; q_1 = 3, the number-hydro generator traditional slots; D_1-inner diameter of the stator core of traditional hydro-generator; D_{H1}= 175mm,-the outer diameter of the stator core of traditional hydro-generator.

Analysis and study of the peculiarities of electromagnetic calculation disk generator in static mode does not allow to evaluate the work make full disk generator. This regard, studies have been conducted dynamic mode disk generator. Studies and calculations were carried out by computer simulation using the program «Ansoft Maxwell». During the simulation studied the characteristics induced EMF in the stator winding disk generator. On Fig.8.shows a fragment of the moment and the magnetic induction field lines at time t = 0.2sec.

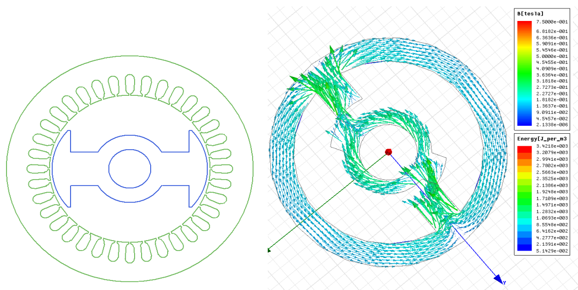

Fig. 9. Unit of magnetic induction and field lines at time t = 0.2sec

The analysis and research of electromagnetic processes based on modeling of hydraulic generator rotor shows that the creation of hydro-generator for micro hydro double-rotor gives a doubling of the speed of hydraulic generator, which can reduce the number of pole pairs, the number of winding turns, as well as to reduce the inner diameter of the stator core. This generally leads to a reduction of geometric and mass dimensions hydro generator, and as a result reduce the cost of micro hydro power plant.

4. Conclusion

Studies have shown that the probability of damage to the insulation is greater in single-layer winding than two-layer, but is treated for electric machines (hydro-generators) at high power. Single-layer windings are widely used in most mass produced electric vehicles up to 100 kW at a voltage of 1000 V. With this tie for birotornogo hydro generator which is a low-power not exceeding 1,000 V and a capacity of less than 100 kW is used in designing a single-layer winding, which is safe to use and economically feasible.

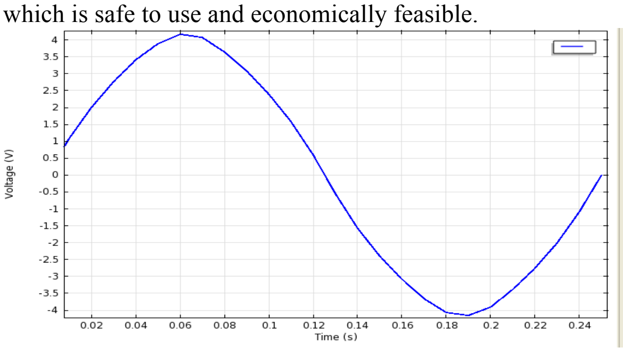

Fig. 10. Voltage waveform disk generator.

Thus, the method of calculation and selection of the parameters used to calculate the main dimensions and electromagnetic processes double-rotor hydro generator.

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