Physical Model of Disk Type Multipolar Switchboard Generator

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Abstract. In the paper the physical model description of disk type multipolar switchboard generator is introduced. Basic principles as to design features in the active zone and rotor disks mutual angular orientation have been determined as demonstrated with the generator model presented.

Key words

Physical model, energy efficiency, multipolar switchboard generator, low-speed generator.

1. Introduction

The design of disk type multipolar switchboard generator [1] developed in Tomsk Polytechnic University makes it possible combined with the electromagnetic type excitation system to lower the machine rotational operation frequency up to a few tens of revolution per minute and use it for direct coupling with the operating turbine shaft (wind or hydro turbine) of electric station.

To verify the main hitherto developed theoretical assumptions as to operation principles and qualitative patterns of changing the generator parameters over a period [2] its physical model was made.

The main objective to be pursued in developing the physical model design consisted in studying the possibly greater versions number of active zone configurations and generator windings electrical connections. Basic geometric relationships of the physical model presented were not optimized and the model didn't seek high values of specific energetic indices.

2. Main part

The photograph of finished physical model of motor-operated multipolar switchboard (low speed) generator is presented in Fig.1. Central stator disk ***1*** and extreme position disks ***2***, ***3*** bear the windings each of which comprises two 300 turns coils. Active zone outer diameter 0.169 m, generator length 0.275 m, pole number 24, rotor ***4*** rotational speed equals 250 rev/min. Textolite was used as basic structural material in making the model active part (rotor disks, central and extreme position stator disks).

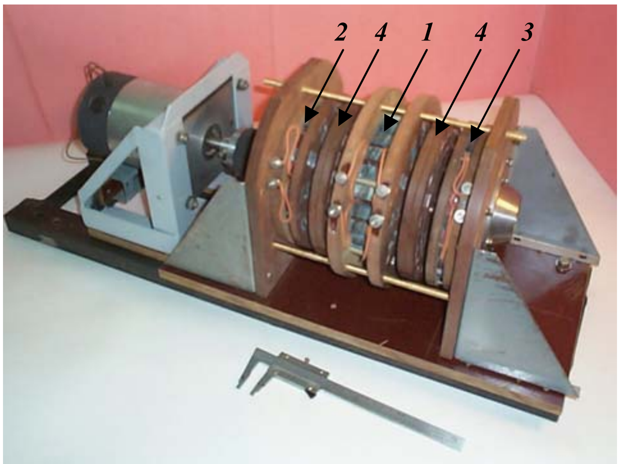


Fig. 1. Generator physical model.

The core was made from electrical sheet steel. The shaft, bearings units and rotor disks hubs were made from structural steel. Stator disks were clamped between each other and about the rotor through *end shields* by brass studs.

As new generator design doesn't conceptually determine the location of excitation system and armature windings (extreme position or central stator disks), then our interest lies in elucidating the optimal version of windings mutual location.

To this end, the experiments carried out are given below. In static conditions when rotor clamped a.c. voltage was supplied in turn to the central winding and the generator extreme position disks winding. The windings serving as an armature were short-circuited. Measuring the current demonstrated that at the equal currents values in the excitation winding (0.5 A) the armature current is about four times higher if the extreme position disks winding serves as an armature, and an excitation one serves as central disk winding. Short-circuit currents relationships in question retained and also in testing the generator in the dynamic conditions (in rotating the excitation part is supplied by d. c. current I_f). The short-circuit curves obtained $I_a = f(I_f)$ are shown in Fig. 2. The curve marked by ***1*** is consistent with the version when central winding was used as excitation one, the curve ***2*** – the version with excitation on the part of the extreme position disks winding. It is evident from comparison that the influence of armature reaction flux on the main flux is considerably less at the excitation on the central winding part (curve ***1***)

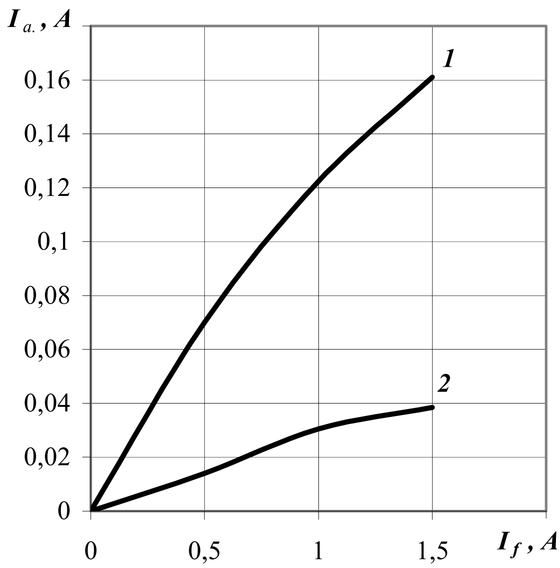


Fig. 2. Generator shot-circuit curves.

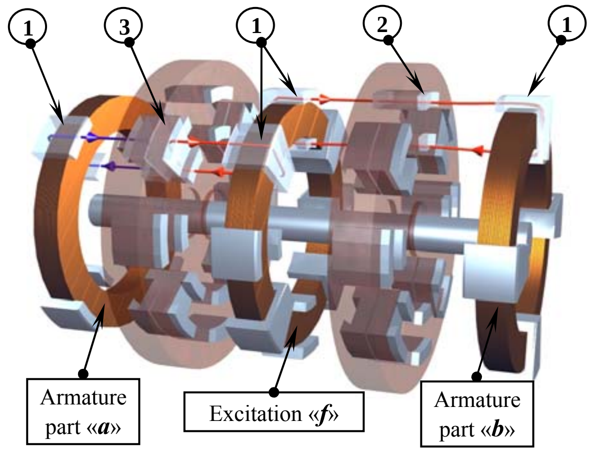
Thus, for further studies the version of mutual windings arrangement in a machine is applicable when central winding is an excitation one and the extreme position disks winding is an armature.

Also, one of the most important features of arranging the generator active zone is mutual angular orientation of rotor disk single-type poles.

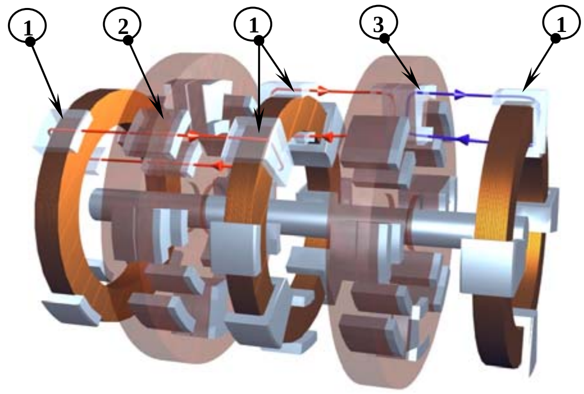
The shift between single-type poles pertaining to different rotor disks influences the generator parameters. For determining this influences a series of experiments without (Fig. 3) and with (Fig. 4) an angular shift into one pole pitch was carried out. The left part of armature winding is denoted by «***a***», the right one of the same winding is denoted by «***b***» and «***f***» marks an excitation winding.

The difference lies in that for the generator in Figs. 3*a* and 3*b* at each extreme angular rotor position (*0* and *180 electrical degrees*) the rotor poles with different conductance **2** and **3** are arranged opposite stator poles **1**. For the generator in Fig. 4*a* at *0 el. deg.* angular rotor position "shunting" magnetic cores **3** of rotor are arranged opposite stator poles **1**, and at *180 el. deg.* angular rotor position (Fig. 4*b*) rotor "through" magnetic cores **2** are arranged opposite stator poles **1**.

The generator parameters values for the extreme angular rotor position were obtained by reference to the experiments results obtained. Taking sinusoidal law as the law of parameters changing the curves of changing the complete and mutual inductances of generator windings were constructed. In Fig. 5 the curves of changing the inductances corresponding to the mutual angular rotor disks arrangement are given. This arrangement was demonstrated in Figs. 3*a* and 3*b*.

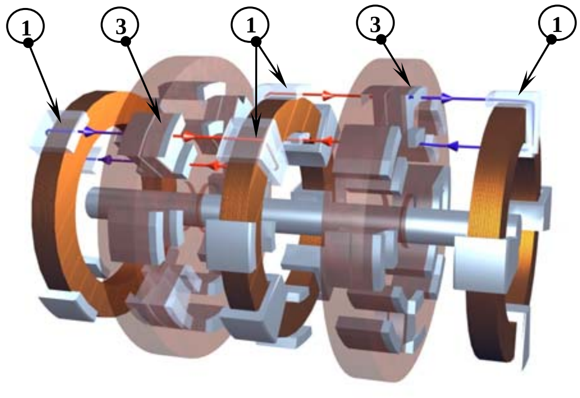


a) γ = *0 el. deg.*

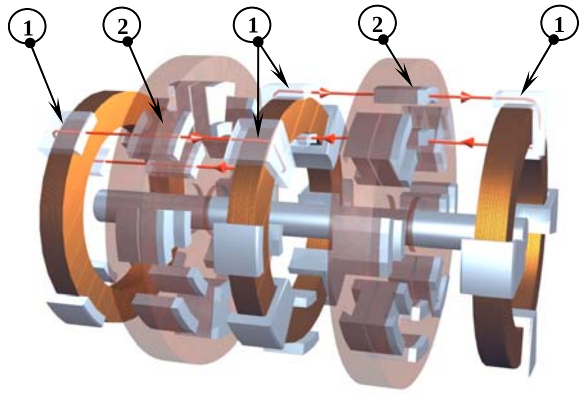


b) γ = *180 el. deg.*

Fig. 3. Rotor disks mutual arrangement ***without*** shift into one pole pitch.



a) γ = 0 *el. deg.*



б) γ = *180 el. deg.*

Fig. 4. Rotor disks mutual arrangement ***with*** shift into one pole pitch.

Here, dash lines demonstrate the dependences of armature winding complete inductances $L_{ab} = f(\gamma)$ and excitation winding $L_f = f(\gamma)$ and also their mutual inductances $M_{abf} = f(\gamma)$ on the rotor turning angle. Solid lines separately demonstrate the dependencies of the coils («*a*» и «*b*») complete inductances forming the armature winding $L_a = f(\gamma)$ and $L_b = f(\gamma)$ and mutual inductances of these coils with excitation winding $M_{af} = f(\gamma)$ и $M_{bf} = f(\gamma)$. Comparison of complete and mutual inductances dependencies of each armature coil shows that the flux commutation by "shunting" rotor cores results in *180 el. degrees* out of phase.

Since armature winding consists of two only electrically connected coils and there is no magnetic coupling between them, the value of armature winding complete inductance equals to common sum of coils inductances $L_{ab} = L_a + L_b$. As electromagnetic processes in the generator right and left parts occur out of phase, the value of armature winding complete inductance L_{ab} at rotor turning remains steady within a period. Excitation winding complete inductance L_f is also constant value (Fig. 5) which is independent on the rotor turning angle as magnetic resistance is constant relative to excitation flux. However, at the equal number of turns in stator winding $W_{ab} = W_a + W_b = W_f$ the value of excitation winding complete inductance L_f is reasonably higher than L_{ab} (Fig. 5) due to less value of leakage fluxes. The dependence of generator windings mutual inductance $M_{abf} = f(\gamma)$ is of an alternating-sign nature relative to the direction of the total *emf* induced in the armature winding coils «*a*» и «*b*».

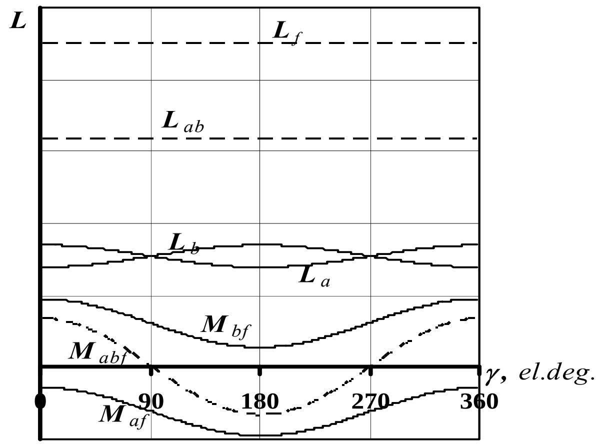


Fig. 5. Curves of changing generator parameters over the period without angular shift between single-type rotor disks poles.

In Fig. 6 the curves demonstrating the qualitative patterns of changing the diagram parameters over the period corresponding to mutual angular rotor disks position are shown. Rotor disks position mentioned is depicted in Fig. 4*a* and 4*b*. Here, also *coils* (L_a, L_b) complete and mutual inductances (M_{af}, M_{bf}) of each generator parts are changing out of phase. However, unlike similar dependences for the previous version of rotor configuration the processes occurring in the right ($M_{bf}, L_b = f(\gamma)$) and left ($M_{af}, L_a = f(\gamma)$) machine parts are in-phase. Thus, the dependencies of complete (L_{ab}, $L_f = f(\gamma)$) and mutual windings inductances $M_{abf} = f(\gamma)$ are of periodic nature and change out of phase to each other.

According to classification assigned for inductor machines [3] applying the first version (Fig. 3) of mutual orientation of rotor disks single-type poles makes the generator to be held for the machines with constant flux, the second version (Fig. 4) for the machines with pulsing flux respectively. Thus, in case of using the rotor with single-type poles shift basic ripple frequency is bound to occur in excitation circuit. This phenomenon contributes to raising the requirements to excitation source and results in enhancing the losses by reversal of magnetization of pole system.

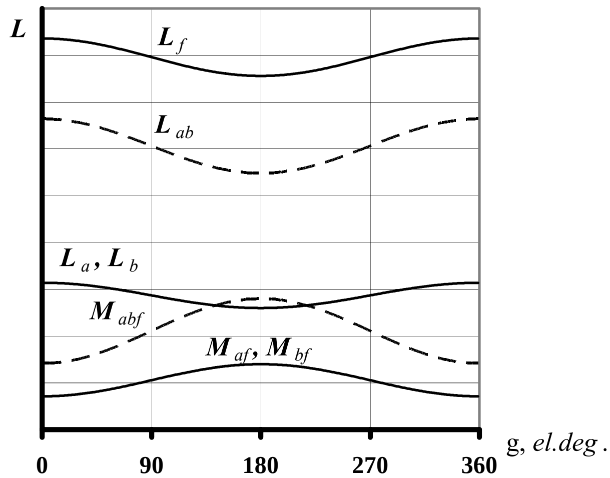


Fig. 6. Curves of changing generator parameters over the period at angular shift between rotor disks single-type poles into one pole pitch.

3. Conclusion

The generator physical model aided tests made it possible to strengthen basic theoretical assumptions previously made as to operation principles and qualitative patterns of changing generator parameters over a period [2].

As basic design principles, the generator excitation system arrangement and also the influence of mutual rotor disks single-type arrangement on the nature of measuring the generator parameters over a period were determined and justified.

Acknowledgement

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