Synthesis And Properties Direct Shaping Of An Additive Subset Of Non-Conventional Combined Independent Brushless Exciting Devices For Synchronous Generators

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Abstract — **Algorithm of the directed formation of properties of structures for additive subset of independent brushless exciting devices for synchronous generators is considered in the paper. The set of exciting device power part elements is synthesized, allowing to apply nonconventional methods of magnetic and electric combination with the purpose of reduction of expenses for active and constructive materials, as well as labor expenditures for manufacture of the power part of the exciting device. The basic electric circuit of the nonconventionally combined brushless exciting device power part was implemented in practice of Russian electromechanical engineering. The scope of use and advantages of brushless nonconventionally combined exciting devices is shown.**

Keywords — synthesis of structures; brushless exciter; magnetic and electric combination; expenses for materials

The article describes the issues with usage of a converted synchronous generator with electromagnetic excitation in order to set up independent brushless excitation systems for vertical-shift synchronous generators with uncontrolled spinning semiconductor converters and small or medium power horizontal-shift generators excited without any external power sources. General permanent magnet synchronous generator is used as a sub-exciter, and both the exciter and the sub-exciter are mounted directly to the shaft of excited generator.

Sometimes the aforementioned design leads to additional difficulties. For instance, the mandatory requested cantilever design of an exciter and a sub-exciter for horizontal-shift hydro-generators or diesel generators could lead to cantilever extension which may cause unexpected problems in development and maintenance of the device. Also the direct connection of permanent magnets to the rotating part of the device does not allow magnetic and electric combination, which could have been used to reduce the cantilever length and to achieve more material-efficient design of an exciting device.

In order to eliminate the flaw by removal of permanent magnets from the rotating part, in this article we present the structure and describe the types of electromechanical converters of the original power section of an exciting device, built with two special subexciters except one permanent magnet sub-exciter. Two subexciters are: one asynchronous subexciter (marked as АПВ on the Fig. 1) and one inductive subexciter (marked as ИПВ on the Fig. 1). The armature windings of the sub-exciters are connected in series.

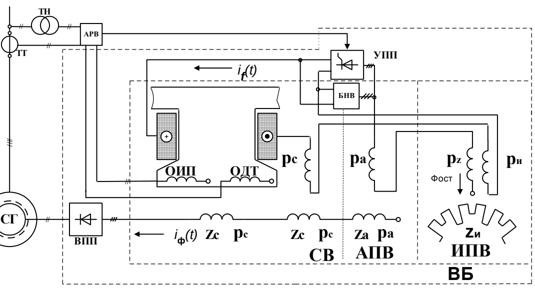

Fig. 1. The structure of the combined multifunctional brushless exciter

Figure 1 shows the structure of the exciting device which consists of the synchronous exciter (marked as СВ) with a number of pole pairs pc separated from two sub-exciters: the asynchronous subexciter (marked as АПВ) with a number of pole pairs pa and the inductive subexciter (marked as ИПВ) with a number of pole pairs pи. The exciting device works in the self-excitation mode. The initial excitation is created by remanent magnetic flux of inductive subexciter poles and could be amplified by enhancing poles with permanent magnets. To start self-excitation, an initial excitation unit (marked as БНВ on the Fig. 1) is activated manually at the generator design-rated rotation speed. The self-excitation process runs until the field-forcing current value in the exciter and the subexciter - if(t) - is achieved. The exciting current of the synchronous generator increases, and also increases the excitation armature current value - iф(t). The power supply of an automatic excitation controller (marked as АРВ on the Fig. 1) is carried out from the synchronous generator and a reserve power source (marked as ОИП on the Fig. 1). The automatic excitation controller activates a controlled rectifier (marked as УПП on the Fig. 1) and disables the initial excitation unit (БНВ) if the specified generator voltage is achieved.

Windings of the developed device can be combined in one magnetic system, but it leads to drastic increase in the number of windings in the device and consequently, to decrease in it's service reliability, which may result in higher costs of construction and maintenance.

In order to try and eliminate this disadvantage we have carried out an analysis of electromagnetic field in the clearance of a generalized synchronous exciter by known methods and an analysis of electromotive forces, induced by components of the resultant field in the pole shoe's winding loop clearance (where x1, x2 are the coordinates of the pole shoe).

The article shows an example of calculations for m = 4, where the m is the number of phases of the exciter armature winding. In the example we assume the m is 4; the number of slots per pole per phase is 1; pitch coefficient of the exciter armature winding is equal to the pole pitch; the numbers of synchronous exciter, asynchronous subexciter and inductive subexciter pole pairs are $p_a / p_c = 3$; $p_c = p_И$ respectively; the number of armature slots is $Zc = ZИ = Za$; and the pitch coefficient of electrically combined sub-exciter armature winding on the pole shoe is 1/3 of exciter pole pitch. If we apply operations of structural, magnetic and electrical combinations to the device with given assumptions, we will have a state named "non-traditional electric and magnetic combination".

After this combination the magnetic system of the exciting device will have only three working windings: the four-phase exciter armature winding on the rotor; the excitation winding of the exciter on the poles; and the sub-exciter armature winding on the pole shoe. This type of exciting device has been called "БиГОС". If we take into account only 1st tooth harmonic of the exciting field of the synchronous exciter and fields created by the armature reaction MMF of the exciter, we will get the EMF value on the armature wiring of the sub-exciter.

In the article this equation is given in a vector notation:

$$\vec{e}_{фтяп} = x_{afd(1z)} \vec{i}_f(t) + (x_{afd(1z)} - x_{(mq\pm1)}) \vec{i}_{Фm1}(t), \quad (1)$$

Here $x_{afd(1z)} \vec{i}_f(t)$ is the EMF of the exciting field of the exciter running idle, modulated by the 1st tooth harmonic of conductivity;

$x_{afd(1z)} \vec{i}_{Фm1}(t)$ is the EMF induced by the 1st harmonic of the armature reaction field of the exciter, modulated by the 1st tooth harmonic of conductivity;

$x_{(mq\pm1)} \vec{i}_{Фm1}(t)$ is the EMF induced by the 1st harmonic of the rotor current and harmonics of the armature reaction field of the exciter of the ν order, where $\nu = mq \pm 1$.

Let us note that exciting device created with parameters to make the subtraction in (1) to be equal to zero $(x_{afd(1z)} - x_{(mq\pm1)}) = 0$ would be the ideal exciting device, because the exciting current of the subexciter would be the exciting current of the exciter at the same time. On the other hand, if the exciting device is created with parameters that make the subtraction $(x_{afd(1z)} - x_{(mq\pm1)})$ in (1) to be more than zero, such device in an uncontrolled mode would self-excite until the magnetic circuit saturation.

The article holds analytical expressions for aforementioned parameters, dimensional ratio of magnetic circuit and parameters of winding suffice for creation of requested exciting device.

The new generation of exciting devices in the "ВБ" series based on the "БиГОС" exciter was created at a factory of the OJSC "Uralelectrotyazhmash".

These exciters successfully replaced "ОГС" exciters with a sub-exciter on permanent magnets. In addition, the weight of "ВБ" type exciters is lower than the weight of "ОГС" exciters.

For example, a non-traditional combined exciter ВБ-59/7-10 is 1.5 times lighter than an ОГС-60/6,5-12 exciter. Also, the average factory expenses for making 1 combined exciter is much lower than the average expenses for creation of two independent devices: an exciter and a subexciter.

The implementing of "ВБ" type exciters allowed the factory to substantially reduce material costs of exciters production and consequently made production of a stationary power plant complex (generator, exciter, control cabinet) 7-11% cheaper. At present hydro-generators with combined "ВБ" exciters successfully work in Russia, Sweden, Italy, Colombia (Fig. 2), and Kazakhstan.

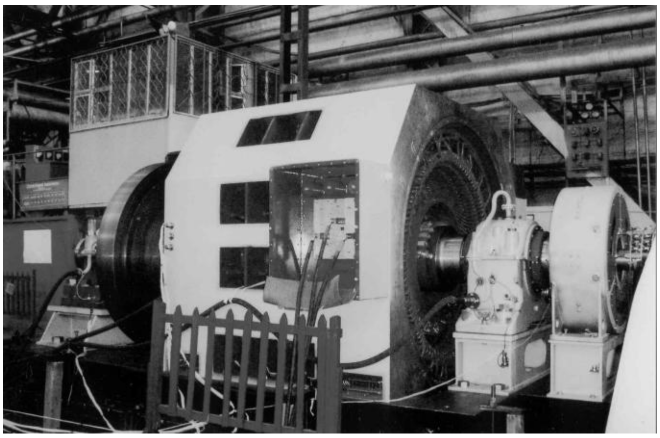

Fig. 2. The hydro-generator СГ-215/106-8Т for Erradura HPP (Colombia)