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Capacitor Activated Self-Excitation System of Synchronous Generator

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Introduction

The project „Wind and Hydrogen Based Autonomous Energy Supply System" within possibility of use of the synchronous generator with independent excitation in autonomous power supply system which is based on wind and hydrogen power is estimated. To use this generator in wind turbine, it is necessary to develop self-excitation system of synchronous generator at which presence there will be no necessity to apply the additional exciter.

For a basis the self-excitation system of synchronous machine [1] with connected to the stator rectifier to which output the excitation winding is connected is chosen.

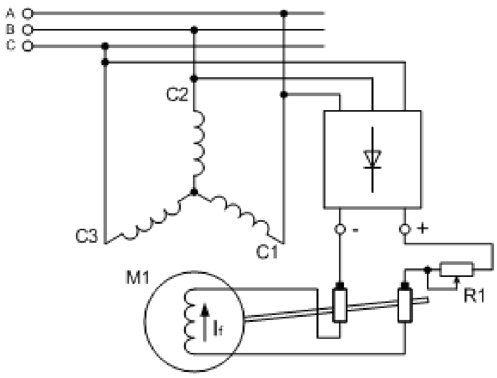

Fig. 1. The self-excitation system of synchronous machine

The main disadvantage of this system is uncertain and, probably, low-level residual magnetism of the generator in the self-excitation beginning that reduces reliability of the system.

In [2] a brushless excitation system of synchronous generator is described. This system consists of a 3-phase stationary field generator which AC output is rectified by a group of rectifiers. The DC output from the rectifiers is connected directly to the field winding of the generator. This system is difficult and unreliable in exploitation because of the built-in exciter.

Similar systems also in [3] and [4] are described.

Functional scheme of the system

The self-excitation system of synchronous generator G1 with independent excitation is realized (Fig. 2.) by connection of an excitation winding Lf to stator phase outputs through three-phase controlled thyristor rectifier.

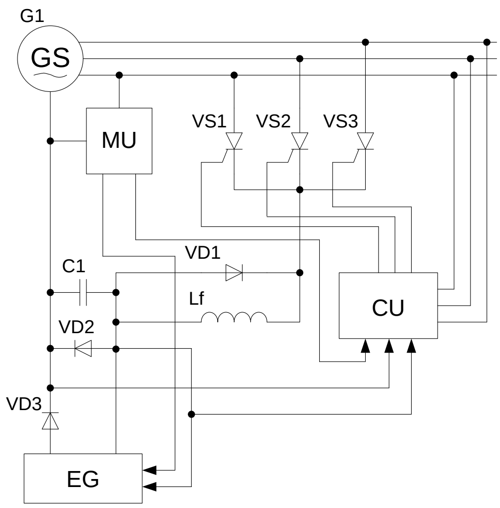

Fig. 2. The self-excitation system of synchronous generator with independent excitation

The excitation winding is connected in a loading chain between the cathodes of coupled thyristors VS1...VS3 and a neutral wire of the generator and is by-passed with reverse to conduction direction of the circuit diode VD1. To put system in action, an initial current impulse an excitation winding is needed. In the given system the impulse moves from capacitor C1 which is charged from low-power electronic generator EG. Capacitor C1 is connected in series with an excitation winding. C1 is by-passed with a conduction direction of the circuit diode VD2. Frequency of the generator voltage is controlled by measuring block MU which is connected between one phase of the generator and a neutral wire. Operation of all system is controlled by control unit CU.

Operation of the system

The system works as follows – at small speed of the generator the induced voltage in a stator winding is low, and it causes residual magnetism in the rotor core. Its frequency is controlled by the measuring unit MU (Fig. 3). Unit work is based on voltage detection on diode VD7. In a half-cycle when voltage on the diode is 0 the output signal of the comparator is equal to logic"0". In the second half-cycle voltage on the diode is more than zero also depends on voltage of a network. In this case the output signal of the comparator is equal to logic "1".

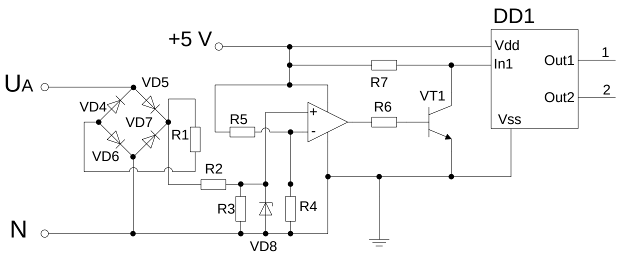

Fig. 3. Frequency measuring unit

Microprocessor DD1 counts up impulses from a comparator output and defines frequency of the generator voltage. When revolution speed of synchronous generator is at proper level then signal is passed to electronic charging generator and capacitor C1 is gradually charged up to necessary voltage.

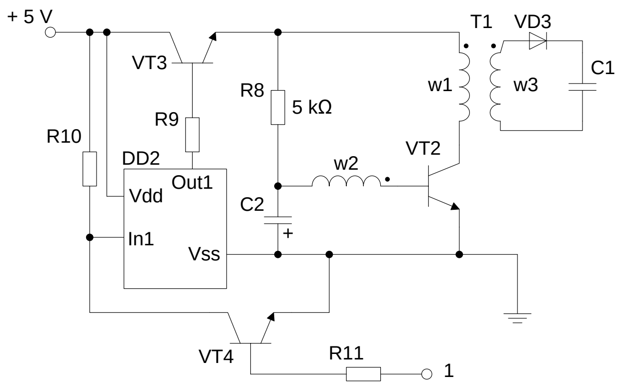

Fig. 4. Electronic generator for capacitor charging

When voltage level is proper high electronic generator is stopped and signal is passed to thyristor control unit which generates firing pulses to all thyristors simultaneously. The closed contour the charged capacitor C1 – a zero wire of the generator – stator phases windings – thyristors VS1...VS3 – an excitation winding Lf – the capacitor C1 is formed. As a result of a capacitor discharge there is an impulse of a current which magnetizes excitation system therefore voltage of the generator increases. In turn, it provides a necessary current which after a capacitor discharge flows in the mentioned contour through diode VD2. When stator voltage reaches the certain level, the control unit passes in a normal operating mode with consecutive generating of signals on thyristors depending on voltage of the generator (Fig. 5.).

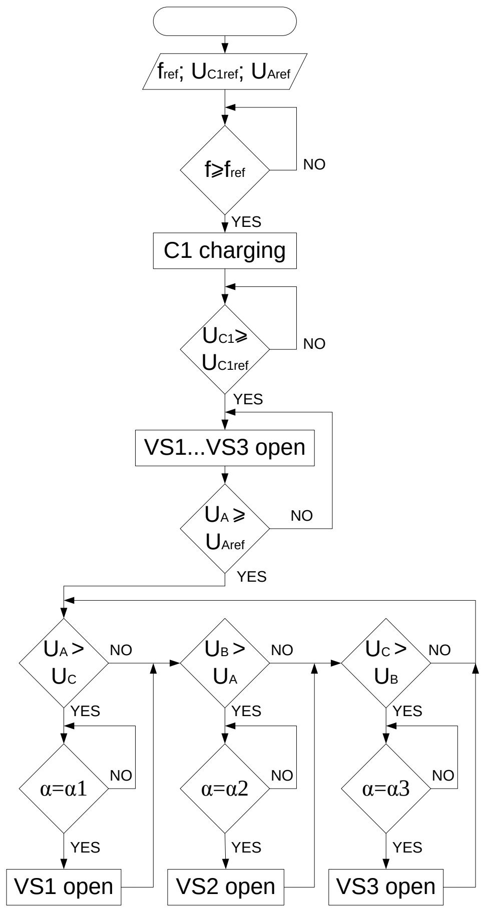

Fig. 5. Simplified thyristors control algorithm

Comparing voltage values on stator phase windings, the control unit generates thyristors opening impulses (Fig. 6.). The thyristor opening degree α value depends on the generator voltage. At increase of voltage α decreases to limit an excitation current.

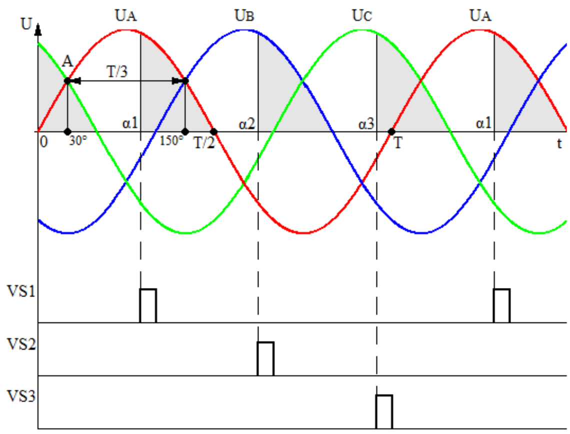

Fig. 6. Thyristors opening impulses

The time delay from a point A to operating impulse VS1 shouldn't exceed 1/3 of period T which is calculated from frequency of the generator voltage that is a degree α1 should be in limits from 30° to 150°. The delays for impulses VS2 and VS3 are similarly defined on the Fig. 6. If speed of a rotor falls below necessary level, work of the operating module stops.

Self-excitation process

Process of self-excitation comprises two stages – at first one previously charged capacitor is discharged through circuit of stator and excitation winding (Fig. 7.) which can be presented as series connection of inductances and resistances of windings and voltage source of dependent on circuits current. At the second stage circuit of capacitor is by-passed with diode and further self-excitation depends on rise of the above mentioned voltage source in circuit connected with rise of current.

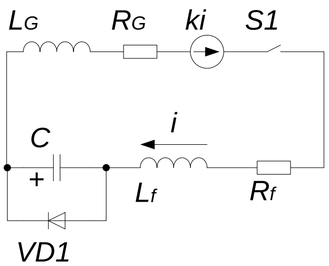

Fig. 7. The self-excitation system equivalent scheme

At the first stage take place oscillating process which is very short and dependent on reactive parameters of the circuit and initial voltage of capacitor U_{co}. Process can be simplified described as

$$\left(L_f + L_G\right)\frac{di}{dt} + \frac{1}{C}\int i\,dt - U_{C0} = 0, \qquad (1)$$

where $L_f + L_G$ is common inductance of the windings in the circuit, C is capacitance of capacitor.

At a discharge of the capacitor the maximal current I_m at end of the process can be calculated as

$$I_m = \frac{U_{C0}}{\sqrt{\dfrac{L_f + L_G}{C}}}. \qquad (2)$$

After a discharge of the condenser the scheme is described by (3)

$$L\frac{di}{dt} + i\left(R - k\right) = 0. \qquad (3)$$

From the (3) it can be stated that process will be developing only if $k > R$, where R is total resistance of the circuit. Indicator k characterizes connection between the equivalent EMF of generator and current in excitation winding and it depends on rotation speed of generator. If speed is higher than k is too higher but if speed is critical low then $k = R$ and excitation can‘t be obtained.

Applied generator has $R = 5\ \Omega$ and indicator k at rated rotation speed 300 rpm is 15. It means that self-excitation can be provided only above rotation speeds about 100 rpm.

Charging voltage of capacitor and $U_{c0} = 50$ V and capacitance - 500 μF. Because total inductance of windings is about 0.14 H the maximum current in the first stage is 2.99 A. As it can be seen from experimental diagram (Fig. 9.) really this value is close to the calculated.

Experimental results

In experiment the simplified scheme (Fig. 8) with uncontrolled rectifier was used.

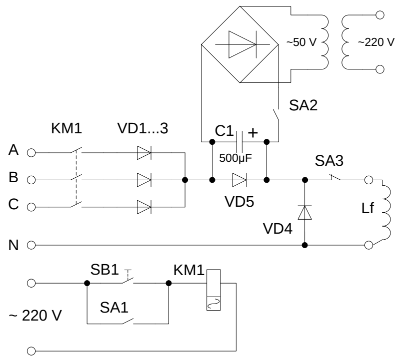

Fig. 8. The self-excitation system simplified scheme

At moment t_0, after the generator reached necessary speed, the self-excitation system is turned on by the button SB1. The capacitor C1 discharges and the excitation current increases (Fig. 9.) in accordance with generator voltage.

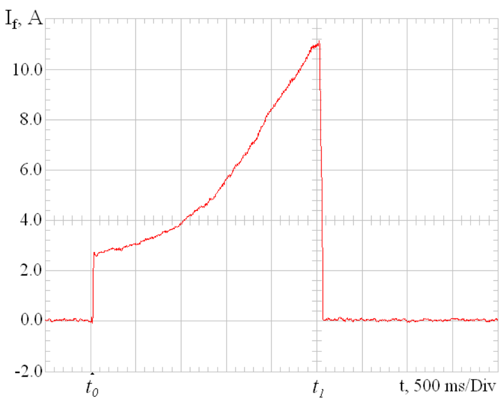

Fig. 9. The excitation current

At moment t_1, when the current reaches a preset value, the system is disconnected by the switch SA3.

Conclusions

The self-excitation system of synchronous generator with independent excitation is realized by connection of an excitation winding to three stator phase outputs through three-phase controlled thyristor rectifier and the neutral wire of the generator.

An initial current impulse moves from capacitor which is charged from low-power electronic generator.

The experimental results show that at a discharge of the capacitor the current impulse magnetizes a generator excitation system therefore voltage of the generator and excitation current increases.

Acknowledgements

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In this paper the self-excitation system of synchronous generator based on capacitor discharge through excitation winding is described. The system comprises three-phase synchronous generator with connected in star scheme stator winding with neutral wire and independent excitation winding. When revolution speed of synchronous generator is at proper level then signal is passed to electronic charging generator and capacitor is gradually charged up to necessary voltage. When voltage level is proper high electronic generator is stopped and signal is passed to thyristor control unit which generates firing pulses to all thyristors simultaneously and capacitor is discharged in oscillating way through excitation winding arising proper excitation current which provides self-excitation of synchronous generator. In the paper operation of system, calculation of processes and results of experimental investigation is described. Ill. 9, bibl. 4 (in English; abstracts in English and Lithuanian).

G. Zaleskis, I. Rankis. Kondensatoriumi aktyvinama sinchroninio generatoriaus susižadinimo sistema // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 7(123). – P. 53–56.

Aprašoma sinchroninio generatoriaus susižadinimo sistema, pagrįsta kondensatoriaus iškrova per sužadinimo grandinę. Sistemą sudaro trifazis sinchroninis generatorius su į žvaigždės schemą įjungtu statoriumi su neutraliu laidu ir nepriklausoma sužadinimo grandine. Kai sinchroninio generatoriaus sukimosi greitis yra reikiamo lygio, signalas siunčiamas į elektroninį krovimosi generatorių ir kondensatorius palaipsniui įkraunamas iki reikiamo lygio. Kai įtampa yra pakankama, elektroninis generatorius sustabdomas ir signalas perduodamas į tiristorinį valdymo bloką, kuris generuoja staigius impulsus visiems tiristoriams iš karto ir kondensatorius yra pulsuojamai iškraunamas per sužadinimo grandinę, kas savo ruožtu sukuria tinkamą žadinimo srovę, dėl kurios sinchroninis generatorius susižadina. Aprašyti sistemos veikimo, procesų skaičiavimo ir eksperimentinio tyrimo rezultatai. Il. 9, bibl. 4 (anglų kalba; santraukos anglų ir lietuvių k.).