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GENERATING SETS USING LIKE DRIVING MOTOR A PNEUMATIC MOTOR WHILE AS POWER SUPPLY A SELF-EXCITED THREE-PHASE SYNCHRONOUS GENERATOR

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***Abstract* – In this paper, the author concentrated his attention on generating sets with the best internal structure. For the beginning, in introduction is presented the use of generating sets like main or emergency electric source. Every generating set has two main components: a driving motor and a three-phase generator. As driving motor, the best results are obtained with a pneumatic motor. The optimal solution, on electric part, in this case is the use of a self-excited three-phase synchronous generator. The author presents especially the advantages of these solutions. Finally are presented the conclusions of the paper.**

Keywords: *generating set, compressor, pneumatic, self-excited, synchronous.*

1. INTRODUCTION

A generating set is made from two components: a driving motor and an electrical generator. Compulsory the electric generator is from alternative current. If is desired as electric energy produced to be of the direct current then alternative current generator is connected with an rectifier bridge (with six diodes).
Always the alternative current generator is from type synchronous (usually three-phase and rarely single-phase). Three-phase asynchronous generators are in experimentally stage, having distinct problems with the drive of stator voltage and the production of reactive power necessary for the magnetization of three-phase stator winding.
Generating set is used for the feeding usually of reserve, of some users of great importance (in civilian and military applications). Generating sets have powers between tens and hundreds KVA. In the next text we'll try to find the optimal solutions for the driving motor and for electrical generator.

2. GENERATING SET WITH PNEUMATIC DRIVING MOTOR

Like driving motor we'll use, in this case, a pneumatic motor, always acted with compressed air.
The pneumatic motor is feeded from a blast-pressure tank (from steel). The receiver is connected at the exit of an air-compressor, fixed on the common shaft of pneumatic motor and a three-phase synchronous generator.

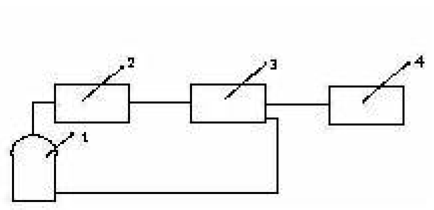

Figure 1: Principled diagram of a generating set with pneumatic driving motor

In Fig. (1) is presented block diagram of a generating set with pneumatic driving motor. It was made the notations:

1- air receiver;

2- pneumatic motor ;

3- air-compressor;

4- three-phase synchronous generator.

In this case we can speak about a mechanical self-excited scheme. For to work is enough to charge once the air receiver. From the air receiver the compressed air arrives in the pneumatic motor. It transforms the mechanical energy of the compressed air in rotations of its shaft. With the help of the air-compressor the volume of compressed air is maintained constant. Thus disappears the necessity of an independent source of compressed air. This is a great advantage of this scheme. For comparison, the scheme with Diesel motor demands all the time of the running feed with diesel oil. As a result running expenses in solution with pneumatic motor are the smallest. The pneumatic motor has the following components: a metallic cylindrical case (current from steel), a rotor shaft, two rolling bearing cases, and a turbine. Metallically cylinder (the case of pneumatic motor) has two orifices: one through which enters the compressed air in the turbine and another by which go out, after its expansion. The turbine transforms the energy of jet of compressed air in mechanical energy for rotation of the shaft. The turbine is composed from a deflecting apparatus and a rotor. The deflecting apparatus is made from a row of fixed guide blades. The deflecting apparatus allows usually the achievement of two functions:

- a correct control of the jet of compressed air to the blades of the rotor;

- an supplementary enlargement of the pressure of the compressed air. The deflecting apparatus can allows, if has and mobile blades and the variation of the compressed air overflow to the rotor and therefore the variation of its the mechanical torque (and implicitly of rotor speed). The rotor has as component elements a variable number of disks (from one upward). Usually the rotor has a single disk. The rotor with a disk is using at high pressures of the compressed air, while that with more for the case in which the pressure of the compressed air is smaller. On the shaft of the turbine there is and a compressor. Its purpose is to produce compressed air which to feed the compressed air tank. Thus is assuring a total independence face of environment as regards assurance generation of the compressed air. The compressor may be axial or centrifugal. The simplest axial flow compressor is made from a rotor with blades, pressing on the shaft and placed in a channel through is moving the air. When the rotor is moving rapidly, the blades, like in a fan, are compressing the air which passes through the channel. In this kind of compressor the air is moving parallel with the shaft. From here is coming and the name of axial flow compressor. The centrifugal compressor is using other principle. After how much is showing graphic and its name, in this case for the compress of air is using the effect of the centrifugal force. Centrifugal air compressor is made from a wheel with blades fixed on its shaft or a disk with blades placed on his flank and a case which surround the rotor. The compressor with this rotor is calling single-sided, towards difference of these double-sided at which the rotor has blades on the both sides (the use of the rotor with bilateral input is explained by the desire to increase air flow on second without to increase the rotor diameter. The centrifugal compressor is used most. The explanation of its running is the following: the air enters by an orifice placed in the case, is assumed from the rotor blades which is turning rapidly and is cranked from the centre to the rotor periphery of the compressor, because of the centrifugal force. The pressure created from the compressor is directly proportional to the speed of the compressor rotor. Usually centrifugal compressor is making with a single stage, this being enough for to multiply through six the pressure.

3. SELF-EXCITED THREE-PHASE SYNCHRONOUS GENERATOR

There are possible two technical solutions for the feed of the field winding of the three-phase synchronous generator. The first, with independent excitation, supposes that field winding is feeded from an independent direct current source (or an ensemble alternative current source-rectifier).

The great disadvantage of the technical solutions with separate field is the presence of an accumulator (at small power). The recharging of the accumulator is making with the help of a rectifier feeded from an external power supply. Self-excited synchronous generators don't depend from any outside power supply.

In Fig. 2 we can see a self-excited three-phase synchronous generator.

Significantly for this excitation system is the fact that thyristors bridge (or diodes) is feeded by the mean of a reducing three-phase voltage transformer, straightly from the terminals of the three-phase synchronous generator.

At low voltages (line voltage of 380V), the reducing transformer can disappear, if the diodes of the rectifier have an adequate maximum reverse voltage. On ensemble, the cost price is decreasing, while reliability increases significant.

For many years this solution was seen with distrust. The principle of the self-excitation of a three-phase synchronous generator is similar to direct current generator.

And for direct current generator and for alternative generator, self-excitation is possible due to remanent magnetic induction of the stator poles, respectively rotor poles.

Technical assumption by which has to exist a running regime in which B (remanent magnetic induction) = 0 must be excluded and therefore the solution of the self-excitation has an emergence probability of 100%.

In Fig. 2 was made the notations: 1- three-phase synchronous generator, 2- field winding, 3- three-phase rectifier, 4- three current transformers connected in star, 5-reducing three-phase voltage transformer, 6- coils.

In the assumption of small claims in respect of changes of the stator voltage and in the absence of voltage regulator this solution appears very interesting, permitting a self regulation of this.

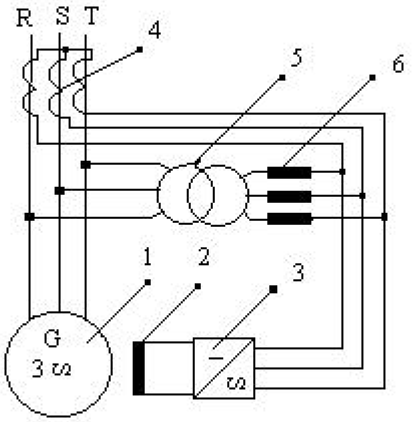

Figure 2: Self-excited three-phase synchronous generator with the vector addition of the input signals in the rectifier

In Fig. 2 is presented a diagram of a self-excited three-phase synchronous generator, where the addition of the voltages from the current transformers and voltage transformer is made in alternative current. As result:

$$\underline{U}_{pt} = k_1\underline{U} + k_2\underline{I} \quad (1)$$

where

$\underline{U}_{pt}$ – the phasor of the input voltage in the rectifier with thyristors (or diodes if there isn't voltage regulator);

$\underline{U}$ – the phasor of the stator voltage;

$\underline{I}$ – the phasor of the stator current;

k_1, k_2 – constants.

If the scheme has stator voltage regulator then the rectifier bridge is made with power thyristors. In this case is necessarily the presence of a stator voltage feedback. The difference between reference stator voltage input and stator voltage feedback drives the regulator.

All Romanian generating sets, are self-excited with addition of the signals proportional with U and I in alternative current. The rotor of these three-phase synchronous generators is driven by a Diesel engine.

In many cases these equipments are used like emergency set in the hypothesis of the falling of the main source of the receiver from the class 0 (from vital importance). So generating sets can be used in military technique, hospitals, theatres, fire engines, etc. There is and an other version of the self-excited synchronous generators. It is presented in Fig. 3. Is observing that the addition of exit signals from the three-phase rectifiers is algebraically.

The expression of the input voltage in winding excitation is given by

$$U_{pt} = k_3U + k_4I \quad (2)$$

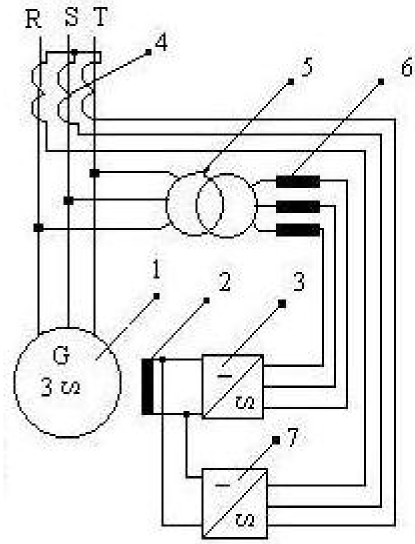

Figure 3: Self-excited three-phase synchronous generator with algebraically addition of the input signals in field winding

In Fig. 3 was made the following notations: 1- three-phase synchronous generator, 2- field winding, 3 and 7- two three-phase power rectifiers, 4- three-phase current transformer, 5- reducing voltage three-phase transformer, 6- coils.

In this version the initial investment is greater, because there are two three-phase power rectifiers. But from the technical point of view this solution is better because in excitation winding enters two signals which are adding algebraically. Practical the solution from Fig. 2 is used by the customers.

4. CONCLUSIONS

Generator sets are elements of distinct importance in civilian and military technique. They are used either as main electrical sources or reserve sources (in this case main source is a power system).

- If we make a classification of the feeding solutions of the vital users can say that optimal option is: from mechanical point that with pneumatic driving motor, while from electric point of view that with self-excited three-phase synchronous generator. On the last place is the solution with Diesel motor with starting electromotor and three-phase synchronous generator with independent excitation, which is using so far and at military central offices RTP/ STAR;

- From the point of the reliability we can say that the solution with self-excited three-phase synchronous generator is a version of the future, for the improvement of the feeding with electrical energy of the vital users ;
- From the point of the efficiency recommended solution, on the mechanical part is that with pneumatic driving motor, while on electric part that with self-excited three-phase synchronous.
- From the point of view of the maintenance the solution with self-excited three-phase synchronous generator and pneumatic motor is the cheapest, since component elements of the system are dense components, easily for tested and of examined from the functional point. The solution with synchronous generator with independent excitation and Diesel motor, used in present at the feeding of many vital users, demands periodical ratings and greater costs of operation (for the accumulators, for the feeding installation with diesel oil of Diesel motor). On the other hand the time repairing in case of depreciation or defect increases at least twice as in the case of the self-excited synchronous generators.
- From the point of view of the control automatics for the feeding systems of the vital users we can say that the level of the intricacy is the same for all the types of studied generators and has a level of the reliability better as electromechanical elements of the generators.
- From the point of view of the conversion costs the solution with pneumatic motor is cheapest, while the most expensive is with Diesel motor.

- Don't exist important improvements in rectifier and control board, in comparison with the types available today. Yet we can mention for the three-phase rectifiers with diodes the appearance of a version denser formed from a single block. The scheme of rectification in the bridge with 6 diodes is keeping (three diodes with common cathode and three diodes with common anode). These six diodes are disposed in a single block, having a single radiator for the cooling. In this mode is reducing appreciably their sizes and the weight. Technical parameters (from among the most important is the form factor) of this block three-phase rectifier with six diodes is the same. Due this modular structure (having three terminals from the connection with power supply and two at the exit in direct current) of the three-phase rectifiers we can say that the solution with self-excited synchronous generator has an easy maintenance and eliminate virtually a specialized operating staff .

- Pollution (with gases and sonorously) of environment is evidently smaller in the case of the use of a pneumatic motor in comparison with a Diesel motor.

Operating costs are also smaller like in the case of the generating set with pneumatic motor and self-excited three-phase synchronous generator in comparison with the generating set with Diesel motor and three-phase synchronous generator with independent excitation.

The optimal solution for a generating set is that with pneumatic motor and self-excited three-phase synchronous generator. It eliminates consumption of compressed air (on mechanical part of the generating set) and power input for the feeding of field winding of the synchronous generator. Thus this optimal generating set has both self-excited, on mechanical part (driving motor) and electrical (synchronous generator).

References

[1] D. Drăgan, *Maşini electrice şi sisteme de acţionări automate,* Editura Academiei Militare, 1983 (vol.1), 1985 (vol.2).

[2] A. Câmpeanu, *Introducere în dinamica maşinilor electrice de curent alternativ*, Editura Academiei Române, 1998.

[3] A. Fransua, M. Covrig, M. Morega, N. Vasile, *Conversia electromecanică a energiei,* Editura Tehnică, 1999.

[4] E. H. Mohamed, *Electrical Energy systems,* CRC PRESS, 2000.

[5] D.Drăgan, *Source of Power with Compound Self-excited Synchronous Generators*, *Proc. COMMUNICATIONS 2004*, vol 2, Bucharest, Romania, June 3-5, 2004, pp. 693–698.

[6] D. Drăgan, *Maşina sincronă,* Editura Academiei Tehnice Militare, 2006.

[7] I. Boldea, *The Electric Generators Handbook (Two-Volume Set)*, CRC PRESS, 2006.