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Features of autonomous and parallel operation of an asynchronous generator with a network of endless power in the current stage of EPS development

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Abstract: The article describes the use of asynchronous machines in generator mode to provide power to three-phase consumers, as well as the features of autonomous and parallel operation of an asynchronous generator with an infinite power network. The use of static sources of reactive power allows widespread introduction of an asynchronous generator in the electric power system as a reliable source of active power.

Key words: self-excitation of an asynchronous generator, static source of reactive power, absolute slip value, dynamic stability.

1 Introduction

In recent years, considerable interest has been caused by the use of asynchronous machines (brushless) in generator mode to provide power to three-phase consumers.

As you know, the use of asynchronous generators (AG) is limited by the fact that they are active power generators and consumers (from outside) of reactive power. Consequently, AGs are capable of operating only in systems in which there are sources of reactive power. These can be either a system in which the source of reactive power is a synchronous machine, which also performs the function of a synchronous compensator, or a static source of reactive power [1-6].

AG are used as peak load generators at small hydroelectric power plants operating without maintenance personnel, since they can be operated without frequency and voltage control systems. It is also known to use AG as generators of wind power plants.

2 The mathematical statement of the problem

AGs are distinguished by high reliability and ease of maintenance in operation, they are easily switched on in parallel operation even with relatively large mismatches of angular velocities. The shape of the voltage curve of the AG is closer to sinusoidal than that of synchronous generators (SG) when operating on the same load, it is more resistant to short circuits and overloads [10-12].

The principle of operation of the AG is as follows: When the rotational speed rises above the idle speed (due to the drive unit), the asynchronous machine switches to the generator mode, sequentially covering the mechanical and additional no-load losses, electrical (idle) and main magnetic losses in the stator for due to the mechanical power of the drive motor. The emf and the rotor current change signs. The electromagnetic torque becomes braking. It changes its phase by 180° and the active stator current, determined by the magnitude of the active load of the generator [7-9].

The energy diagram allows you to judge the nature of the distribution of power consumed by the motor from the network. It can be obtained using the diagram below (Fig. 1):

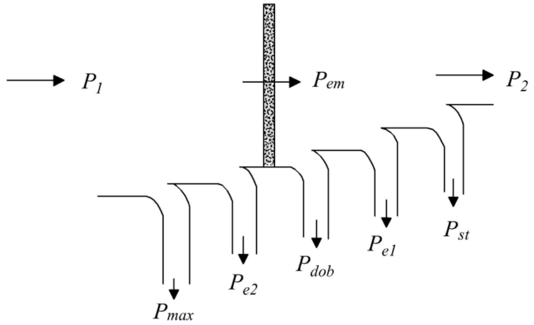

Fig.1. Energy diagram of power conversion of an asynchronous generator

P_1-mechanical power on the shaft; P_{mech}–mechanical losses; P_{e2}-losses in the rotor winding; P_{em} - electromagnetic power; P_{dob}-additional losses; P_{e1}-losses in the stator winding; P_{st}-losses in steel; P_2-generator net power.

It should be noted that the reactive component of the stator current, determined by the values of the magnetizing current and the current compensating for the power of the dissipation fields of the stator and rotor windings in the generator mode, as in the motor mode, will have the same phase (inductive in relation to the mains voltage).

During autonomous operation of the AG, the reactive component of the AG current and the load is compensated by the capacitive current in the capacitor bank. The equivalent circuit of the AG phase, which forms an autonomous network with a load Z_L, is shown in Fig. 2.

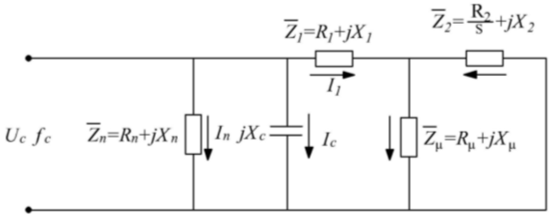

Fig. 2. Equivalent circuit of a self-excited AG

The process of self-excitation of the AG is explained in **Fig. 3.** The residual EMF with AG, due to the magnetization of the rotor Eos, when it disappears, is restored by short-term switching on of the stator winding to the network. For self-excitation of the AG to the required EMF, the capacitance of the capacitor is required.

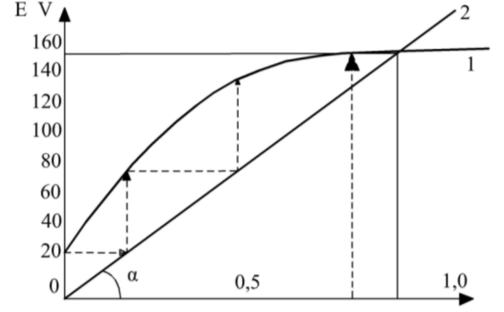

Fig. 3. AG self-excitation process
1 - characteristic of idling of the AG; 2 - dependence of the voltage across the capacitor on the capacitor current.

The required battery capacity C must exceed a certain critical value C_0, which depends on the parameters of an autonomous asynchronous generator: only in this case, the generator self-excites and a three-phase symmetric voltage system is installed on the stator windings. The voltage value ultimately depends on the characteristics of the machine and the capacitance of the capacitors [13-18].

The required reactive power Q of capacitors for exciting induction generators is determined by:

$$Q = 0.314 \cdot U2 \cdot C \cdot 10^{-6},$$

where: C-the capacitance of the capacitors, μF.

With AG load (increase in the absolute value of slip s), the voltage decreases due to an internal voltage drop and a decrease in emf E_1 as a result of a decrease in the network frequency.

The most effective voltage stabilization is with additional regulating capacitors. In this case, the capacitors not only compensate for the reactive current of the AG, but also change the operating point of the magnetic characteristic of the generator, compensating for the internal voltage drop.

Voltage stabilization with increasing s is possible by increasing P_1 and, consequently, f_1.

When the AG operates on a network of comparable power, the constancy of U_C, f_C is ensured by appropriate over excitation of synchronous machines operating on the network and compensating for the reactive component of the AG current and the network load.

The operation of an asynchronous machine in a generator mode on a high-power network (U_C=const, f_C=const) is described by the same equations, an equivalent circuit, as in the motor mode, with the exception of the slip sign ($s<0$). The voltage and frequency of the generator are the same as those in the network. The useful power of the generator depends only on the rotor speed, which is set automatically, respectively, the power of the drive.

The study of the problem of generation and distribution of reactive power in modern electric power systems (EPS) and possible, from a technical and economic point of view, ways to cover the required reactive power of the AG show the following:

In the incoming part of the balance of reactive power in the EPS, one should take into account: the charging power of the transmission line, the available reactive power of the SG, the power of various sources of reactive power and an increase in the voltage class of the transmission line and the distance.

Despite, the wide possibilities for regulating reactive power both in terms of output and consumption, synchronous compensators have a number of disadvantages, which, in particular, include; the presence of rotating parts, inertia, an increase in the short-circuit power, relatively high operating costs, etc. Meanwhile, the operating modes of modern EPS require almost instantaneous voltage regulation in the system.

Static sources of reactive power (SSRP) are devoid of these disadvantages, Their speed is 2-4 periods, they allow you to regulate the voltage in phases, solve a number of problems of a regime nature and, according to experts, are 1.5-2 times cheaper than synchronous compensators of the same capacity [19-23].

The noted trends in the development of power systems show the expediency of the layout of power plants with a mixed composition of SG and AG, which improves the operating conditions of the SG, since the reactive power available by them will be used. As studies show, in this case, the level of static and dynamic stability of the SG, its reliability increases, and the technical and economic indicators of the station and the system as a whole improve.

It may also be possible to reduce the number and capacity of reactors installed at the starting end of the transmission, which requires justification on a case-by-case basis.

The widespread introduction of SSRP will make it possible to create long-distance AC power lines with a station at the starting end, entirely consisting of AGs with their own and evenly distributed along the line. The indisputable advantages of the proposed power transmission are: no problem of dynamic stability in its traditional sense, practically unlimited length, the ability to take off power at any point in the line.

3 Conclusions

Thus, the modes of modern power systems, the observed trend and new technical means for the generation and distribution of reactive power solve the problem of covering the reactive power of the AG and open up prospects for the creation of long-range and ultra-long-range AC power transmissions. Experiments have shown that the introduction of powerful AGs into modern EPS is a reliable and technically feasible way to improve their static and dynamic properties.

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