THE INFLUENCE OF THE HYDROGENERATOR OPERATION MODES ON THE RELIABILITY OF ITS DESIGN ELEMENTS

Podorvanov D.S., bachelor, Geraskin O.A., Ph.D., associate professor
Igor Sikorsky Kyiv Polytechnic Institute, Department of Electromechanics

Introduction. Hydrogenerators (HG) as powerful electric machines are often used to cover peak loads of the Ukraine's energy system network.

HG are extremely important sources of electricity in the world, in particular in Ukraine, as our country has a sufficient number of reservoirs, which are a key factor for the operation of hydropower. Also, the construction of HG is more profitable than, for example, thermal power plants.

The main elements of the HG are: the stator, which consists of the body, core, winding, and the rotor, which is connected to the turbine shaft. Also, the construction of HG includes: core, rim, poles, current leads, support, etc.

The stator winding, the most responsible node of the HG, determines the durability and reliability of operation. There are coil and rod windings of stators. A coil winding has several turns connected in series. The rod winding usually consists of half-sections of rods, representing a half-turn, less often – from whole uncut sections forming a turn.

In terms of strength and reliability of the insulation, the core winding is better because the inter-turn insulation in it is twice as thick as the insulation from the body. The rod winding provides better filling of the groove, facilitates the laying of sections in the grooves, their extraction and replacement during installation and repairs [1].

Often in HG there are such injuries as:

- burnout and deformation of the sheets of the electrical steel pole package due to excess currents in the rods of the damper winding (Fig.1Figure 1);
- burnout of stator winding insulation due to overheating or short circuit;
- thermal damage to the surface of the contact rings.

The aim of the work. To analyze the influence of the operating modes of the HG on the reliability of its design elements.

Materials and research results. In the process of operation of HG, deviations from the nominal operating conditions are inevitable: in terms of voltage, frequency, stator current, power factor, temperature of the cooling agent, etc. In addition, in the operating conditions there are transient and emergency modes of operation of different durations. So that deviations from the nominal operating conditions and possible abnormal modes do not lead to failure and premature wear of the HG, it is necessary not to exceed the permissible limits in operation.

Figure 1 – Changing the pole colors of the capsule hydrogenator
SGK 538/160–70M type [3]

A change stator voltage or current. When the voltage is reduced below 95% of the nominal value, an increase in the stator current above 105% of the nominal value is usually not allowed. This is explained by the fact that in machines with indirect air cooling, the temperature difference in the stator winding insulation is proportional to the square of the current, and an excessive increase in the gradient of this difference can lead to irreversible relative displacements of the body insulation layers of the winding rods and decrease in the service life of the insulation [2].

Frequency change. HG, as a rule, are calculated from the condition of their operation with nominal power for frequency changes within ± 2.5% of nominal. However, when the frequency is reduced relative to the nominal one, it is not allowed to increase the voltage above the nominal one. This is due to the fact that in order to maintain a constant value of the voltage when the frequency decreases, the magnetic flux and rotor current must be increased. If at the same time the voltage is increased, that is, the working magnetic flux in the machine is increased even more, then the core and stator winding will heat up, and the temperature of the rotor winding may exceed the permissible limits.

Power factor change. When cosφ is reduced compared to the nominal mode and the overexcitation mode, it is not possible to maintain the full power, because the rotor current is higher than the nominal one. Exceptions are cases when the excitation winding and exciter have sufficient heating reserves. During the operation of HG with reduced cosφ and underexcitation (capacitive and active-capacitive load), the permissible reactive power is limited by the heating of the extreme packages of the stator core and the conditions of stable operation of the power transmission line.

Change in water and air temperature. Operation of the HG at a temperature of the air entering the machine below +15°C is not recommended, and below +10°C is not allowed, because it threatens to break the insulation of the stator winding. Air coolers should not be overcooled in winter to avoid moisture condensation on them.

Asymmetric mode of operation. The asymmetric mode, characterized by the inequality of the currents in the phases of the stator winding of the generator, is caused by the presence of powerful single-phase loads, for example, single-phase furnaces, electric traction loads, or occurs during a wire break of a power transmission line, during the disconnection or non-disconnection of one phase of a circuit breaker with phase-by-phase control, during operation of the generator through an incomplete phase transformer group and during asymmetrical short-circuits.

In addition, the magnetic field of the reverse sequence creates a torque that can cause excessive mechanical stresses and vibrations in the machine elements.

The experience of HG operation shows that long-term operating modes, even with very limited asymmetry of currents, are dangerous precisely because of the destruction of insufficiently rigidly fixed structural elements of the rotor poles, inter-pole connections, in which material fatigue processes are manifested due to the action of alternating forces. Therefore, timely determination of their own oscillation frequencies, tuning from possible resonances, tight installation of coils on pole cores, and rigid fixing of all inter-pole electrical connections are very important.

Asynchronous mode. Asynchronous HG mode can occur as a result of resetting a large active load while maintaining electrical connection with the system, unsuccessful self-synchronization, loss of excitation, erroneous disconnections of the field extinguishing machine, etc. In asynchronous modes, there are large current and voltage pulsations, which cause increased vibrations of the HG and significant mechanical forces in individual nodes. Transient currents induced in the rotor circuits cause large additional local overheating of the windings, the values of which, especially in the contact area, can be dangerous and cause the machine to fail. Therefore, operation of HG in asynchronous mode is not allowed [2]. In case of falling out of synchronism, the machine should be disconnected from the network in an emergency.

Conclusion. It is shown that during the HG operation, special attention should be paid to the fact that the parameters of its operation modes do not go beyond the permissible nominal values, otherwise this may threaten the overheating of its elements, their increased vibrations, which can lead to the destruction of the structure of the HG.

References

1. Електронний ресурс - Експлуатація генераторів - елементи конструкції гідрогенераторів [https://leg.co.ua/arhiv/generaciya/ekspluataciya-generatorov-2.html. Дата звернення – 06.10.2022].
2. Електронний ресурс - Експлуатація генераторів - режими роботи гідрогенераторів [https://leg.co.ua/arhiv/generaciya/ekspluataciya-generatorov-5.html. Дата звернення – 08.10.2022].
3. Васьковський Ю.М. Вплив ексцентриситету ротора на демпферну обмотку капсульного гідрогенератора потужністю 23 МВА/ Ю.М. Васьковський, О.А. Гераскін // Гідроенергетика України. – 2020. – № 1-2. – С. 59-64.

Режим доступу до статті: https://uhe.gov.ua/sites/default/files/2020-07/15.pdf