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Voltage Fluctuations Synchronous Hydro Autonomous in a Concrete Building

The paper presents a concrete situation appeared at a micro hydro-autonomous central. The central consists of two similar turbines, which train a synchronous self-excited generator, respectively an induction generator operating at constant load. The two generators feed two not interconnected groups of consumers. When the two generators are operating simultaneously, in the synchronous generator appearce a voltage fluctuation with low frequency (0,5÷2 Hz). This fluctuation is shown in a disturbing change in luminous flux of light sources. When the synchronous generator is operating alone, this fluctuation of voltage is not present. In the presented work we analyzed the mentioned situation end, have established the causes of these fluctuations and proposed solutions to eliminate it.

Keywords: *voltage fluctuations, autonomous synchronous generator autoexcitate*

1. Introduction

In an isolated location, electricity was made by two asynchronous generators, autoexcitate using capacitors, a solution that led to large variations in voltage in relation to the load.

To eliminate this major shortcoming, makers have decided to mount on one of a turbine a self-excitetd autonomous synchronous generator (figure 1).

In this figure, HT is hydraulic turbines, SAG is self-excited synchronous generator from which through a rectifier the DC motor CCM, is fed which regulates water flow through the device manager of the turbine, depending on the required electrical power of the generator. On turbine that drives AsAG asynchronous generator, there is a directory apparatus which is adjusted manually, in a certain position, depending on the requirements of the consumer group, powered by it.

The Output of this generator is constant, feeding the auxiliary consumer, when the main consumer does not need the power [1].

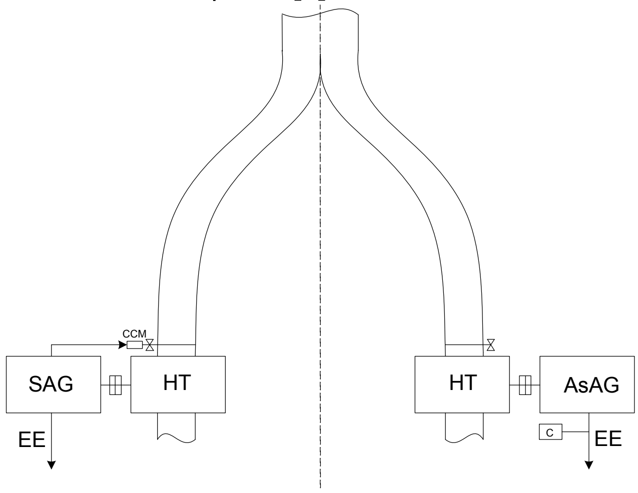

Figure 1. Arrangement of the two turbines and generators.

The asynchronous generator reactive power for magnetization is provided by a battery of capacitors with capacity C. The frequency energy produced by the induction generator varies between 50÷60 Hz.

The autonomous synchronous generator is self-excited through a supply and loop and excitation control with DC resulting from a controlled recovery. The terminal voltages of SAG may vary between 90% and 110% of nominal voltage. The frequency of this voltage is controlled by control loop, which can vary between 47.5 Hz and 52.5 Hz. This variation is provided by director of the turbine unit, which is driven by DC motor, CCM.

2. Research created the theoretical fluctuation

The voltage fluctuation at the synchronous generator terminals may be caused by electrical or mechanical causes. Given the low frequency of these fluctuations and high response speed, the loop control of voltage leads to the conclusion that the voltage fluctuation cannot have electrical reasons.

We analyze the mechanical causes that may lead to such fluctuations.

In theory, synchronous generator has constant speed (constant frequency) if pregnancy does not varies. The presence of fluctuations leads to the conclusion that there is an irregularity in the operation of synchronous generator. If we denote θ the angle of movement variable rotor turbine and synchronous generator, it can be expressed in terms of internal angle θ_0 of synchronous generator, as follows:

$$\theta = \theta_0 + \alpha + \omega_s \cdot t \,, \tag{1}$$

where α is the angle that the rotor axis deviates from its average position and ω_s voltage pulsation synchronous generator considered constant.
Differentiating equation (1) with respect to time, we have:

$$\frac{d^2\theta}{dt^2} = \frac{d^2\alpha}{dt^2} \quad (2)$$

Motion equation of synchronous generator rotor and turbine, becomes:

$$\frac{J}{p} \cdot \frac{d^2\alpha}{dt^2} = M_m + M \ , \quad (3)$$

where: J is the moment of inertia of the rotating parts (rotor and turbine rotor synchronous generator), p is the number of pairs of poles of synchronous generator, M_m is torque mechanically determined by the turbine mechanical torque drive M_{m1} and torque M_0, corresponding loss of mechanical ventilation and synchronous generator M is electromagnetic torque of the synchronous generator.

In general [2], electromagnetic torque M of the synchronous generator has two components:

- Synchronous torque M_{si}, whose expression is:

$$M_{si} = M_{simed} + M_s \cdot \alpha \quad (4)$$

- Asynchronous torque M_{as}, with the expression:

$$M_{as} \cong -k_a \cdot \frac{d\alpha}{dt} \quad (5)$$

In relations (4) and (5) M_{simed} is the average synchronous torque dependent on the mean angle θ_{0med}, M_s torque synchronized and k_a is a constant of the synchronous generator.

The electromagnetic torque M of the synchronous generator is the expression resulting from relations (4) (5):

$$M = -M_{simed} - \alpha \cdot M_s - k_a \cdot \frac{d\alpha}{dt} \quad (6)$$

The minus sign of the two components of the synchronous torque is because under generator the synchronous torque opposite to the movement.

The resulting mechanical torque M_m with the above mentioned components should be constant because the hydraulic turbine, does not, normally present the drive torque variations. In this case, voltage fluctuations may occur due to changes in electric charge of the synchronous generator. These oscillations would be free and would cushion after a while, having no repetitive character. Consequently, voltage fluctuations, which have repetitive character, can not be determined only by variations in drive torque. So the torque drive M_m is not constant, showing an average component M_{mmed} and a variable component ΔM_m. This latter component, whose case we present below, is responsible for the appearance of repetitive voltage fluctuations.

$$M_m = M_{mmed} + \Delta M_m \qquad (7)$$

Entering into (1) components will result equation torque the movement:

$$\frac{J}{p} \cdot \frac{d^2\alpha}{dt^2} + k_a \cdot \frac{d\alpha}{dt} + M_s \cdot \alpha = \Delta M_m \qquad (8)$$

Because the synchronous generator is connected to a network, it can not be synchronized torque ($M_s = 0$)and no damping torque ($k_a = 0$).Frequency synchronous generator voltage is determined by the speed rigid rotor. Motion equation reduces to:

$$\frac{J}{p} \cdot \frac{d^2\alpha}{dt^2} = \Delta M_m = \sum_{\nu=1}^{\infty} M_{\nu\max} \cdot \cos(\nu \cdot \Omega_s \cdot t - \varphi_\nu), \qquad (9)$$

where: $M_{\nu\max}$ is the amplitude of harmonic order ν and Ω_s is the angular velocity .

The solution of equation (9) for harmonic ν is:

$$\alpha_\nu = -\frac{p}{J} \cdot \frac{M_{\nu\max}}{(\nu \cdot \Omega_s)^2} \cos(\nu \cdot \Omega_s \cdot t - \varphi_\nu) \qquad (10)$$

The instantaneous angular velocity results from the derivation relation (10), are:

$$\frac{d\alpha_\nu}{dt} = \frac{p}{J} \cdot \frac{M_{\nu\max}}{\Omega_s} \sin(\nu \cdot \Omega_s \cdot t - \varphi_\nu) \qquad (11)$$

If the torque deviation ΔM_m is repetitive, then the position deviation angle angular velocity varies repetitively. Angular velocity varies between two limits $\Omega_{\min}$ and $\Omega_{\max}$, leading to a degree of irregularity harmonic order ν:

$$\delta_\nu = \frac{2 \cdot M_{\nu\max}}{J \cdot \nu \cdot {\Omega_s}^2} \qquad (12)$$

We believe that this degree of irregularity in the movement of the rotor induced voltage is due to pulsations.

3. Experimental results

We found the occurrence of low frequency voltage fluctuations (0.5 ÷ 2 Hz) when making adjustments to equipment automation autonomous synchronous generator. Because between the two generators there is no electrical connection and voltage control loop having a synchronous generator speed response, large enough, we concluded that the voltage fluctuation can occur through interference of electrical phenomena of the two generators, transmitted through water drive [3].

So, exciting torque variation ΔM_m of the turbine driving the synchronous generator could occur only through repetitive variation of water pressure in the two pipes to each other (Figure 1). Repetitive variation of water pressure could not occur because water flow Q or fall of water H, which were the same for both turbines.

To verify the reasoning I stopped briefly ass-cron generator, closing the valve located on the supply of its turbine. Low-frequency voltage fluctuation disappeared. So, the cause of its variable repetitive components ΔM_m must be sought in the phenomena that occur in asynchronous generator operation at another frequency than the synchronous generator.

We noted with f_1 the frequency voltage produced by the synchronous generator and f_2 the frequency induction generator voltage products. Both generators operate with unbalanced loads, leading to variations in electromagnetic couples, instant, of the two generators. These couples, couples that are resistant for hydraulic turbines, water creates pressure variations in the two turbines.

Because we are interested only in the qualitative aspect of the phenomenon, we consider that the amplitude variation of pressures in the two turbines is the same ΔP. So, the expression of the two pressures, is:

$$\Delta p_1 = \Delta P \sin(\omega_1 \cdot t + \varphi_1) \qquad \Delta p_2 = \Delta P \sin(\omega_2 \cdot t + \varphi_2) \tag{13}$$

Composing the two pressure variations, results:

$$\begin{aligned} \Delta p_1 + \Delta p_2 &= \Delta P[\sin(\omega_1 \cdot t + \varphi_1) + \sin(\omega_2 \cdot t + \varphi_2)] = \\ &= \Delta P \cdot \sin\frac{(\omega_1 + \omega_2)\cdot t + (\varphi_1 + \varphi_2)}{2} \cdot \cos\frac{(\omega_1 - \omega_2)\cdot t + (\varphi_1 - \varphi_2)}{2}, \end{aligned} \tag{14}$$

where: $\omega_1 = 2 \cdot \pi \cdot f_1$, $\omega_2 = 2 \cdot \pi \cdot f_2$ are pulses and φ_1, φ_2 are initial stages for the effects of the two pressures. The qualitative analysis that follows, we consider these phases null.

We note that in the expression obtained by composing pressures, there is a function that depends on the sine pulsation amount and cosine function that depends on the difference pulsations. The pulse close in value, sine function can be approximated by sine function that occurs in the electric voltage induced expression, but that is modulated by the cosine function. The pulsation that occurs in the cosine function is of little value and it causes small frequency variation of water pressure, which is found in the electric voltage fluctuation induced in the synchronous generator windings.

For example, if $f_1 = 56$ Hz and $f_2 = 52$ Hz, results the voltage fluctuation frequency 2 Hz and for $f_1 = 53$ Hz and $f_2 = 52$ Hz, results the voltage fluctuation frequency 0,5 Hz.

As the two frequencies can also take other pairs of values, it is justified the occurrence of the voltage fluctuation with frequencies assessed, without measuring instruments, with frequencies between 0.5 ÷ 2 Hz.

4. Conclusion

From the above it follows that to reduce the voltage fluctuations are necessary the following measures:

- The relation (12) that have increased moment of inertia J the rotating parts. This involves fitting a common turbine wheel axle, respectively synchronous generator;
- Replacement of existing asynchronous generator with a synchronous generator and parallel connection of two synchronous generators;
- Installation of a hydroelectric power plant of a single autonomous synchronous generator of higher power, avoiding interference between two independent generators, even the same type.

The conclusions from this work can lead to explaining various pendulum swings of frequency or voltage in any situation in which two turboagregate are supplied with water from the same main duct.

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