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Online Monitoring of the Air Gap for Large Synchronous Hydrogenerators with the Purpose to Prevent some Operating Troubles

This paper refers to the online monitoring of the air gap for large synchronous hydrogenerators by tracking down in time some significant modifications of the air gap with the purpose to prevent some operating troubles determined by unpermitted variations of the air gap.

Keywords: synchronous *hydrogenerator, air gap monitoring, measurement fixed coil, rotor, stator, electromotive voltage.*

1. Introduction

The air gap can be considered as the heart of the machine because it constitutes the interface between the mechanical forces in the turbine and the electromagnetic forces in the generator.

The energy transfer in the conversion process of the mechanical energy into electric energy takes place by the agency of the air gap.

As this transfer takes place in best conditions a constant air gap is required.

In real conditionS both the rotor and the fixed coil present variations from the ideal round shape, a fact which also determines irregularities of the air gap.

Researches regarding the influence of irregularities in the air gap on the operation of the hydrogenerators has taken place a long time ago, but more imortant results could be obtained in the last period due to some advanced diagnosis procedures, by means of some modern computer acquisition and data processing systems.

It can be proved that in the case of three-phase electric machines with a certain number of poles, the unbalance radial force has two components: a continuous component and an alternative component.

The alternative component varies with the double of the supply frequency in the case of a static eccentricity.

In the case of the existence of a dynamic eccentricity, the unbalanced forces vary with the double of the supply frequency multiplied with the slip.

The eccentricity of the air gap can be divided in two categories:

- the eccentricity of the stator;
- the eccentricity of the rotor;

The alternative force component increases with the increase of the poles number of the generator.

Usually, the high power hydro-generators have a large number of poles which determines a reduced alternative component compared to the continuous component of the respective forces.

The expression of the continuous component of the unbalanced force, for the case when the rotor is parallel to the stator is found by integrating the projection on the horizontal and vertical of the tensor of Maxwellian tensions.

Thus, for the magnetic interaction force we have the relation:

$$f_e = \frac{\mu_0 S_S^2 R_S^3 h \pi}{2 p^2 \Delta R^2} \cdot \frac{\varepsilon}{\sqrt{\left(1-\varepsilon^2\right)^3}} \qquad (1)$$

2. Tests and results of measurements

Tracking down in time some significant changes of the air gap can prevent important variations by a careful checking of the hydrogenerator mounting.

The monitoring installation is composed of the following component parts:

- measuring device of the magnetic flux through the air gap of the machine;
- data acquisition system;
- process computer for the determination of the parametres of the generator.

As sensor of the magnetic flux we have chosen a winding formed of 1-2 spires fixed by one or more elementary paquets in the magnetic core.

Thus, by knowing the afferent scheme of the elementary paquets on which the spires are fixed and the frequency of the supply voltage on the basis of the induced electromotive voltage in the spire, we can determine the value of the corresponding magnetic induction.

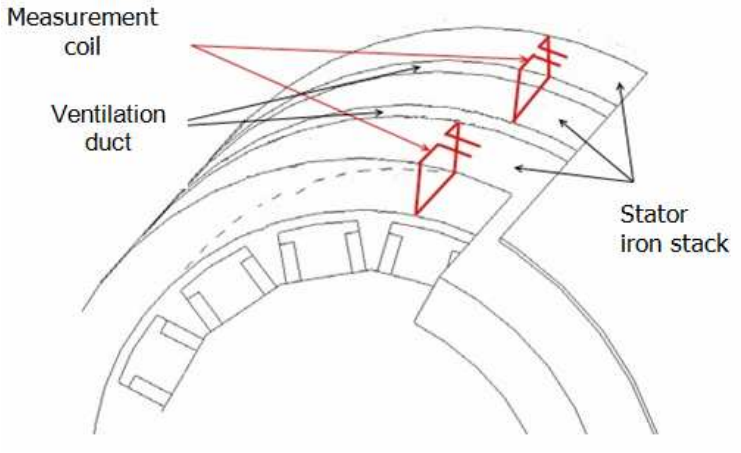

Figure 1. Air gap monitoring equipment

The monitoring of the electromotive voltage is achieved by the agency of two acquisition modules NI SCXI 1313 using the environment of virtual instrumentation, LabView.

Figure 2. The National Instruments acquisition system

On the magnetic core of the generator's fixed coil in CHE Ostrovul Mare a group of six coils on the superior part and a group of six coils on the inferior part. The induced electromotive voltages are measured both in direct current and alternating current.

In direct current regime, we supply the excitation winding of the rotor with current impulses of different dimensions, checking the electromotive voltage induced by the variations of magnetic flux created by the current impulses.

In alternating current, the excitation winding of the rotor is supplied by a source of alternating voltage which will determine an alternating flux through the statoric magnetic core, which will induce a electromotive voltage in the measurement coils. As the flux is dependent on the value of the air gap it results that the induced electromotive voltage will be a function of the air gap.

Checking the electromotive voltage in direct and alternating current is achieved for different positions of the rotor shifted to 90^0 between them, the results being displayed according to the scheme below:

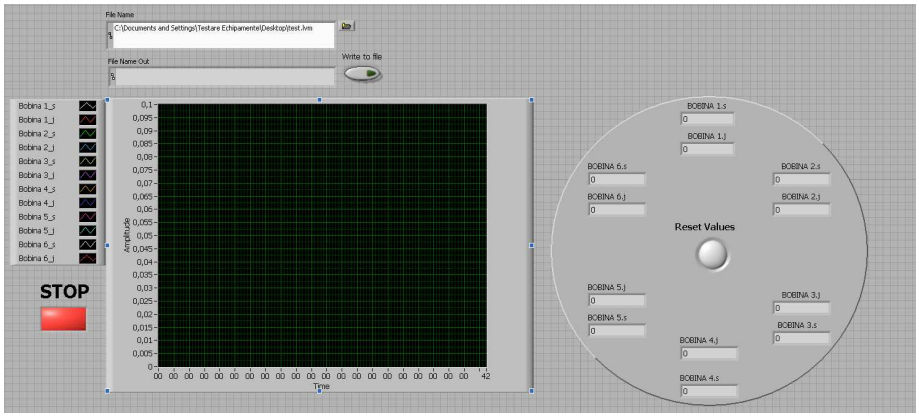

Figure 3. Voltage display panel

The processing of the acquired signals takes place in LabView according to the chart below:

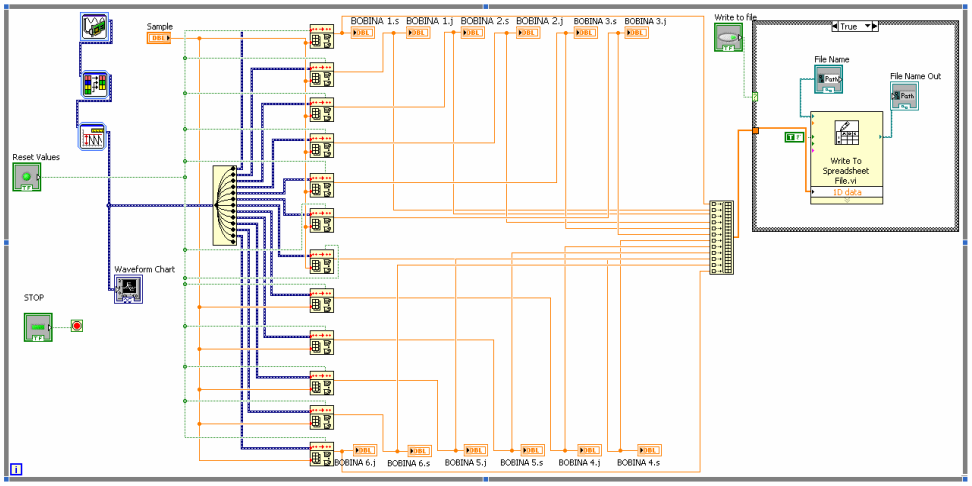

Figure 4. Signals processing block diagram

The interpretation of results having in view the determination of the magnetic axis is accomplished on the basis of the results displayed in the next figure:

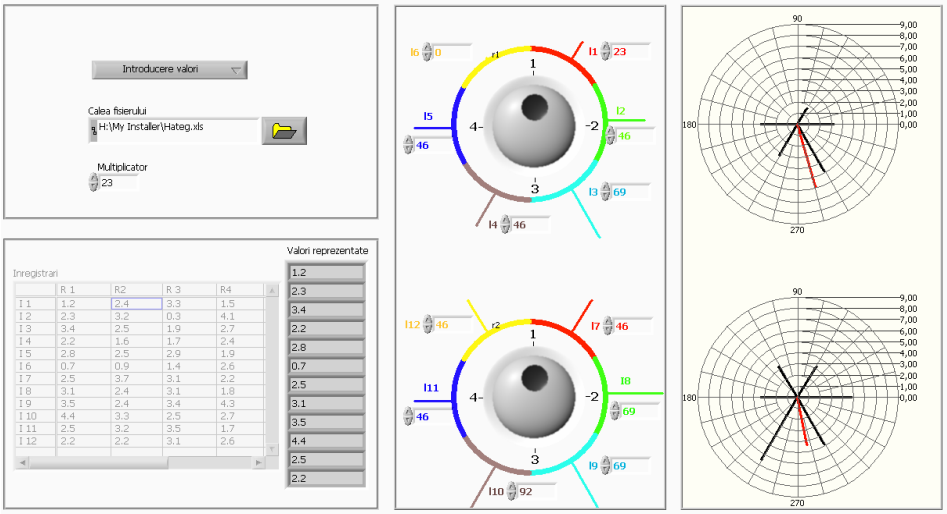

Figure 5. Electromotive voltages diagrams

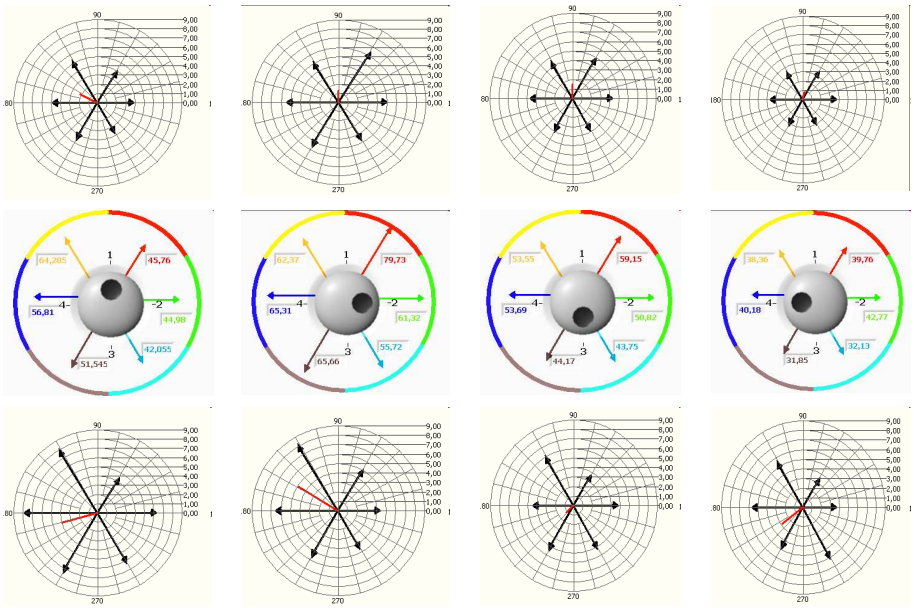

Figure 6. Unbalanced magnetic forces diagrams after the geometric centering

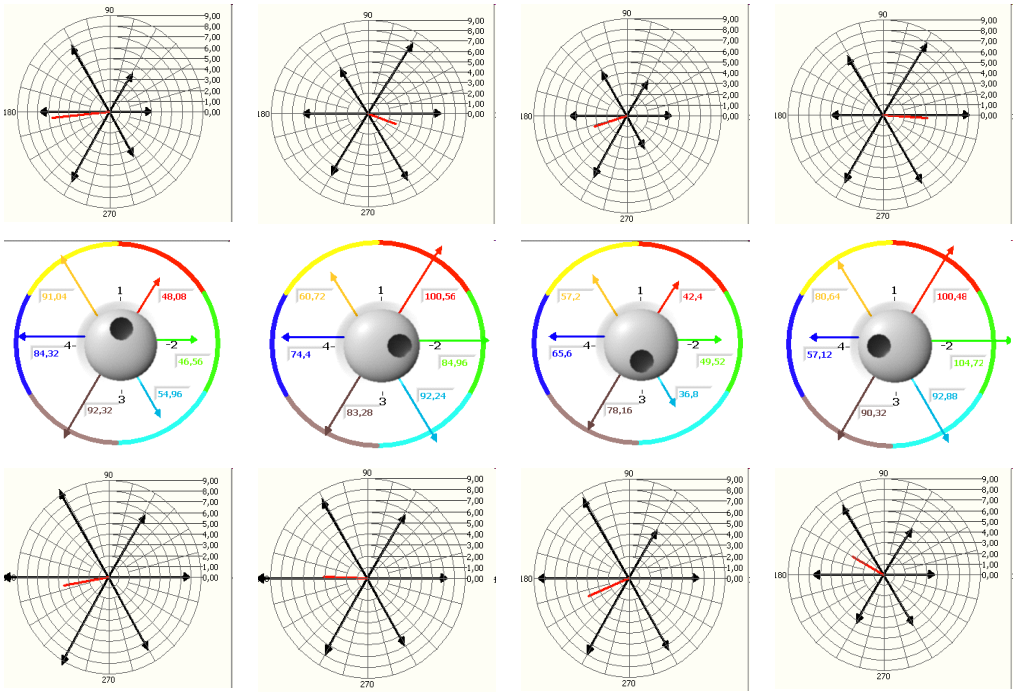

Figure 7. Unbalanced magnetic forces diagrams after the geometric re-centering

3. Conclusions

The irregularities rotor-stator of large synchronous hydrogenerators finally led to irregularities of the air gap. Generally the operation of the hydrogenerator supposes a constant air gap. Changes of the air gap during the operation led to variations of the electromagnetic energy stored in the volume of the air gap which finally determines the appeareance of some supplementary forces in radial direction which can endanger the good operation of the generator. This is the reason why it is necessary an online monitoring of the air gap with the aim of preventing some troubles determined by unpermitted variations of the air gap.

Industrial practice does not generally use some monitoring installations of the air gap which permits the apearance of some important defects whose causes remain in most of the cases unelucidated. In this study we have highlighted the main electric, magnetic and mechanical solicitations which can additionally appear in the case of

some irregularities of the rotor or fixed coil. The researches in this field have proved the fact that these solicitations can greatly influence the operation of the respective hidrogenerator. We consider very often the irregularities rotor-fixed coil only for the geometric centring of the rotor unto the fixed coil, not taking into account that an exact evaluation of these irregularities is not possible for geometric measurements. After the tests of the magnetic axis it was observed that this one was always different as compared to the geometric axis determined by measurements.

We can state that the results obtained by taking into consideration the unbalanced forces on radial direction determined by the irregularities rotor-stator are able to help in a corresponding equilibration of the rotor both from the geometric and magnetic point of view. This is the reason why, we have to take into consideration the results presented in this study and their application in the cases of maintenance works.

The described method was applied in: HG no.1 CHE Cârneşti 2, HG no.1 CHE Orlea, HG no.1 CHE Păclişa, HG no.2 CHE Ostrovul Mic, HG no.1 CHE Ostrovul Mare, HG no.1 and HG no.2 CHE Plopi, HG no.2 CHE Toteşti 1.

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