European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

International Conference on Renewable Energies and Power Quality (ICREPQ'12)
Santiago de Compostela (Spain), 28th to 30th March, 2012

External Magnetic Fields of Powerful Generators

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Abstract. Results of the magnetic field factory measurements near the surface of turbogenerator housings within the wide power range at no-load and short circuit conditions are presented. Presented also are the results of measurements of the external magnetic fields under the conditions of direct load with overexcitation and underexcitation.

The analysis of the external magnetic fields dependence upon the rated power, electromagnetic loads, design features and efficiency of the internal magnetic fields shielding by means of the turbogenerator housing and end shields was conducted.

Key words

External magnetic field, turbogenerator, measurements.

1. Introduction

For the equipment of the electric power plants the requirements of ensuring the environmental safety and electromagnetic compatibility are established. In this connection the level of the electromagnetic fields is important. These fields influence the health of the power plant personnel and generate the interferences in operation of control, monitoring and measuring systems.

The source of the power-frequency electromagnetic fields at electric power plants is the high-current electric equipment, those are the generators, transformers, bus ducts, etc. The magnetic component contains the greater part of low-frequency electromagnetic field energy.

In the already published papers [1-4] the most attention was concentrated on the electric machine external magnetic field calculation. The object of this paper is to compare and analyze the results of measurements of the magnetic fields at an operating frequency of 50 Hz near the external surfaces of turbogenerators of different rated power capacity and design version under the load steady-state conditions.

2. Measurement Results

The measurements of the three-dimensional external magnetic fields strength were conducted during the factory rig tests on the serial synchronous turbogenerators under the steady-state thermal conditions of no-load at the rated voltage and of short-circuit at the rated stator current. The turbogenerators were of the two-pole design with different cooling systems, that is the air, hydrogen-water and complete water cooling systems. Subject to tests were the turbogenerators with the rated output capacity ranging from 15 MVA to 1333 MVA.

The measurements were conducted by using the multi-turn induction sensor capable of being shifted at a distance of 100 mm from the generator surface along its perimeter in the plane of the axis of rotation. The electromotive force induced in the sensor by the generator external magnetic force was measured by means of the narrow-band analyzer of «Bruel&Kjaer» Co. make.

The results of measurements of the magnetic field strength vector magnitude distribution along the 22.5 MVA turbogenerator surface are shown in Fig. 1.

Given in Table 1 are the averaged in accordance with the standard [5] results of measurements conducted on the generators of different rated power capacities and design versions under the no-load and short-circuit conditions.

Presented in Fig. 2 and in Table 2 are results of the external magnetic field strength magnitude measurements for the 116 MVA asynchronized turbogenerator under the conditions of direct load with overexcitation and underexcitation.

3. Experimental Data Analysis

A. External Magnetic Field Distribution

Under the no-load conditions at the rated voltage the main source of the external magnetic field is the generator stator core. Under the short-circuit conditions at the rated stator current the magnetic flux in the stator core is of minor value and the external magnetic field is defined by the leakage in the winding end portions. Correspondingly, the highest external magnetic field may be expected to be in the generator middle longitudinal centerline plane under the no-load conditions and in the end zone under the steady-state short-circuit conditions. However, the experimental data, for example those presented in Fig. 1,2 do not prove it. The maximum values of the external magnetic field are concentrated in the generator end zone.

The turbogenerator elaborate design, the availability of structural components between the stator core and housing, which re-distribute the external magnetic field, as well as the rotor shaft effect upon the field distribution outside the end shields account for the aforesaid. The magnetic field secondary sources induced in the structural components, in the housing and end shields may intensify the magnetic field in end zone of the two-pole turbogenerators as, for example, it is proved by the analytical solution of the boundary problem [4].

Since the external magnetic field is measured in the air, the below presented relationship between the magnetic flux density vector $\vec{B}$ and the magnetic field strength vector $\vec{H}$ is true:

$$\vec{B}[\mu T] = 1.256 \cdot \vec{H}[A/m] \quad (1)$$

As it is seen from the experimental data, the external magnetic field exceed terrestrial magnetic field (about 40 A/m), but amounts to the hundredth parts of per cent of the magnetic field in the generator active components. That is why, even the slight and minor changes in the turbogenerator design, technological procedures and assembly quality may influence the turbogenerator external magnetic field.

B. Effect of the Power Capacity, Electromagnetic Loads and Design Features

The results presented in Table 1 are obtained for the turbogenerators, which have different power capacity and design. The magnetic flux density in the stator core increases slightly with the rated power increase, while the current load increases proportionally to the power capacity to the power 0.15-0.3. The external magnetic field also increases with the power capacity growth, yet the turbogenerator structural embodiment is of vital importance. For example, the air-cooled 137 MVA generator has the noise-protection enclosure provided with the maintenance man-holes soundproofed with rubber along their perimeters. The magnetic field shielding efficiency therewith is well below the efficiency of shielding the 1111 MVA turbogenerator leakage-proof thick steel housing filled with hydrogen under pressure. That is why, the external magnetic field of the hydrogen-cooled more powerful generator is somewhat less than that of the air-cooled generator. There is no internal higher pressure in the water-cooled 1333 MVA generator, and the housing is provided with a number of inspection windows, thus resulting in the magnetic field shielding efficiency decrease.

Table I. External magnetic field strength of turbogenerators with different power capacities. Averaged magnitudes

Rated power, MVA	15	19	22.5	137	1111	1333
Cooling system	Air				Hydrogen	Water
Induction, p.u.	1	1.01	1.04	1.04	1.04	1.03
Current loading, p.u.	1	1.06	1.15	1.81	4.17	3.64
Magnetic field at no-load, A/m	42	49	48	106	88	155
Magnetic field at short-circuit, A/m	47	56	36	134	102	184

C. External Magnetic Field Under the Conditions of Overexcitation and Underexcitation

Presented in Table 2 are the results of measurements of the external magnetic field strength of the asynchronized turbogenerator [6] under the conditions of back-to-back loading with the other generator used as motor. The operating conditions with overexcitation and underexcitation at the stator rated current were limited to the capability curve. The similar excitation current was supplied to two rotor windings arranged along the longitudinal axis and along the transverse axis.

Table 2. External magnetic field strength at the asynchronised turbogenerator loads. Averaged magnitudes

Operating condition	Overexcitation		Underexcitation	
Mode number	1	2	3	4
Power factor	0.825	1.0	0.95	0.338
Stator current, p.u	1.0	1.0	1.0	1.0
Voltage, p.u	0.9	0.72	0.7	1.0
Currents in two rotor windings, p.u.	1.0	0.75	0.65	0.3
External magnetic field, A/m	75	77	71	63

As evident from Table 2, in the wide range of the load change the transfer from the overexcitation to the underexcitation at the stator rated current and rotor current decrease by 70% of the rated one results in less than 20% decrease of the external magnetic field. The weak maximum of the external magnetic field is attained at the purely active load.

4. Conclusion

External magnetic field an operating frequency 50 Hz nearby to powerful turbogenerators exceed terrestrial magnetic field.

The presented results of measurements of the turbogenerator external magnetic fields demonstrate as a whole the magnetic field increase with the rated power capacity and electromagnetic loads growth. Yet, the turbogenerator structural embodiment is of vital importance, that is the powerful turbogenerator provided with a well-shielding housing shows the less external magnetic field.

The change of the turbogenerator operating conditions from the overexcitation to the underexcittaion changes the level of the external magnetic field within the range of 20%, with the rotor current being decreased by 70%
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The levels of the noise-carrying external magnetic field shall be taken into consideration when exploitation the powerful turbogenerators, when installing the diagnostic, monitoring and control systems.

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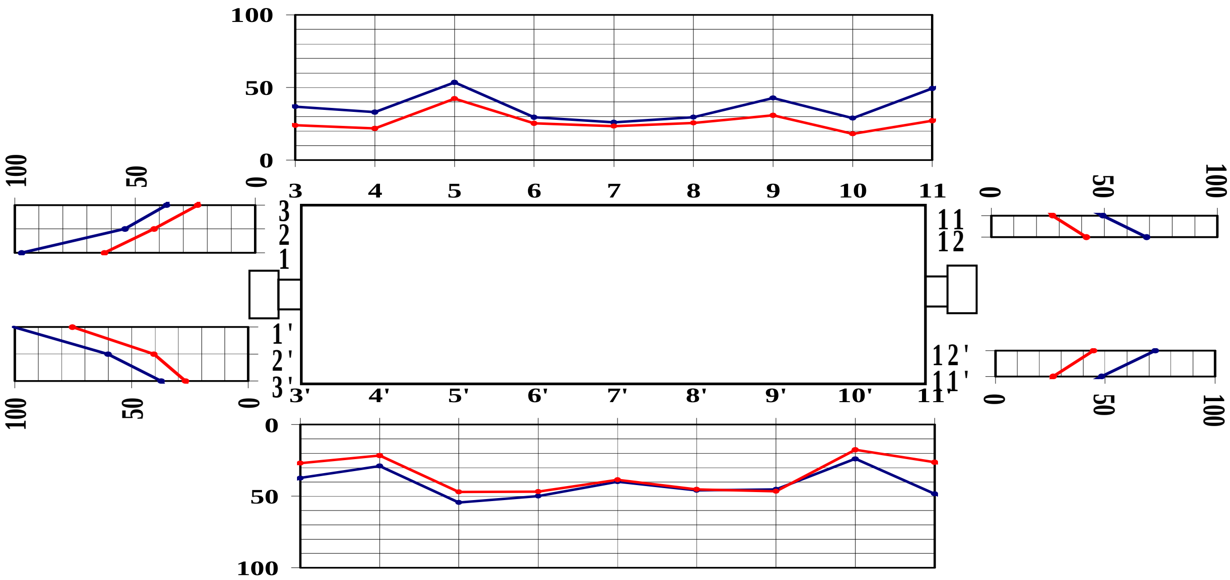

Fig.1. External Magnetic Field Strength Distribution for 22.5 MVA Turbogenerator
Blue – No-Load Condition
Red – Short Circuit Condition

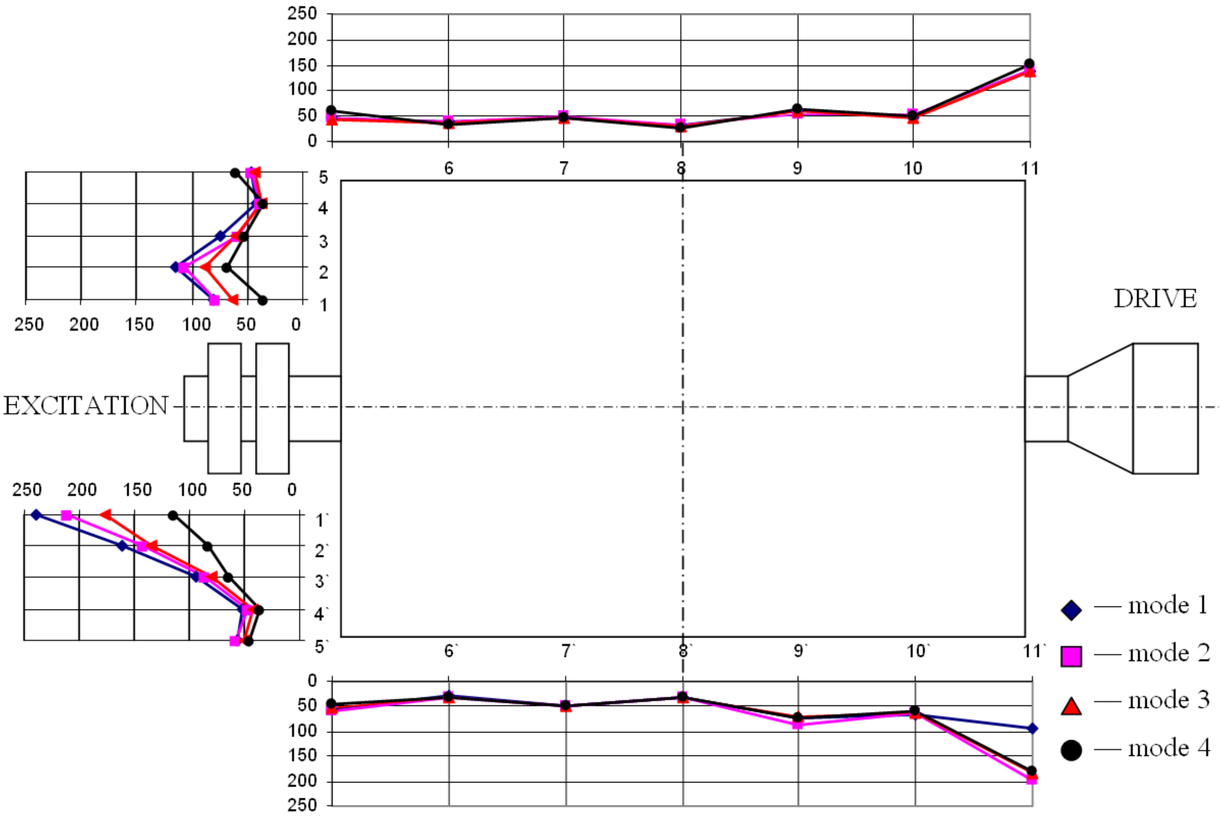

Fig.2. External Magnetic Field Strength Distribution for 116 MVA Asynchronized Turbogenerator