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# MAGNETIC FIELD EMISSIONS FROM SYNCHRONOUS GENERATORS

*A. Mariscotti, A. Motta*, P. Pozzobon*

Dipartimento Ingegneria Elettrica – Università di Genova – Genova – Italy
* Ansaldo Energia S.p.A.– Genova – Italy

**Abstract** – Measurements of the magnetic field emissions over [10 kHz, 30 MHz] frequency range of large power synchronous generators are reported; recorded spectra are correlated with the operating conditions of the machine under test. Comparison is made with other results obtained in a similar configuration.

**Keywords**: Electromagnetic compatibility, Synchronous generators, Electromagnetic measurements, Magnetic fields

## 1. INTRODUCTION

It is now commonly believed [1] that electrical drive systems must be CE marked also for EMC 89/336 directive [2], which implies the application of the product standard EN 61800-3 [3] or the generic standards EN 50081 [4] and EN 50082 [5]. A comprehensive discussion of EMC issues for electrical drive systems may be found in [6].

Electrical drive systems are "relevant apparatus", that is "they must have a dedicated purpose requiring no further modification by the end user". This definition may be easily extended to large power synchronous generators, which are marketed without any significant further modification for power generation.

Only recently electrical rotating machinery has been considered as a source of electromagnetic emissions other than the magnetic field at the supply frequency and its harmonics. Few contributions may be found in the literature concerning the measurement of electromagnetic emissions, all concentrated in the last five years [7,8,9]. In the last years limits on the electromagnetic emissions have been proposed to ensure the electromagnetic compatibility (EMC) of electrical rotating machinery. The first contribution to the definition of emission limits was the amendment A2 to EN 60034-1 [10], where the problem of electromagnetic emissions from rotating machinery is addressed with particular attention to commutator machines. After, the standard EN 60034-1 has been issued as version 2 [11], where some measurement guidelines are added to the emission limits. The limits are still specified for the high frequency range (above 30 MHz); the low frequency range (between 9 kHz and 30 MHz) is considered only for conducted emissions. It may be expected in general that EMC problems – if any – are more likely to occur in the low and medium frequency range (below some MHz), where the rotating machine is judged to be a significant source of radiated emissions and where effective shielding of magnetic emissions cannot be obtained by means of thin metallic sheaths or the enclosure itself. It must be reminded that in section 12 of the standard EN 60034-1 [11] it is specified that "the requirement of section 12 ("Electromagnetic Compatibility") do not apply to machines when the EMC performance is significantly affected by the final enclosure and assembly".

## 2. MEASUREMENT SETUP

Only measurements of magnetic emissions have been performed on the basis of previous experience [8] made on separate measurements of electric and magnetic field from three different machines: a dc motor, a separately excited synchronous generator and a brushless synchronous generator. The machines have been tested in the Generator Test Room at Ansaldo Energia, Genova, Italy.

Measurements are performed over the [10 kHz, 30 MHz] frequency range at different distances from the machine under test. Industrial EMC standards [4] and the EN 60034-1 [3] consider the [30 MHz, 1 GHz] frequency range for limits on emissions (radiated field). The medium frequency range [10 kHz, 30 MHz] is chosen, as it is done also in railways EMC standards [7], on the basis of the considerations done in the introduction. Emissions below 10 kHz are not considered here, since first, they are not treated by any industrial EMC standards and second, they are much more specific and depend on machine characteristics, so that it is very difficult to derive results of general validity.

During the measurements attention has been given to the dependence of field intensity on machine load and to the evidence of peculiar spectral components. Before and during all measurement campaigns, the ambient electromagnetic noise has been measured.

Several readings (10 to 12 depending on test) are performed for each test, so the displayed spectra are the result of averaging, to cancel spurious emissions. The used measuring equipment is described in Table I.

TABLE I. Measuring equipment

| **Spectrum analyser (Tektronix 2754P)** | |
|---|---|
| Bandwidth | 10 kHz – 22 GHz |
| Sensitivity | –117 dBm |
| Overall accuracy in 10 kHz – 30 MHz (as per calibration certificate) | 1.5 dB |
| Internal noise in [10 kHz – 4.2 GHz] at BW 10 kHz | –105 dBm |
| **Loop antenna (EMCO 6502)** | |
| Bandwidth | 9 kHz – 30 MHz |
| Antenna factor accuracy (as per calibration certificate) | 1 dB |

The receiver bandwidth is fixed to either 1 kHz or 10 kHz depending on the scanned frequency range.

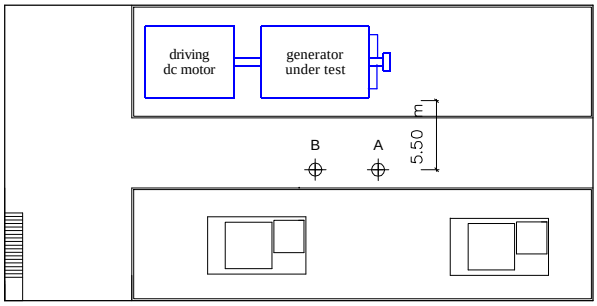



Fig. 1. Place of the generator and measuring points

The characteristics of the tested synchronous generators (one is shown in Fig. 2) are reported in Table II. It must be underlined that the generators were in their final configuration, with all enclosures properly mounted.

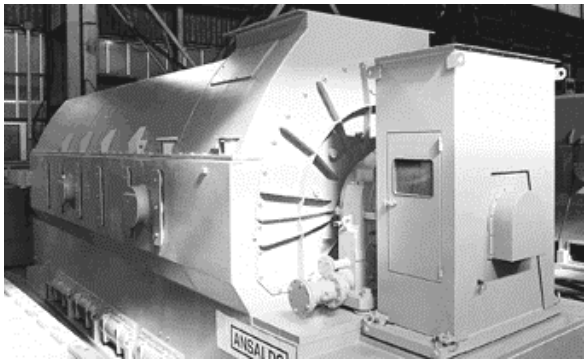


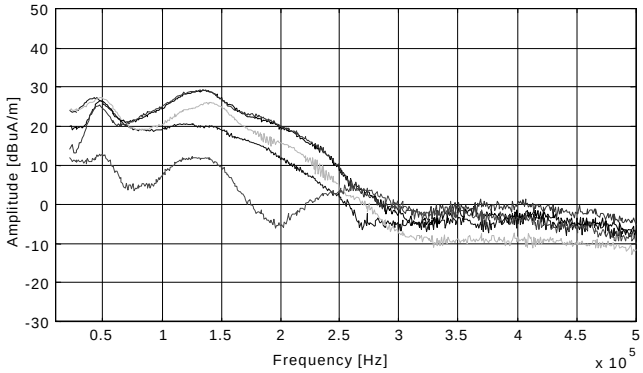
Fig. 2. The first tested generator

TABLE II. Synchronous generator characteristics

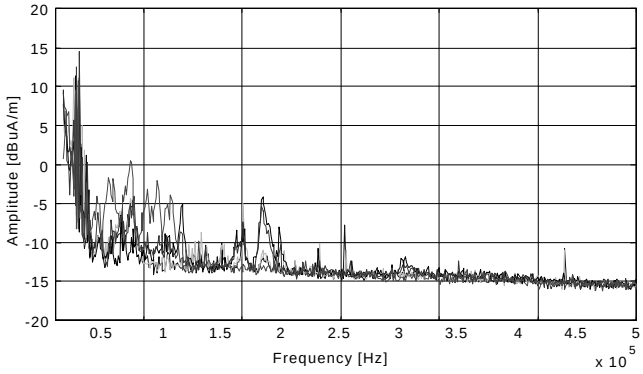
| | |
|---|---|
| Machine model | WX21Z-092LLT |
| Rated power [MVA] | 170 |
| Rated stator voltage [V] | 15000 |
| Rated stator current [A] | 6232 |
| Rated field voltage [V] | 261 |
| Rated field current [A] | 1246 |
| Rated speed [rpm] | 3000 |
| Rated frequency [Hz] | 50 |

## 3. MEASUREMENT RESULTS

The displayed spectra are all the result of average operation performed on multiple acquisitions (ranging between 10 and 12 depending on test). The results for the “moved”, “no load” and “short circuit” operating conditions are shown in Fig. 3, Fig. 4 and Fig. 5 respectively.

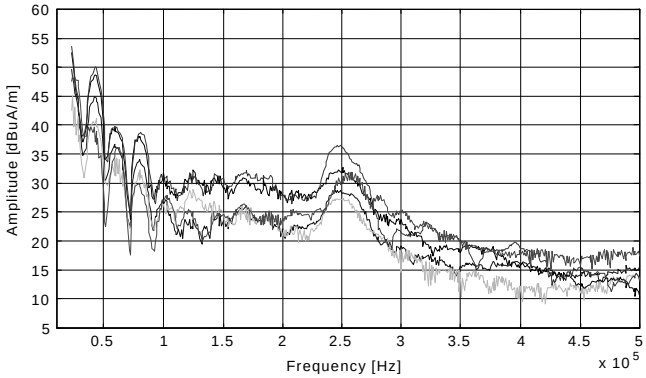



(a)

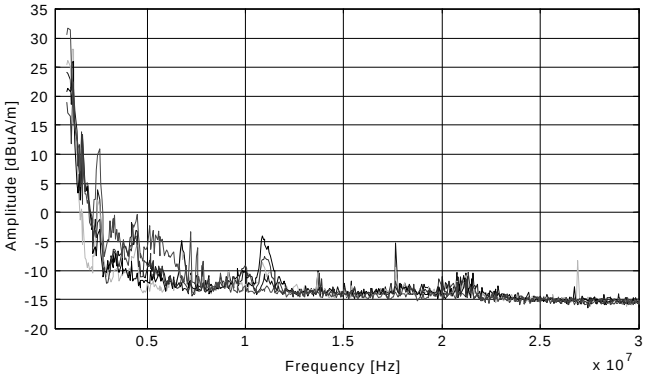



(b)

Fig. 3. H field at pos. A “moved” condition (RF 20dB): (a) 10 kHz – 500 kHz, BW 1 kHz, (b) 300 kHz – 30 MHz, BW 10 kHz

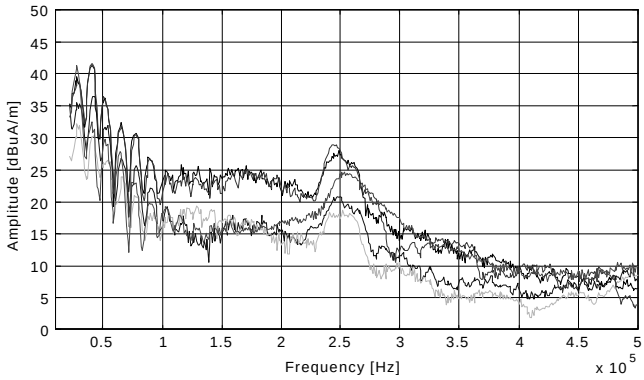



(a)

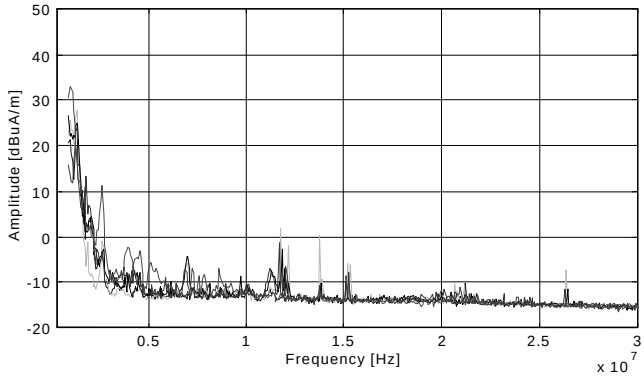



(b)

Fig. 4. H field at pos. A “no load” condition (RF 20dB): (a) 10 kHz – 500 kHz, BW 1 kHz, (b) 300 kHz – 30 MHz, BW 10 kHz




(a)




(b)

Fig. 5. H field at pos. A "short circuit" condition (RF 20dB): (a) 10 kHz – 500 kHz, BW 1 kHz, (b) 300 kHz – 30 MHz, BW 10 kHz

It may be noted that a large power synchronous generator is a source of significant magnetic emissions only at low frequency below 1 MHz. The large part of the peaks appearing above 1 MHz is due to external disturbance, mainly produced by radio communication. The time behaviour must be observed to recognise such disturbance, since they may appear and disappear during tests and the rule of "permanent presence" (applicable to radio broadcast) is no longer valid.

Additional measurements were made to investigate a series of sharp peaks in the medium frequency region (between 1 and 5 MHz) and the results are shown in Fig. 6 and Fig. 7.

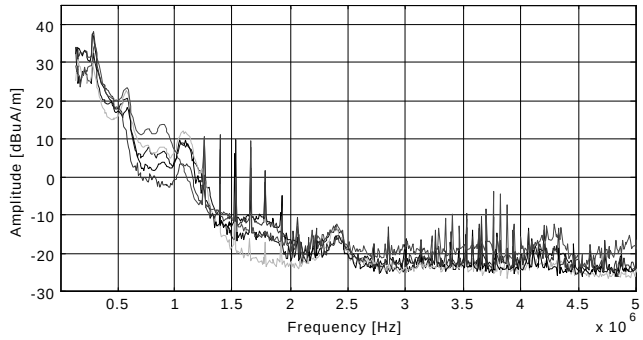



Fig. 6. H field at pos. A, "no load" condition, RF 20dB, BW 1 kHz, 10 kHz–5 MHz

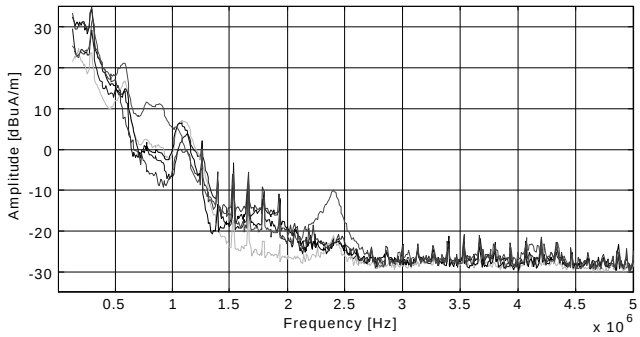
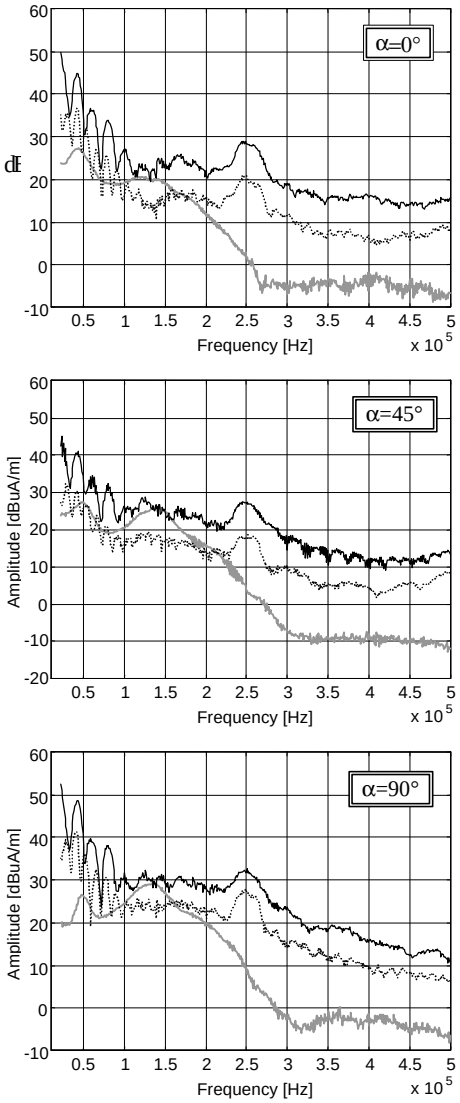



Fig. 7. H field at pos. A, "short circuit" condition, RF 20dB, BW 1 kHz, 10 kHz–5 MHz

The presence of these peaks is related to commutation disturbance introduced into the field winding by the supply rectifier. The peaks for the "no load" test are about 15 dB higher than those for the "short circuit" test and this is due to the different amplitude of the field winding current and different commutation condition of the supply rectifier.

Then, a comparison is made of the H field levels attaining to "moved", "no load" and "short circuit" conditions in the low frequency range for each orientation; the results are shown in Fig. 8.



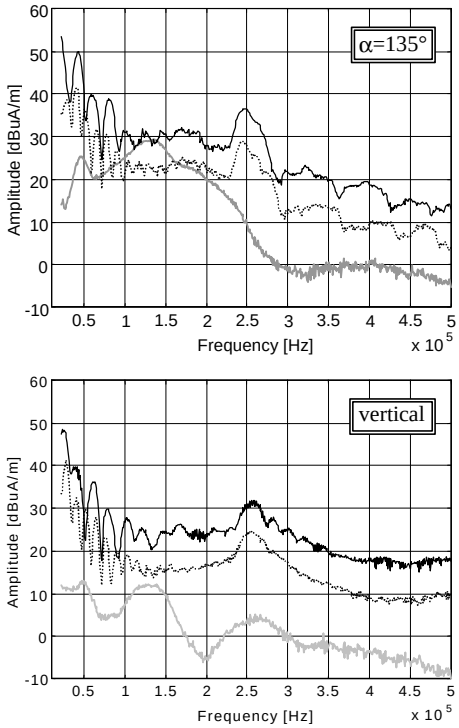



Fig. 8. H field at pos. A for different antenna orientations: "moved" (grey), "no load" (dotted), "short circuit" (solid); RF 20dB, 10 kHz – 500 kHz, BW 1 kHz

A peak at 250 kHz is always present in all tests where the generator field winding is connected to the supply rectifier. Above this point it may be stated that the difference between "moved" and "no load" emissions is about 15 dB, while the difference between "no load" and "short circuit" emissions is about 6 dB. In the low frequency range harmonic components are clearly visible, but we must underline that the specific profile is influenced by the chosen bandwidth BW, since the harmonic components are narrowband components with frequency separation smaller than BW.

The variability of magnetic field emission from identical machines is now considered. This kind of information is useful to assess the reliability of the results obtained with type tests performed on a single item and the possibility of extending them to all other items of the same type or model (identical for design and manufacturing).

From measurements made on two identical synchronous generators (see Table I) the range of machine emissions amplitude (with the measurement performed at the same position and distance from the machine) is only about 5 dB over the 10 kHz – 5 MHz frequency range.

## 4. CONCLUSIONS

Magnetic emissions from synchronous generators have been measured over the 10 kHz – 30 MHz frequency range. Subsequently, the investigated frequency range has been limited to 10 kHz – 5 MHz to increase measurement speed (reduced sweep time) and enhance frequency resolution; machine emissions – as it may be expected – cannot be distinguished above some MHz.

Attention is given to the conducted emissions of the rectifier supplying the generator field winding, responsible for the large part of generator magnetic emissions; in particular harmonic components at low frequency and sharp peaks around 1 MHz are clearly visible.

Enclosure and covers are properly setup, so the recorded magnetic emissions are those of the final installation.

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**Authors:**
Andrea Mariscotti, Dipartimento Ingegneria Elettrica, Università di Genova, Via all'Opera Pia, 11A – 16145 – Genova – Italy Tel. +39 010 3532169, Fax: +39 010 3532700 mari@die.unige.it;
Antonio Motta, Ansaldo Energia S.p.A., Via Nicola Lorenzi, 1 – 16149 – Genova – Italy Tel. +39 010 6556751, Fax: +39 010 6556751 motta@aen.ansaldo.it;
Paolo Pozzobon, Dipartimento Ingegneria Elettrica, Università di Genova, Via all'Opera Pia, 11A – 16145 – Genova – Italy Tel. +39 010 3532181, Fax: +39 010 3532700 pappo@die.unige.it