

MEASURING ELECTROMAGNETIC EMISSIONS FROM LARGE POWER ROTATING MACHINES

P. Ferrari, A. Mariscotti and P. Pozzobon

Electrical Engineering Department
University of Genova – Genova – Italy

Abstract: The electromagnetic emissions from a large power rotating machine (synchronous generator) are considered. The results of two measurement campaigns are reported: attention is focused on the measurement methods and on the evaluation of the results, considering the reactive behaviour of the field (the value of the wave impedance and its impact on the limits on the electric field amplitude in the standards), the extension of the source of emissions (the size of the machines is comparable to the measuring distance), the electromagnetic environment (presence of reflecting surfaces and sources of electromagnetic noise), a series of practical factors (safety distances, reproducible test conditions, etc.).

Keywords: Synchronous generator, Electromagnetic emissions

1 INTRODUCTION

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 are found in the literature, all concentrated in the last five years [1, 2].

The test procedures and limits for EMC assessment proposed in the amendment A2 to EN 60034-1 [3] are limited to the high frequency range (above 30 MHz) and are derived from other EMC standards, which are not strictly applicable [4]. No limits are given for low frequency emissions.

Moreover, a series of measurement problems shall be considered [2]: the source of emissions is quite extended in space, both in the direction of emissions and in the orthogonal plane; these machines often require several auxiliary systems and the generated electromagnetic noise cannot be easily identified and separated; the test site is far from being similar to an Open Area Test Site (as described by CISPR 16 [5]); the test conditions are sometimes critical and the machine operating conditions cannot be held constant for long time intervals.

2 GENERAL FRAMEWORK

The electric and magnetic fields from a 200 MVA synchronous generator have been measured separately in the Generator Test Room at Ansaldo Energia, Genova.

Measurements are performed over the [9 kHz, 30 MHz] frequency range at different distances from the machine under test. The ambient electromagnetic noise has been always monitored (section 3).

3 TEST ROOM NOISE

A preliminary evaluation of the ground noise is very important to determine the minimum measurable emission level and hence, the best positions and the maximum measuring distance. The machinery under test is placed on the test bench (concrete platform with connections to supply and auxiliaries) as shown in Figure 1b.

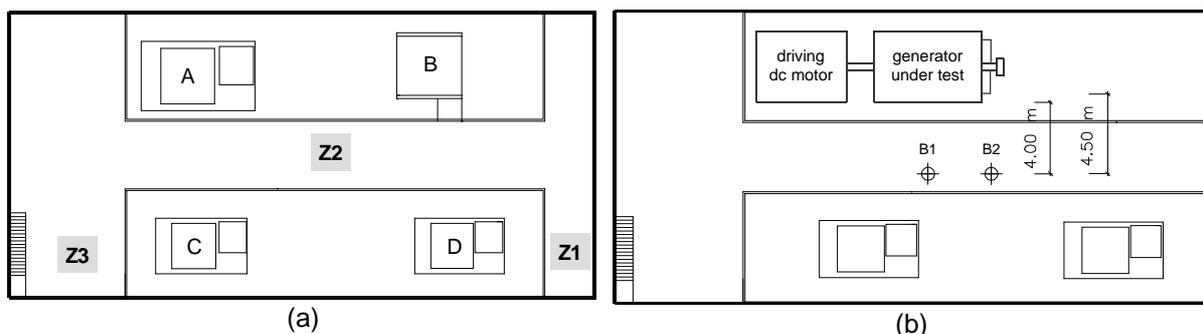


Figure 1. (a) Map of the Generator Test Room and (b) placement of the synchronous generator

E and H fields have been measured in the three areas indicated as Z1, Z2 and Z3. The four letters A, B, C and D indicate the four platforms where the machines are normally set-up for tests. The ground noise was measured with the auxiliary services in normal operation. The receiver bandwidth for these measurements is 200Hz for [9kHz–150kHz] and 9kHz for [150kHz–30MHz].

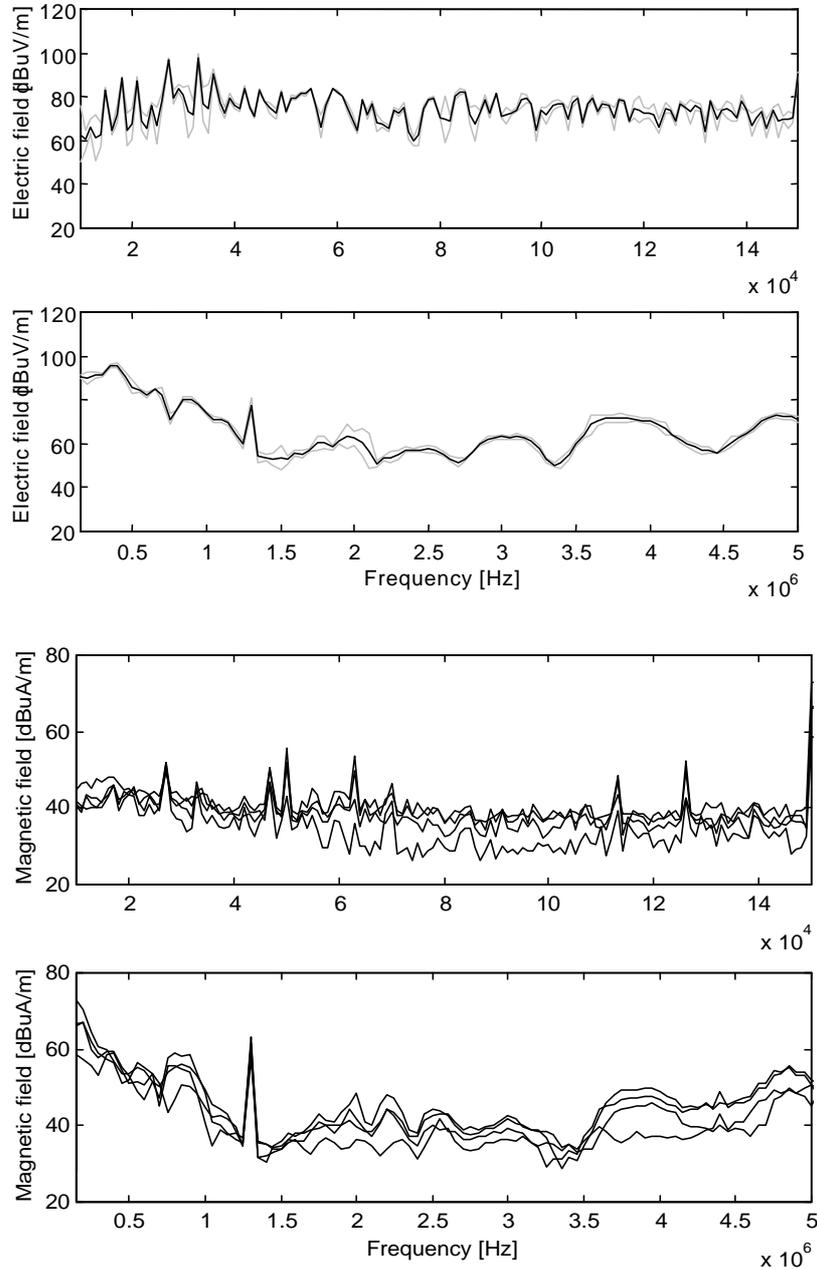


Figure 2. Average E-field (with $\pm 3\sigma$) and H-field (loop antenna at 0° , 45° , 90° and 135°) in Z2

Direct computation of the wave impedance Z_w of the measured fields as

$$Z_w = |E|/|H| \tag{1}$$

gives low values (normally in the 20 to 60 Ω range, occasionally as high as 100/200 Ω), below the free space impedance $Z_0=377 \Omega$ (51.5 dB Ω), indicating that the noise sources are magnetic in the reactive field region in this frequency range.

4 EMISSIONS FROM THE DC MOTOR AND SYNCHRONOUS GENERATOR

The main characteristics of the synchronous generator under test are reported in Table 1.

Table 1. Main characteristics of the synchronous generator under test

Rated power [kW]	205
Rated stator voltage [V]	15000
Rated stator current [A]	7890
Rated field voltage [V]	295
Rated field current [A]	1361
Rated speed [rpm]	3000
Rated frequency [Hz]	50

The electromagnetic emissions from the synchronous generator have been measured and recorded through two measurement campaigns (for a total of 6 days); after a first consistency evaluation, the data are averaged to produce the results shown in Figure 3 and 4.

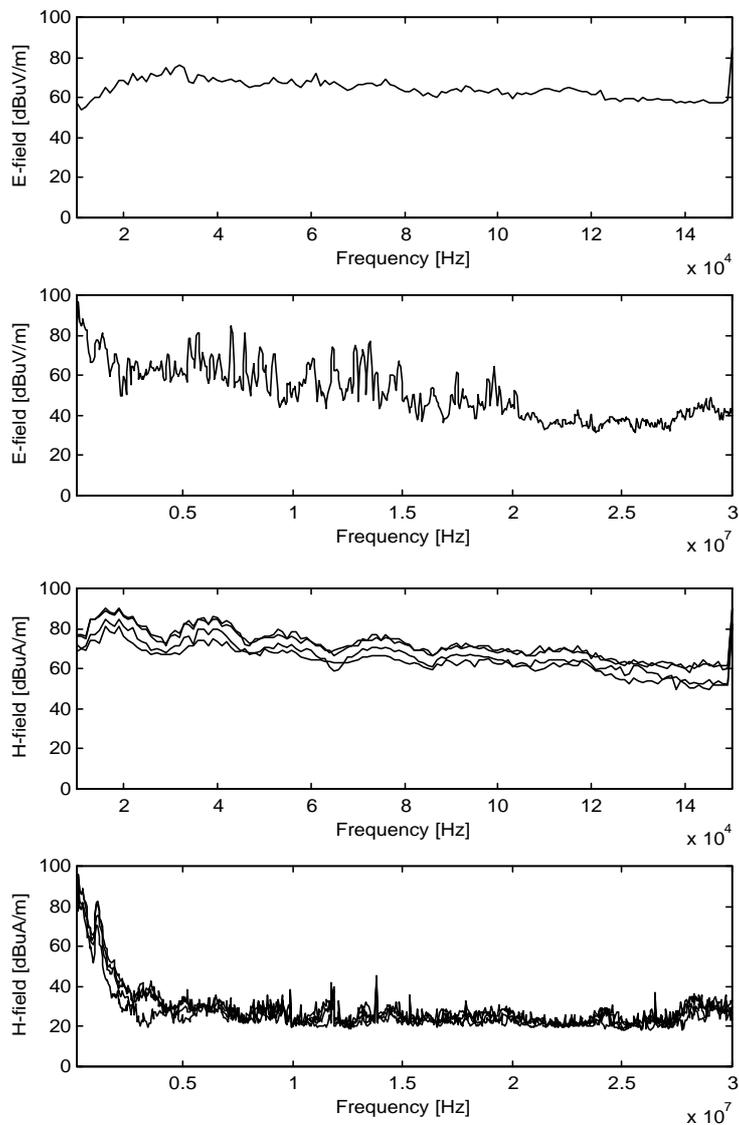


Figure 3. Emissions during no-load test on the synchronous generator (pos. B1)

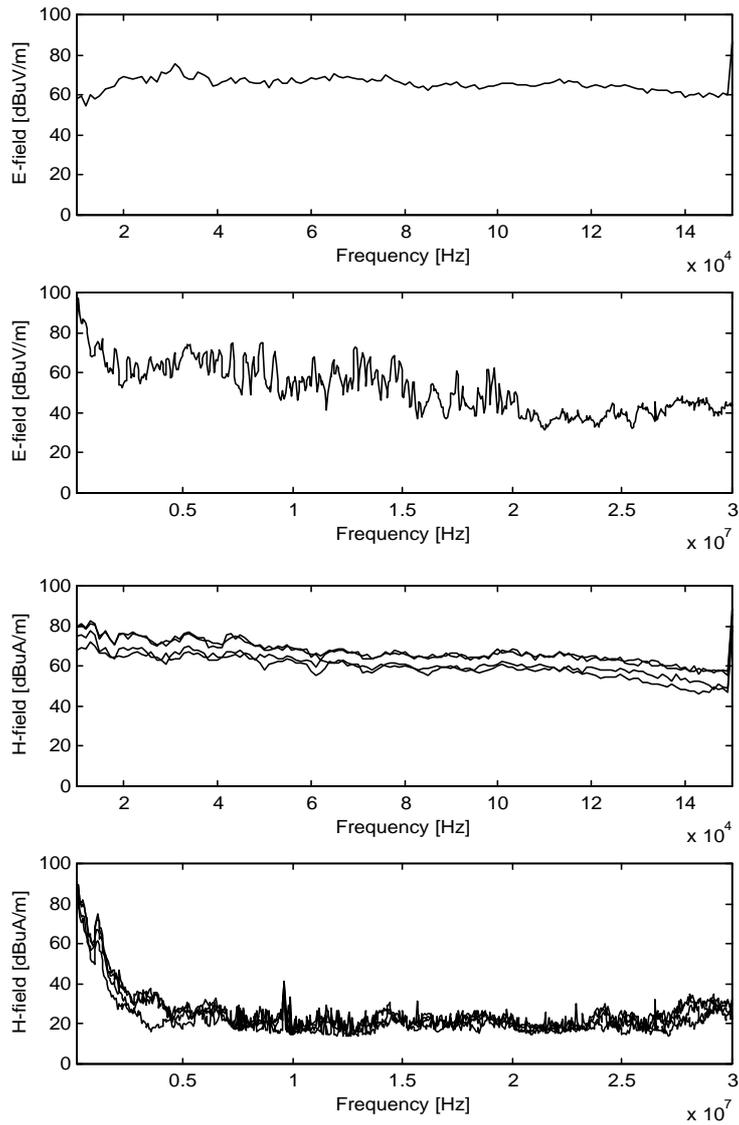


Figure 4. Emissions during short circuit test on the synchronous generator (pos. B2)

The wave impedance of the electromagnetic emissions from the synchronous generator over the whole frequency range is shown in Figure 5 (pos. B1) and Figure 6 (pos. B2) for the no-load and short circuit tests.

The wave impedance values are pre-processed (normalised moving average FIR filter) for plotting; this gives a neat curve (free of jag and noise) and cancels out all the narrow-band sharp lines (the emissions from the generator are assumed to be relatively broad-band signals).

The wave impedance is very low up to some hundreds kHz, where the emissions are all prevalently magnetic and reaches Z_0 (51.5 dBΩ) as the frequency increases; above nearly 10 MHz the test room noise (Z2 zone) is prevalent and it's impossible to evaluate the real value of the wave impedance.

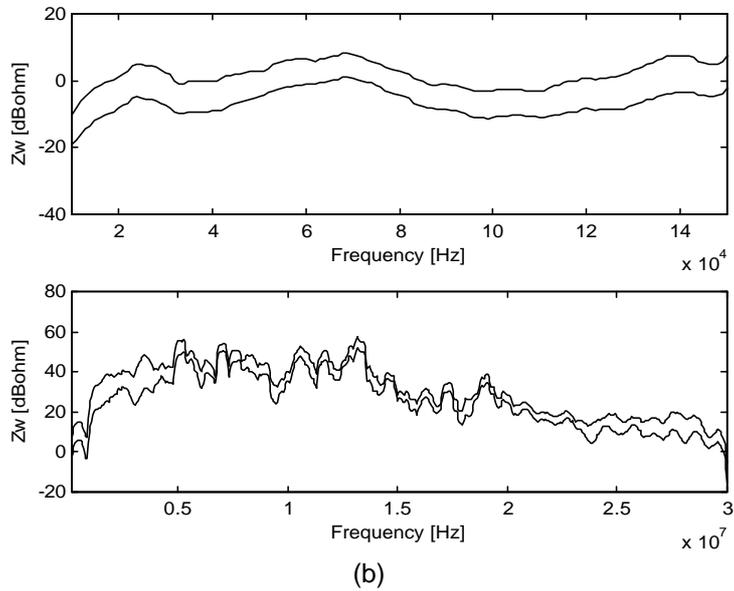
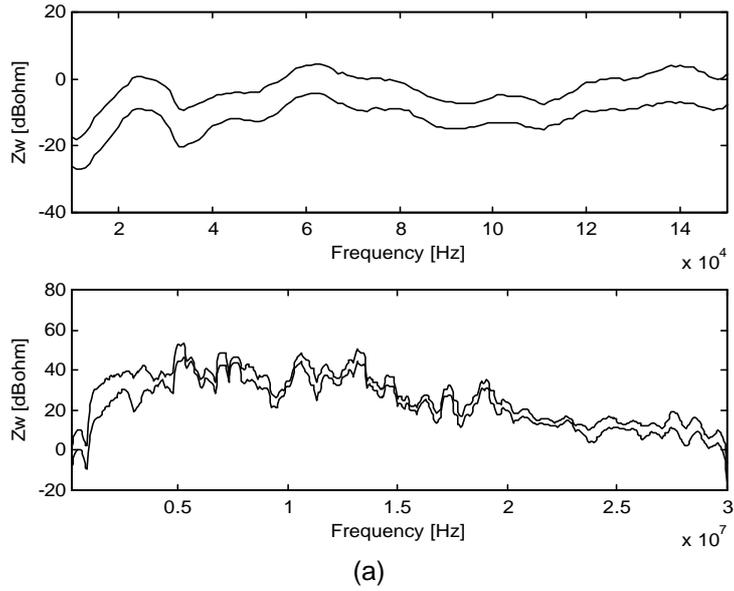
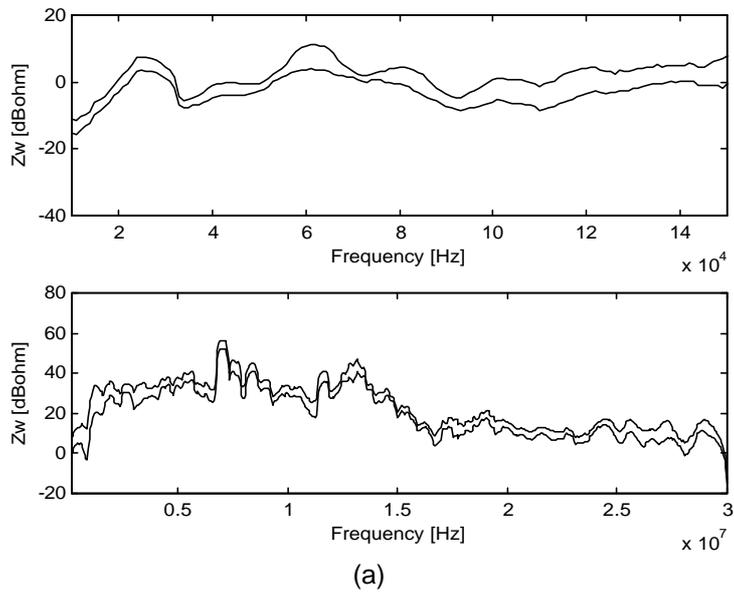


Figure 5. Min and max limits of Z_w for the (a) no-load and (b) short circuit tests (pos. B1) (filtered data)



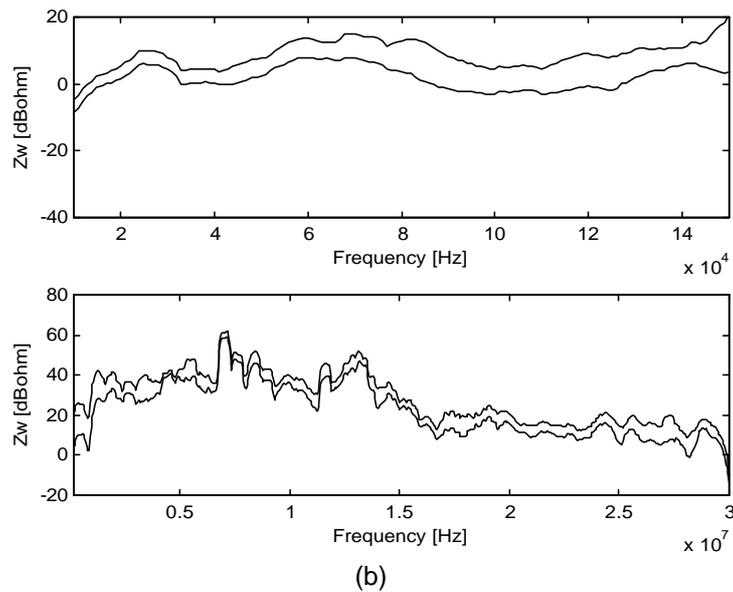


Figure 6. Min and max limits of Z_w for the (a) no-load and (b) short circuit tests (pos. B2) (filtered data)

The low frequency values of Z_w are higher for position B2 (B1 is in the center of the stator emitting windings), in particular for the short circuit test. Also the spread of the Z_w values (max curve minus min curve) is higher for position B2.

The decrease of Z_w above 10 MHz indicates that the recorded H-field values deviate from the far field model; this is a confirmation that the test room noise is uniformly higher than machine emissions, as it can be noted from the H-field spectra in Figure 2 and 3.

5 CONCLUSIONS

The measuring distance was always shorter than 10 m distance indicated in the standard [3], so, a corrective factor, considering the reactive properties of the fields in the near field region, must be determined: from -18 dB to -8 dB for increasing frequency.

The low values of the wave impedance of the emissions from the two machines even at the higher frequencies suggest that first, E-field limits [3] could be inadequate and second, H-field measurements may be necessary above nearly 10 MHz.

It may be stated that large power electrical machines are source of low frequency magnetic emissions; emissions at higher frequency are peculiar to the specific machine.

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AUTHOR: Andrea Mariscotti, DIE, Via all'Opera Pia, 11A, 16145 Genova, e-mail: mari@die.unige.it