Simulation of the effects of the unbalanced magnetic pull in four-poles slim generators

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ABSTRACT

Rotor eccentricity can occur in rotating electrical machines, as a consequence of different causes (errors during assembly, bearings wear, bow of the shaft, etc.) or of the normal operating of a flexible machine. In rotating electrical machines with eccentric rotor, an imbalance of the electromagnetic forces acting upon rotor and stator surfaces occurs, so that a net radial force is developed. This force, known as Unbalanced Magnetic Pull (UMP), causes vibrations and noise emission, speeds up the bearing wear and can even produce a rub between rotor and stator with a consequent damage of the windings.

The majority of the works in literature take into consideration the induction motors, mainly for two reasons: they are the most spread in industry (from small to large power) and their air-gaps are smaller than other machines (0.3-3 mm).

If synchronous machines are considered, for instance generators of large power with smooth poles, “slim” rotor and larger air-gap (30-100 mm), few papers are present in literature.

Moreover, they consider rotor orbits as circular [1]. This can be a first and rough approximation, since such kind of large machines are supported by oil film bearings, whose anisotropy can hardly determine circular orbits. Aim of the paper is to consider a more consistent and realistic model.

The model employed introduces a very accurate calculation of the air gap distribution depending on the position in a general time instant of the rotor inside the stator. [2]. The UMP, which is calculated by means of the air gap permeance approach, is therefore function of both time and position.

The UMP is calculated for all the elements of the generator model that corresponds to the active part, i.e. to the slotted part (Figure 1).

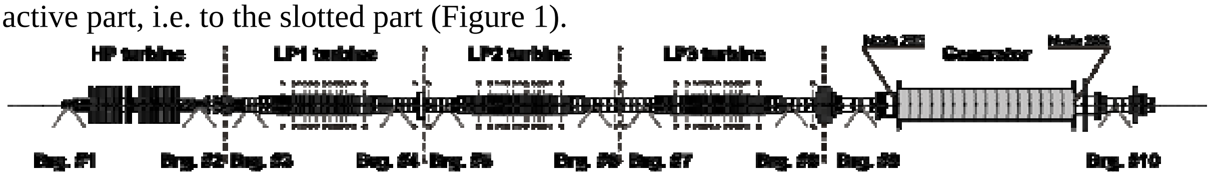

Figure 1. Finite beam model of the turbo-generator. The shaded elements of the generator are those on which the UMP is calculated.

The Newmark method is used to integrate the non-linear dynamic equations of the fully assembled machine (rotor + bearings + foundation) and the dynamical behaviour is calculated. An example is shown for a 900 MVA, 1500 rpm 3-phase steam turbo-generator, which is modelled by means of standard finite beam elements normally used in rotor dynamics and has 1148 degrees of freedom.

The effect of the UMP is rather evident if the shaft average dynamical deformation and the orbit of the nodes is compared after and before the magnetic field is generated in the air-gap, once the steady state is reached (Figure 2).

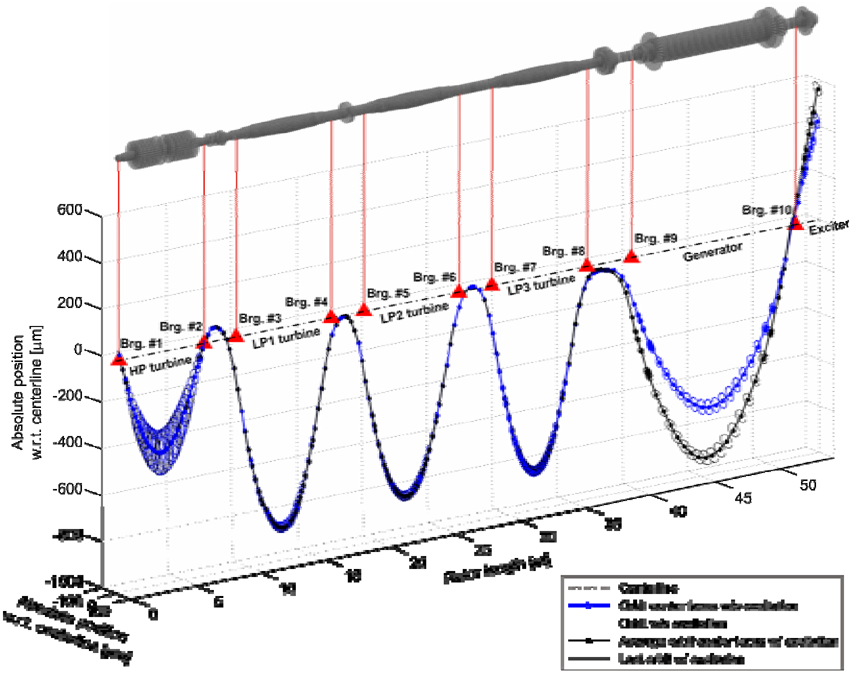

Figure 2. Rotor deformation and orbits of the nodes (steady state).

The obtained results confirm the presence of the constant (not rotating) and 2X harmonic component force, as forecasted by simplified models proposed in literature, but show the presence of a 1X component and of non-linear effects too (Figure 3).

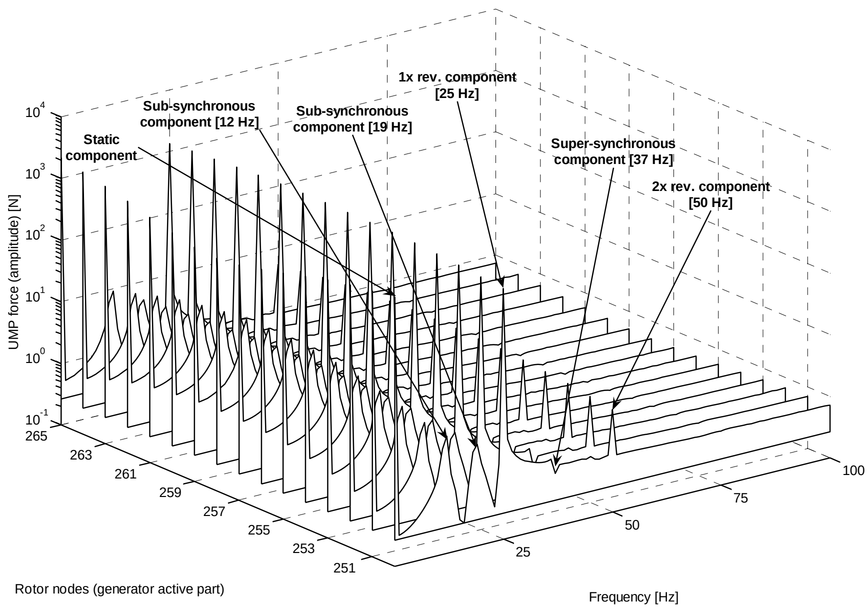

Figure 3. Spectrum of the horizontal component of the UMP forces.

[1] Guo D, Chu F and Chen D, "The Unbalanced Magnetic Pull and its Effects on Vibration in a Three-Phase Generator with Eccentric Rotor", *Journal of Sound and Vibration*, 254(2), 2002, 297-312.
[2] Pennacchi P and Frosini L, "Dynamical Behaviour of a Three-Phase Generator Due to Unbalanced Magnetic Pull", *IEE Proc. Electric Power Applications*, Vol. **152**, No. 6, 2005, ISSN 1350-2352, pp. 1389-1400..

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