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# An approach to model shaft voltage of wound rotor synchronous machines

K. Darques<sup>1,2</sup>, A. Tounzi<sup>1</sup>, Y. Le Menach<sup>1</sup>, K. Beddek<sup>2</sup> and M. Biet-Evrard<sup>2</sup>

<sup>1</sup>Univ. Lille, Centrale Lille, Arts et Métiers ParisTech, HEI, EA 2697 - L2EP - Laboratoire d'Electrotechnique et d'Electronique de Puissance, F-59000 Lille, France

<sup>2</sup>EDF R&D/THEMIS, 7 boulevard Gaspard Monge, F-91120 Palaiseau, France

**Abstract**— In the case of high power synchronous machines, shaft voltage can induce high currents yielding to bearing damages but it can also constitutes a variable to be used to diagnosis some machine defects. Therefore, it is important to well model the phenomenon in order to use it in further diagnosis tool.

**Index Terms**—Fault diagnosis, finite element model, shaft voltage, synchronous generator.

## I. INTRODUCTION

Several causes such as magnetic asymmetries, short-circuits either in the stator or the rotor, etc. can generate a circumferential magnetic flux. The latter induces a shaft voltage which is an electric potential difference between both ends of the shaft (Fig. 1a) leading to possible high bearing currents. However, by differentiating between the various causes, it can be used as a preventive diagnostic variable. In previous works [1, 2], this voltage is modeled using FEA through an external circuit coupling the shaft to the casing. To go deeper in the physical representation of the shaft voltage while studying the effect of each cause, we propose an approach considering the whole machine as a magnetic tore.

## II. PROPOSED APPROACH

In order to model the shaft voltage, a 2-pole simplified synchronous structure is studied at no load using finite element analysis. It is constituted of a shaft, a rotor with 3 slots per pole, a smooth cylindrical stator, a casing and an area relative to the air around the machine. Moreover, a regular prismatic mesh is used to avoid numerical errors. The approach to determine this voltage consists in using a set of equidistant virtual search coils [3] that capture tangential magnetic flux between the center of the machine and the outer casing perimeter at different positions (Fig. 1b). Putting these coils in series is equivalent to a tore winding all around the machine that catches the circumferential magnetic flux.

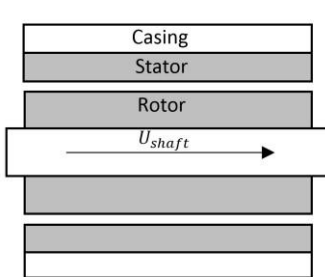


Fig. 1a. Location of the shaft voltage due to a magnetic asymmetry

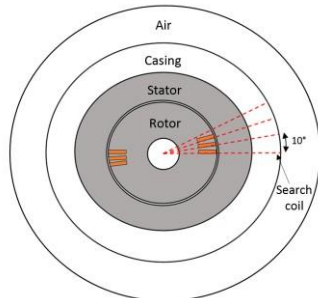


Fig. 1b. Schema describing the positioning of the search coils

Hence, each search coil catches a leakage flux leading to an emf arising at its end. In the case of an ideal healthy machine, the emfs induced in the coils have the same magnitude but are phase shifted by the same angle  $2\pi/n$  ( $n$  being the search coil number). Therefore, the sum of all the fluxes, and all the emfs,

is nil while this is not the case if a fault occurs. The analysis of this resultant emf can then be used to diagnosis a possible defect.

## III. APPLICATION TO THE CASE OF STATIC ECCENTRICITY

To highlight the effectiveness of the proposed approach, a study is carried out on a simplified structure whose geometrical quantities are similar to those of a high power synchronous generator. Using vector potential formulation, both healthy case and a 20.8% static eccentricity have been studied. Fig. 2 shows the magnetic flux density distribution in a cross section of the machine in the case of static eccentricity and Fig. 3 presents the time shaft voltages. The latter is almost nil in the case of healthy conditions while it shows a sinusoidal behavior at the rated frequency due to the static eccentricity [1, 2].

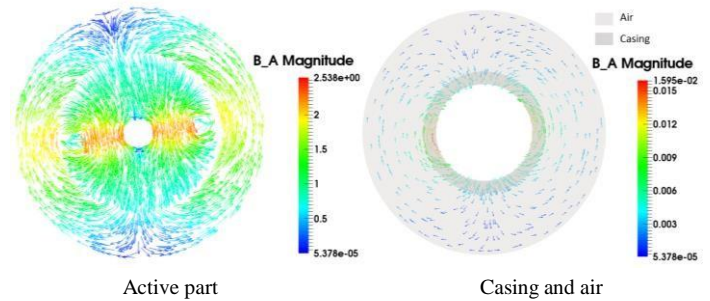


Fig.2. Magnetic flux density in the cross section of the machine with static eccentricity

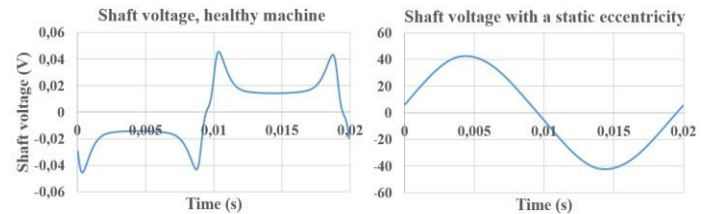


Fig. 3. Shaft voltages

In the extended version, the effect of the static eccentricity severity will be presented along with the results relative to other defects.

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