ARTICLE IN PRESS

Journal of Sound and Vibration ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Journal of Sound and Vibration

journal homepage: www.elsevier.com/locate/jsvi

Eccentrically mounted rotor pack and its influence on the vibration and noise of an asynchronous generator

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ARTICLE INFO

Article history:
Received 14 July 2014
Received in revised form
1 December 2014
Accepted 19 January 2015
Handling Editor: M.P. Cartmell

ABSTRACT

Time-varying magnetic forces are the main source of vibrations in rotating electrical machines. A number of papers dealing with computational modelling of the dynamic behaviour of rotating electrical machines have been published. Almost all of these papers do not consider electro-mechanical interaction between the stator and the rotor of the machine. A computational model including electro-mechanical interaction is proposed in this paper. The influence of the air gap eccentricity due to eccentric mounting of the rotor pack on the shaft of the rotor is investigated. Electromagnetic coupled-field analysis was performed to obtain the dependence of the magnetic forces, which act on the stator and the rotor pack, on the time and air gap eccentricity. Attention has been paid to the air gap eccentricity due to the interaction between the stator and the rotor and the influence of the air gap eccentricity on the vibration and sound power of the machine. The obtained results show that the air gap eccentricity affects the amplitude spectrum of the magnetic forces. This change of amplitude spectrum causes a significant increase in the torsional vibration of the stator of the examined machine. The air gap eccentricity is also significantly reflected in the trajectory of the rotor centre line and radial load of bearings in the machine.

1. Introduction

The time-varying magnetic field of a rotating electrical machine induces magnetic forces which act on the winding of the machine. Tangential components of the magnetic forces create torque, which is necessary for the operation of the machine. Radial components of the magnetic forces are the main source of vibration of the machine.

Time dependence of the magnetic forces is formed from a number of harmonic components. Amplitudes and frequencies of the harmonic components are influenced primarily by the winding construction especially the number of stator winding slots, the number of rotor winding slots, the number of pole pairs of the stator winding, the parallel paths in the winding, the magnetic properties of the materials of the winding and others.

The magnetic forces, which act on the winding at any given time, are in equilibrium in an ideal symmetrical machine. In the case of an asymmetric machine, for example due to geometric deviations of the winding from the ideal cylindrical shape or failure of the winding, the magnetic forces are not in equilibrium and create an additional load that is also called the

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http://dx.doi.org/10.1016/j.jsv.2015.01.033
0022-460X/

Please cite this article as: M. Donát, & D. Dušek, Eccentrically mounted rotor pack and its influence on the vibration and noise of an asynchronous generator, *Journal of Sound and Vibration* (2015), http://dx.doi.org/10.1016/j.jsv.2015.01.033

unbalanced magnetic pull. The vector of the unbalanced magnetic pull is oriented in the direction of the largest gradient of the magnetic potential, and thereby contributes to further increase the asymmetry of the machine.

Negative effects of the magnetic forces on the machine structure are evident. First, there are vibrations that are manifested by noise and cyclic loading of the machine structure. Second, there is unbalanced magnetic pull, which disrupts the smooth operation of the machine rotor and causes an additional load on the rotor bearings.

There are a number of publications which deal with the computational modelling of the dynamic response of the rotating electrical machine on the application of magnetic forces. Guo et al. [1] studied the influence of the air gap eccentricity and the number of pole pairs on the amplitude of the unbalanced magnetic pull and vibration of the rotor of the small three-phase generator. The computational model consists of the Laval computational model of the rotor and an analytical computational model of the unbalanced magnetic pull. In this paper, the computational model of the unbalanced magnetic pull has been based on the idea of modulating the fundamental magneto-motive force wave by air gap permeance expressed as a Fourier series. Lundström and Aidanpää [2,3] created the computational model of the rotating electrical machine that enables the examination of different types of air gap eccentricity on the dynamic behaviour of the rotor. This computational model consists of the Laval rotor and the analytical computational model of the unbalanced magnetic pull, which is derived through the law of energy conservation. The stability of the motion of the large hydro-power generator rotor due to air gap eccentricity is analysed in this paper. Another computational model of the dynamic response of the large generator rotor was suggested and experimentally validated by Pennacchi [4]. The finite element computational model of the rotor and the analytical computational model of the unbalanced magnetic pull were used in this paper. For more precise analysis of the magnetic forces, the finite element method can be used. Negoita and Ionescu [5] used a finite element computational model of the magnetic field of the rotating electrical machine and presented the differences between an ideally symmetric induction motor and motor with 15 per cent static eccentricity in terms of the amplitude and frequency spectrum of the magnetic forces. Considerable attention is also paid to the influence of magnetic forces on the dynamic response of the stator of the machine. Ishibashi et al. [6] and Neves et al. [7] deal with the prediction of the vibration of the machine stator. They used the finite element method and Fourier analysis to determine the most significant harmonic components of the magnetic forces and the frequencies of these harmonic components are then compared with the natural frequencies of the stator. Fengge et al. [8] studied the effect of the stator winding structure on the vibrations of the stator of the rotating electrical machine. Noise is closely related to vibration. According to [9], the magnetic field is the main source of noise in low speed rotating electrical machines. Roivainen [10] deals with numerical modelling of the sound power level radiated by the outer surface of the stator of the hydro-power generator due to time-varying magnetic forces. It can be stated that the computational models of the dynamic responses of the rotor of the rotating electrical machines assume that the stator of the machine is absolutely rigid and conversely the computational models of the dynamic response of the stator assume that the rotor of the machine is absolutely rigid.

The computational model of the dynamic response of the three-phase vertical asynchronous hydro-power generator, which takes into account an interaction between the stator and the rotor of the machine, is created in this paper. Firstly, an electro-magnetic coupled-field analysis of the magnetic field of the machine was used to obtain the dependence of the magnetic forces on the time and air gap eccentricity. In the second part of this paper, the dynamic response of the machine on the magnetic forces and the influence of the rotor pack eccentricity on the noise and vibration of the machine are investigated. Steady-state operation of the machine is considered only.

2. Magnetic forces

With respect to the type of solved task, the computational model of the magnetic field of the rotating electrical machine based on the solution of the coupled electro-magnetic problem was chosen as the most suitable for calculation of the time dependence of the magnetic forces, which act on the winding of the machine.

2.1. Computational model

The computational model consists of two sub models: the computational model of the magnetic circuit of the machine, Fig. 1, and the computational model of the electric circuit of the machine, Fig. 2. The computational model of the magnetic

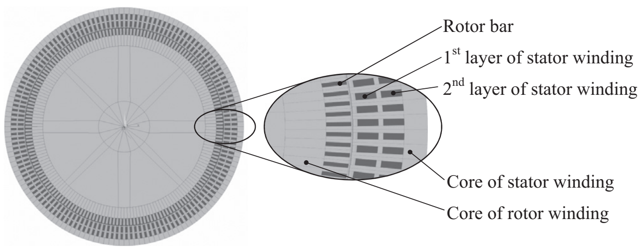

Fig. 1. Magnetic circuit of the machine.