Electromagnetic Field Analysis on Inter-turn Short Circuit of Rotor Winding for Turbogenerator Based on Meshless Method

Xiaoming Chen[1], Guangyuan Yang[1], K. R. Shao[1], Youguang Guo[2], Jianguo Zhu[2]
[1]College of Electrical and Electronic Engineering, Huazhong University of Science and Technology, Wuhan, 430074, China.
xiaominghust@gmail.com; krshao@hust.edu.cn.
[2]Faculty of Engineering, University of Technology, Sydney, N.S.W. 2007, Australia.
youguang@eng.uts.edu.au, joe@eng.uts.edu.au,

Abstract **—**According to the variable characteristics of electromagnetic speciality and the related electrical quantities when inter-turn shortcircuit of rotor winding occurs in turbogenerators, the meshless method is proposed to be used for short circuits fault. The 2D electromagneticfield of turbogenerator is simulated and calculated by the radial basis function (RBF) meshless method procedure. Consequently, the electromagnetic distribution diagram is achieved under the normal state of turbogenerator and rotor winding inter-turn short circuit with different degrees and positions. Through the comparison of the air gap magnetic flux density and the harmonics before and after fault conditions, the fault features can be identified, which establishes the foundation for further analysis of rotor winding inter-turn short circuit fault.

I. INTRODUCTION

The rotor winding inter-turn short circuit is one of the common faults, and the causes of this fault have many [1], which will cause rotor vibration and even develop rotor earth, rotor winding burned-out, generator loss of excitation, generator components magnetization and so on. So it is important to analyze the mechanism and diagnosis method of rotor windings inter-turn short circuit fault.

Short-circuited turns in power generator rotor windings cause operational problems, such as high vibration levels; therefore, early detection is essential. Similarly to the case of stator winding-related faults, inter-turn short circuits usually appear because of mechanical, electromagnetic, or thermal stress conditions. Normally, the resistance of the windings on opposite poles is identical. The heat produced by Joule's effect is distributed symmetrically about the rotor forging. If the inter-turn insulation is damaged in such a way that two or more turns of the winding become short-circuited, then the resistance of the damaged coil diminishes and, if the poles are connected in series, less heat is generated than in the symmetrical coil on the opposite pole. The rotor body thus experiences asymmetric heating, which produces a thermal bow in the rotor body, causing vibration. The unbalanced magnetic forces on the rotor produced by the change in the magneto-motive force (MMF) from the winding contribute to increased vibration [2].

Unlike stator design, cage rotor design and manufacturing has undergone little change over the years. As a result, rotor failures now account for around 10% of total induction motor failures [3][4]. However, in the field of fault diagnosis and the condition monitoring of electrical machines, most of the research presented in the literature deals with induction motor rotor failures, while bearing-related failures, which account for 40-50% of motor failures, are not so widely discussed. Rotor cage-related faults perhaps received so much attention in the literature as a result of their well-defined associated fault frequency components.

II. MESHLESS METHOD ANALYSIS OF ELECTROMAGNETIC FIELD IN TURBOGENERATOR

Recently, numerous meshless methods have arisen for solving partial differential equations (PDEs) in many contexts, including electromagnetic field computation; see, for instance, [5][6]. The attractive characteristic with meshless techniques is that they do not need a mesh to divide the domain; only nodes are used. It works with the weak form of the problem, in a manner similar to that of the finite element method (FEM).

In 2D condition, the electromagnetic field of turbogenerator can be determined by the magnetic vector potential equation

$$\begin{cases} \frac{\partial}{\partial x}(v\frac{\partial A}{\partial x})+\frac{\partial}{\partial y}(v\frac{\partial A}{\partial y})=-J+\sigma\frac{\partial A}{\partial t} \\ A_{\Gamma}=0 \end{cases} \qquad (1)$$

where A is magnetic vector potential, v is the reluctivity of the material and J is the exciting current. Γ is the boundary of the region of solution, total transverse section of the turbogenerator, it satisfies the boundary condition of first type.

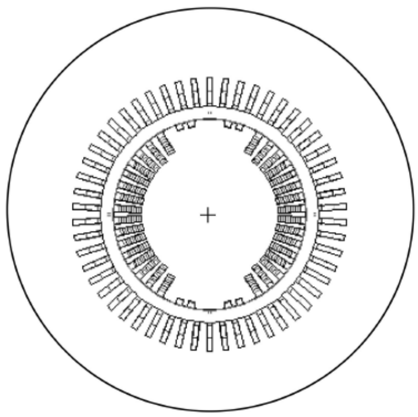

Fig.1. The region of solution of 300MW turbogenerator

Consider a set of nodes $x_1, x_2, \dots, x_N \in R^n$.The RBF centered at x_j are defined as

$$\varphi_j(x)=\varphi(\|x-x_j\|,c)\in R^n,\ j=1,2,.......N \qquad (2)$$

where $\left\| x - x_j \right\|$ is the Euclidian norm. The MQ is defined as $\varphi_j(x) = (\left\| x - x_j \right\| + c^2)^{1/2}$. where *c* is a shape parameter.

We approximate *u* by $u_h(t, x)$ and assume

$$\mu_h(t, x) = \sum_{j=1}^{N} a_j(t)\varphi(\left\| x - x_j \right\|, c) = \sum_{j=1}^{N} a_j(t)\varphi_j(x) \quad (3)$$

where $a(t) = [a_1(t), \ldots, a_N(t)]$ are unknown coefficients to be determined at each time step. In this paper, two practical difference scheme on time discretization are discussed, they are implicit scheme and Crank–Nicolson time matching scheme respectively.

We discuss the electromagnetic field in normal and inter-turn short circuit conditions.

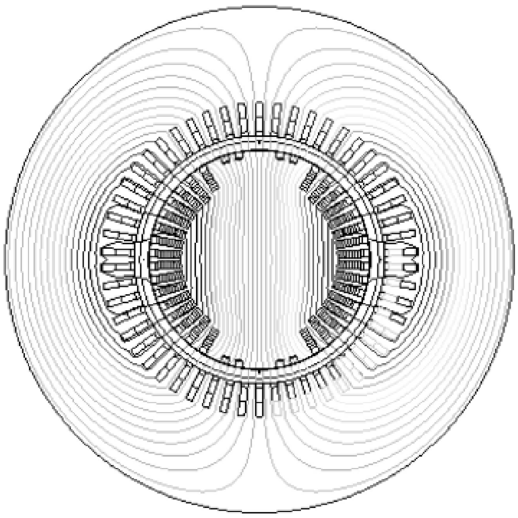

Fig.2. Normal with no-load condition

We assume there have 50% inter-turn short circuit with different level happens in generator on no-load.

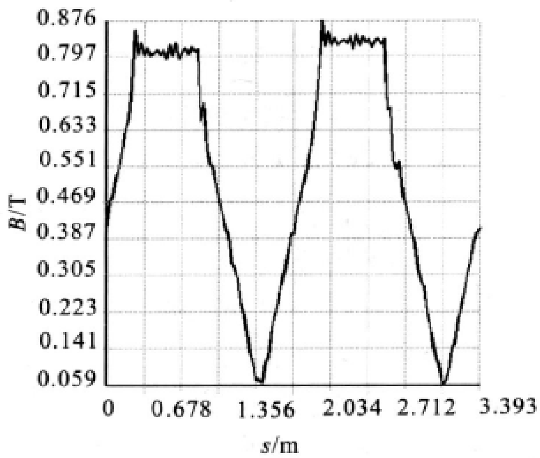

Fig.3. Magnetic field figure of winding of NO.1 with 50% inter-turn short circuit with different level happens in generator on-load.

III. Conclusion

In this paper, we use RBF meshless method to analyze the electromagnetic field of turbogenerator in no-load normal and inter-turn short circuit conditions. Results indicate that it can reflect the influence of the inter-turn short circuit of rotor winding in turbogenerator. Perhaps the most important contribution from this paper is an meshless way of thinking about analysis the problem of inter-turn short circuit of rotor winding for turbogenerator. We will present the whole results in the next version.

IV. References

[1] J.W. Wood, R.T. Hindmarch, “Rotor Winding Short Detection,” *IEEE Trans. Electric Power Applications,* Vol. 133, Issue. 3, pp. 181-189, May 1986.

[2] J. Ramirez-Nino, A. Pascacio, “Detecting inter-turn short circuits in rotor windings,” *IEEE Computer Applications in Power*, Vol. 14, Issue 4, pp. 39-42, 2001.

[3] E.P. Cornell, E.L. Owen, J.C. Appiarius, “Improved Motors for Utility Applications,” *Publication EL-2678*, Vol. 1, 1763-1, final report, October, 1982.

[4] Kliman, G.B., Premerlani, W. J., Koegl, R.A., Hoeweler, D., 1996, ‘A new approach to on-line fault detection in ac motors’, *The 1996 IEEE Industry Applications Society Conference: The 30th IAS Annual Meeting*, San Diego-CA, USA, Oct. 6-10, 1996, pp. 687-693.

[5] Y. Zhang, K.R. Shao, Y.G Guo, J.G. Zhu, “An Improved Multiquadric Collocation Method for 3-D Electromagnetic Problems,” *IEEE Trans. Magn*, Vol. 43, No. 4, pp. 1509-1512, April 2007.

[6] Y. Zhang, K.R. Shao, Y.G Guo, J.G. Zhu, “A Meshless Method for Electromagnetic Field Computation Based on the Multiquadric Technique ,” *IEEE Trans. Magn*, Vol. 43, No. 4, pp. 1509-1512, April 2007.