INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Design and the Modeling of Wind-Driven Self-Excited Synchronous Reluctance Generator and its Applications

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SHORT ABSTRACT

Abstract

The use of fossil fuels for power generation over a long period is one of the major cause for the global warming, which has now become a serious environmental concern. An attempt to reduce the effects of climate change due to carbon dioxide production and to meet the future energy requirement has resulted in significant research in renewable energy sources for power generation. The present thesis is mainly focus towards the design and development of generator suitable for low power wind conversion systems.

The machine specifications have been obtained from the wind turbine model, such as torque, speed, and power. Based on these specifications, the design of a synchronous reluctance generator (SRG) with a rating of 2.1kW is proposed in the thesis. Due to its ruggedness, and good efficiency, its potential application may be towards the electrification of the rural area of a country. In SRG, the design of the rotor is the most challenging part of the design. Here, the thickness of the axial and tangential ribs plays a significant role in its performance. The design procedure presented in the work includes the effect of stator resistance, as it cannot be neglected in the design of SRG with low power ratings. Various parameters of the designed machine are analyzed through an analytical model and cross-verified through Ansys Electronics Desktop software. Further, the thesis includes experimental validation of the results. The formulae to approximate the minimum values of the excitation capacitor requirement, for a self-excited SRG with inductive load, are developed. Further analysis of the generator's performance under different conditions of wind speed and loads is evaluated.

The effects of placing the ferrite magnet into the rotor air barrier of synchronous reluctance generators (FM-SRG) on its electromagnetic performance have been analyzed. The difference between average electromagnetic torque and ripple torque is used as a measure of the performance index. Here, in the analysis, a magnetic material is placed in the middle of each air barrier, and its size is symmetrically increased on both sides to increase the percentage of the

volume of the magnetic material. The effect of an increase in the volume of the magnetic material on its performance is presented. Moreover, the variation in electromagnetic features such as the d− and q − axes inductance and flux linkage is also explored and compared for different volumes and ferrite material.

Design and analysis of electromagnetic performance in itself are not enough to secure the durability and reliability of the machine. The mechanical and thermal modeling of the machine also plays a significant role in machine design. Hence, the thesis also includes the mechanical and thermal analysis of SRG.

The mechanical analysis consists of the analysis of the change in the mechanical stress due to the presence of centripetal force, wind speed, and rotor speed on the tangential and radial ribs with different thicknesses. Moreover, the variation in the electromagnetic feature such as the q− and d − axes flux, reactance ratio, inductance, torque, and torque ripple are discussed for different thicknesses of tangential and radial ribs. Increasing both tangential and radial rib thickness has an effect on the electromagnetic performance, but it is observed that the effect is significantly more with the variation of tangential rib thickness. Similarly, the mechanical stress analysis for rotor design has been explored in this work. It is observed that a high concentration of peak stress on the rotor ribs, which limits the range of rotor speed.

The study focused on the thermal analysis of the synchronous reluctance generator (SRG) with a rating of 2.1 kW, mainly uses explicit, and implicit finite difference methods for the thermal analysis to reduce the complexity of thermal calculation for the machine's components. It compares the results with the results obtained using a finite element analysis (FEA) and includes the experimental verification of the obtained results. The explicit, and implicit finite difference thermal analysis is relatively simple and computationally fast. Once the design parameters are known, the electric losses and iron losses of the SRG are evaluated. These machine parameters are utilized in developing the explicit finite difference (EFD), the implicit finite difference (IFD), and the 3D FEA model for thermal analysis. It is observed that the obtained results from the EFD, IFD, FEA, and experiments are very close to each other, and the temperature rise for the designed machine is within the desired and acceptable range.