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Abstract of PhD dissertation entitled:

„ OPERATION AND FAULTS ANALYSIS OF ENERGY-SAVING PERMANENT MAGNET SYNCHRONOUS GENERATOR FOR SMALL WIND TURBINES"

In this thesis the design, theoretical analysis, experimental validation and operation of a novel Permanent Magnet Synchronous Generator (PMSG) for Small Wind Turbines (SWT) is presented. First an introduction about the motivation to analyse the faults in wind turbines and more specifically small wind turbines is given. Also, an introduction to the employed approach called co-simulation is presented. Then the goals and thesis are presented.

In the second Chapter an Interior Permanent Magnet (IPM) machine was designed based on a series produced induction motor (IM). An approach called consequent pole (sometimes induced pole) was applied in the rotor design. A sweep parameter optimisation with the Finite Element Method was done in order to obtain the highest back EMF with low total harmonic distortion. The result is a PMSG with almost double the power density of the IM on which is based. This is confirmed by the validation from the laboratory measurements.

Next chapter shows the modelling of demagnetization and advances in the Finite Element Analysis software in order to represent more accurately the materials characteristics and behaviour. The theoretical background is also presented and an initial demagnetization investigation of the designed PMSG is presented. The results show that for constant speed the three phase short circuit is not able to demagnetize the machine when the magnet temperature is bellow 110°C, indicating that the chosen magnets are adequate for the PMSG.

In the fourth chapter the Wind Turbine Generators are analysed. The different topologies, their advantages and disadvantages are compared and the selection of a PMSG with direct-drive is justified based on the tendency of the main manufacturers and the demonstrated performance of similar SWTs.

In chapter V the control topologies for wind turbines are presented. The power electronics for SWTs are analysed and the theory of the different control topologies for the full converter are discussed. Then some Maximum Power Point Tracking strategies are presented.

Next part of the dissertation deals with the behaviour of the full Wind Energy Conversion System (WECS) under different PMSG operating conditions. The operation of the PMSG with a passive rectifier is analysed. The advantages of analysing the WECS through the co-simulation approach are shown and comparison with the analytical model of the PMSG and laboratory measurements are presented. Then the behaviour of the complete WECS with a PMSG in saturation is shown and compared with the classical simulation.

In chapter VII the operation of the PMSG with a two level voltage source converter (2L-VSC) is shown. This last topology was controlled with the Field Oriented Control (FOC). Another validation comparison is shown and the extreme case of a short circuit between the PMSG and the 2L-VSC is analysed through the co-simulation.

In the next chapter the operation of the PMSG without some of its magnets is presented and compared with the extreme case of short circuit shown in the previous chapter. Here four cases are analysed, these are: Healthy, one magnet less, two magnets less same side and two magnets less opposite side. The similarities between the demagnetization by two phase short circuit at 150°C and the two magnets less opposite side indicate that the extraction of magnets as a method to analyse partial demagnetization is valid as reported by previous literature. This also shows that the demagnetization model contained in the FEA software is demagnetizing the rotor as expected for such extreme cases.

In chapter IX the comparison between the SimPower systems' toolbox and the co-simulation is shown again but for the WECS with a 2L-VSC. Here the interaction between the aerodynamic model of the three blades Horizontal Axis Wind Turbine (HAWT) model and the PMSG is presented. Another comparison between the healthy PMSG and the two magnets les opposite side is shown.

Finally, a summary and some research conclusions of each chapter of the thesis are given and the main achievements and discoveries of the thesis are explained. A list of the publications done during the development of the thesis is presented. The annexes contain a description of the HAWT aerodynamic model and the parameters of the PMSG used in the classical mode, including some remarks about the operating region of the PMSG.

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