ANALYSIS AND CONTROLLER DESIGN OF SELF EXCITED INDUCTION GENERATOR FOR MICRO HYDRO APPLICATIONS

by

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DEPARTMENT OF ELECTRICAL ENGINEERING

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Dedicated with love ……….

To
my wife Chhinjo
my children Singgam and Mishka
and
my parents Apir and Yater

CERTIFICATE

This is to certify that the dissertation entitled "**ANALYSIS AND CONTROLLER DESIGN OF SELF EXCITED INDUCTION GENERATOR FOR MICRO HYDRO APPLICATIONS",** being submitted by Mr. Sarsing Gao to the Indian Institute of Technology, Delhi for award of **Doctor of Philosophy in Electrical Engineering**, is a record of bonafide research work carried out by him. He has worked under our supervision and guidance and has fulfilled the requirement for submission of the thesis. The matter recorded in this dissertation has not been submitted in part or full for the award of any other degree or diploma.

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ABSTRACT

Alternative energy resources are being explored for electricity generation due to increasing awareness about global warming and climate change which are caused by green house gas emission owing to the burning of fossil fuels for power generation and other applications. Induction generators are considered to be very appropriate for renewable energy systems due to their rugged and maintenance free nature and low cost. The ability of the induction generator to generate power at varying speed facilitates its application in various modes of operations such as (i) self-excited stand-alone (isolated) mode; (ii) in parallel with synchronous generator to supplement the local load; and (iii) in grid-connected mode. Various investigations have been made in the last couple of decades to address the issues related to the use of self excited induction generator (SEIG) as potential alternative to the synchronous generator to utilize small hydro, bio and wind energy to accomplish the future energy requirement, and to feed the generated power to remote and far flung areas, where extension of grid is economically not feasible.

To understand the suitability of induction generators for stand-alone generating systems, it is essential to carry out steady state and transient study of its operational and control aspects under balanced/unbalanced, static/dynamic and single-phase load conditions. These studies have been carried out for both three-phase as well as single-phase SEIGs in the available literature, with complicated iterative algorithms, for determining the values of excitation capacitors, magnetizing reactance (X_{ml}) and generated frequency (F) for a given prime mover speed and load conditions. In this thesis, a comprehensive and generalized analytical procedure is presented to predict the steady-state performance of both three-phase

as well as single-phase SEIGs with “fsolve” optimization tool of Matlab. This tool is found to be effective and elegant and yields precise values of X_{ml} and F satisfying the steady state governing equations of SEIG. With the prediction of steady state performance, the 2-capacitor and 3-capacitor operation of a three-phase SEIG feeding single-phase loads have been evaluated and the merits of one scheme over the other has been brought out. Also, the performance comparison of single-phase and three-phase SEIGs has been done when they are feeding single-phase loads. This performance comparison will allow the end-user to make a judicious choice for a particular application.

The transient study of both three-phase and single-phase SEIGs has been carried out using the inbuilt asynchronous machine block of Matlab/Simulink. This allows one to have an estimate of the unbalance caused in the stator and rotor currents due to the single-phase loading of the three-phase generator. Experimental results are also obtained under similar conditions to validate the simulation results especially for the unbalanced operation of the machine. Transients under sudden connection/disconnection of load are studied.

In micro hydro based power generation using an SEIG, the voltage and frequency regulation may be achieved by using an electronic load controller (ELC) as this is characterized by a constant power input. The ELC helps in maintaining the SEIG terminal voltage constant at varying consumer loads by suitably switching the power between the consumer load and the dump load. A complete modeling and simulation of an SEIG-ELC system are done in Simulink to assess the system performance. The same system has been implemented in hardware using a dsPIC microcontroller which is a simple yet powerful processor making it suitable for field trials. The simulation results have been validated with the help of the experimental set up.

As the output power that can be achieved from a single-phase SEIG is constrained, use of three-phase SEIG for supplying single-phase loads is a requirement especially, for electrifying rural and remote locations where the loads are of single-phase nature. This mode of operation, however, causes unbalance in the machine voltages and currents. The machine, therefore, needs to be de-rated in order to limit the maximum current in the windings. In this work, design and analysis of a STATCOM has been carried out to achieve current balancing in a three-phase SEIG feeding single-phase loads. The modeling of an SEIG-STATCOM system is done in Simulink and performance of the overall system is studied. It is found that the system works satisfactorily yielding balanced currents and voltages.

To sum up, the following are major contributions of this research work:

(i) Steady state analysis of the three-phase and single-phase SEIGs have been carried out using an elegant Matlab tool "fsolve" to study their behavior under balanced and unbalanced operating conditions. A performance comparison of single-phase and two different connections of three-phase SEIGs feeding single-phase load is done to make an appropriate choice depending on the application involved.

(ii) Transient study of three-phase and single-phase SEIGs have been carried out in Simulink environment using the model available in SimPowerSystem blockset. The stator and rotor currents have been analyzed under various unbalanced transient operating conditions to see if the limits on the machine currents have not been exceeded.

(iii) The modeling and analysis of SEIG-ELC system for constant power operation is done in Simulink. A similar experimental set up is built using a simple and powerful microcontroller dsPIC30F6010. The setup is found to work very well such that the voltage and frequency are regulated under varying load conditions. The simulated and experimental results match with each other.

(iv) When a three-phase SEIG is feeding single-phase loads especially in the 3-capacitor configuration, the currents and voltages are grossly unbalanced. Unbalance compensation can be provided by a STATCOM. An appropriate STATCOM is designed, modeled and simulated and found to balance the three-phase currents in the windings of SEIG even under a serious unbalanced condition of the three-phase SEIG feeding a single-phase load.

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