AN INVESTIGATION ON VARIOUS ASPECTS OF APPLICATION OF GENERALIZED IMPEDANCE CONTROLLER FOR VOLTAGE AND FREQUENCY REGULATION OF SELF-EXCITED INDUCTION GENERATOR

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An Investigation

On

Various Aspects of Application of Generalized Impedance Controller for Voltage and Frequency Regulation of Self-Excited Induction Generator

by

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CERTIFICATE

This is to certify that the thesis entitled, **"An Investigation on Various Aspects of Application of Generalized Impedance Controller for Voltage and Frequency Regulation of Self-Excited Induction Generator",** being submitted by **Mr. Chauhan Priyesh Jagdishchandra** for the award of the degree of **Doctor of Philosophy,** is a record of bona fide research work carried out by him in the Department of Electrical Engineering, Indian Institute of Technology Delhi, New Delhi.

Mr. Chauhan Priyesh Jagdishchandra worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to my knowledge has reached the requisite standard. The matter embodied in this thesis has not been submitted for the award of any degree or diploma elsewhere to the best of my knowledge.

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ABSTRACT

There has been a paradigm shift in electric power generation technology from the fossil fuel based centralized bulk power generation to alternative energy sources based decentralized medium and small scale power generation. The self-excited induction generator (SEIG) is emerging as a popular choice in the distributed small-scale power generation schemes for standalone and autonomous microgrid applications, which can cater to the power demands of grid-isolated remote loads by utilizing locally available renewable energy sources. Poor voltage and frequency regulation of SEIG under source and load perturbations, however, limit the use of SEIG in such applications.

This thesis details the research work on various aspects of application of a generalized impedance controller (GIC), developed for addressing the abovementioned operational issue of the SEIG. Structurally, the GIC is a pulse-width-modulated voltage-source-converter with a dc bus battery, having controllable four-quadrant equivalent input impedance.

Attention is focused mainly on simplicity and reliability of control system for alleviation of transient and steady state response of amplitude and frequency of the SEIG terminal voltage and, cost effectiveness and flexibility of the GIC configuration to make it suitable for applications, where SEIG operates with unregulated speed prime movers or feeds 3-phase 4-wire balanced/unbalanced loads or operates in microgrid interactive environment.

Detailed comparative analysis of the GIC based SEIG voltage and frequency regulator, having only voltage feedback based single-loop control strategy, and both voltage and frequency feedbacks based conventional two-loop control strategy, has been carried out to highlight the superior transient and steady state performance of the SEIG output with single-loop control. The control structure and design in the single-loop control strategy are also greatly simplified. The GIC configuration in terms of a non-fragile voltage-PI controller design and its parameters, viz. the coupling reactance and the dc bus voltage has been identified for further improvement and optimization of transient response of amplitude and frequency of SEIG terminal voltage.

A novel scheme, for regulation of amplitude and frequency of the SEIG terminal voltage under varying prime-mover speed and balanced/unbalanced loads, has been introduced and investigated, which maintains the active and reactive components of the SEIG stator currents at shaft speed based reference setting using 3-phase 4-wire (3P4W) configuration of the GIC. The GIC operation at fixed reference frequency makes this

technique more robust as compared to the contemporary control techniques dealing with similar issue.

A novel and simple approach for improved power extraction in variable speed wind turbine based integrated SEIG-GIC standalone generation scheme has been proposed, which is free from complex online computation used in the existing MPPT algorithms. Modifications in the torque-speed curves of wind turbine and the SEIG through variations in the gear ratio and SEIG rotor resistance respectively have been analyzed for identification of suitable gear ratio and rotor resistance to achieve above 95% efficiency of power capture from the given wind turbine in the entire operating range of wind velocity of the site, while keeping higher average efficiency of overall generating unit; and supplying the connected loads at regulated voltage and frequency under fluctuating wind velocities and load variations.

A novel modular 3P4W configuration of GIC has been introduced, which has multiple identical units of low rating 1-phase H-bridge VSC and battery combination. A flexible number of such units are connected in parallel at each phase depending on the battery voltage/charge condition and per phase active and reactive power requirement for regulating amplitude and frequency of the SEIG terminal voltage under severe unbalanced loading and varying wind velocity. Such modular GIC makes cost effective utilization of the capacity of converters and batteries, and provides higher reliability, redundancy and flexibility for upgrading its power rating. Control strategy has been evolved for management of active/reactive power sharing among the parallel connected units at individual phases.

Aptness of the GIC has been displayed for regulation of voltage and frequency in autonomous microgrid application of SEIG, wherein, a 3P3W grid interactive WECS having gearless wind turbine driven SCIG has been interfaced via matrix converter with the SEIG-GIC based 3P4W standalone WECS. The amplitude and frequency of the SCIG stator voltage have been controlled through matrix converter i/o modulation to regulate the active power imported from the SCIG and supply variable reactive power demand of SCIG while keeping unity power factor on the PCC side.

The results of comprehensive analytical, simulation and small-scale laboratory investigations of the integrated SEIG-GIC system have demonstrated that this project has contributed a promising technology in the renewable energy sources based standalone generation and autonomous microgrid applications for better environment, economy and social advancement of grid-isolated remote locations through provision of improved quality of electric power.

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