ANALYSIS, DESIGN AND DEVELOPMENT OF VOLTAGE AND FREQUENCY CONTROLLERS FOR ASYNCHRONOUS GENERATORS IN ISOLATED POWER GENERATION

By

GAURAV KUMAR KASAL
Department of Electrical Engineering

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to the

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Dedicated

to

My Parents

CERTIFICATE

This is to certify that the thesis entitled, "Analysis, Design and Development of Voltage and Frequency Controllers for Asynchronous Generators in Isolated Power Generation" being submitted by Mr. Gaurav Kumar Kasal 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 of Indian Institute of Technology, Delhi.

Mr. Gaurav Kumar Kasal has 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 results obtained here in have not been submitted to any other University or Institute for the award of any degree.

Bhim Singh 10-12-2008

(Prof. Bhim Singh)
Electrical Engineering Department
Indian Institute of Technology, Delhi
Hauz Khas, New Delhi- 110016, India.

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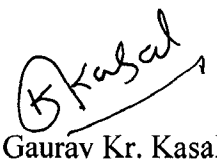

Gaurav Kr. Kasal

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ABSTRACT

In isolated electric power generation for harnessing renewable energy from available non-conventional energy sources like small hydro, wind, bio-gas, bio-mass etc., an squirrel cage induction machine driven by constant speed prime mover operated as an isolated asynchronous generator (IAG) with its excitation met by a capacitor bank connected across its terminals, has become the compatible options since last two decades. However, the fundamental problems for its commercialization are its inability to control the terminal voltage under varying load conditions. In order to regulate its terminal voltage with varying loads and utilize the machine to its rated capacity, an external source of reactive current is required for its excitation and to meet the reactive power requirements of the loads. Moreover, for feeding various type of consumer loads such as linear/nonlinear, three phase three wire and three phase four wire loads, an asynchronous generator based isolated system requires an effective voltage and frequency controller. In three phase four wire systems, an isolated generator feeds unbalanced and/or non-linear loads, with a result three-phase terminal voltages and stator currents are also unbalanced and may also consist harmonics. These harmonics in voltage and current increase the power losses, create unequal heating and cause torque pulsations on the shaft of the generator and distorted voltage to the loads. If it is used with neutral wire, 3-phase unbalanced currents yield a current in the neutral conductor that involves further power losses and heating. Therefore an efficient and effective operation of a 3-phase 4-wire asynchronous generator system with suitable voltage and frequency controller is investigated here along with neutral current compensation. This research work mainly focused on three phase four wire applications of IAG driven by various prime movers

such as constant speed prime movers (bio-gas, bio-diesel and gasoline engines), constant power prime mover (pico hydro turbine) and variable power (wind turbine system) wind energy conversion system.

In case of constant speed prime movers driven IAGs, various topologies of STATCOM (static compensator) based voltage regulators are designed, modeled and simulated and their performances are analyzed for feeding 3-phase, 3-wire and 3-phase, 4-wire linear/nonlinear, balanced/unbalanced and dynamic consumer loads. These topologies of STATCOM are based on three-leg voltage source converter (VSC), two-leg VSC, three-leg VSC with capacitor mid point, four-leg VSC and three single-phase VSCs. In addition to these, 3-phase 4-wire topologies of STATCOMs, some new topologies of STATCOMs based voltage regulators are also proposed which are based on these VSCs with different transformer configurations such as zig-zag transformer, star-delta transformer and T-connected transformer. A laboratory prototype is also developed of STATCOM based voltage regulator for IAG system under different loading conditions for feeding balanced/unbalanced linear/non-linear and dynamic loads.

In case of constant power prime movers driven IAGs such as small pico-hydro turbine system with no governor control, an IAG has been found the most suitable candidate due to simple in construction, economically feasible, maintenance free, capable to operate in adverse environmental conditions to provide, good quality of generated power. For such applications, the simplest control strategy is considered that the IAG should operate at a single point operation by ensuring a constant input power to and constant output power from the machine. Seasonally input power to a pico hydro turbine is almost constant and the output power is maintained constant by having electronic load controller (ELC) which

ensures a constant load at the generator terminals in spite of variation in the connected consumer loads. As consumer load reduces, the electronic load controller diverts the excess active power to an auxiliary load. This investigation covers analysis, design, and simulation of various topologies of electronic load controllers, which can make system suitable to feed various types of consumer loads including three phase four wire and non-linear loads.

Incase of variable power prime movers such as constant speed wind turbine, an IAG for isolated WECS (wind energy conversion system) consisting of VSC (voltage source converter) with BESS (battery energy storage system) is employed to feed three phase three wire and three phase four wire consumer loads. The main challenges in an asynchronous generator based stand alone wind generating system are to control the magnitude and frequency of the generated voltage under the condition of varying consumer loads and varying wind velocity. The various topologies of voltage and frequency (VF) controllers are also investigated in this research work for an asynchronous generator based stand alone wind energy conversion system. These VF controllers make IAG based stand alone wind energy conversion system suitable to feed various type of consumer loads along with meeting power quality standards.

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