DESIGN AND DEVELOPMENT OF VFD BASED VOLTAGE AND FREQUENCY CONTROLLERS FOR A SEIG IN MICRO-HYDRO POWER GENERATION

by

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CERTIFICATE

This is to certify that the thesis entitled, "**Design and Development of VFD Based Voltage and Frequency Controllers for a SEIG in Micro-Hydro Power Generation**" being submitted by **Mr. RAJASEKHARAREDDY CHILIPI** for the award of the degree of Doctor of Philosophy is a record of bonafide research work carried out by him in the Department of Electrical Engineering of Indian Institute of Technology Delhi.

Mr. Rajasekharareddy Chilipi has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to our 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.

Date:

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ABSTRACT

Renewable energy has now become an imperative option for power generation due to the problem of conventional energy causing green house gas emissions resulting in climate change. Hydro, wind, bio and solar energies are in the forefront of such green power technologies. Amongst these renewable energy sources, hydro is found to be very cheap, clean and reliable source of energy for generating electricity. Large hydro involving big dams and storage reservoirs pose some serious problems such as deforestation, environmental degradation and displacement of population. Therefore, small/micro-hydro units up to a few hundred kW of unit sizes requiring minimal civil works and limited effects on environment are being preferred to generate electricity to energize remote and far-flung rural communities. As the power capacity of micro-hydro is low and typically in the range of 1 kW to 100 kW and it is not economically and technically feasible to feed such low power to the grid. Even the quality of the grid in such isolated locations is often very poor with wide variation of voltage in addition to unreliable supply due to frequent interruptions. In many cases, installing transmission lines to such locations is itself impractical and uneconomical. An alternative method is to supply the generated electricity to local communities which makes the generating system grid independent.

Traditionally, hydro systems employ conventional synchronous generators which are found to be expensive, complex in construction and less reliable due to continuous maintenance requirements. Therefore, self-excited induction generators (SEIGs) are being favored due to their overall operational and maintenance simplicity. Moreover, robustness, low cost, inherent short-circuit protection, high torque/weight ratio, absence of dc excitation etc. are some of the advantages of SEIG over conventional synchronous generator. It has been customary to use a speed governor in conventional large hydro power systems to regulate

power input to the turbine. However, as a cost effective and less maintenance solution, speed-governor-free turbine systems are highly recommended for small isolated hydro systems.

Despite the attracting features of SEIG, poor voltage and frequency regulation have been the major drawbacks of governor-free micro-hydro turbine driven SEIG systems. Therefore, when a SEIG is driven by an uncontrolled hydro turbine, voltage and frequency controllers (VFCs) have to be incorporated to ensure better quality power delivered to the consumers. The output voltage of the SEIG falls rapidly with the load application as the machine pulls out of saturation due to the increasing gap between the VAR supplied by the capacitor bank and that demanded by the machine. The terminal voltage of SEIG can be controlled by continuously adjusting the level of capacitor excitation to meet the reactive power demand of the generator and loads. The generation frequency fluctuates as the load varies due to the imbalance between power generated and power consumed. The frequency control of a small-hydro fed SEIG system can be achieved by having an electronically controlled auxiliary load at the generator terminals in parallel to consumer loads. These auxiliary loads are controlled to consume the difference between the constant power output provided by the SEIG and the power absorbed by the connected consumer/actual loads.

Considerable amount of literature is available on VFCs for small/micro hydro driven SEIGs. These VFCs employ electronically controlled auxiliary loads comprise of either dump resistors or battery energy storage and they are inapplicable to the systems higher than 10 kW rating. Therefore, major challenge lies in indentifying, investigating and implementing an alternative, efficient and effective method of utilizing the power in excess of consumer loads that is applicable to higher rating systems.

In this research work, system frequency control by utilizing the excess power generated for pumping applications such as irrigation and overhead tank water storage is proposed. Due to the random varying nature of consumer loads, the excess power available for pumping also varies randomly. In order to utilize the varying excess power for pumping, VFCs employing variable frequency drive (VFD) coupled to a pump acting as an auxiliary load are investigated.

This research work includes design, modeling, simulation, and development of various topologies of VFD based VFCs for uncontrolled constant power micro-hydro turbine driven SEIGs feeding various kinds of loads such as linear/nonlinear, balanced/unbalanced and dynamic loads. These VFCs are broadly classified as three-phase three-wire and three-wire four-wire VFCs, and then further classified as decoupled VFCs and integrated VFCs based on their configuration. The four-wire VFCs use four-leg voltage source converters (VSCs) or transformer connections for realizing the fourth wire which is the neutral terminal for feeding single-phase consumer loads.

Another emphasis is given on developing control algorithms for the proposed VFCs. The reference current signals of the VSCs for terminal voltage control and power quality improvement are derived using adaptive filters based on adaptive noise cancellation (ANC) theory and second order generalized integrator (SOGI). A new control algorithm based on single-phase synchronously rotating D-Q frame theory for voltage control is also investigated. A digital signal processor (DSP) dSPACE DS1104 controller is used for implementing these control algorithms. For frequency control using VFD, direct torque control (DTC) and field oriented control (FOC) techniques are investigated. The control of VFD is carried out on another DSP (TMS320F2812). Test results of the developed VFD based VFCs are validated with the simulation results and their performance is found to be satisfactory. They are able to effectively control the system voltage and frequency along with power quality improvement.

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