INVESTIGATIONS ON RENEWABLE ENERGY BASED SINGLE PHASE POWER GENERATION USING SELF EXCITED INDUCTION GENERATORS

by

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Submitted

In fulfilment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

to the

INDIAN INSTITUTE OF TECHNOLOGY DELHI

MAY 2013

To My Country

Republic of India

CERTIFICATE

This is to certify that the thesis entitled, "**Investigations on Renewable Energy based Single Phase Power Generation using Self Excited Induction Generators**" being submitted by **Mr. VUDDANTI SANDEEP** 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. Vuddanti Sandeep 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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ACKNOWLEDGEMENTS

First, I am deeply indebted to **Prof. S. S. Murthy** and **Prof. Bhim Singh** for agreeing to advise me on an area of renewable energy, which is challenging and of immense importance. During my Doctoral study, they have been constant sources of invaluable guidance, support, encouragement, and motivation. I want to thank Prof. Murthy for his words of advice on issues related not only to academics but, to life in general. It is my valued opportunity to learn the rigorous attitude toward study and research from Prof. Bhim Singh. Their profound knowledge, professional codes and gentle personality toward research will benefit my career as well as my whole personal life.

I would like to express my most sincere gratitude to my Ph.D. dissertation committee members Prof. G. Bhuvaneswari, Prof. Sukumar Mishra and Prof. T.S. Bhatti, for giving valuable comments that helped me to make this work better.

I owe an enormous debt of gratitude to Prof. P.M.V. Subbarao, Mechanical Engineering dept., for his valuable expertise, advice, and support made this work possible testing for practical field deployment. I thank specially Mr. Rajkumar who gave his valuable continued support to conduct the experiments in Micromodel Lab, CRDT, IIT Delhi. I would like to extend my sincere thanks to Mr. Kailashnath B. Sutar, RS, Mech. Dept.

I would like to acknowledge gratefully the support provided by Ministry of Micro, Small and Medium Enterprises (MSME), Govt. of India and FITT, IIT Delhi for this research work.

I would also like to thank Chandra Sekhar, Surender Reddy, Mr. Mallesham, Sreenath, and Jayaram for invaluable support and assistance. I wish them all the best of luck and brightest future.

My sincere thanks to the PG Machines Lab staff, Sh. Srichand Sh. Puran Singh, Sh. Gurcharan Singh and Sh. Jugbeer Singh for providing facilities and equipment required for my doctoral study.

Particular acknowledgments go to all of my colleagues at the PG Machines Lab at EE Department, IIT Delhi. Their valuable comments and continuous encouragement are

greatly appreciated. I will always cherish the moments I had with Mr. Rajasekhara Reddy, Adlan Pradana, M. Sandeep, Swami Naidu, Mr. Rajesh, Mr. Phaneendra Babu, Mr. Satish Babu, Vashist Bist, Jeevanand, Mr. Sabharaj Arya, Arun Verma, Gurdiyal Singh, Bharat Babu, Srinivas Kadagala, Chinmay Jain, Ujjwal Kalla, Gaurang Vakil and Sankar. This list is still not complete and I apologize to those not listed as you all contributed to my experience.

Last but most importantly, I am infinitely grateful to my parents, *Shri. Srinivasulu* and *Smt. Suguna*, for their never-ending support, love, encouragement and prayers that helped me complete this work. They have been behind me throughout my extended academic career.

Finally, let me express my deepest gratitude to God for his/her wonderful blessings.

Thank you all…. (V. SANDEEP)

Date:

ABSTRACT

Man needs energy to meet desired quality of life in the form of heat, light and motion. In developing economies with large dispersed population, electricity is also a promoter of good education, healthcare, agriculture and population control. Electricity is considered to be the best vehicle to carry energy from source to the load. According to International Energy Agency (IEA), about 1.3 billion people worldwide lack access to electricity services with nearly 2.7 billion without clean cooking facilities. 404 million people in India currently do not have access to electricity and the daily average per capita electricity use is about 2 kWh for connected population. Despite massive rural electrification plans, India has nearly 45000 un-electrified villages (2012). In most of the electrified villages not only the connected households are a fraction of the total but the power is available on an average of a few hours per day. This is not acceptable if 'electricity to all' is the motto with all ensured 24x7 hours power. Many developing economies need to have massive capacity addition of power generation to meet the growing need of electricity for industrial, commercial, agricultural and domestic sectors. Since global warming and climate change caused by unwanted emissions are the global problems, it must be tackled with global synergy. *'Think global and act local'* is the *mantra,* since solutions are not unique with many local variants although one may evolve some generalized philosophies. Efforts are made by different countries individually and collectively to address this energy related climate change issue. Role of scientists and engineers is to make *'conventional energy sustainable'* and *'renewable energy available'* for the above solution.

With fossil fuel based power generation causing unwanted emissions, playing havoc with the environment and threatening the future of the planet, search for viable and deployable low carbon technologies to meet the growing power demands of global population has become imperative. Therefore the major challenges in electricity sector are two-fold: a) expanding access to electricity for sections of populations not reached by the grid, and b) meeting increased demands from sections of populations within the reach of the grid.

India is finding it difficult to establish and maintain remote rural area electrification. The cost of delivering power to such areas is becoming prohibitively high due to large investments in transmission lines and resultant transmission and distribution losses (26 %). The grid power has often become inadequate or not available to several remote and inaccessible locations. Often the power is available only for a few hours per day even in electrified rural areas as aforementioned. Renewable energy (RE) is the main tool that can help the situation. Thus, local RE sources such as small hydro, bio, wind and solar are considered attractive and viable options in this venture for supplying energy to rural and remote areas. Rural electrification to meet unmet demand through renewable energy is a priority by itself.

Technology requirements of grid-fed and off-grid systems using RE are entirely different. The objective is to provide quality power (constant voltage, frequency and harmonic free) to the consumer at varying loads using available local energy sources. Each source has distinct features on the type of power it provides. Bio energy driven governor controlled engine provides varying power to the load as per demand by adjusting the input fuel to the engine. It is a near constant speed variable power

arrangement. In standalone small hydro units (say upto 100kW), typically classified as micro, pico, nano hydro systems, it is apt to use uncontrolled constant power turbines with constant head and discharge. Thus the generated power is always constant while the consumer load varies.

This research work is motivated by the current need of off-grid single phase power generation especially for isolated consumers using locally available renewable energy sources such as bio and small hydro. The bulk of the domestic appliances loads in rural/ remote areas are single phase loads. Single wire earth system is often suggested for rural/ remote area electrification. Generation of three phase power is suitable for only high power ranges typically above 100 kW. Since this thesis primarily concerns low power standalone applications of unit sizes of few kW, the generation of single phase power is very relevant. It is essential to study all possible configurations to arrive at best possible solution for given source and load keeping in view the need of consumers, to have acceptable power quality across the load. This thesis attempts to find a viable technological solution to above problems by designing a suitable single phase power generating system by transforming the research on self- excited induction generator (SEIG) to a user friendly system adapted to the above need.

Therefore, this thesis elegantly investigates on analysis, design and development of single phase SEIG for off-grid renewable energy applications. There are two possible ways to supply single phase loads from a SEIG. One system envisages two winding (main and auxiliary) single phase SEIG and other uses three winding (conventional three phase induction machine) single phase SEIG. Critical performance comparison of different topologies on above two generators is carried out extensively in this research

work. Unified and comprehensive performance prediction analysis of two winding and three winding single phase SEIGs has been evolved for off-grid generating systems. Methodology for estimation of excitation capacitor and additional capacitor topology is presented for voltage regulation. The experimental and computed results have been presented to validate the theoretical analysis. A design based computational procedure is developed for performance analysis of single phase SEIG. This thesis reports a first successful virgin effort on the design and development of a 5 kW, 50 Hz, 230 V, 4-pole single-phase two winding SEIG. Performance of both three winding and two winding SEIGs driven by a prime mover supplying single phase loads are compared as regarded voltage regulation, power capacity under identical conditions to guide prospective users. Experimental investigation on performance of engine driven single phase SEIG is carried out with variety of bio-energy input like wood pellets, leaf pellets etc.

Finally, this research work promises a unified, generic and green technology to produce single phase electric power from small hydro and bio energy for rural and remote areas electrification by developing a suitable generator for such applications. This solution would be ideal to meet the local needs of energy.

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