

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

by

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**To My Country**  
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## **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.

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## 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.



## **CHAPTER- IV COMPREHENSIVE PERFORMANCE ANALYSIS OF TWO WINDING SINGLE PHASE SEIG**

4.1	General	45
4.2	Unified Equivalent Circuit Model	45
4.3	Method of Solution	49
	4.3.1 Effect of Assumptions	51
	4.3.2 Performance Analysis	53
4.4	Results and Discussion	57
4.5	Conclusions	60

## **CHAPTER- V DEVELOPMENT OF DESIGN BASED COMPUTATIONAL PROCEDURE FOR PERFORMANCE PREDICTION OF TWO WINDING SINGLE PHASE SEIG**

5.1	General	61
5.2	Design Based Computational Procedure	61
	5.2.1 Design Philosophy	62
	5.2.2 Determination of Parameters from Design Data	65
	5.2.3 Determination of Magnetisation Characteristics and Variation of $X_m$	66
	5.2.4 Curve Fitting of the Magnetisation Characteristics	67
	5.2.4.1 Definition of Best Fit	68
	5.2.4.2 Choice of Approximation Function	69
	5.2.4.3 Approximation by Explicit Expressions	72
5.3	Results and Discussion	79
	5.3.1 Performance Prediction	79
	5.3.2 Effect of Design Parameters	83
5.4	Conclusions	89

## **CHAPTER- VI DESIGN AND DEVELOPMENT OF 5 KW TWO WINDING SINGLE PHASE SEIG**

6.1	General	91
6.2	Design of Two Winding Single Phase SEIG	92
	6.2.1 Selection of Stator Magnetic Circuit	97
	6.2.2 Selection of Rotor Magnetic Circuit	100
	6.2.3 Design of Asymmetrical Two Phase Stator Windings	103
6.3	Design Based Computational Procedure for Performance Analysis	105
	6.3.1 Design with SPEED Software	105
	6.3.2 Performance Prediction	107
6.4	Development of Prototype Model	108
	6.4.1 Selection of Stator Stampings	108
	6.4.2 Selection of Rotor cage and Shaft	109
	6.4.3 Winding Connections	109
	6.4.4 Assembling and Testing	109

6.5	Testing of Prototype Machine and Results	110
6.5.1	Selection of Excitation Capacitor	110
6.5.2	Effect of Series Capacitor for Required Voltage Regulation	110
6.5.3	Effect of Shunt Capacitor for Required Voltage Regulation	111
6.5.4	Results and Discussion	112
6.6	Conclusions	117

**CHAPTER- VII INVESTIGATIONS ON CRITICAL COMPARISON OF DIFFERENT CAPACITOR TOPOLOGIES ON THREE WINDING (DELTA AND STAR) SINGLE PHASE SEIG**

7.1	General	119
7.2	Classification of Different Topologies	120
7.3	Unified Analysis for Three Phase SEIG with Single Phase Output	123
7.3.1	Generalized Model for Delta connected SEIG with Single Phase Output	123
7.3.2	Generalized Model for Star connected SEIG with Single Phase Output	129
7.4	Method of Solution	133
7.5	Results and Discussion	135
7.5.1	Performance Evaluation	136
7.5.1.1	Non -Workable Schemes	137
7.5.1.2	Workable Schemes with Poor Results	141
7.5.1.3	Workable Schemes with Good Results	147
7.5.2	Summary of Critical Comparison	153
7.6	Conclusions	155

**CHAPTER- VIII MODELLING AND SIMULATION OF SELECTED TOPOLOGIES OF THREE WINDING SINGLE PHASE SEIG**

8.1	General	157
8.2	Classification of Generating Schemes	157
8.3	MATLAB based Modeling and Simulation of Generating Schemes	160
8.4	Results and Discussion	162
8.4.1	Transient Performance of Generating Schemes	162
8.4.1.1	Performance of delta connected lagging phase excitation series compensated three winding single phase SEIG feeding R loads	163
8.4.1.2	Performance of delta connected lagging phase excitation series compensated three winding single phase SEIG feeding RL loads	166
8.4.1.3	Performance of delta connected lagging phase excitation short shunt compensated three winding single phase SEIG	169

	feeding R loads	
8.4.1.4	Performance of delta connected lagging phase excitation short shunt compensated three winding single phase SEIG feeding RL loads	172
8.4.1.5	Performance of delta connected lagging phase excitation long shunt compensated three winding single phase SEIG feeding R loads	175
8.4.1.6	Performance of delta connected lagging phase excitation long shunt compensated three winding single phase SEIG feeding RL loads	178
8.4.1.7	Performance of delta connected lagging phase excitation shunt compensated three winding single phase SEIG feeding R loads	181
8.4.1.8	Performance of delta connected lagging phase excitation shunt compensated three winding single phase SEIG feeding RL loads	184
8.5	Conclusions	187

## **CHAPTER- IX ANALYTICAL PERFORMANCE COMPARISON OF TWO WINDING AND THREE WINDING SINGLE PHASE SEIG**

9.1	General	189
9.2	Performance of Two Winding Single Phase SEIG	189
	9.2.1 Results and Discussion	191
9.3	Performance of Three Winding Single Phase SEIG	193
	9.3.1 Results and Discussion	194
9.4	Critical Comparison of Results	196
9.5	Conclusions	197

## **CHAPTER- X EXPERIMENTAL INVESTIGATIONS OF ENGINE DRIVEN SEIG**

10.1	General	199
10.2	Experiment Details And Methodology	200
	10.2.1 Selection of Fuel and its Properties	201
	10.2.2 Biomass Gasification	202
	10.2.3 Details of Engine	202
	10.2.4 Tested Generator - Single Phase SEIG	204
	10.2.5 Connected Loads	204
10.3	Calculation of Biomass Gasification Efficiency	204
10.4	Performance Results of the Generator	204
	10.4.1 Petrol Engine driven single phase SEIG	205
	10.4.2 Bio-engine driven Single Phase SEIG using leaf pellets input	209
	10.4.3 Bio-engine driven Single Phase SEIG using wood pellets input	210

10.5	Comparison of Results and Discussion	211
10.6	Conclusions	214
<b>CHAPTER- XI MAIN CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK</b>		
11.1	General	215
11.2	Main Conclusions	216
11.3	Suggestions for Further Work	219
<b>REFERENCES</b>		221
<b>APPENDICES</b>		241
<b>LIST OF PUBLICATIONS</b>		261
<b>BIO-DATA</b>		263