

**INVESTIGATIONS ON COMPUTER AIDED ANALYSIS AND
CONTROL ASPECTS OF
THREE-PHASE SELF-EXCITED INDUCTION GENERATOR
FOR DECENTRALIZED POWER GENERATION**

By

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In
Loving Memory
Of
My Grand Parents Laala ji & Beji
Late
Sh Mansa Ram Ahuja & Smt Ramditi Ahuja

CERTIFICATE

This is to certify that thesis entitled **“Investigations On Computer Aided Analysis And Control Aspects Of Three Phase Self Excited Induction Generator For Decentralized Power Generation ,”** being submitted by **Mr. Rajesh Kumar Ahuja** for the award of the degree of **Doctor of Philosophy** is a record of bonafide work carried out by him under my guidance and supervision.

Mr. Rajesh Kumar Ahuja has fulfilled the requirements for the submission of this thesis, which to my knowledge has reached the requisite standard. The results obtained herein have not been submitted in part or in full to any other University or Institute for the award of any degree.

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ABSTRACT

In last two decades, self excited induction generator (SEIG) has attracted considerable attention due to its applicability as a standalone generator using some of conventional and non conventional energy resources. Supplying electrical energy to rural and hilly areas is another area of concern as it involves high cost and hard maintenance requirements. Application of SEIG in stand alone mode has emerged as a viable option due to its numerous advantages over conventional synchronous generator such as simpler construction, robustness, small in size, reduced unit cost, easy to maintain, absence of DC supply, brushless feature and better transient response.

The steady state analysis of self excited induction generator (SEIG) is vital for proper implementation of induction machine operation as a generator in a stand alone mode through appropriate modeling. Considerable literature is available on the steady state analysis of the SEIG which illustrates the correlation among the reactive power requirements, speed of prime mover and balanced/unbalanced loads. The reported literature is found to have complicated algorithm to find the behavior of SEIG with load or to know the excitation requirement of SEIG with load. In this thesis an attempt has been made to develop a user friendly software based solution for complete evaluation of steady-state behavior of SEIG and a design tool to estimate the capacitance requirement under different operating conditions. It can also predict the performance of SEIG with different types of prime movers such as oil / bio engines, wind and small hydro turbines. The mathematical modeling of the machine is carried out and then simulated in MATLAB's Graphical User Interface (GUI) environment and active windows are created with these models. As a basis for developing an attractive and easy to use design tool, some of MATLAB's GUI operations are implemented in creating an active link with these models. The simulation results

obtained through the presented methodology are validated through relevant experimental verification.

This thesis presents a critical comparison and analysis of different modes of using a normal three-phase induction motor as a self-excited induction generator (SEIG) to feed single phase loads specially for energizing isolated locations using locally available renewable energy. Both star and delta connected machines are considered with different capacitor excitation topologies. A generalized analytical procedure for performance prediction of all such systems has been presented using the concept of symmetrical components with some simplifying assumptions. The method is suitable to account for saturation and resultant non-linear magnetizing reactance. Unlike most of the previous approaches, the proposed method does not require the detailed derivation of the equations to be solved. Instead, the method uses a numerical-based 'F-solve' subroutine of MATLAB that drastically reduces the time and effort needed to formulate the problem and evaluate the performance. Extensive experimental data of a 7.5kW machine in the laboratory are presented and shown to match with predicted ones thus validating the procedure used. Performance of different machine and excitation topologies are studied and critically compared with a view to provide guidelines to a user on the best system to choose for a given application. A user friendly MATLAB GUI based software tool for complete evaluation of steady-state behavior of SEIG under different operating conditions based on above analysis is also presented in this thesis.

Recently renewable energy systems (RES) have attracted great attention recently due to problems of conventional energy such as its impact on environment pollution, green house gas effects and climate change. Wind energy has emerged as a viable RES with several gigawatts (GW) of grid fed wind power units installed globally and

this capacity steadily increasing. For isolated remote and rural areas with rich wind potential stand alone off grid systems are attractive as it avoids drawing of long grid lines and grid interface issues. For RES, selection of generator and designing of the controller is a challenging task due to varying prime mover characteristics, for example in a wind system, wind speed and hence the output of the wind turbine varies. In this situation to maintain constant voltage and frequency is difficult. Due to its low maintenance cost and rugged construction, self excited induction generator is attractive for such renewable energy application. This thesis also attempts to provide such a user friendly software package using MATLAB tool boxes with GUI facility for capacitor and maximum power point (MPP) estimation under different operating conditions for wind turbine driven three-phase self-excited induction generator.

Other prominent case of stand alone power generation relates to engine driven generators. Fuel for such engines may be oil, gas, biomass. Governor control of engine ensures automatic power balance unlike a small hydro turbine with no governor control. Here the speed is nearly constant with marginal drop from no load to full load. SEIG can be an attractive option here too. But suitable controller needs to be developed for desired power quality of voltage and frequency at varying loads and nature of loads. This thesis presents a control structure for Self Excited Induction Generator (SEIG) for stand alone operation under variable loads. The proposed system uses PWM Voltage Source Inverter, DC-DC Boost Converter and diode bridge Rectifier with SEIG. The required reactive power for the SEIG is supplied by means of a capacitor bank and the PWM converter to build up the voltage. The DC-DC Boost Converter maintains constant dc link voltage at the input terminals of PWM Voltage Source Inverter. The consumer load is connected across VSI through LC filter. The proposed control strategy has good ac voltage regulation at all loads with

no harmonic problems. The performance of proposed controller is simulated using MATLAB SIMULINK to demonstrate its capability as a voltage regulator and a harmonic eliminator. This scheme can be efficiently used for decentralized power generation in suitable applications.

This thesis presents the detailed design, fabrication and analysis of an analog electronic load controller (ELC) suitable for stand alone pico-hydel power stations having a three-phase SEIG feeding single phase load, which is simple, cost effective and encapsulate protective features. Proposed ELC incorporates 0-100% duty ratio of chopper for PWM pulses which makes ELC to remain in service starting from zero speed hence SEIG can be started at any combination of main and dump load. This prevents the SEIG from unnecessary loading and improves its transient behavior during self excitation process. Power supply for controller and cabinet cooling fan is also extracted from SEIG terminals. Proposed ELC is very cost effective and viable with minimum number of components and full protections, tested in laboratory for 5.5kW load. Performance of the above system is simulated and supplemented with experimental results.

TABLE OF CONTENTS

	Page No.
Certificate	i
Acknowledgements	ii
Abstract	iv
Table of Contents	viii
List of Figures	xv
List of Tables	xxiv
List of Symbols	xxv

CHAPTER-I INTRODUCTION

1.1	General	1
1.2	Self excited induction generator for off grid power generation	3
1.2.1	The phenomenon of self-excitation in SEIG	4
1.2.2	Conditions for self excitation	6
1.3	State of art	6
1.4	Scope of the work	9
1.5	Organization of the thesis	12

CHAPTER-II LITERATURE SURVEY

2.1	General	14
2.2	Literature review	15
2.2.1	SEIG driven by constant speed prime movers	19

2.2.2	SEIG driven by constant power prime movers	20
2.2.3	Voltage and frequency control through improved power quality controller	21
2.3	Identified research areas	22
2.4	Conclusions	23

CHAPTER-III A USER FRIENDLY COMPUTER BASED ANALYSIS OF THREE PHASE SELF EXCITED INDUCTION GENERATORS USING GRAPHICAL USER INTERFACE BASED METHODOLOGY OF MATLAB

3.1	General	24
3.2	Modeling and analysis of self excited induction generator	26
3.3	Demonstration of developed tool	29
3.4	Simulation results	31
3.5	Experimental verification	41
3.6	Conclusions	47

CHAPTER-IV STEADY STATE ANALYSIS AND COMPARISON OF DIFFERENT CONFIGURATIONS OF THREE-PHASE SELF EXCITED INDUCTION GENERATOR FEEDING SINGLE-PHASE LOADS

4.1	General	48
4.2	System description and model equation	50
4.2.1	Star connected machine	52
4.2.2	Delta connected machine	55
4.3	Single phase operation	58
4.3.1	Star connected machine with three capacitors	58
4.3.2	Star connected machine with two capacitors	59
4.3.3	Delta connected machine with two capacitors	60

4.3.4	Delta connected machine with three capacitors	61
4.4	Method of solution	62
4.4.1	Star connected machine	64
4.4.2	Delta connected machine	
4.5	Performance equations	66
4.5.1	Star connected machine	67
4.5.2	Delta connected machine	67
4.6	Experimental details	68
4.7	Results and discussion	69
4.7.1	Star connected machine	69
4.7.1.1	Three capacitors topology	69
4.7.1.2	Two capacitor topology	73
4.7.2	Delta connected machine single-phase load	74
4.7.2.1	Two capacitor excitation topology	74
4.7.2.2	Three capacitors topology	78
4.8	Discussion	79
4.9	Conclusions	81

CHAPTER-V MATLAB GUI BASED STEADY STATE ANALYSIS OF THREE PHASE SELF EXCITED INDUCTION GENERATOR FEEDING SINGLE PHASE LOADS WITH DIFFERENT CONNECTIONS AND CAPACITOR CONFIGURATIONS

5.1	General	83
5.2	Matlab GUI based analysis of three phase star connected induction machine used as SEIG for single phase operation using three capacitor (star) configuration	

5.2.1	Demonstration of developed tool	87
5.2.2	Simulation results	89
5.2.3	Experimental verification	94
5.3	Matlab GUI based analysis of three phase delta connected induction machine used as SEIG for single phase operation using two capacitor (c-2c) configuration	
5.3.1	Demonstration of developed tool	98
5.3.2	Simulation results	99
5.3.3	Experimental verification	107
5.4	Conclusions	110

CHAPTER- VI CAPACITIVE VAR AND MPPT ESTIMATION OF WIND TURBINE DRIVEN THREE PHASE SELF EXCITED INDUCTION GENERATOR USING MATLAB GUI

6.1	General	111
6.2	Wind turbine driven self excited induction generators	112
6.3	Modeling of wind turbine	113
6.4	Demonstration of developed tool for wind turbine driven SEIG	115
6.5	Simulation results	116
6.6	Experimental verification	120
6.7	Conclusions	121

CHAPTER-VII VARIOUS CONTROL ASPECTS OF THREE PHASE SELF EXCITED INDUCTION GENERATOR

7.1	General	123
7.2	Switched capacitance scheme	124

7.2.1	Simulation results	126
7.3	Integral cycle control	128
7.3.1	Simulation	130
7.4	Capacitive VAR control using DSTATCOM	133
7.4.1	SRF (synchronous reference frame) theory based control algorithm of DSTATCOM	
7.4.1.1	Simulation with SRF (synchronous reference frame) theory based control algorithm	
7.4.2	IRPT (instantaneous reactive power theory) based control algorithm of DSTATCOM	
7.4.2.1	Simulation with instantaneous reactive power theory (IRPT) based control algorithm	
7.5	Capacitive VAR control with STATCOM	147
7.5.1	Control scheme of SEIG-STATCOM system	148
7.5.1.1	Capacitive VAR control with STATCOM feeding single phase load using two-capacitor configuration	
7.5.1.1.1	Simulation of SEIG system with STATCOM feeding single phase load using two-capacitor configuration	
7.5.1.2	Capacitive VAR control with STATCOM feeding single phase load using three-capacitor configuration	
7.5.1.2.1	Simulation of SEIG system with STATCOM feeding single phase load using three-capacitor configuration	
7.6	Three phase SEIG electronic load controller (ELC)	160
7.6.1	Simulation of SEIG –ELC system	161
7.7	Conclusions	163

**CHAPTER-VIII SOLID STATE VOLTAGE CONTROLLER OF THREE
PHASE SELF EXCITED INDUCTION GENERATOR
FOR DECENTRALIZED POWER GENERATION**

8.1	General	165
8.2	Principal of operation of circuit	166
8.3	Modeling of self excited induction generator	168
8.4	Design of PI controller and control of boost dc-dc converter	170
8.5	Simulation results	171
	8.5.1 Performance of the system feeding loads	
8.6	Conclusions	182

**CHAPTER-IX A PRACTICAL, VIABLE AND LOW COST
ELECTRONIC LOAD CONTROLLER FOR OFF-GRID
SMALL HYDRO UNIT USING SELF EXCITED
INDUCTION GENERATOR**

9.1	General	183
9.2	System description and operating principles	186
9.3	Design of ELC	187
	9.3.1 Power circuit design	187
	9.3.2 Snubber circuit design	189
	9.3.3 Power supply	191
	9.3.4 Control circuit	193
9.4	ELC-UNIT	197
9.5	Experimental results	200
9.6	Simulation results	212
9.7	Effect of sudden change of load	214

9.8	Load characteristics	219
9.9	Conclusions	219

CHAPTER-X MAIN CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

10.1	General	221
10.2	Main conclusions	222
10.3	Suggestions for further work	226

REFERENCES

APPENDICES

LIST OF PUBLICATIONS

BIO-DATA