سامية محمد مصطفى

شبكة المعلومات الجامعية

# بسم الله الرحمن الرحيم


سامية محمد مصطفى

شبكة المعلومات الجامعية


# شبكة المعلومات الجامعية

# التوثيق الالكتروني والميكروفيلم


شبكة المعلومات الجامعية

سامية محمد مصطفى

# جامعة عين شمس

## التوثيق الإلكتروني والميكروفيلم

# قسم

## نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات


# يجب أن

## تحفظ هذه الأقراص المدمجة بعيدا عن الغبار

سامية محمد مصطفى

شبكة المعلومات الجامعية


# بعض الوثائق الأصلية تالفة

سامية محمد مصطفى

شبكة المعلومات الجامعية


# بالرسالة صفحات لم ترد بالأصل

ALEXANDRIA UNIVERSITY

FACULTY OF ENGINEERING

# *Performance Improvement of Self Excited Induction Generator for Renewable Energy System*

A thesis submitted to the

Department of Electrical Engineering

in partial fulfillment of the requirements for the degree of

**Master of Science**

by

***Eman Saad Hamed El-Hawatt***

supervised by

***Prof. Dr. Mohamed Shafik Abou El-Ela***
***Prof. Dr. Nagi Sorial***

1994

*We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science.*

*Exam Comittee:*

***1. Prof. Dr Adel Lotfy Mohamadain.***

*Department of Electrical Engineering.*

*Alexandria University.*

***2. Prof. Dr. Nagy Sorial.***

*Department of Electrical Engineering.*

*Alexandria University.*

***3. Prof. Dr. Mohamed Mostafa El-Shanawany.***

*Department of Electrical Engineering.*

*Elmonofia University.*

***4. Prof Dr. Mohamed Shafik.***

*Department of Electrical Engineering.*

*Alexandria University.*

## ABSTRACT

During the last recent years, a large number of research projects focused on the use and development of new systems utilization alternative sources of energy.

The work covered the development of sources and increase in their productivity, reliability, efficiency and economy. The research project presented aims at improving the performance of self excited induction generators (S.E.I.G.). This type of generators has been known for a long time but it limited in its application, although it offers advantages in other aspects.

The research focuses on improving the performance characteristics of S.E.I.G by introducing control on its exciting capacitors when the three phase induction generator is used to supply single phase load, i.e at an unbalanced operation. Obtained results showed substantial improvement in voltage regulation and stability by introducing a feed back control loop with excitation current using SCR devices. Laboratory investigation were also performed to show the practicality of the solution performed to show the validity of the proposed techniques. The research outlines the main characteristics of self excitation, and the theory behind it. It also surveys recent researches topics relevant to that subject. A brief description of the theory of self excitation is given with a complete evaluation for the performance obtained and its limitations.

# *Acknowledgment*

*The author wishes to express her sincere gratitude to Prof. Dr. Mohamed Shafik Abou El-Ela for his inspiration, encouragement, valuable suggestions and patience throughout the course of this research, and Prof Dr. Nagi Sorial for his indispinsable help and interest during this work.*

# TABLE OF CONTENTS



Page

Abstract . . . . . i

Contents . . . . . ii

Chapter I INTRODUCTION

1.1 General Introduction . . . . . 1

1.2 Historical review . . . . . 3

1.2.1 Small and medium wind energy system (S.W.E.S) . . . . . 8

1.2.1.1 Electricity generation . . . . 8

1.2.1.1.1 Stand alone D.C. system . 8

1.2.1.1.2 Stand alone 50 Hz system 10

1.2.1.2 Mini hydro electric plant . . . 14

1.2.1.2.1 Pneumatic conversion for law hydro electric power . . . 14

1.2.1.2.2 Pneumatic hydro electric - duct system . . . 17

1.3 Thesis objectives. . . . . 19

1.4 Thesis organization. . . . . 20

Page

Chapter II THEORY AND CHARACTERISTICS OF CAPACITIVE SELF EXCITING INDUCTION GENERATOR


2.1 Introduction . . . . . 22

2.2 Theory of C.S.E.I.G . . . . . 22

2.2.1 The induction machine as a motor operation 23

2.2.2 The induction machine as a generator . . . 25

2.3 Parameter which affect the generator output voltage . . . . . 27

2.3.1 Effect of terminal capacitor . . . . . 28

2.3.2 Effect of machine parameter . . . . . 31

2.3.2.1. Stator resistance $R_s$ . . . . . 31

2.3.2.2. Leakage reactance $X_s$, $X_r$ . . . . 31

2.3.2.3. Magnetizing reactance $X_m$ . . . . 33

2.3.2.4. Rotor resistance $R_r$ . . . . . 33

2.3.3 Effect of speed . . . . . 33

2.4 Balance operation of the self excited induction generator . . . . . 37

2.5 Unbalanced operation of C.S.E.I.G . . . . . 38

2.6 Load characteristic of induction generator . . . 47

2.6.1 No-load characteristic . . . . . 47

2.6.2 Load characteristic . . . . . 47

page

2.7 Self excited single phase induction generator . 49
2.7.1 Single winding stator . . . . . 51
2.7.2 Two winding induction generator . . . . . 51
2.7.3 Final working scheme . . . . . 53
2.8 Effect of system parameters . . . . . 55
2.8.1 Effect of power factor . . . . . 55
2.8.2 Effect of excitation capacitor . . . . . 55
2.8.3 Effect of auxiliary winding parameter . . 55
2.8.3.1 Effect of winding resistance . 55
2.8.3.2 Effect of leakage reactance . . 57
2.8.4 Effect of rotor parameter . . . . . 57
2.8.4.1 Effect of rotor resistance . . . 57
2.8.4.2 Effect of rotor leakage reactance 57
2.8.5 Effect of series capacitor . . . . . 57
2.9 Load characteristic curves . . . . . 59
2.10 Summary and comments . . . . . 59

Chapter III VOLTAGE REGULATION OF C.S.E.I.G

3.1 Introduction . . . . . 62

3.2 Capacitor evaluation for C.S.E.I.G. . . . . 62
3.2.1 Calculation of slip . . . . . 63
3.2.2 Calculation of excitation capacitor . . . 67
3.2.3 Computer program to calculate slip and capacitor excitor . . . . . 72

page

3.2.4 Frequency calculation in unbalance operation . . . . . 72
3.2.5 Computation technique . . . . . 84
3.3 Methods of voltage regulation . . . . . 89
3.3.1 Thyristor controlled inductor . . . . . 93
3.3.2 Inductivity loaded AC/DC converter . . . 93
3.3.3 Switched capacitors . . . . . 93
3.3.4 D.C. power control . . . . . 96
3.3.5 Comparison between voltage regulator methods . . . . . 96
3.4 Design of capacitance variation regulation . . . 99
3.4.1 Manual control circuit diagram . . . . . 99
3.4.2 Automatic control circuit diagram . . . . 109

Chapter IV PRACTICAL RESULTS

4.1 Introduction . . . . . 112
4.2 Analytical results . . . . . 112
4.2.1 Relation between slip and load at balance operation . . . . . 112
4.2.2 Relation between frequency load resistance at unbalance operation . . . . 114
4.3 Practical result . . . . . 117
4.3.1 Open circuit characteristics . . . . . 117

page

4.3.2 Load characteristic . . . . . 119

4.3.2.1 Balance load characteristics . . 121

4.3.2.2 Unbalance operation . . . . . 124

4.3.2.3 Capacitance variation voltage regulation result . . . . . 126

4.4 Waveform of the output voltage . . . . . 129

Chapter V Conclusion

5.1 Introduction . . . . . 135

5.2 Achievments and conclusions . . . . . 136

5.3 Future work. . . . . 137

References . . . . . 139

Appendix I . . . . . .

Appendix II . . . . . .

Appendix III . . . . . .

Appendix IV . . . . . .

Appendix V . . . . . .

# LIST OF SYMBOLS

| | |
|---|---|
| OM | Motoring vector. |
| OG | Generator vector. |
| V | Output terminal voltage. |
| $R_1$, $R_s$ | Stator resistance. |
| $X_1$, ($X_s$) | Stator reactance. |
| $R_2$, ($R_r$) | Rotor resistance. |
| $X_2$, ($X_r$) | Rotor reactance. |
| $X_m$ | Magnetizing reactance of induction machine. |
| $x_c$ | Excitation capacitor reactance. |
| $R_m$ | Magnetizing resistance of induction machine. |
| $V_{0.C}$ | Open circuit voltage. |
| $V_m$ | Working voltage (operating voltage) when the machine act as a motor. |
| $I_m$ | Magnetizing current. |
| $I_c$ | Capacitor current. |
| S | Slip of rotating machine |
| $L_s$ | Stator inductance. |
| $L_r$ | Rotor inductance. |
| $L_{sr}$ | Magnetizing inductance. |
| w | Angular frequency. |
| $I_D$ | Stator direct axis current. |
| $I_Q$ | Stator quadrature axis current. |
| $I_d$ | Rotor direct axis current. |
| $I_q$ | Rotor quadrature axis current. |
| $V_Q$ | Stator quadrature axis generator voltage. |
| C | Excitation capacitance for 3-phase induction generator. |