



**AIN SHAMS UNIVERSITY  
FACULTY OF ENGINEERING  
ELECTRICAL POWER AND MACHINES DEPT.**

# **Improvement of Microgrid Systems Using Synchronverters**

**A Thesis**

**submitted in partial fulfillment of the requirements of the  
degree of**

**Doctor of Philosophy In Electrical Engineering  
(Electrical Power and Machines Engineering)**

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## **STATEMENT**

This Thesis is submitted to Ain Shams University in partial fulfillment of the requirements for Doctor Degree of Philosophy in Electrical Power and Machinery.

The included work in this thesis has been carried out by the author at the department of electrical power and machines, Ain Shams University. No part of this thesis has been submitted for a degree or a qualification at any other university or institution.

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**Mohamed Hassan Shaalan**

**Cairo, Egypt, 2018**

## **Abstract**

In typical electrical power system, enormous synchronous generators (SGs) driven by different types of prim-movers generate the major bulk of electrical power. Virtually the individual inertia of separate SGs are summed to give an equivalent huge inertia rotating at synchronous speed. In case of a fault or disturbance, the kinetic energy reserved in this huge inertia is injected to the power system to maintain the energy balance, prevents sudden changes in frequency, and enhances the stability of power system.

The contribution of renewable energy sources is gradually taking a remarkable share of the total electrical power generated. The trend is to inject the energy obtained from these resources in main grid or small local grids using inverter-based systems. With this trend, these renewable sources have no contribution to rotating inertia, and stability problems may arise specially in small power networks -called micro grids- or when the total share of renewable resources reaches a remarkable percent of the total power generated (case of distributed generation DG).

If the mathematical model of SG is combined with the inverter control algorithm to emulate the dynamic behavior of a SG, the above renewable-energy sources can enhance power system performance in the same way as adding conventional SGs.

They can take a certain share of the active and reactive power depending on their rating as well as contributing to the system inertia and consequently the stored kinetic energy. This preserves the original features of the conventional power system and makes the best use of renewable-energy resources. The two terms Synchronverter (SV) and Virtual Synchronous Generator (VSG) are used equivalently or interchangeably to name the above system.

The issues concerning SV and VSG including; mode of operation whether stand alone or connected in a microgrid (MG), synchronization method with grid or with each other's, methods of control of active and reactive power share,... etc., have attracted great deal of engineering research in the last two decades.

This dissertation deeply investigates two cases of SV and introduces suggestions to improve MG performance. First case of SV is based on the full mathematical model of SG expressing its electrical and mechanical parts without restricting assumptions. In this case of SV details of simulation are presented and problems normally arise including synchronization, active power sharing and reactive power sharing are thoroughly investigated. Both standalone and micro-grid modes of operation are considered. Improvements of micro-grid performance using SV are clarified. Instead of the complicated Phase Locked Loop (PLL)

synchronization units normally used [1], [2] this thesis presents and verifies a simple synchronization unit based on ideal synchronization condition.

The second case of SV considered here is based on the swing equation of the SG. This instance of SV -mostly called (VSG) - is concerned only with grid or micro-grid mode of operation. In this case, the gating signals of the PWM inverter of SV is continually synchronized with micro-grid voltage signals. Problems relating to synchronization are completely absent in this case. Normally, active power share of VSG is controlled indirectly by control of frequency [3]. Here, this thesis introduces another control approach for active power sharing based on direct control of power angle. This SV scheme improves MG performance more noticeably than the previous scheme especially in those aspects concerning frequency stability when MG is subjected to severe disturbances.

This thesis presents Simulink models and simulation results for each part of the work to prove feasibility, effectiveness and improvements gained. A detailed review of the existing SV topologies and control schemes is presented.

**Key Words:** Distributed generation, frequency drooping, load sharing, microgrid, smart grid, synchronous generator, synchronverter, virtual synchronous generator.

# **TABLE OF CONTENTS**

<i>SUPERVISORS COMMITTEE</i> .....	I
<i>STATEMENT</i> .....	III
<i>Researcher Data</i> .....	IV
<i>ACKNOWLEDGMENT</i> .....	V
<i>Abstract</i> .....	VI
<b><i>LIST OF FIGURES</i></b> .....	XII
<b><i>LIST OF TABLES</i></b> .....	XVIII
<b><i>LIST OF MAIN SYMBOLS AND ABBREVIATIONS</i></b> .....	XIX
<b>CHAPTER 1 INTRODUCTION</b> .....	<b>1</b>
1.1 Microgrid (MG).....	1
1.2 Fundamentals and Structure of SV .....	2
1.3 Synchronverter in Microgrid .....	3
1.4 Existing SV Topologie .....	5
1.5 Thesis Objective and Layout.....	6
1.5.1 Aims and Objectives.....	6
1.5.2 Novel Contributions of the thesis .....	6
1.5.3 Organization of the Thesis.....	6
1.6 Published Work [1-3].....	7
<b>CHAPTER 2 CONTROL TECHNIQUES FOR MICROGRID BASED ON SV</b> .....	<b>8</b>
2.1 Introductioni .....	8
2.2 Droop Control.....	10
2.2.1 Droop Control Concept .....	10
2.2.2 Droop control limitations .....	14
2.2.3 Enhancements on the droop control .....	15
2.3 Power Sharing.....	19

CHAPTER 3            MODELING, ANALYSIS, AND DESIGN OF SVs FOR MG ..... 20

3.1 General ..... 20

3.2 Mathematica Model of SV based on the full system of equation representing the SG ..... 21

3.2.1 Mathematical Model of SG ..... 21

    3.2.1.1 Electrical Part..... 21

    3.2.1.2 Mechanical Part..... 23

3.2.2 Implementation of a SV..... 24

    3.2.2.1 Electrical Part..... 25

    3.2.2.2 Mechanical Part..... 26

3.2.3 Operation of a SV ..... 27

    3.2.3.1 Frequency Drooping and Regulation of Real Power ..... 27

    3.2.3.2 Voltage Drooping and Regulation of Reactive Power ..... 29

    3.2.3.3 The Peak Voltage, Phase Angle and Frequency Acquisition..... 30

3.2.4 Description of building blocks of SV unit..... 33

    3.2.4.1 The SV control unit ..... 34

    3.2.4.2 PWM Inverter ..... 35

    3.2.4.3 LC filter unit ..... 35

    3.2.4.4 Automatic synchronization unit ..... 35

    3.2.4.5 The Grid unit..... 35

3.3 Mathematical Model of SV based on a linearized small-signal model of swing equation of SG..... 35

3.3.1 Introduction ..... 35

3.3.2 Model of Synchronous Generator ..... 36

3.3.3 The Mechanical Model of Synchronous Generator and Swing Equation ... 37

3.3.4 Suggested Power Angle Control ..... 39

CHAPTER 4	SYSTEM SIMULATIONS AND CASE STUDIES .....	41
4.1	Introduction .....	41
4.2	Case Study One.....	42
4.2.1	Three phase Signal Acquisition Circuit response (Peak Voltage, Phase Angle and Frequency) .....	43
4.2.2	Comparison of Induction Motor load Cases.....	44
4.2.3	Case of 16-kVA ratings.....	47
4.2.4	Case of 31.3-KVA ratings .....	51
4.2.5	Comparison of Response with Change Inertia .....	55
4.3	Case Study Two.....	57
4.3.1	MG Test.....	58
4.3.2	Effect of Increasing the Inertia.....	60
4.4	Case Study Three .....	63
4.4.1	Two SVs of 31.3KVA in MG.....	63
4.4.2	One 31.3kVA SV and One 16kVA SV forming a MG .....	64
4.5	Case Study Four .....	66
4.5.1	Transfer from Grid Isolated Mode-Grid Connected Mode and Vice Versa	67
4.5.2.1	One SV operated in the two modes (Island/Grid) with resistive loads	67
4.5.2.2	One SV operated in the two modes (Island / Grid) with inductive and motor loads .....	69
4.6	Effects of Damping Constant D and Inertia Constant H in PAC of SV .....	71
CHAPTER 5	CONCLUSIONSANDRECOMMENDATION FOR FUTURE WORK....	74
5.1	Conclusions.....	74
5.2	Recommendation for Future work .....	74
REFERENCES	.....	75
APPENDIX (A)	.....	83

## ***LIST OF FIGURES***

<b>Fig. No.</b>	<b>Title</b>	<b>Page</b>
Figure 1-1:	Microgrid structure of multi parallel DC/AC converters supplied by RESs [5].	1
Figure 1-2:	Inverter structure containing six IGBTs with LCL filter.	2
Figure 1-3:	General Structure and concept of the SV.	3
Figure 2-1:	MG structure includes RESs with its DC/DC, AC/DC and DC/AC.	9
Figure 2-2:	Master- Slave Control System.	9
Figure 2-3:	Power flow control between two voltage sources nodes.	11
Figure 2-4:	Two islanded inverters connected to a load.	11
Figure 2-5:	P- and Q-V droop control curves.	13
Figure 2-6:	Diagram of droop control.	14
Figure 3-1:	Structure of an idealized 3-phase round-rotor SG, modified from[97].	22
Figure 3-2:	Power part of a SV—a three phase inverter, including LC filters.	24
Figure 3-3:	Electronic part of a SV. interacts with the power part via e and i.	25
Figure 3-4:	Regulation of the real and reactive power in a SV.	27
Figure 3-5:	Proposed regulation of the real and reactive power in a SV.	28
Figure 3-6:	Block diagram measurements unit.	31
Figure 3-6:	Detailed Simulink model of Measurement unit.	31
Figure 3-8:	Details Simulink model of Synchronization Unit.	31
Figure 3-9:	9 Complete Simulink model of one SV operated in the two modes.	32
Figure 3-10:	Simulink model of two SVs simulating MG in the two modes.	32
Figure 3-11:	Complete Simulink model of SV.	34
Figure 3-12:	Complete Simulink model of SV control.	34
Figure 3-13:	Synchronous machine equivalent circuit.	36
Figure 3-14:	Power-angle curve.	37
Figure 3-15:	The Suggested Power Angle Control Scheme.	40
Figure 3-16:	The Small Signal Model of Power Angle of SG.	40
Figure 4-1:	Output of the 3-phase Signal Acquisitions.	43

## LIST OF FIGURES ....Cont.

<b>Fig. No.</b>	<b>Title</b>	<b>Page</b>
Figure 4-2:	Schematic diagram of the 31.3-KVA SV with Motor No Load (MNL).....	44
Figure 4-3:	Diagram of 31.3KVA SVwith Motor Start N L Then Loaded at 1S (MSNL).....	45
Figure 4-4:	Schematic diagram of the 31.3-KVA SV with Motor Start Loaded (MSL).....	45
Figure 4-5:	Comparison of frequency stability of MNL, MSNL and MSL (31.3kVA).....	46
Figure 4-6:	Comparison of terminal voltage of MNL, MSNL and MSL (31.3kVA).....	46
Figure 4-7:	Comparison of active power of MNL, MSNL and MSL (31.3kVA).....	46
Figure 4-8:	Comparison of reactive power of MNL, MSNL and MSL (31.3kVA).....	47
Figure 4-9:	Comparison of apparent power of MNL, MSNL and MSL (31.3kVA).....	47
Figure 4-10:	Schematic diagram of the 16KVA INV.....	48
Figure 4-11:	Schematic diagram of the 16KVA SG.....	48
Figure 4-12:	Schematic diagram of the 16KVA SV.....	48
Figure 4-13:	Comparison of frequency stability of INV, SG and SV (16kVA).....	49
Figure 4-14:	Comparison of terminal voltage of INV, SG and SV (16kVA).....	50
Figure 4-15:	Comparison of current of INV, SG and SV (16kVA).....	50
Figure 4-16:	Comparison of active power of INV, SG and SV (16kVA).....	50
Figure 4-17:	Comparison of reactive power of INV, SG and SV (16kVA).....	51

## LIST OF FIGURES ....Cont.

<b>Fig. No.</b>	<b>Title</b>	<b>Page</b>
Figure 4-18:	Comparison of apparent power of INV, SG and SV (16kVA)..	51
Figure 4-19:	Schematic diagram of the INV 31.3KVA rating.....	52
Figure 4-20:	Schematic diagram of the SG 31.3KVA rating.....	52
Figure 4-21:	Schematic diagram of the SV 31.3KVA rating.....	52
Figure 4-22:	Comparison of frequency responses of INV, SG, SV of 31.3KVA rating.....	53
Figure 4-23:	Comparison of voltage responses of INV, SG, SV of 31.3KVA rating.....	53
Figure 4-24:	Comparison of current responses of INV, SG, SV of 31.3KVA rating.....	53
Figure 4-25:	Comparison of active power responses of INV, SG, SV of 31.3KVA rating.....	54
Figure 4-26:	Comparison of reactive power responses of INV, SG, SV of 31.3KVA rating.....	54
Figure 4-27:	Comparison of apparent power responses of INV, SG, SV of 31.3KVA rating.....	54
Figure 4-28:	Schematic diagram of the SV 31.3KVA rating with changing inertia by $\pm 20\%$ .....	55
Figure 4-29:	Comparison of frequency stability of SV with changing inertia by $\pm 20\%$ .....	55
Figure 4-30:	Expanded view at $t=2S$ of Fig 4.29.....	56
Figure 4-31:	Comparison of voltage responses of SV with changing inertia by $\pm 20\%$ .....	56
Figure 4-32:	Expanded view at $t=3.5S$ of Fig 4.31.....	56
Figure 4-33:	Diagram of MG comprising a SG in parallel with INV.....	57