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)

By

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CAIRO - EGYPT - 2018

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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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ACKNOWLEDGMENT

First and foremost I want to thank the source of every success to **ALLAH;** Next I want to thank my advisors **Prof. Dr. Mohammad Anwar Elsayad** and **Dr. Amr Magdy Abdin** for their guidance and supports throughout the work.

Last and surely not least, I want to acknowledge my **family** for their encouragement throughout my educational adventure. Their support means everything to me.

It is always impossible to personally thank everyone who has facilitated successful completion of this thesis. To those of you who I did not specifically name, I also give my thanks for moving me towards my goal.

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] 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, 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 sever 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.

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