Ain Shams University

Faculty of Engineering

Electrical Power and Machines Department

Primary and Secondary Control on Autonomous Microgrid operation

M.Sc. Thesis

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Submitted in partial fulfilment of the requirements for the M.Sc. degree in Electrical Engineering

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STATEMENT

This Thesis is submitted to Ain Shams University in partial fulfillment of the requirements for M.Sc. degree in Electrical Engineering.

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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Abstract

The energy industry sector is moving into an era where electrical grids are more intelligent and flexible. However, production of energy from large number of small geographically distributed sources is the main trend now. Microgrids realize the aforementioned trends. They comprise different technologies such as power electronic converters, distributed generation, energy storage systems, and communications. These new power generation paradigms rely much on their control strategies for proper operation. Hierarchal control strategy is employed, in which control functions are divided into three levels: Primary, Secondary, and Tertiary.

Microgrids are operated either in grid connected mode or in stand-alone (Islanded) mode. In grid connected mode, most of the system-level dynamics and microgrid frequency are dictated by the main grid. The control objective of the microgrid in this operational mode is that DG units residing in the microgrid share the active and reactive power injected into the main grid according optimal operation conditions, thereby, the microgrid works as a single point providing active power and ancillary services to the grid. That is the role of the tertiary control. In stand-alone mode, the system dynamics are dictated by DG units, by their interaction, and by the network itself. In stand-alone mode, the most critical control objective is to regulate micro-grid voltage magnitude and frequency and the system remains intact operating stably. This is achieved by sharing active and reactive power among different DG units through primary control.

In this thesis, a hierarchal control strategy for ac microgrid is presented. First, a mathematical model and a voltage frequency control scheme for inverter interfacing grid forming DG unit is introduced. Hence, the DG unit can operate in isolated mode. The introduced control scheme utilizes the well understood dq-frame current control scheme that is used with inverter interfacing grid following DG units. Minimum modifications are made to the control software of the grid following units to convert them to grid forming units. Hence, allowing grid isolated operation of the DG with black-start capability. The introduced control scheme is characterized by fast disturbance rejection, start-up transients, and mitigation of dynamic coupling between control loops and load dynamics. Second, conventional static droop characteristics are built on top of the voltage frequency control scheme to establish the primary control strategy which permits sharing of active and reactive power among DG units in parallel operation during isolation mode.

Third, secondary frequency controller is proposed to restoring frequency back to the nominal value after compensating the deviations produced as a result of using droop characteristics. In addition, a discussion of tertiary control, its role in both grid-connected and islanded, and the smooth transfer between the two modes are presented. The discussion illustrates the unified operation scheme of microgrids that are based on grid forming DG units. In the whole discussion energy sources are modeled as fixed dc sources, that is, the focus is on the interaction between power electronic interfaces, loads, and the grid and not the dynamics of energy sources. The whole control scheme of the microgrid is tested using a proposed test system on MATLAB/SIMULINK simulation environment.

Thesis Objective:

A proposed modular approach for implementing a hierarchal control strategy for inverter based ac microgrids is presented. The thesis introduces a detailed discussion of modeling of inverter based DG units comprising the microgrid and building a hierarchical control strategy for micro-grid including primary; secondary; and tertiary controllers to allow parallel operation of inverters, frequency restoration, and seamless transfer of microgrid from grid-connected to grid-isolated mode and vice versa, respectively.

In this thesis, A modular approach is adopted while building the control hierarchy. That is, if results show unsatisfactory performance of the control system in a given test case, an extra block is added on top the hierarchy to enhance the performance rather than making changes in the core of the control. This philosophy is adopted because the trend is to have DG units with Plug-and-play capability. Thereby, to solve a performance issue it is better to add than change the core. For example, the voltage frequency control of DG unit is tuned under RL load. When this DG unit drives a motor load, growing oscillations takes place. To solve this issue a stabilizer unit is added to damp the oscillations without changing the voltage frequency control parameters. Then two grid forming DG units are tested under parallel operation. A droop scheme is used to optimally share the load among the two DG units. To solve the issue of frequency droop due to power sharing a secondary control is used to restore frequency back to 1 pu. All these control blocks are built in modular hierarchal fashion.

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Chapter 3: Primary, Secondary, and Tertiary Control DG units