AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
ELECTRIC POWER AND MACHINES DEPARTMENT

A HYBRID DISTRIBUTED CONTROLLER FOR A HYBRID RENEWABLE NANOGRID

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Ph.D. Thesis

By

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Submitted in partial fulfillments of the requirements for the Ph.D. degree in electrical engineering

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Statement

This thesis is submitted to Ain Shams University in fulfillment of the requirements for the Ph.D degree in Electrical Engineering. The included work in this thesis has been carried out by the author at the Electrical Power and Machine Department, 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

Utilization of solar and wind power has become increasingly significant, attractive and cost-effective, since the oil crises of early 1970s. However, a common drawback with solar and wind energy is their unpredictable nature. As the advantages of solar and wind energy systems became widely known, system designers have started looking for their integration. The term hybrid renewable energy system (HRES) is used to describe any energy system with more than one type of generator usually a conventional generator powered by diesel, and a renewable energy source such as PV, wind, and PV/wind. For remote areas, HRES are often the most cost-effective and reliable way to produce power.

The HRES invariably includes battery storage to meet the demand when either the demand is peak load demand or renewable energy source is not available. Battery storage also smoothen the mismatch between time of occurrence of peak load and maximum power generated. One such HRES are the microgrid and the nanogrid. The sources of special interest for these grids are small (<100 kW) units. The term "micro" and "nano" has been coined to describe the grid capacity. As the microgrid capacity is about 100 kW, while 20 kW capacity for the nanogrid.

A nanogrid is a standalone HRES that uses renewable and non-renewable sources to supply power to local loads. The nanogrid has power electronics converters to interface the sources and loads to the system. The control flexibility afforded by the use of power electronics interface converters opens the door to new transmission and control possibilities.

With the use of power electronics interface converters, renewable sources can be connected directly to a distribution network or combined with other local generators and loads to form an independent power system. As a promising topology for this application, resonant converters offer low switching losses due to zero voltage switching (ZVS) making them popular for high frequency applications. The basic idea of a resonant converter is to operate the MOSFETs with either a minimum distorted sinusoidal voltage or by running a minimum distorted sinusoidal current through it. The switching instant must be selected in proximity to the zero crossing of the sinusoidal voltage or current. The dissipated power will then be very small.

A comparison between resonant converter and conventional converter indicates that the resonant converter has the better efficiency for different values of loading current and improves the efficiency at normal operating point by more than 3% under wide range of input voltage. Results are obtained using Matlab/Simulink.

The control structure of the nanogrid aims to schedule the sources, such that the non-renewable source improves the system reliability during the long-term shortage of the renewable source. This is achieved by Dc-Bus Signaling (DBS) to reduce, as much as possible, the participation of the non-renewable sources in the electricity generation process, taking the maximum advantage of the renewable sources available.

This thesis presents the control method used for sources scheduling of a nanogrid, and it also develops an algorithm that calculates the voltage thresholds for each source which satisfies the aimed scheduling.

However, there are some considerations to improve the system response and extend the functionality towards harmonics mitigation. The performance of the nanogrid is not totally satisfactory as large over shoots may occur in the output voltage, and current disturbances may occur at load side. Interaction can occur between the source and the load interface converters results in an under damped or unstable system in the small signal sense. Thus unit sizing of the nanogrid is necessary to ensure system stability. In this thesis, to improve the system stability the passive filter is designed to damp out the over shoot of the output voltage and to suppress the current disturbances from the load side. Also the system still has low-order harmonics in the load voltage at frequencies that are lower than the resonance frequency of the filter. To solve this problem, the interface controller is used as an active filter to inject harmonics, as well as to interface AC loads to the nanogrid, this can reduce the size of the output passive filter. Active filtering is used to inject the same amplitude of harmonic voltages with an opposite sign to cancel out the grid harmonics.

PUBLISHED PAPERS

1- N. H. Saad, A. A. El-sattar, N. M. Rady “High Efficiency LLC Resonant Interface Converter for a Renewable Generation”, International Journal of Emerging Technologies in Sciences and Engineering (IJETSE), Volume 6 Number 1, March, 2012, pp 1-7.

2- Ahmed. A. El-sattar , Naggar. H. Saad , Nessreen. M. Rady, “Calculation of Voltage Thresholds for Source Scheduling in a Hybrid Renewable Nanogrid”, Journal of Electrical Engineering (JEE), accepted and under publication.

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