Thesis Title: DESIGN, CONTROL AND IMPLEMENTATION OF AN AC MICROGRID

Student's Name: DEEPU VIJAY M

Entry Number: 2015EEZ8403

Abstract

Limited fossil fuel resources, increased demand for electrical energy, increased population, impact on atmospheric conditions, greenhouse gas emissions, and insufficient centralized generation, have forced the world to go for distributed generation with renewable energy sources. The quest for reliable and stable solutions for the energy crisis seen by the world and known issues associated with the conventional utility grid, have resulted in a new concept known as microgrids. The commonly used renewable energy sources in a microgrid are solar PV generation and wind energy conversion system (WECS). The use of microgrids, enhances the reliability and resiliency of the system as it operates autonomously during grid outages. Investigations on different AC microgrid configurations with the solar PV array and WECSs are made in this thesis. For the microgrid applications, a new WECS with a position sensor-less synchronous reluctance generator (SynRG), is proposed in this thesis. The simple, brushless, compact structure of SynRG, along with a full-scale converter, makes it suitable for variable speed wind power generation. SynRG is economical and robust due to the absence of permanent magnets and windings in the rotor, thus eliminating rotor losses. The use of back-to-back connected configuration provides smooth grid synchronization and decoupled operation. The WECS and the grid are sharing a common DC-link through their respective voltage source converters (VSCs). The VSC connected to the machine side provides the required reactive power to the SynRG and operates it at a speed, decided by the maximum power extraction (MPE) algorithm. Rotor position/speed sensor-less field-oriented control with novel flux estimation techniques are implemented for controlling the SynRG.

In this research work, design, modeling and implementations of different AC microgrid configurations comprising a combination of solar PV array, SynRG based WECS and a battery, are carried out. A total of ten microgrid configurations are discussed in this thesis. Different control algorithms are also introduced for the successful operation of the microgrids during grid-connected and standalone modes of operation. The issues associated with the increased grid penetrations of renewable energy sources are also addressed. Harmonics are injected into the grid currents by the nonlinear loads connected at the point of common coupling (PCC). In addition to the increased cost of electricity per unit, the major challenge faced by the utility companies, is the mitigation of power quality issues at the PCC for each consumer caused by the local loads. Efficient control algorithms are implemented for the grid side converter of all the proposed microgrid configurations, which enhance the power quality at the PCC as per the IEEE 519 standard as well as maintain unity power factor at the PCC. For quick dynamic performance during the variation in power generation from the solar PV array and WECS, feed-forward components are included in the control algorithms. Different synchronization controls are proposed for the seamless operation of the microgrid during grid outages/restoration. These improved techniques estimate the amplitude, frequency, and phase of the grid phase voltages in a fast and accurate manner, even for adverse grid conditions. Due to the intermittent nature of power generation from the solar PV array and WECS, battery banks are included in the microgrid configurations. For the protection and longevity of the battery, bidirectional converters are used. MATLAB/ Simulink platform is used for the modeling and simulation of all the microgrid configurations and developed laboratory prototypes are used for the experimental validations. This research work is expected to make significant addition to the existing knowledge on the design, development, and control approach for PV-Wind and battery-based AC microgrid.