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Stability analysis and control of microgrids by sliding mode control

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ABSTRACT

In this paper stability analysis and control of microgrids using sliding mode control are presented. Renewable energy based distributed generation (DG) is increasingly play a dominant role in the generation of electricity. Microgrid consists of cluster of load and distributed generators that operate as a single controllable system. The interconnection of the DG to the grid by power electronic converters has raised concern about safe operation and protection of the equipment. Many control strategy have been proposed for enhancing the stability of microgrid as for proper load sharing. Parallel converters have been proposed to deliver desired real power and reactive power to the system. The active power and reactive power sharing can be achieved by controlling two independent quantities, of frequency and voltage magnitude. In this paper, a sliding mode control (SMC) is proposed to smooth transition between grid connected and islanded modes of operation which this work through converter firing pulses controlled the output voltage magnitude. Finally the simulation results obtained using the MATLAB/SIMULINK software. Simulation results show the effectiveness of using SMC in transient response of load current and in load voltage and current during immediate load variations.

Introduction

The increasing effects of renewable energy sources are giving rise to a challenging scenario in the electrical power systems. The distributed generation integration is increasing significantly in the last decade, mainly, due to the integration of wind power and plant photovoltaic in medium and low voltage grids. A microgrid is a combine of sources and loads operating as a single controllable system that provides required power to its local area. In [1], a seamless control methodology for a photovoltaic-diesel generator (DG) microgrid to operate both in the grid connected and islanded mode has been proposed. In [2] uses a nonlinear sliding mode control scheme to reactive power and control torque of DFIG system. The reactive power of DFIG is adjusted by control system to improve voltage quality in the important central bus of a microgrid. There is no decoupled control of proportional-integral (PI) based method; so the control system is not dependent to the system parameters accuracy [2]. The proper operation of a microgrid requires storage devices that increase the inertia and prevent system instability. An energy storage system (ESS) control using super-capacitor in grid-connected microgrids presented in [3]. The ESS is composed of AC/DC and DC/DC converters which are connected by a dc link. A sliding mode strategy is introduced to control a bidirectional dc/dc converter, which can operate correctly under all circumstances to control [3].

Power balancing control utilized in microgrids is called as Power Frequency Droop. Proportional Integral (PI) controllers utilize for voltage magnitude control contemporary power frequency droop schemes in [4]. This reference introduces an adaptive sliding mode voltage controller that can increase the power control loop bandwidth [4]. A Q–δ droop control strategy using virtual frequency is proposed for VSI reactive power control in [5]. The complex control is implemented by microgrid inverter and introduces two operation modes of Grid-connected and Grid-disconnected for microgrid inverter in [6]. On the Grid-connected operation, hysteresis current tracking is used and on the Grid-disconnected operation, it voltage close loop control is used. When the gird fails, inverter can switch smoothly between two modes of Grid-connected and islanding operations [6].

Azevedo presents a control scheme that allows microgrid power converter operates in both operations mode of grid-forming and grid-supporting. Also, the transient response in the operation mode changes occurs smoothly [7]. The microgrid have their special needs, such as: enhancing local reliability, supporting local voltages, reducing feeder losses, providing increased efficiency through the use of waste heat, voltage sag correction [8]. The focus is on distributed resources system that can change from grid connection to island operation mode without causing problems for critical loads [9]. Different control strategy of microgrid and power

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management techniques is discussed in [10–14]. Parallel converters have been controlled so as to deliver desired active and reactive power to the system. A common approach for active and reactive power sharing is drooping control of two independent quantities the frequency and the fundamental voltage magnitude [15–23]. Robust voltage regulation and harmonic suppression under island and decoupled active and reactive power flow control under grid connected mode is proposed in [15]. The impact of distributed generation technology and the penetration level on the dynamic of a system in investigated in [17].

In this paper a solution for transient control from grid connected mode to island mode will be proposed. In the scope of the paper, a sliding mode control (SMC) method is presented to achieve a fast transient and a good operability in between grid connected mode and island mode. Seamless switching between island mode and grid connected mode is achieved by this control technique and sinusoidal line current waveform at nonlinear local load is guaranteed. This strategy is presented in the paper and evaluated through simulations.

Converter structure

The converter structure is shown in Fig. 1. This contains three H-bridge converters that are connected to the DG sources, denoted by V_{dc1}. The outputs of the H-bridge are connected to three single-phase transformers that are connected in "*wye*" (Y-shaped) for required isolation and voltage boosting [18]. The resistance R_f represents the switching and transformer losses, while the inductance L_1 represents the leakage reactance of the transformers. The filter capacitor C_f is connected to the transformers output in order to bypass switching harmonics. The inductance L_1 is added to provide

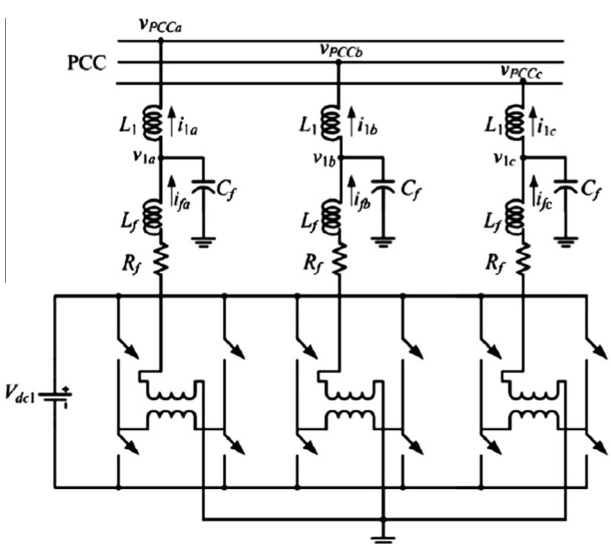

Fig. 1. Three phase converter structure.

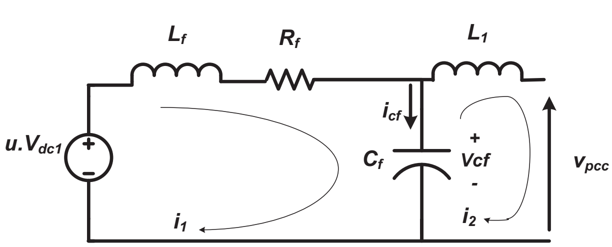

Fig. 2. Single phase equivalent circuit of converter.

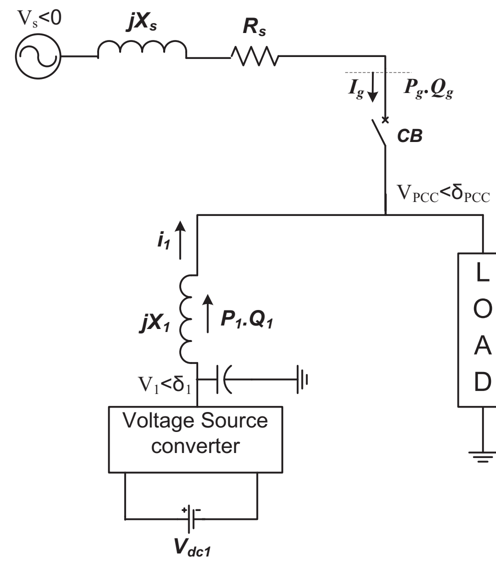

Fig. 3. Microgrid system under consideration.

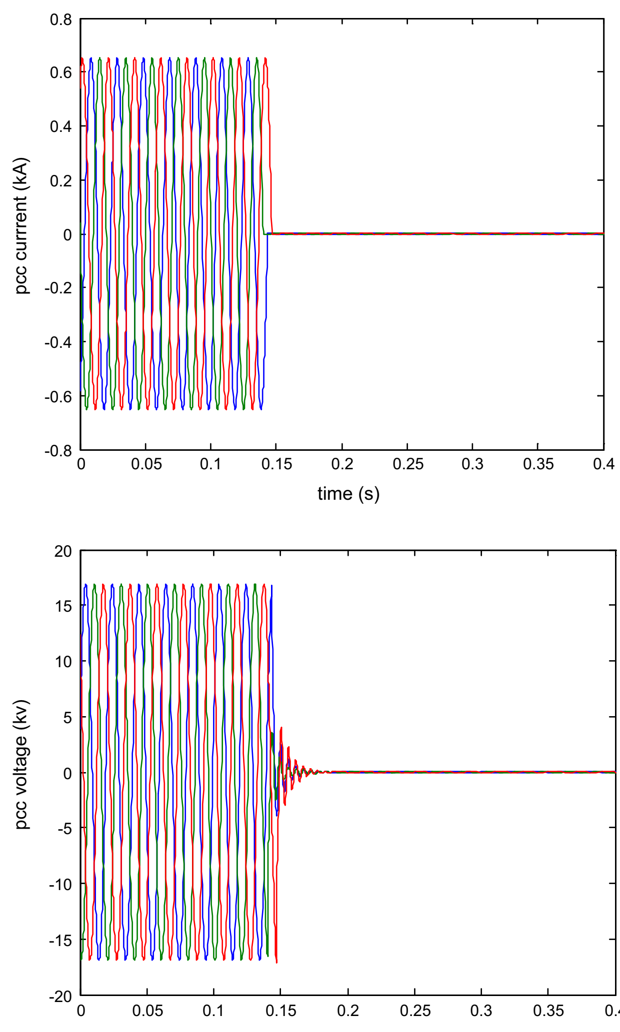

Fig. 4. PCC voltage and current during islanding.