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A novel topology and control strategy for a soft-switched single-phase grid connected inverter

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Abstract

This paper represents a novel soft switched PWM inverter topology and a control strategy using switching flow graph theory. The switching flow graph is a unique graphical model for analysis of PWM switching converters. All power switches operate at zero-voltage-switching (ZVS) turn-ON and turn-OFF conditions as a result, commutations of power switches have lower losses furthermore higher efficiency is reached. The proposed approach is analyzed theoretically and demonstrated experimentally by making a testing prototype.
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Keywords: Renewable energy; DC–AC power converters; Zero-voltage-switching; Switching flow graph theory; Soft-switching

1. Introduction

Solar and wind energies are the most significant sources of renewable energies available in the world. Furthermore, grid connected inverters are increasing and developing quickly and their performance are improved day to day. Due to the increased electrical energy demand globally the mentioned renewable energy resources are the most effective solutions. However, the most significant disadvantage of such renewable energy resources is that their produced output power is discrete and unregulated since some techniques such as maximum power point tracking (MPPT) method is used to get constant output voltage and power out of solar arrays or wind turbines. Various inverter topologies and control strategies have been proposed for grid connected inverters in literatures (Pierquet and Perreault, 2013; Prasanna and Rathore, 2013; Batzel and Adams, 2013). Soft switching techniques are used extensively to reduce switching losses associated with power switch commutations (Li and Wolfs, 2007; Jain and Agarwal, 2008; Todorovic et al., 2008; Rathore et al., 2008). Switching converters are pulsed converters and have nonlinear dynamic behaviors (Smedley, 1991). Linear feedback control structures are significantly used to control nonlinear systems. If a system

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is more complicated the conventional linear control theory approach may not be useful. In this paper a novel unique nonlinear modeling method, the switching flow graph technique, is developed and applied to demonstrate the nonlinear dynamic behavior of power switching converters. This technique utilizes some concepts from state space averaging method as well as extension of linear circuit flow graph theory (Smedley, 1991). A switching converter is equivalent to ON-circuit when the switch is in the ON state and it is identical to OFF-circuit when the switch is in the OFF state. The switching flow graph is extracted by combining the flow graphs of the ON-circuit and the OFF-circuit. The switching flow graph decomposes a system to its basic components and clearly evaluates the effects of input parameter changes on system outputs. Switching flow graphs can be used to extract transfer functions between arbitrary points in the power switching converter. The switching flow graph can easily be concluded from the electrical system topology. The signals are represented by nodes which are depicted by small signals in the switching flow graph. The nodes are connected by branches which are arrows moreover the signals flow only in the arrow direction furthermore each arrow has a gain illustrated next to the arrow. The signal at a node is the sum of all signals entering to the node. Nodes with just outputs and no inputs are called source nodes and represent independent variables. However, sink nodes, nodes with only inputs and no outputs show dependent variables on the other hand mixed nodes have both inputs and outputs.

The procedure for building a switching flow graph is very simple. First, all electrical variables of elements i.e. voltages and currents of all electrical elements in power switching converter are assigned nodes in the switching flow graph. Next, the nodes are interconnected with arrows according to electrical rules between voltages and currents of all elements. Once all the nodes are conveniently connected the switching flow graph will be completed. The power converter presented in this paper implements a novel type of grid-connected topology as well as a novel nonlinear control strategy using switching flow graph theory. The proposed topology has higher efficiency in addition it operates under continuous constant output power condition furthermore that provides zero-voltage switching (ZVS) capability for all power switches.

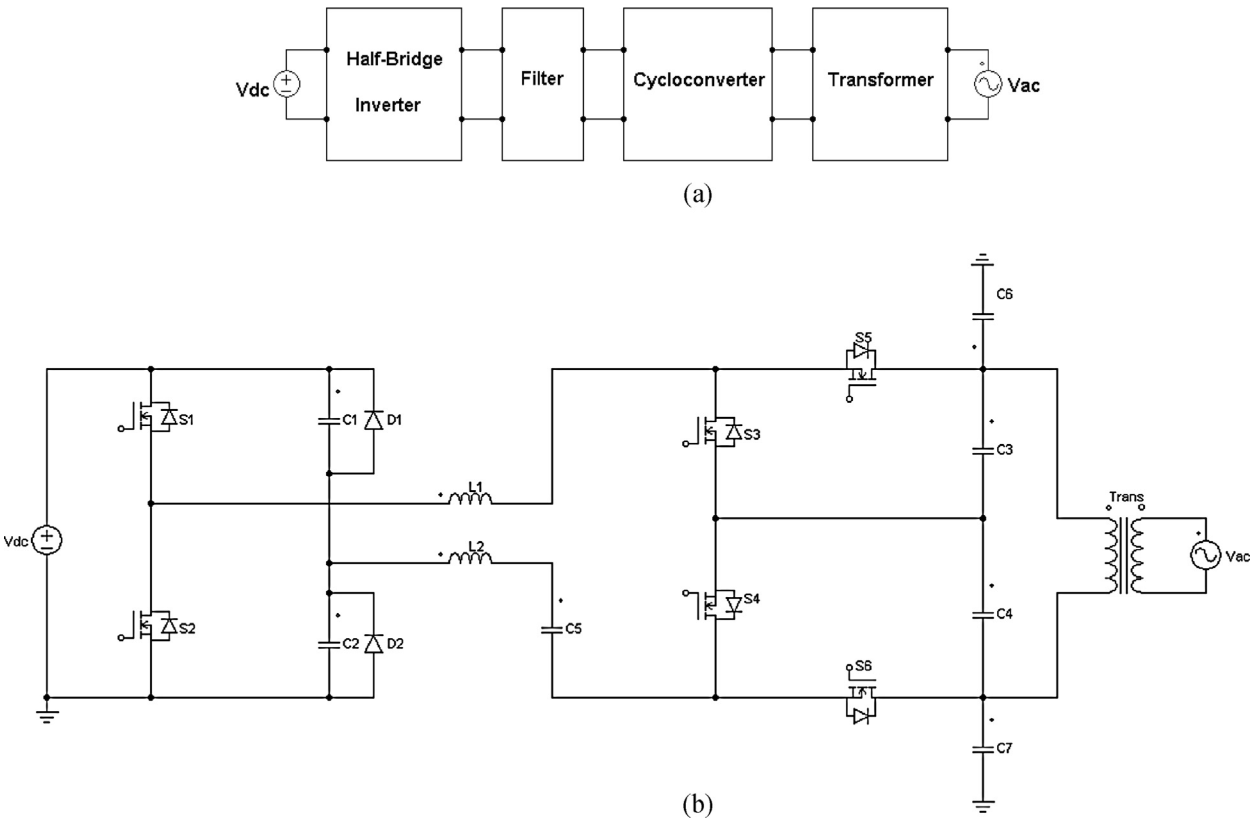

Fig. 1. Proposed grid-tied inverter: (a) block diagram and (b) circuit schematic.

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