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Novel deadbeat power control strategy for grid connected systems

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Abstract

This paper introduces a novel approach for power control of three phase voltage source inverter (VSI) in grid connected distribution generation system. In this approach, the control of active and reactive power is based on deadbeat control strategy. First, the difference between the reference and actual currents are introduced in different approach. Then current to power substitutions are carried out to obtain direct relationship between the required inverter voltage and instantaneous power errors. There is no need for coordinate transformation or PLL, where the required inverter voltage vector calculations carried out in α–β stationary reference frame. The proposed technique introduces two cross coupling components in the control function. Including these two components, the controller can achieve nearly zero steady-state tracking error of the controlled variables. To obtain fixed switching frequency operations, space vector modulation (SVM) is used to synthesize the required inverter voltage vector and to generate the switching pulses for the VSI. The proposed strategy has the simplicity of the direct power control (DPC) technique and doesn't require any current control loops. The proposed strategy is experimentally implemented using fixed-point microcontroller. Simulation and experimental results are presented to confirm the superiority of the proposed strategy.

Keywords: Deadbeat; Power control; Grid-connected system; Distributed generation

1. Introduction

The demand for renewable energy generation systems has been growing rapidly nowadays. Photovoltaic, wind and fuel-cell energies gain the largest utilities as renewable energy sources (Mohamed and El-Saadany, 2011; Blaabjerg et al., 2006; Alsayed et al., 2013). To transfer power from these sources to the utility grid; three phase DC/AC VSI is required. Control of VSI can be divided into direct and indirect control strategies. Although these control strategies can achieve the same main goals, such as accurate and fast power control and near-sinusoidal currents, their principles differ (Monfared and Rastegar, 2012; Larrinaga et al., 2007). The commonly used method of indirect power control is the voltage oriented control (VOC) (Malinowski et al., 2001; Malinowski, 2001; Aurtenechea et al., 2006). VOC is based

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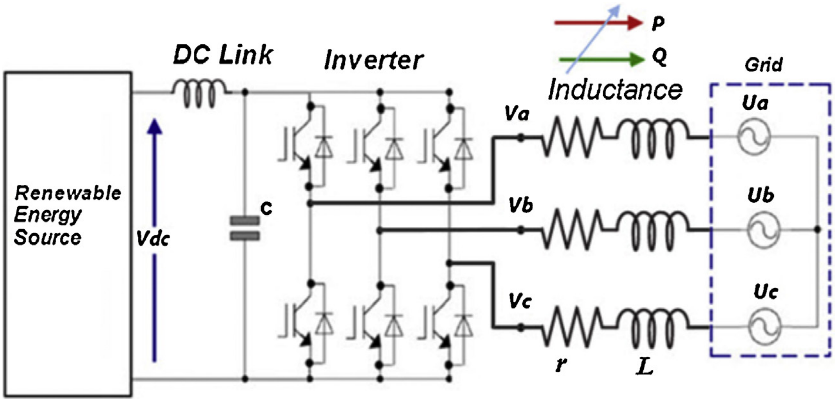

Fig. 1. Grid connected system.

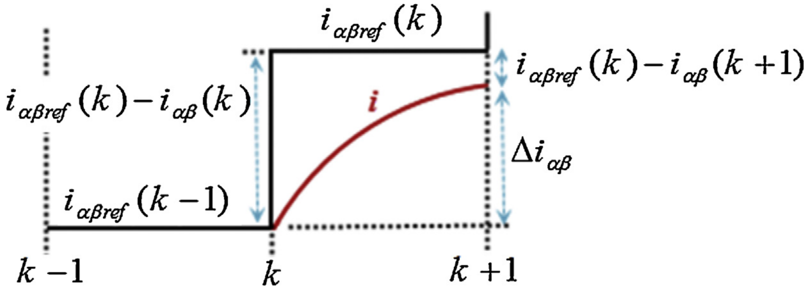

Fig. 2. Discretized reference and actual current.

on the current vector orientation with respect to the grid voltage vector. In this technique, the line currents are decoupled into active and reactive power components in the *d–q* reference frame. Phase-locked loop (PLL) is usually used to extract the angle of transformation. Also, two PI current controllers are needed to control the decoupled components of the line currents to achieve indirect power control. The control signals of the inverter switches can be generated using SVM or sinusoidal PWM strategy. VOC provides good transient behavior and PI current controllers ensure zero steady state error. Besides its complexity, one main drawback for VOC control scheme is that the performance relies highly on the tuning of the PI controller parameters.

Direct Power Control (DPC) is based on the instantaneous active and reactive power control (Noguchi et al., 1998; Hu and Zhu, 2011; Atia and Salem, 2013). In DPC, there are no internal current control loops and no PWM modulator, because the inverter switching states are appropriately selected by a look-up table based on the instantaneous errors of the power components (Hu and Zhu, 2011). Compared to VOC, DPC has a simpler algorithm, no current control loops, no coordinate transformation, no separate PWM voltage modulator, no need for decoupling between the control of the active and reactive power components, and it has better dynamics performance. On the other hand, the variable and higher switching frequency are the well-known disadvantages of the DPC scheme (Atia and Salem, 2013). Also, the angular information of the grid voltage is required, because the selection of the inverter output vectors mainly depends on this angle. Then a PLL is required to extract this information as in the VOC.

A constant switching frequency DPC strategy with SVM based on a predictive power model was developed in (Atia and Salem, 2013; Malinowski et al., 2004; Bouafia et al., 2010a,b; Restrepo et al., 2013). In all of those trials a complicated mathematical calculations were introduced and the advantages of DPC was lost. A deadbeat power control strategy for low cost three phase converter was presented in (Monfared and Rastegar, 2012). In which, the required converter voltage was directly calculated based on reference and measured values of active and reactive power. Calculations were carried out in the synchronous reference frame that needs PLL for grid angle information.

This paper introduces a novel approach for direct power control of three phase voltage source inverter. The control of active and reactive power is based on deadbeat control strategy. First, the difference between the reference and actual currents are introduced in different approach, then, current to power substitutions are carried out to obtain direct