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Parallel-Connected Legs in a Grid-Tied Inverter System for Distributed Generation

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Abstract. Grid-connected high-power inverters are often used in distributed generation and power quality systems. Those inverters have to handle high currents in order to achieve high power values without resorting to higher voltages. Connecting inverter legs in parallel is a proper way to achieve such high currents. Such parallel connection is made by means of inductors and achieving balanced currents among the legs becomes a critical issue. Circulating currents may produce additional losses and stress to the converter's power devices. Therefore, they should be controlled and minimized. An efficient technique to achieve such balance is presented in this paper. The proposed strategy has been developed on a grid-connected three-phase system. Each phase of the inverter is made up of three legs in parallel. Besides, the control implemented in this work allows full regulation of the power factor. This way, any desired power factor value can be achieved in order to meet grid-connection requirements. Simulation and experimental results are shown in this paper.

Key words

Grid-connected converter, Distributed generation, Converter Control, Pulsewidth Modulation, Parallel legs.

1. Introduction

Significant electrical grid changes are being produced nowadays. Distributed generation systems are becoming more and more common; thus, huge central stations are starting to share electricity production with such distributed systems. Many of those generation devices require to process voltages and currents through power electronic converters for a proper grid connection. Some examples include renewable energy systems; e. g. solar photovoltaic, wind turbines, and marine energy. Other promising generation sources are fuel cells. Some other systems that require grid-connected converters are storage energy and power quality devices, such as active filters, static compensators (STATCOMs), dynamic voltage restorers (DVRs), etc.

In order to increase the rated power of power electronic converters, either the voltages or the currents can be increased (or both of them). Multilevel inverters are based on increasing the voltages handled by the converter. The main reason for this is because they can deal with higher voltages.

On the other hand, paralleling devices, legs, or converters is a way to increase the current values [1]-[5]. Parallel-connected legs of a voltage-source inverter (VSI) require the use of inductors to obtain a single output voltage from several input legs. It would be optimal if current sharing among the legs was balanced; however, there is no guaranty for this unless a proper control is used. Several techniques can be applied to achieve current balance among the legs. Most of them are based on PIs [3]-[5], [7] or optimal controllers [8] which can usually provide good balancing performance. However, they need parameter tuning and the balancing dynamic may not be optimal. Quick response of the balancing control is crucial to avoid long transitory overcurrents on specific legs which might be destructive. The balancing strategy used in this paper is based on [9] and it can achieve current balance very quickly since the exact modification of the modulation signals is calculated and applied. The method is performed without distorting the output voltages and currents.

In voltage-source inverters (VSIs), if the dc-link is fed by a current source, the converter itself takes care of the dc-link voltage regulation. Therefore, a proper control loop is needed. In this work, a voltage-oriented control (VOC) is used [10],[11].

This paper is organized as follows. Firstly, an introduction to paralleling legs by means of inductors is made. Then, a three-phase parallel-legged grid-connected system is introduced. In the following sections, the current balancing technique used in this application is presented and the control loop is described. Finally, some simulation and experimental results are presented

2. The grid-connected system

The core of the plant used to test the control strategy is a grid-connected inverter whose phases are made up of three parallel legs (Fig. 1). The primary source of energy is represented by a current source. This current could come from different kinds of applications, such as