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Inverse Clarke Transformation based Control Method of a Three-Phase Inverter for PV-Grid Systems

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Abstract—A photovoltaic (PV)-Grid System integrates electric energy generated by PV modules and a grid. A Maximum Power Point Tracker (MPPT) is required due to PV characteristic. It will force the PV modules produce maximum power in the DC voltage. It is needed an inverter to convert DC into AC voltage and to match the grid voltage. A standard inverter topology used in active filtering is functioned to inject harmonic and reactive power components but it must be able to transmit active power component in PV-Grid System. Instantaneous power concept is often used to control an active power filter due to its simplicity. In this paper, a control method for a three-phase three-legs inverter is proposed. This is based on inverse Clarke Transformation. The inverter is implemented by Voltage Source Inverter (VSI) that is operated as a controlled current source by using a current controller. Inverter output currents will be compared to references produced by inverse Clarke Transformation. To achieve power equilibrium, the voltage of the DC-link is kept constant. The obtained results have proven that all the power generated by the PV modules can be transmitted into the grid.

Keywords — PV-Grid System; active power; Inverse Clarke power equilibrium

I. INTRODUCTION

Recently, a PV-Grid Systems is the most popular method in utilizing electric energy generated by PV modules. The system is capable to integrate such electric energy to a grid system. This can be implemented by single-stage systems or two-stages systems. Due to the characteristic of PV modules that is composed by voltage-current source, a converter is required to operate PV modules near their maximum power point. This converter is named as a Maximum Power Point Tracker (MPPT). In a two-stages PV-Grid system, a DC-DC converter is used as an MPPT and an inverter is used as an interface to the grid. While in a single-stage system, an inverter must be functioned as an MPPT and an interface. One Cycle Control can be applied to control a single phase inverter in a single-stage PV-Grid System [1]. By using template modulated current in phase with respect to the grid voltage, a PV-Grid system is capable to transfer power [2]. Digital control implemented by fuzzy logic can also be applied [3].

A two-stages PV-Grid system requires simple control circuit because each controller can run separately. The first controller is used by the MPPT to forces the PV modules generates their maximum power. Some control methods have been developed by many researchers, these are constant voltage, perturb and observe, incremental conductance, etc [4], [5]. The second stage may be implemented by standard topologies or other topologies of inverters. A half-bridge inverter can be used to transmit the power into the grid with plug-in repetitive current controller based on a fourth-order linear phase IIR filter [6].

Instantaneous power theory is a concept that is often used in active power filtering. It is able to calculate instantaneous power by using Clarke Transformation [7], [8]. This Transformation is very simple to be understood. Based on the inverse Clarke Transformation, the proposed control circuit for a three-phase three-legs inverter is described. The change of the DC-link voltage is used as an input for a Proportional-Integral controller, then it will be proceeded by using inverse Clarke Transformation to obtain current references for a current controller of the inverter. To verify the analysis, simulation work were done.

II. THREE-PHASE THREE-WIRE PV-GRID SYSTEM

Integrating power generated by PV modules into the grid offers some advantages so this method is being developed. The common type of the PV-Grid Systems is two-stage type that consists of a DC-DC converter as an MPPT and an inverter as an interface to the grid. An MPPT is functioned to maximize the power generated by the PV modules while an inverter converts DC voltage into AC voltage. Inverters used in the PV-Grid Systems can be operated as voltage sources or current sources. Synchronization is needed for the inverter that is operated as a voltage source, this will result in complexities. While operating the inverter as a current source is simpler. A controlled current source needs the DC voltage as its input with magnitude higher than the peak value of the grid voltage. For it is a current source, the synchronization is not required anymore so the complexities will be reduced.

The proposed three-phase three-wire PV Grid System is depicted in Fig. 1. This consists of a boost chopper and a three legs inverter with inductors connected at its AC side. To obtain maximum power produced by the PV modules, an MPPT controller requires voltage and current detection of the PV...