DUAL MODE SINGLE PHASE PV INVERTER

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Abstract: This document presents the design and implementation of a 1kW dual mode single phase PV DC/AC inverter. The inverter uses a supervisory controller system to transit between grid-tied and grid-forming modes of operation. A high level block diagram for the single-phase PV system is also presented.

Key words: DC/AC Inverter. Single-phase, Grid-forming, Grid-tied, Controller.

1. INTRODUCTION

Solar powered systems are becoming more popular in the modern days due to their advantageous capabilities to provide both clean and sustainable energy [1]. In these systems, it is a significant requirement for the DC/AC inverter to be capable of producing and maintaining a stable power supply to any type of load connected to the system. The inverter can operate in grid-forming mode and grid-tied mode [2]. The grid-forming operation mode is when the utility main grid is disconnected or absent and the inverter will be controlled to act as a voltage source providing constant voltage and frequency operation to the load. The grid-tied operation mode happens when the utility grid is connected and the inverter is controlled to act as a current source providing a suitable alternating current (constant real power and reactive power) into the main grid [3].

There are several challenges that come with the operation of the PV inverter that need to be observed and taken into consideration during the design. The most challenging part of the design involves designing a supervisory controller system that will provide a stabilised switching transition operation between the two modes discussed above. The controller must also be able to perform grid synchronization without affecting the response of the solar powered system [4]. This paper deals with the design of a Dual mode single phase 1kW PV inverter and a supervisory controller system that will be able to switch between the two modes of operation depending on whether the grid is connected or disconnected. The paper is organized as follows, first the background regarding the design scope and literature review of similar or related works is discussed in section 2. The inverter design is presented in section 3.

2. BACKGROUND

This section presents a literature review on single phase inverter designs and control strategies that have been conducted by other authors. It also outlines the design scope specifications of the PV Installation inverter such as the proposed constraints and assumptions.

2.1 Literature Review

Satheesh Kumar and Ramya.N.D in [5] presented a design and analysis of a single phase grid connected inverter. The inverter is configured as a full-bridge using four power MOSFETs, IRF840. The switches are controlled using sinusoidal PWM with the help of Arduino Atmel 328 controller. Hysteresis current controller is employed to provide grid synchronisation. Their work focuses only on the grid-tied mode. Haoyan Liu [2], Kulkarni1 and Chaphekar [6] presented a control design of a grid-connected single-phase H-bridge inverter. Both designs support two modes of operation, the grid-forming and grid-tied mode. In [2], for the grid-forming mode, the inverter is controlled using proportional-resonant (PR) and PQ controllers. A proportional capacitor current feedback method is applied for the grid-tied mode. An amplitude detection based method is used for grid synchronisation.

Another approach of controlling of single-stage single-phase PV inverter is represented in [7], two current controllers, a proportional-resonant plus a harmonic compensator controller with phase lock loop (PLL) and Grid current (PI) controllers are implemented. The study demonstrated that the proportional-resonant controller performs better than the grid current PI controller. In [4], an investigation was carried out to study the behaviour of power system during the transition between the two modes. A feedback controller is proposed to reduce the transition transients in the system.

2.2 Design Scope

Figure 1 shows a high level block diagram of a Solar powered PV system connected to the grid. It includes the PV configuration module, the power inverter, controller and the utility grid or load. For this project, the design focuses on the power inverter with the output filter and the supervisory controller system. The design specifications, constraints and assumptions are as follows:

- The MPPT controller along with the DC-DC converter are assumed to be incorporated within the PV configuration module. The PV Array supplies the DC-AC inverter with 400 $\pm$ 10% V DC. There is no battery storage.
- The inverter can supply a maximum power of 1kW and the controller system should be able to counteract changes in the DC Bus supply, also be able regulate the power requirements for any type of load rated within the safe conditions.
- The earthing protection is already incorporated in the entire system. Monitoring the internal components of both the inverter and the controller is complex, therefore the designed system only monitors at the terminals for electrical fault protection.
- The inverter and the controller low-voltage components can be powered by either a separate voltage source or a step down converter powered from the 400 V from the PV array. However, using the converter might not be ideal because for most low-voltage components, the operating supply voltage is less than 12V, therefore stepping from a high voltage of about 400 V to 12 V or less will result to a high power dissipation.
- The cost analysis of the design is not requited.

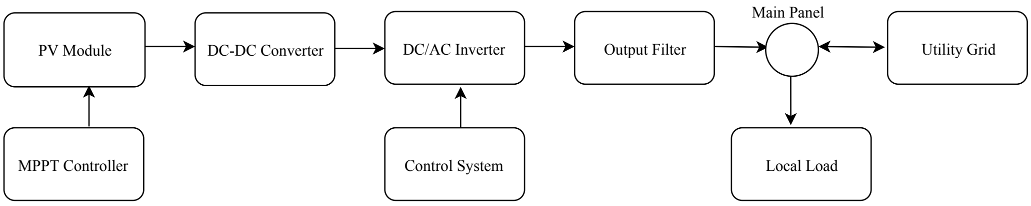

Figure 1 : Solar powered PV system.

3. DESIGN METHODOLOGY

3.1 System Overview

A typical power inverter can be configured as a half-bridge or full-bridge constructed with two or four switching components depending on the configuration and application [8]. The switches are controlled through a Pulse Width Modulation (PWM) and an output filter is employed to obtain a high switching frequency of the bridge and to provide an output signal with a suitable fundamental frequency[8]. A typical Single Phase full-Bridge Inverter block diagram is shown figure. This type of an inverter design is chosen because of its high-efficiency and simplicity to implement.

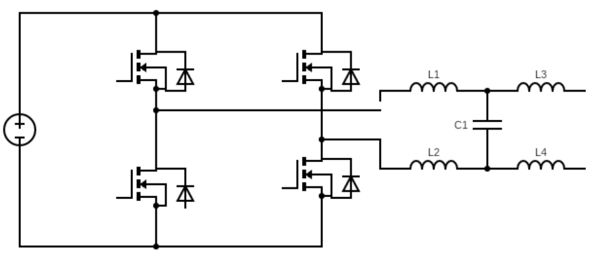

Figure 2 : Solar powered PV system.

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