The University of Witwatersrand, Johannesburg 2050, South Africa

School of Electrical and Information Engineering

ELEN 4000 - Electrical Engineering Design II

Design of a Dual mode Single Phase PV Inverter

Author: Karabelo Maqabe (1149346)

Supervisor: Professor I. Hofsajer

Date: 20 September 2019

Abstract

The purpose of the report is to present the design of a 1kW dual mode inverter. The design inverter consists of four switches connected in an H-bridge topology. The inverter provides two modes of operartion using different controllers. The SPWM control method allows the system to behave as a voltage source that has magnitude and frequency (Grid forming). The second operation mode is achieved using vector control to convert the system to only supply current and be synchronised to the Grid(Grid tie). The inverter is equipped with an LCL filter to minimise harmonics that are caused by the switching of the inverter bridge. The system has a constant nominal input of 400 V DC and outputs AC voltage of 230 V at 50 Hz.The reliability of the system will be proven using matlab/Simulink

Keywords: Single phase, VSI, Inverter, SPWM

1. INTRODUCTION

Inverters are considered crucial elements in designing PV systems. These elements change the DC voltage in to a variable voltage (AC) that is required by household appliances. Inverters can function as grid connected in which they perform as current sources and inject current to an already existing grid or as stand alone micro grids that supply voltage magnitude at the required frequency. The inverter alone only converts the DC voltage in to a square that can not be used by the appliance or load as it has multiple odd harmonics and therefore requires PWM to be able to eliminate harmonics. Different switching schemes can be used to create the sinusoidal varying ac voltage. Some common controll methods used in inverters include PWM, predictive control and hysteresis control. The use of these techniques ensure the output is a sine Wave with a decreased (Total Harmonic Distortion) THD. In order to comply with IEEE 519 1992 the THD of a system is required to be less than 5%, This can be achieved through the use of a filter for the inverter.

The proposed system combines two different operating modes to provide a system that is able to be stand alone or grid connected. The proposed inverter is 1kW with output frequency of 50 Hz which resembles the existing grid specifications. The system is equipped with switches controlled through PWM to create a sinusoidal output at the inverter. A filter is introduced to provide a pure sinusoidal output to supply the load.

The first section of the report entails the background of the system which reviews existing literature , followed by overview of the inverter interconnected with PV system components.

2. BACKGROUND

2.1 Literature review

S. Samerchur et al.[1] presents the design of a Grid connected Voltage Source Inverter.The system design is based on a vector controlled method that controls power by decoupling control of active and reactive current components.The author decreases phase current distortion by controlling the power factor at the grid terminal to improve efficiency of the inverter.This paper is adapted in the proposed system for its active and reactive power control.

Faete Filho [2] designs an H bridge single phase inverter. This inverter is Grid connected and uses PLL(Phase Locked Loop) algorithm to match the phase and frequency of the Grid to that of the photo voltaic system.This algorithm together with the SPWM current control that incorporates input from MPPT form an optimal synchronisation of the system to match the grid.In agreement with [2] Slamet Riyadi [3] designs an H bridge inverter system.He emphasises on the current sensor that gives feedback to the PWM driver circuit in order to provide the inverter with the correct modulation pulse.The current control basics of these two systems are adapted in the Grid connected VSI design of the proposed system.

Georgios A. Tsengenes and Georgios A [4]. Adamidis discuss and analyse three methods pf controlling current of a Grid-tied VSI.The authors analyse hysteresis control,carrier comparater PI and SVPWM methods. The results are analysed using matlab/Simulink and conclude SVPWM as best suitable for current control and results in better THD with low harmonics compared to the hysteresis and PI controller methods. This work supports the design of Faete Filho [2] and is also incorporated in the designing of the systems control subsystem.

Emre Kantar [5] designs an LCL filter for a PWM controlled VSI .The design caters for both active and reactive current components to produce a decreased THD with less frequency ripple.The authors filter design aims to increase efficiency, increased power factor and reduced THD which all result in a better performing system as harmonicas are filtered out. The proposed system adopts this filter design to further reduce ripple caused by switching of the H-bridge.

2.2 Contextualisation

Inverters are able to operate in two different modes, namely as a current source or voltage source. The designed consists of the two operational modes that require different components only at the control stage of the PV system. These two modes distinguish them as either grid tied systems or grid forming system. The Grid connected mode has the role of being synchronised with the Grid. This ensures that it does not introduce distortions in the already operating grid and therefore results in a synchronised supply to the grid. The system controls the current and phase angle to achieve this synchronization. The system can be considered a current source since it is responsible for supplying current only. The second mode is a grid forming operation. This presents the system as a standalone micro grid that is able to supply the load with the required power and can therefore be used as a stand alone grid. Both these systems are required to have a THD that is less than 5 % according to IEEE standards. The system design will focus on the design of the dual mode inverter that combines the two operational modes discussed above. The inverter receives 400 V from PV panels that already includes an optimisation of the MPPT.

2.3 Methodology

The proposed system combines the inverter operating as a grid forming component and as a grid connected current source. This flexibility allows the system to be used in different situations without having to buy additional components. This system is a 1 kW system that is able to provide power to basic household appliances. The design specifications of the system are presented in the Table 1 below.

Table 1 : Design specifications

Specification	**Value**
Nominal voltage	400 V
Output frequency	50 Hz
Output voltage	230 V
No. phases	1
Output power	1 kW
Power factor	1

2.4 System Overview

The high level design overview of the system is presented in Figure 1. An H-bridge inverter will be used for the design of the inverter. The bridge consists of four ideal switches witch assist in creating a sine wave with the use of Pulse Width Modulation. The two modes are incorporated by using different control systems for the Voltage source inverter. The grid forming system uses the sinusoidal PWM by comparing the square wave created by the inverter with a carrier triangle wave and therefore switches on the requires part of the H bridge. The system can switch into a current source mode by using vector control of the active and reactive power. This operation mode requires a connection to an existing grid to provide synchronisation.

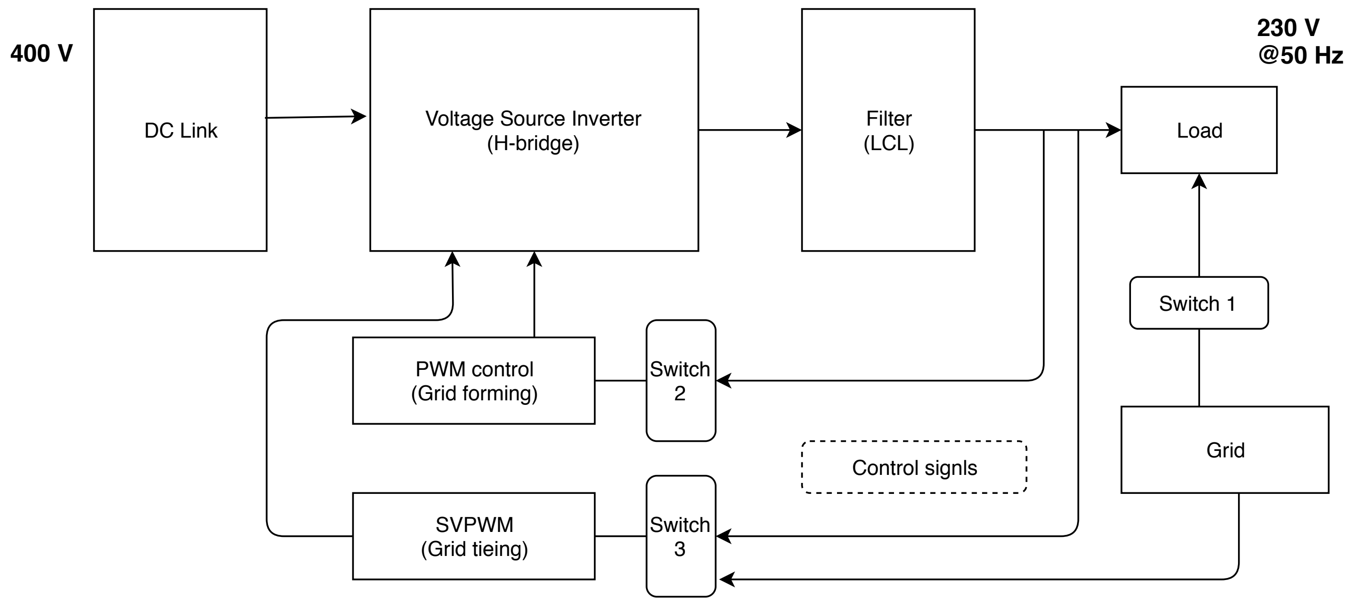

Figure 1 : Caption

2.5 Operation

The DC link provides 400 V constant from the PV panel. The power is transferred to the inverter and travels through two switches that are turned on depending which part of the sinusoidal waveform is being generated. the filter is used to filter out any harmonics that re caused by the switching of the inverter bridge. In Grid forming mode only switch 2 is on to allow the controller to get a feed back sine wave that is compared to a carrier wave and therefore resulting in the switching of the h bridge inverter. The current operating mode requires the switching on of switch 2 and 3 and switching off the controller of grid forming mode. The similar feedback mechanism is used where the sine signal on the output of the filter is fed into the controller together with a reference signal which is the grid waveform to be able to provide the correct switching of the bridge that results in a synchronised output to the load as both the grid and the system wikll supplying power to the load.

REFERENCES

[1] S. Samerchur and S. Premrudeepreechacharn. "Power Control of Single-Phase Voltage Source Inverter for Grid-Connected Photovoltaic Systems." 2011.

[2] F. Filho, Y. Cao, and L. M. Tolbert. "11-level Cascaded H-bridge Grid-tied Inverter Interface with Solar Panels." *International Journal of Scientific Engineering Research*, 2010.

[3] S. Riyadi. "Single-Phase Single-Stage PV-Grid System Using VSI Based on Simple Control Circuit." *International Journal of Power Electronics and Drive System*, vol. 3, no. 1, pp. 347–354, Mar. 2013.

[4] G. A. Tsengenes and G. A. Adamidis. "Study of a Simple Control Strategy for Grid Connected VSI Using SVPWM and p-q Theory." *XIX International Conference on Electrical Machines*, 2010.

[5] E. Kantar, S. N. Usluer, and A. M. Hava. "Design and Performance Analysis of a Grid Connected PWM-VSI System."