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Research paper

Design and simulation of fuzzy controller for three phase grid connected PV systems

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Abstract

this paper presents a design, complete simulation and hardware implementation of three phase grid connected inverter. The proposed scheme is fuzzy logic current control to control the current through the PV inverter switches. The inverter control system algorithms are developed and simulated in MATLAB/SIMULINK. A 9.1 Kw system is implemented and tested in MATLAB/SIMULINK. The proposed scheme achieves low harmonic distortion. A comparison between the fuzzy logic controller and other classical controllers proposed in literature is given. the controller is implemented on Arduino and a complete system is built on hardware. results show the superior performance of the fuzzy logic controller.

Keywords: *Inverter; Fuzzy Logic; Grid Connected.*

1. Introduction

Scientists all over the world are searching for renewable, sustainable, and environmental energy sources. The sun is one of the most sustainable energy sources. This led many scientists to search for techniques to harvest the sun energy and convert it into electricity. PV systems are built for this task. PV systems however suffer from relatively high installation and maintenance cost and low efficiency. This motivates researchers to search for techniques and methods to increase the system efficiency and hence decrease its cost.

Renewable energy sources produce DC power, hence the need for an inverter to convert the energy from DC power to AC power to be able to connect to the grid. The research is going towards grid connected PV systems. The inverter control is very critical to energy conversion process as it is operation is to inject low harmonic distortion current to the grid. For this reason, international standards such as IEEE Standard 519 and 1547, are often in place to limit the harmonic currents injected into the grid. Typically, 5 percent (THD) limit is imposed.

There are many classical methods for controlling the inverter such as proportional integral and proportional resonant. controller.

Proportional integral is widely used controller for control- ling three phase inverter (1). A PI controller calculates an error value which is the difference between a measured inverter output current and desired injected current to the grid, then the controller tries to minimize the error between them. The PI current control has the advantage of steady state response, low current ripple, well defined harmonic content and constant switching frequency(1). As a consequence of the shortcomings of the PI controller such as steady state error when tracking
sinusoidal reference signals, and the need for complex methods to find the values of the controller gains. Alternative control solutions have been proposed.

Proportional resonant (PR) has become one of the popular strategies in three phase grid connected control. (2) The advantage of the PR controller is the ability to remove steady state errors when tracking AC signals by generating an infinite gain at a known resonant frequency of the, and s highly attenuated gain at other frequencies.(3)

A comparison between PI and PR controllers is proposed in (4). The study show that PI controller suffered from a steady state error. In comparison PR has zero steady state error when following a sinusoidal reference. Recently more attention has been given to the fuzzy logic controller (FLC) (5). FLC has the advantage of controlling a nonlinear system such as the PV inverter system and there is no special design procedure involved in fuzzy control such as root-locus design, frequency response design, pole placement design, or stability margins, because the rules are often nonlinear. (6)

Fuzzy logic controller also shows better performance in reducing overshoot parameters of the inverter compared to PI controller.

In (7) a comparative study between fuzzy logic controller and PI controller is proposed. The study shows the Superior performance of the fuzzy controller in terms of fast response and minimum THD. IN this paper a comprehensive study of three phase grid connected inverter is presented. A complete system model for a 9.1 KW system is built using MATLAB/SIMULINK.A comparison between proposed scheme and other schemes from literature is given.

The paper is organized as following section 2 provides a complete description of the control scheme section 3 describes the fuzzy controller in details. Section 4 introduces the Simulink model and simulation results. Section 5 introduces a comparison between proposed scheme and other schemes from literature. Section 6 proposes the hardware implementation of the inverter. Section 7 is the conclusion of the work.

2. Control scheme

the configuration of the grid connected PV system is shown in figure 1. It consists of a PV panels, MPPT, DC/AC converter, loads, and the grid

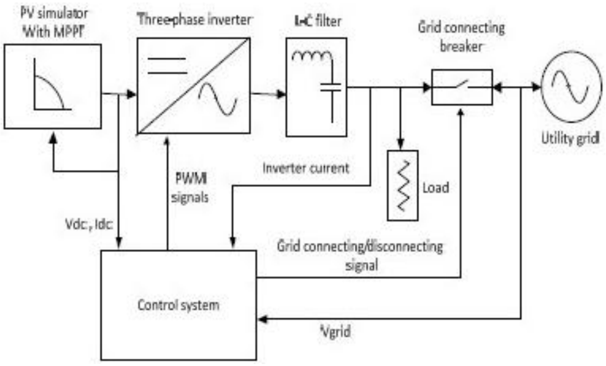

Fig. 1: System Model (8).

The MPPT is responsible for tracking the point that produces maximum power from the PV panel. The DC/AC converter converts the output DC power to equivalent AC power synchronized with the grid and suitable for loads

In (9) it is stated that the control tasks of the grid connected inverter can be divided into two parts: Input-side controller and Grid-side controller. The control objective on the Input side controller is to capture maximum power from the input source. However the control objectives on the grid side controller are to control the power delivered to the grid to ensure high quality of the injected power and grid synchronization. In this work two control loops are used one for grid synchronization and another to regulate the grid current.

In our work we implement the inverter with fuzzy controller that is responsible of insuring synchronization between the grid and the inverter output. Park transformation is used to transform an abc frame to an dq frame. This transformation causes the grid current and voltage to be transformed into a reference frame that rotates simultaneously with the grid voltage. In this manner control variables are changed to DC variables that are easily controlled the simplest synchronization algorithm is the zero crossing detection. However, this method has many disadvantages such as low dynamics. in addition it is affected by noise and higher order harmonics in the utility grid now-days, the most common synchronization algorithm for extracting the phase angle of the grid voltage is the PLL. A phase locked loop (PLL) is used to synchronize the voltage with the grid voltage. The PLL gives outputs in terms of sinwt and coswt which are used as the reference frequency in the calculation of park transformation.

3. Fuzzy logic control strategy

A FLC is defined as the nonlinear mapping of an input data set to a scalar output data. In our work we have two FLC controllers voltage regulator

- Responsible for regulating the voltage and synchronization with the grid.

Current regulator

- Responsible to ensure that the injected current is synchronized with the grid.

4. Simulink model and simulation results

Figure 2 shows the Simulink model the simulation is done with two situations: the first situation using 2KW load noting that the PV panels generate 9.1KW power this means there will be excess power fed to the grid. The second situation using 12Kw load this means that the power generated from PV panels isn't sufficient for the loads, hence power is drawn from the grid

a) low load power

in this simulation the load power is low so excess power is fed to the grid

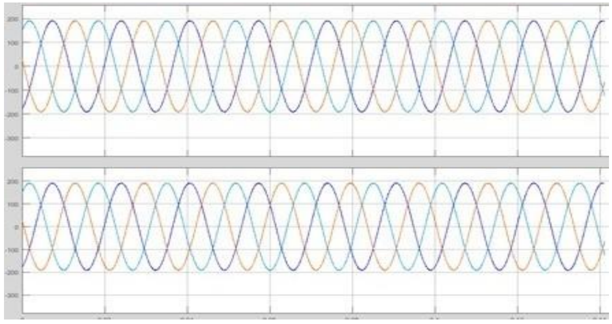

Fig. 3: Inverter and Grid Voltage.

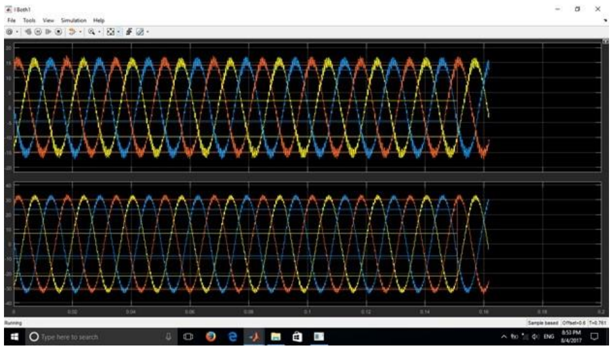

Fig. 4: Inverter and Grid Current.

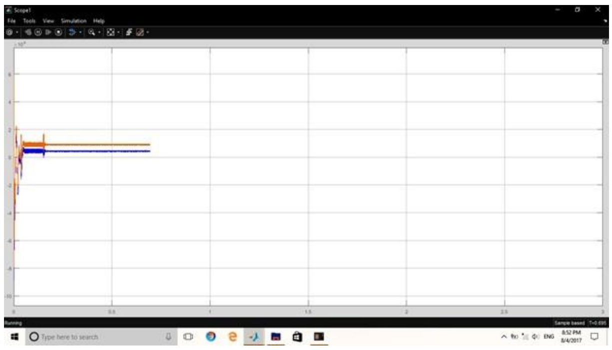

Fig. 5: Inverter and Grid Power Situation 1.

The panel is generating 9.1 Kw, the loads consume 2 Kw and the rest is fed to the Grid. (the Grid Power is positive meaning the rest power is being supplied to the Grid)

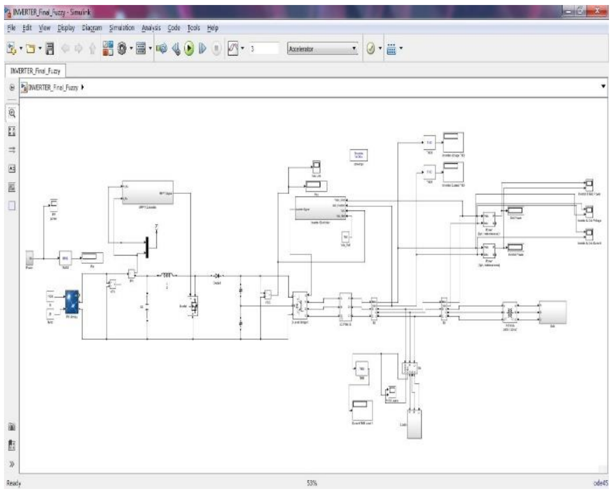

Fig. 2: Simulink Model of the System.

b) high load power

In this situation the load power is high so it takes power from both the grid and PV size.

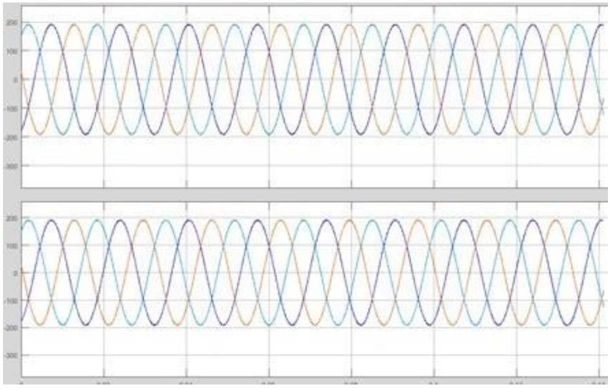

Fig. 6: Inverter and Grid Voltage.

Fig. 7: Inverter and Grid Current.

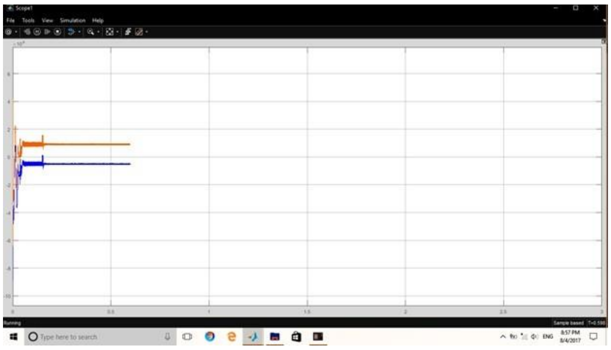

Fig. 8: Inverter and Grid Power Situation 2.

The panel is generating 9.1 Kw, the loads consume 12 Kw which is supplied by both the Grid and the inverter. (the Grid Power is negative meaning the rest power is being supplied from the Grid) the THD in this case .9 voltage and 4 for current which is below the 5 percent limit

5. Comparison section

in this section we compare our work with other work provided in literature to prove our superior performance in Low harmonic distortion

Features	Ref.3	Ref.7	Proposed
current THD	3.82	4.64	3.8
voltage THD	-	2.48	.9
Topology	3-phase, 3level	3-phase,3-level	3-phase,3-level
control algorithm	APR	Fuzzy	Fuzzy
environment	Simulink	Simulink	Simulink

6. Hardware implementation

In this section we provide a detailed description of the proposed hardware we implement a 260 watt prototype system
hardware to test the fuzzy controller. there are many ways to implement fuzzy controller in hardware
In (10) DSP TMS320f2812 based inverter employing proportional integral controller is proposed. However, it requires software coding experience. In (1) dsPIC30F3010 micro- controller is used to implement a proportional integral controller along with the PWM. However, it requires software coding experience despite that it is a low-cost device.
In (11) FPGA based PV inverter employing proportional integral controller and PWM controlling algorithm. However, it requires a lengthy software code and VHDL programming experience. This has the advantage of using simple low cost Arduino controllers for our implementation without excessive programming. In addition the controller is implemented in low cost micro-controller.

a) Inverter circuit

the IR2110 high and low side driver is chosen in this circuit. The driver is used to convert the controller signal to
be able to turn the switches on and off.

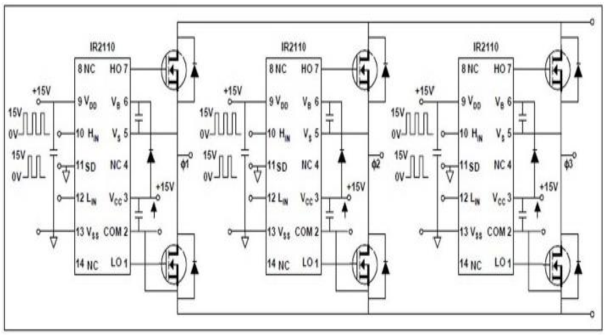

Fig. 9: Schematic of the Inverter (1).

Figure 10 shows the inverter hardware

Fig. 10: PCB Implementation of the Inverter

In Figure 11 We See the Output 3 Phase Voltage.

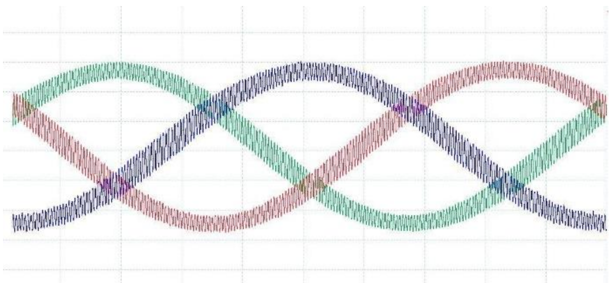

Fig. 11: 3 Phase Voltages.

In the following figure we show the three phase currents

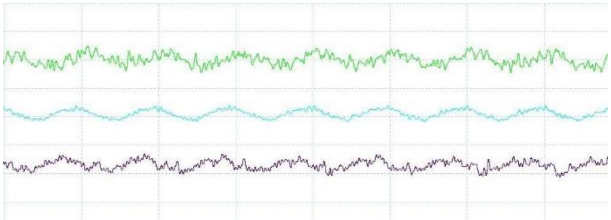

Fig. 12: 3 Phase Currents.

7. Conclusion

A current controlled three phase grid connected inverter system is presented. the Simulink model of the system achieves low harmonics distortion of .9% of current waveform distortion. a complete comparison with grid connected inverter controllers is performed. the comparison shows the superior performance of the proposed fuzzy controller. A complete hardware setup was implemented. The fuzzy controller implemented in Arduino controller

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