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Fuzzy Logic Control of a Single Stage Boost Inverter for Grid Connected PV Systems

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Abstract

T Grid interconnection of PV system based on a single stage boost inverter is presented in this article. This boost inverter directly converters low voltage DC into high voltage AC without using boost converter and DC-AC converter known as two stage conversion. Normally grid interconnection of PV system requires two stage conversions, which is bulky, complicated and costly. The above mentioned disadvantages are eliminated by using the presented boost inverter because it is a single stage conversion. For achieving good response, the boost inverter is controlled by the Fuzzy Logic Controller. The effectiveness of the proposed system is validated by MATLAB/SIMULINK software and the appropriate results are presented.

Keywords: Boost Inverter, Fuzzy Logic Controller, PV System, Renewable Energy Sources (RES)

1. Introduction

Energy consumption is increasing day by day due to the advancement in technologies. Conventional energy sources such as thermal; hydel, etc. are having the disadvantages of polluting the atmosphere, low efficiency and limitedly available etc. For eliminating the above disadvantages people are concentrating on Renewable Energy Sources (RES). The main advantage of Renewable Energy Sources is that they do not pollute the atmosphere and also they are limitless[1,2]. There are so many numbers of RES existing such as PV, wind and fuel cell etc. Among all the RES, Photovoltaic system (PV) has the advantages of clean, light and easily installable cell converts sun radiation directly into electricity. The basic element of PV cell is silicon. Usually the voltage obtained from the PV cell is very low (0.4-0.5 v). For grid interconnection of PV systems, we generally first convert low voltage DC obtained from the PV system into high voltage DC using boost DC-DC converter and then convert this high voltage into AC by using voltage source inverter. This process is called two stage conversion systems[3] which are shown in Figure 1.

The disadvantages of two stage conversion system are as follows:

- Lower efficiency.
- Low reliability.
- Higher cost and larger size.

For eliminating the above disadvantages, the single stage conversion system is used in this paper[4] which is shown in Figure 2.

Features of the single stage conversion system are as follows:

- Simple circuit topology.
- Higher efficiency.
- Low cost.

The boost inverter controlled by Fuzzy Logic Controller, which is a nonlinear controller presented in this paper and the appropriate results are also presented.

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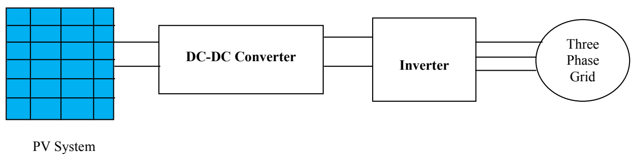

Figure 1. Two stage conversion system.

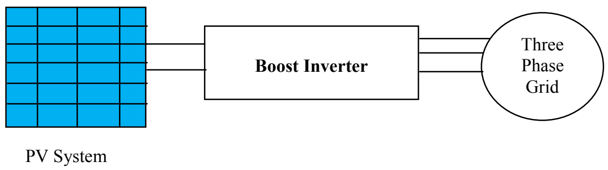

Figure 2. Single stage conversion system.

2. Working of Boost Inverter

The following Figure 3 depicts the circuit diagram of boost inverter comprises of two DC-DC converters.

The two DC-DC converters produce DC biased sine output which is anti phase with each other makes the output voltage maximum[5].

The output voltages of these two converters are given as:

$$V_a = V_{dc} + V_m sin\omega t \quad \text{(a)}$$

$$V_b = V_{dc} - V_m sin\omega t \quad \text{(b)}$$

The voltage across the load is given as:

$$V_0 = V_a - V_b = 2V_m sin\omega t \quad \text{(c)}$$

The two converter model of a boost inverter and their characteristics are shown in the Figures 4 and 5 respectively.

The voltage gain of the proposed boost inverter is given by:

$$\text{Gain} = \frac{V_0}{Vin} = \frac{2D}{D(D-1)} \quad \text{(iv)}$$

3. PV System

The basic element of a PV cell is silicon and it generates electricity by using sun radiations. The electrical equivalent model of a PV cell is shown in the below diagram.

It consists of a current source, diode in parallel with it. Practical PV cell consists of shunt resistance Rsh and a series resistance Rse[7]. For high voltages, PV cells have to be connected in series and for high current they have to be in parallel.

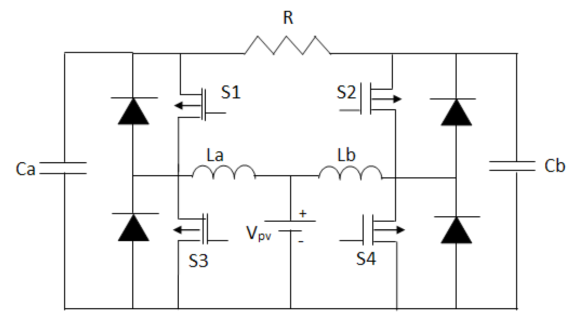

Figure 3. The boost inverter.

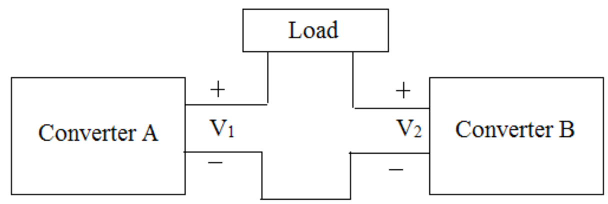

Figure 4. Two converter model of boost inverter.

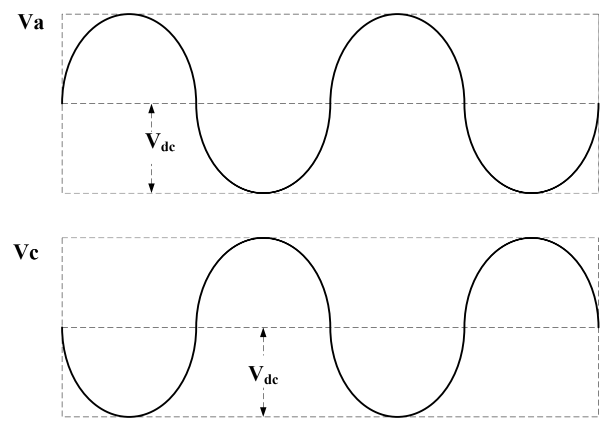

Figure 5. Output characteristics of two converters.

The insolation current is given by:

$$Iph = Id + IRp + I \quad \text{(iv)}$$

Where I = load current,

$$I = Iph-(Io[e(v+IRs/VT)-1]+V+IRs/Rp) \quad \text{(v)}$$

Where Iph = Insolation current.

I_{0} = Reverse saturation current.

The following graph shows the I-V and power curves of a solar panel.

The voltage obtained from the PV cell is about 0.5–0.7 V. Interfacing of PV system with the existing grid requires an efficient converter to make this system effectively. Conventional grid connected system uses

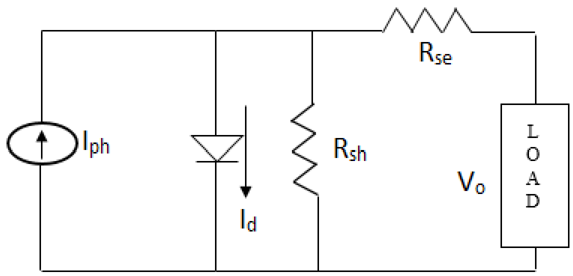

Figure 6. Electrical equivalent model of a PV cell.

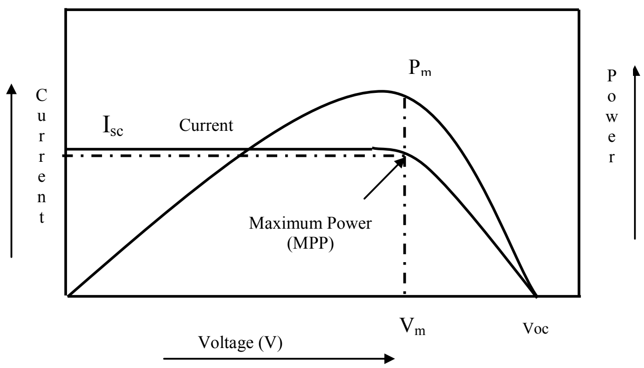

Figure 7. I-V characteristics of solar panel.

two types of converters such as DC-DC converter and inverter which increases the overall cost of the system. In order to eliminating the above disadvantages, this paper proposes a single stage conversion system utilizing single converter known as boost inverter. The proposed inverter is controlled by a Fuzzy Logic Controller to make this converter work efficiently.

4. Fuzzy Logic Controller

One of the most powerful artificial intelligence controller used for the nonlinear systems is Fuzzy Logic Controller (FLC). L. A. Zadeh was the person to introduce the concept of fuzzy set theory in 1965. A Fuzzy Logic Control system essentially incorporates the experience, intuition of a human plant operator. The Fuzzy Logic Controller utilizing the fuzzy logic converts a linguistic control strategy into automatic control strategy. The basic approach of FLC is shown in Figure 8.

In this paper FLC is used to generate the switching signals for the proposed boost inverter which injects the power into conventional grid without violating the grid rules. The following Figure 8 shows the membership functions and fuzzy rules for the proposed converter. Two

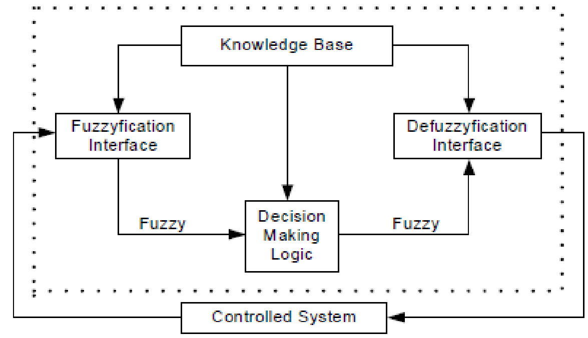

Figure 8. Fuzzy Logic Controller.

input variables, error (e) and change of error (de) are used in this fuzzy logic system. The single output variable (u) is duty cycle of the proposed boost inverter.

The error and change in error of the output voltage of a boost inverter are the inputs of Fuzzy Logic Controller. These two inputs can be classified into five groups; NB: Negative Big, NS: Negative Small, ZO: Zero Area, PS: Positive Small and PB: Positive Big and its parameter[8–10]. The following Table 1 shows the fuzzy rules for the proposed converter.

5. Simulation Results

The following Figure depicts the MATLAB/SIMULINK diagram of the proposed inverter with Fuzzy Logic Controller. It consists of four switches S1, S2, S3 and S4. Pulses for these switches are obtained from the Fuzzy Logic Controller. The FLC senses the actual voltage and compare it with reference value. The error (Vref–Vact) is the input for the Fuzzy Logic Controller. The FLC process the error and produce the corresponding signal for the switches.

The following Figure 13 shows the switching signal generator for the proposed inverter.

The corresponding switching signal for the inverter is shown below:

The following Figure 14 shows the grid connected current and grid voltage which are in phase with each other.

From the Figure 15, the grid connected current and voltage is both sinusoids and also they are in phase with each other. FFT analysis of grid connected current is shown in Figure 16.

From the Figure 17, THD of the current is 1.41%, which is under the tolerance of IEEE-519 rule.

Table 1. Fuzzy rules for the proposed inverter

(de) \ (e)	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	ZO
NS	NB	NB	NS	ZO	PS
ZO	NB	NS	ZO	PS	PB
PS	NS	ZO	PS	PB	PB
PB	ZO	PS	PB	PB	PB

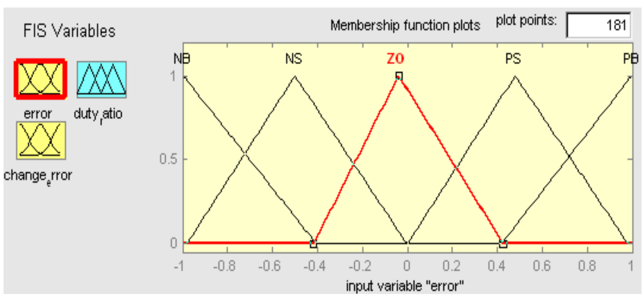

Figure 9. Membership function for input variable error.

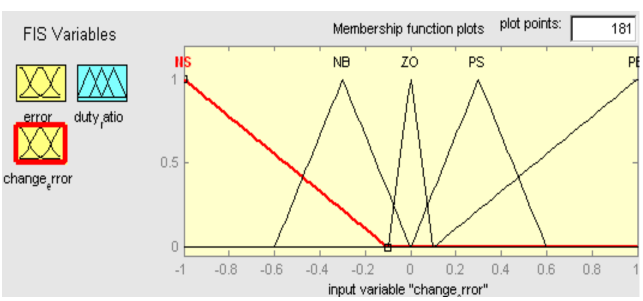

Figure 10. Membership function for input variable change in error.

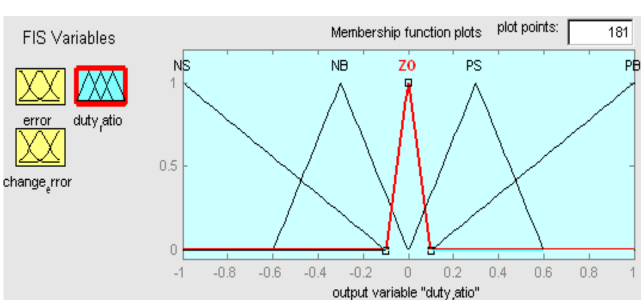

Figure 11. Membership function for input output variable change duty ratio.

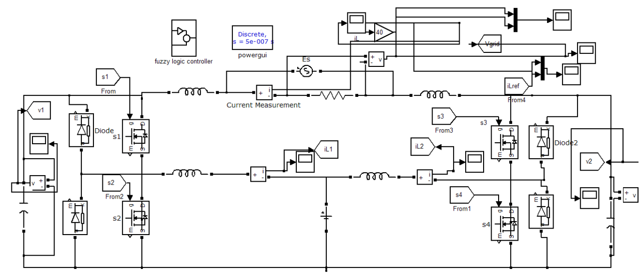

Figure 12. MATLAB/SIMULINK diagram of the proposed inverter.

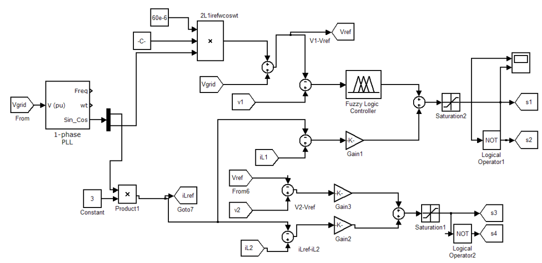

Figure 13. Switching signal generator for the proposed inverter.

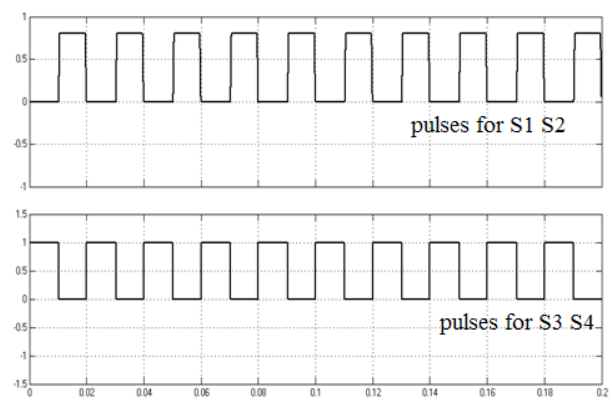

Figure 14. Pulses for the switches S1, S2, S3 and S4.

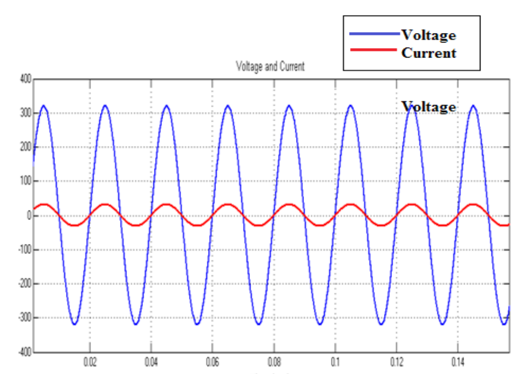

Figure 15. Grid voltage and grid connected current.

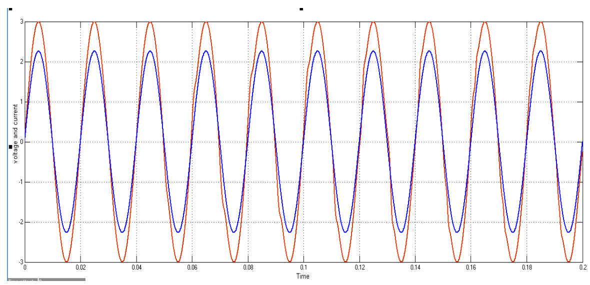

Figure 16. Actual grid connected current and reference current.

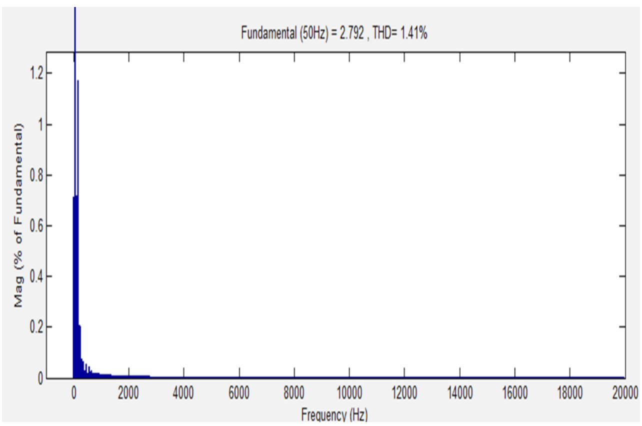

Figure 17. FFT analysis of load current.

6. Conclusion

This paper presents a new single stage conversion system for the grid interconnection of PV system. The proposed boost inverter directly converts the low voltage DC obtained from the PV system into AC. In order to get the good transient response the proposed inverter is controlled by the Fuzzy Logic Controller. By using FLC, the grid connected current and grid voltage are in phase with each other. The proposed concept is verified by using MATLAB/SIMULINK environment and corresponding results are presented in this paper.

7. References

1. Shimizu T, Hashimoto O, Kimura G. A novel high performance utility interactive Photovoltaic inverter system. IEEE Transactions on Power Electronics, America. 2003 Mar; 18(2):704–11.
2. Chen YK, Yang CH, Wu YC. Robust fuzzy controlled Photovoltaic power inverter with Taguchi method. IEEE Transaction on Aerospace and Electronic Systems, America. 2002 Jul; 38(3):940–54.
3. Jain S, Agarwal V. A single-stage grid connected inverter topology for solar PV systems with maximum power point tracking. IEEE Transactions on Power Electronics. 2007 Sep; 22(5):1928–40.
4. Liang TJ, Kuo YC, Chen JF. Single-stage Photovoltaic energy conversion system. IEE Proceedings -Electric Power Applications, Stevenage. 2001 Jul; 148(4):339–44.
5. Caceres RO, Barbi I. A boost DC-AC converter: Analysis, design and experimentation. IEEE Transactions on Power Electronics. 1999 Jan; 14(1):134–41.
6. Prasadarao KVS, Amarendra A. Integration of grid connected hybrid generation system using boost inverter. IJEEE. 2013; 3(2):122–6.
7. Mosazade SY, Fathi SH, Radmanesh H. An overview of high frequency switching patterns of cascaded multilevel inverters suitable for PV applications and proposing a modified method. Indian Journal of Science and Technology. 2014 Jan; 7(9). DOI: 10.17485/ijst/2014/v7i9/33636.
8. Sadeghi M, Gholami M. Fuzzy logic approach in controlling the grid interactive inverters of wind turbines. Indian Journal of Science and Technology. 2014 Jan; 7(8). DOI: 10.17485/ijst/2014/v7i8/47339.
9. Jackson D, Dev Anand M, Sivarajan T, Mary Synthia Regis Prabha DM. Development of utilizing magnetic brake in small wind turbine speed control using Fuzzy Logic Controller. Indian Journal of Science and Technology. 2016 Apr; 9(13). DOI:10.17485/ijst/2016/v9i13/9056.
10. Guo L, Hung JY, Nelms RM. PID controller modifications to improve steady state performance of digital controllers for buck and boost converters. IEEE Applied Power Electronics Conference and Exposition, Dallas, TX. 2002; 1:381–8.