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Design of Half-Bridge Photovoltaic Microinverter System Using Fuzzy Logic Controller

S.Mounika, B.Pushpa Lakshmi, T.Rajashree
Final Year -Department of Electrical and Electronics Engineering
Velammal College of Engineering & Technology,
Madurai – 625009,India

***Abstract*—Growth of science and technology has a tremendous effect in the usage of alternative energy sources. Solar energy is one among the growing sources of energy. It has a greatest potential among all sources. Power electronics plays a vital role in the control of electrical energy. This project presents a new technique of implanting fuzzy logic control in the inverter section for a load connected boost half bridge micro inverter system in order to achieve high efficiency with low distortion. The proposed topology deals with a PV panel from which voltage is obtained and is integrated with a boost converter cascade and a H-bridge pulse width modulated inverter to regulate the current to the load. An expert system namely"Fuzzy logic controller" is used to modulate pulse width under various load conditions. Improvement of power factor and reliability is guaranteed in the project.**

Keywords—boost half bridge; microinverter;Photovoltatic; Fuzzy Logic Control.

I. INTRODUCTION

The Concept of micro inverter has become future trend or single-phase load connected photovoltaic (PV) power systems, for its removal of energy yield mismatches among PV modulus. In general , a PV micro inverter system is often supplied by a low voltage solar panel, which requires a high voltage step-up ratio to produce desired output AC Voltage [1]-[3]. Hence a DC-DC converter cascaded by an inverter is the most popular topology, in which a high frequency transformer is often implemented within the DC-DC conversion Stage [4]-[10].

In terms of the pulse-width modulation (PWM) techniques employed by the PV micro inverter system, two major categories are attracting most of the attentations. In the first, PWM control is applied to both of the DC-DC converter and the inverter [4]-[6]. In addition a constant voltage DC link decouples the power flow in the two stages such that the DC inputs is not affected by the double-line-frequency power ripple appearing at the AC side. By contrast, the second configurations utilize a quasi-sinusoidal PWM method to control the DC-DC converter in order to generate a rectified sinusoidal current (or voltage) at the inverter DC link. Accordingly, a line-frequency commutated inverter unfolds the DC link current or voltage to obtain the sinusoidal form synchronized with the load [7]-[10].

A boost dual-half-bridge DC-DC converter for bidirectional power conversion application was first proposed in [11] and then further investigated in [12]-[14]. It integrates the boost converter and the dual-half-bridge converter together by using minimal number of devices. High efficiency is realizable when the zero voltage switching (ZVS) techniques is adopted. A full bridge PWM inverter with an output LCL filter is incorporated to inject synchronized sinusoidal current to the load. In general, its performance is evaluated by the output current total harmonic distortions (THD), power factor and dynamic response.

Fuzzy controllers are very simple conceptually. They consist of an input stage, a processing stage and an output stage. The input such as switches, thumbwheels, and so on, to the appropriate membership functions and truth values. The processing stage invokes each appropriate rule and generates a result for each, then combines the result of the rules. Finally, the output stage converts the combined result back int a specific control output value. The proposed current controller exhibits the following superior features:

1. High power factor is obtained
2. Current harmonic distortions caused by the grid voltage non-ideality are minimized
3. Outstanding current regulations is guaranteed within a wide range of load conditions.
4. Fast dynamic response is achieved during the transients of load or solar irradiance change.

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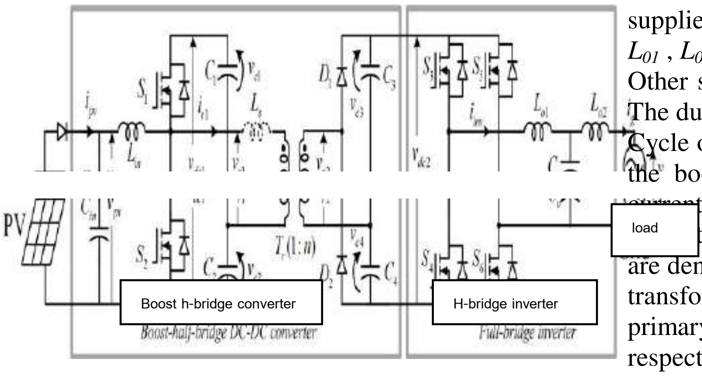

Fig. 1. Topology of boost half bridge PV micro inverter.

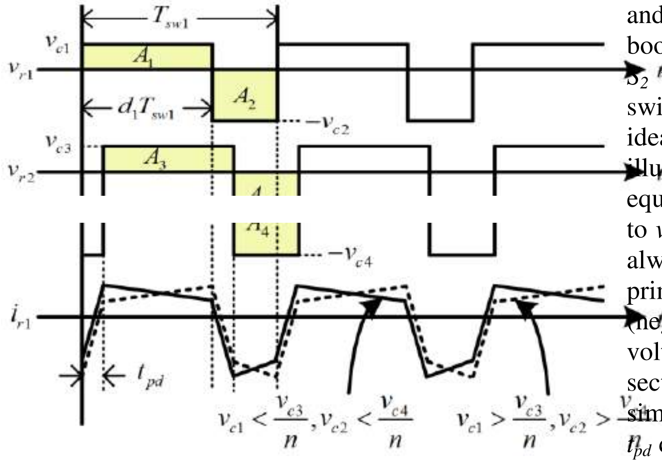

Fig .2. transformer voltage and current.

II. INVERTER

The dc-ac converter, also known as the inverter, converter dc power to ac power. The boost-half-bridge micro inverter topology for grid connected photovoltaic systems is depicted in Fig. 1. It is composed of two decoupled power processing stages. In the front-end DC-DC converter, a conventional boost converter is modified by splitting the output DC capacitor into two separate ones. C_{in} and L_{in} denote the input capacitor and boost inductor, respectively. The center taps of the two MOSFETs (S_1 and S_2) and the two output capacitors (C_1 and C_2) are connected to the primary terminals of the transformer T_r , just similar to a half bridge.

The transformer leakage inductance reflected to the primary is represented by L_s and the transformer turns ratio is 1: *n.* A voltage doubler composed of two diodes (D_1 and D_2) and two capacitors (C_3 and C_4) is incorporated to rectify the transformer secondary voltage to the inverter DC link. A full bridge inverter composed of 4 MOSFETs (S_3 ~ S_6) using SPWM control serves as the DC-AC conversion stage. Sinusoidal current with a unity power factor is supplied to the grid through a third order LCL filter (L_{01} , L_{02} and C_0).

Other symbol representations are defined as follows. The duty

Cycle of S_1 is denoted by d_1 . The switching period of the boost half- bridge converter is T_{sw1} . The PV current and voltage are represented by i_{pv} and v_{pv} , respectively. The voltages across C1,$C2$, C_3 and C_4 are denoted by v_{c1}, v_{c2} , v_{c3} and v_{c4}, respectively. The transformer primary voltage, secondary voltage and primary current are denoted as v_{r1} , v_{r2} and r_{1i} , respectively. The low voltage side (LVS) DC link voltage is v_{dc1} and the high voltage side (HVS) DC link voltage is v_{dc2} . The switching period of the full bridge inverter is T_{sw2}. The output AC currents at the inverter side and the grid side are represented by i_{inv} and i_g , respectively. The grid voltage is v_g . The boost-half-bridge converter is controlled by S_1 and S_2 with complementary duty cycles. Neglect all the switching dead bands for simplification. The idealized transformer operating waveforms are illustrated in Fig. 2. When S_1 is on and S_2 is off, v_{r1} equals to v_{c1} . When S_1 is off and S_2 is on, v_{r1} equals to v_{c2} . At the steady state, the transformer volt-sec is always automatically balanced. In other words, the primary volt-sec A_1 (positive section) and A_2 (negative section) are equal. So are the secondary volt-sec A_3 (positive section) and A_4 (negative section). Normally, D_1 and D_2 are on and off in a similar manner as S_1 and S_2 , but with a phase delay t_{pd} due to the transformer leakage inductance. Ideally, the transformer current waveform is determined by the relationships of v_{c1} ~ v_{c4} , the leakage inductance L_s , the phase delay t_{pd} , and S_1 's turn-on time d_1 T_{sw1} [12].

In order to reach an optimal efficiency of the boost-half-bridge converter, ZVS techniques can be considered for practical implementation, as guided by [12]. It is worth noting that engineering trade-offs must be made between the reduced

Switching losses and increased conduction losses when soft

Switching is adopted. Detailed optimal design processes of the

Boost-half-bridge converter will not be addressed in this paper.

For simplicity, hard switching is employed and the transformer leakage inductance is regarded as small enough in this paper.

III. H-BRIDGE CONVERTER

It is an electronic device used whenever we want to change DC electrical power efficiently from one voltage to another. They are needed because unlike AC, DC cannot simply be stepped up or step down using a transformer, as they essentially just change the input energy into a different impedance level.

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Whatever the voltage level may be the output power comes from the input. There is no energy manufactured inside the converter.

A. *Power in a DC-DC converter*

The basic power flow in a given by this equations

$P_{in}= P_{out} + P_{loss}$

P_{in} is the fed into the converter

P_{out} is the output power

P_{loss} is the power wasted inside the converter

There would be no loss, and P_{out} would be exactly the same as P_{in}. We could then Say that:

$V_{in} * I_{in} = V_{out} * I_{out}$

By re arranging we get

$V_{out} / V_{in}= I_{in} / I_{out}$

In other words, if we step up the voltage we step down the current, and vice versa. There is no such thing as perfect DC-DC converter, just as there are no perfect transformers. So we need the concept of efficiency, where

Efficiency = P_{out}/P_{in}

Now days some types of converter achieves an over 90% using the latest component and circuit techniques. Most other at least 80%-85% is most standard AC transformers. There are many different types of converter each of which tends to be more suitable for some types of application than for others. For convenience they can be classified are only suitable for stepping down the voltage.

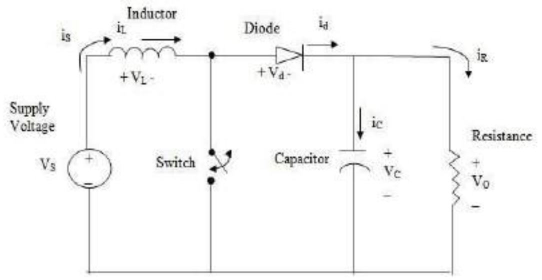
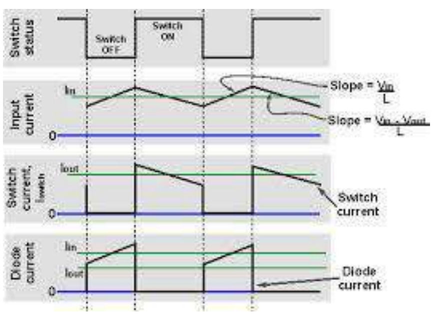


Fig 3. Block diagram of boost converter.



IV. FUZZY LOGIC CONTROLLER

In the energy industry, while controlling a system, it is expected that the stability and safety of the system will be assured. The system must also be cheap, easy to use, understandable, repairable, and changeable, and, above all, must increase the performance to the desired level. To achieve all of these goals, the structure and the dynamic properties of the system that will be controlled must be known and must also be mathematically modeled. Sometimes, however, due to some nonlinear systems, mathematic models are not possible. Even if the modeling is done, the controller that will be used in that system might cause some design problems and high costs. Therefore, the controller might not work at the desired performance level. In situations like this, an expert's information is utilized. The expert presents the information and experiences as fuzzy or uncertain types to do the controlling.

These characterizations are transferred to the computer, ending the need for the expert. The differences among the controls of different experts also come to an end, and the controlling of the system thus becomes flexible. The term "fuzzy logic" can be explained as a method that utilizes the experiences of people for numerical expressions, instead of verbal and symbolic expressions, to produce the functional rules of a system. Fuzzy logic is established based upon the logical relations. In daily life, the terms that are used usually have a fuzzy structure type.

In fuzzy logic, instead of consideration based on exact data, approximate consideration is used. In fuzzy logic, all data are shown as values between 0 and 1. The information in fuzzy logic is verbal, such as "big," "small," "more," or "few." The fuzzy implication process is conducted according to rules that are defined between the verbal expressions. Every

Logical system can be defined as fuzzy. Fuzzy logic is very suitable for systems whose mathematical models are hard to develop. Fuzzy logic has the ability of processing uncertain or incomplete information.

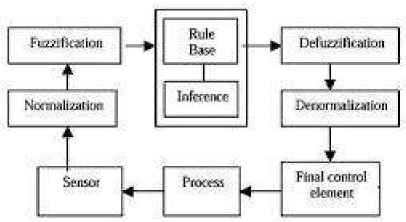


Fig 4. Block diagram Fuzzy Logic Controller.

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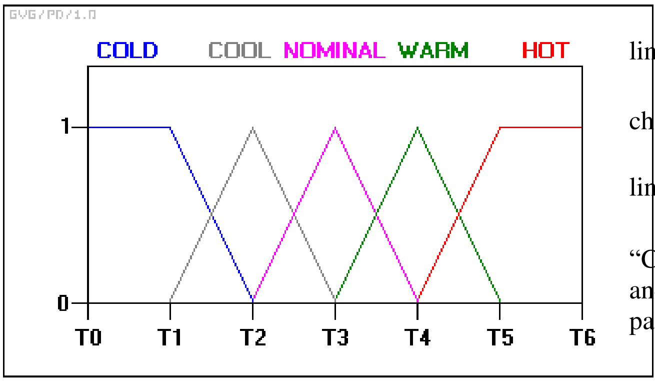

Fig 5. Variation of error membership functions.

With this scheme, the input variable's state no longer jumps abruptly from one state to the next. Instead, as the temperature changes, it loses value in one membership function while gaining value in the next. At any one time, the "truth value" of the brake temperature will almost always be in some degree part of two membership functions: 0.6 nominal and 0.4 warm, or 0.7 nominal and 0.3 cool, and so on. The input variables in a fuzzy control system are in general mapped into by sets of membership functions similar to this, known as "fuzzy sets". The process of converting a crisp input value to a fuzzy value is called "fuzzification".

A control system may also have various types of switch, or "ON-OFF", inputs along with its analog inputs, and such switch inputs of course will always have a truth value equal to either 1 or 0, but the scheme can deal with them as simplified fuzzy functions that are either one value or another.

V. Experimented and Results

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The template is designed so that author affiliations are not repeated each time for multiple authors of the same affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization). This template was designed for two affiliations.

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B. Identify the Headings

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Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include ACKNOWLEDGMENTS and REFERENCES, and for these, the correct style to use is "Heading 5." Use "figure caption" for your Figure captions, and "table head" for your table title. Run-in heads, such as "Abstract," will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

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1) Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation "Fig. 1," even at the beginning of a sentence.

TABLE I. TABLE STYLES

Table Head	Table Column Head		
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a. Sample of a Table footnote. *(Table footnote)*

b.

Fig. 1. Example of a figure caption. *(figure caption)*

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity "Magnetization," or "Magnetization, M," not just "M." If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write "Magnetization (A/m)" or "Magnetization (A (m(1)," not just "A/m." Do not label axes with a ratio of quantities and units. For example, write "Temperature (K)," not "Temperature/K."

Conclusion

A novel boost-half-bridge micro inverter for grid-connected
Photovoltaic systems have been presented in this paper. A plug-in Fuzzy Logic controller was proposed and illustrated. The Operation principles and dynamics of the boost-half-bridge DCDC converter were analyzed and a customized MPPT control method was developed correspondingly. Simulation and experimental results of the 210 W prototypes were shown to verify the circuit operation principles, current control. The minimal use of semiconductor devices, circuit simplicity and easy control, the boost-half-bridge PV micro inverter possesses promising features of low cost and high reliability. According to the experimental results, high efficiency (97.0%~98.2%) is obtained with the boost-half-bridge DC-DC Converter over a wide operation range. Moreover, the current Injected to the grid is regulated precisely and stiffly. High power factor (> 0.99) and low THD (0.9%~2.87%) are obtained under both heavy load and light load conditions.

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