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Implementation of a Voltage Multiplier based on High Step-up Converter using FLC

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ABSTRACT

A Front end of the Photovoltaic Solar Panel is been proposed based on Step-Up Converter. The use of distributed energy resources is increasingly being pursued as a supplement and an alternative to large conventional central power stations. The specification of a power electronic interface is subject to requirements related not only to the renewable energy source itself but also to its effects on the power-system operation, especially where the intermittent energy source constitutes a significant part of the total system capacity. Implementing a voltage multiplier module, an asymmetrical interleaved high step-up converter obtains high step-up gain without operating at an extreme duty ratio. The voltage multiplier module is composed of a conventional boost converter and coupled inductors. An extra conventional boost converter is integrated into the first phase to achieve a considerably higher voltage conversion ratio. The two-phase configuration not only reduces the current stress through each power switch, but also constrains the input current ripple, which decreases the conduction losses of metal–oxide–semiconductor field-effect transistors. In addition, the proposed converter functions as an active clamp circuit, which alleviates large voltage spikes across the power switches. Finally, the simulation circuitry with a 40V input voltage and 230V output voltage is operated to verify its performance analysis with respect to the Fuzzy Logic Controller. The highest efficiency is 97.75%.

KEYWORDS: *Boost/fly-back converter, high step-up converter, photovoltaic system, voltage multiplier module, Fuzzy Logic Controller.*

I. INTRODUCTION

As conventional sources of energy are rapidly depleting and the cost of energy is rising, photovoltaic energy becomes a promising alternative source. Among its advantages are that it is: 1) abundant; 2) pollution free; 3) distributed throughout the earth; and 4) recyclable. The main drawbacks are that the initial installation cost is considerably high and the energy conversion efficiency is relatively low. To overcome these problems, the following two essential ways can be used: 1) increase the efficiency of conversion for the solar array and 2) maximize the output power from the solar array. With the development of technology, the cost of the solar arrays is expected to decrease continuously in the future, making them attractive for residential and industrial applications. The state-space-averaging method [9] is widely used to derive expressions for small-signal characteristics of pulse width modulated (PWM) converters [9], [10]. However, this method is sometimes tedious, especially when the converter equivalent circuit contains a large number of elements. To obtain the models of dc/dc converters, the principle of energy conservation is used in this paper to derive the model and transfer function for the system [11]. The models are especially convenient in analyzing complicated converter topologies and for including parasitic components.

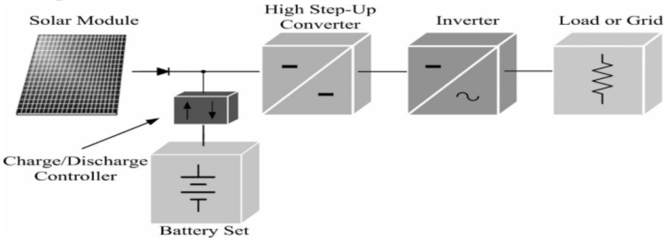

Figure 1 Typical PV System

The increasing number of renewable energy sources and distributed generators requires new strategies for the operation and management of the electricity grid in order to maintain or even to improve the power-supply reliability and quality. In addition, liberalization of the grids leads to new management structures, in which trading of energy and power is becoming increasingly important. The power-electronic technology plays an important role in distributed generation and in integration of renewable energy sources into the electrical grid, and it is widely used and rapidly expanding as these applications become more integrated with the grid-based systems.

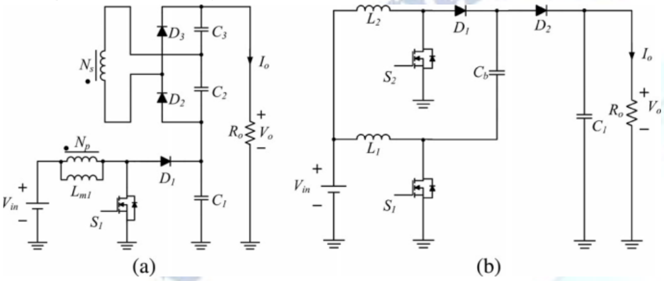

Figure 2 Integrated fly-back boost converter

Modifying a boost fly-back converter, shown in Fig. 2(a), is one of the simple approaches to achieving high step-up gain; this gain is realized via a coupled inductor. The performance of the converter is similar to an active-clamped fly-back converter; thus, the leakage energy is recovered to the output terminal [12]. An interleaved boost converter with a voltage-lift capacitor shown in Fig. 2(b) is highly similar to the conventional interleaved type.

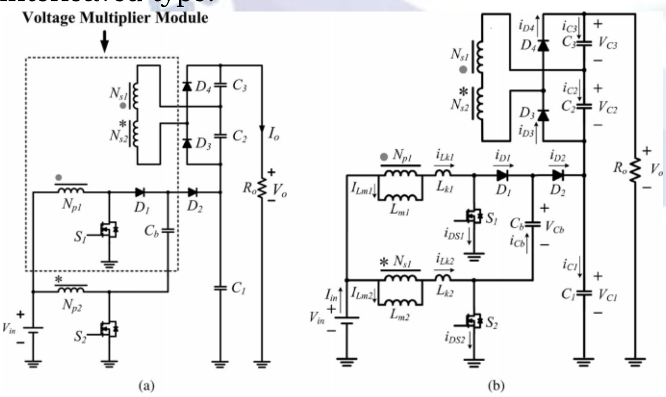

Figure 3 Proposed Voltage Multiplier Circuit

The advantages of the proposed converter are as follows:

1. The converter is characterized by a low input current ripple and low conduction losses, making it suitable for high power applications.
2. The converter achieves the high step-up voltage gain that renewable energy systems require.
3. Leakage energy is recycled and sent to the output terminal, and alleviates large voltage spikes on the main switch.
4. The main switch voltage stress of the converter is substantially lower than that of the output voltage.

II. Literature Survey

Photovoltaic systems normally use a maximum power point tracking (MPPT) technique to continuously deliver the highest possible power to the load when variations in the isolation and temperature occur. It overcomes the problem of mismatch between the solar arrays and the given load. A simple method of tracking the maximum power points (MPP's) and forcing the system to operate close to these points is presented. The principle of energy conservation is used to derive the large- and small-signal model and transfer function. By using the proposed model, the drawbacks of the state-space-averaging method can be overcome. The TI320C25 digital signal processor (DSP) was used to implement the proposed MPPT controller, which controls the dc/dc converter in the photovoltaic system. [1], [13].

The use of distributed energy resources is increasingly being pursued as a supplement and an alternative to large conventional central power stations. The specification of a power electronic interface is subject to requirements related not only to the renewable energy source itself but also to its effects on the power-system operation, especially where the intermittent energy source constitutes a significant part of the total system capacity. In this paper, new trends in power electronics for the integration of wind and photovoltaic (PV) power generators are presented. A review of the appropriate storage-system technology used for the integration of intermittent renewable energy sources is also introduced. [2]

A substantial increase of photovoltaic (PV) power generators installations has taken place in recent years, due to the increasing efficiency of solar cells as well as the improvements of manufacturing technology of solar panels. These generators are both grid-connected and stand-alone applications. We present an overview of the essential research results. The paper concentrates on the operation and modeling of stand-alone power systems with PV power generators. Systems with PV array–inverter assemblies, operating in the slave-and-master modes, are discussed, and the simulation results obtained using a renewable energy power system modular simulator are presented. These results demonstrate that simulation is an essential step in the system development process and that PV power generators constitute a valuable energy source. They have the ability to balance the energy and supply good power quality. It is demonstrated that when PV array–inverters are operating in the master mode in stand-alone applications, they will perform the task of controlling the voltage and frequency of the power system. The mechanism of switching the master function between the diesel generator and the PV array–inverter assembly in a stand-alone power system is also proposed and analyzed. [3]

III. Principle Operation

The proposed high step-up converter with voltage multiplier module is shown in Fig. 3(a). A conventional boost converter and two coupled inductors are located in the voltage multiplier module, which is stacked on a boost converter to form an asymmetrical interleaved structure. Primary windings of the coupled inductors with N_P turns are employed to decrease input current ripple, and secondary windings of the coupled inductors with N_S turns are connected in series to extend voltage gain. The turn's ratios of the coupled inductors are the same. The equivalent circuit of the proposed converter is shown in Fig. 3(b), where L_{M1} and L_{M2} are the magnetizing inductors, L_{K1} and L_{K2} represent the leakage inductors, S_1 and S_2 denote the power switches, C_b is the voltage-lift capacitor, and n is defined as a turn's ratio N_S/N_P

The proposed converter operates in continuous conduction mode (CCM), and the duty cycles of the power switches during steady operation are interleaved with a 180^0 phase shift; the duty cycles are greater than 0.5. The key steady waveforms in one switching period of the proposed converter contain six modes, which are depicted in Fig. 4, and Fig. 5 shows the topological stages of the circuit.

Stage A [t_0, t_1]: At $t=t_0$, the power switches S_1 and S_2 are both turned ON. All of the diodes are reversed-biased. Magnetizing inductors L_{M1} and L_{M2} as well as leakage inductors L_{K1} and L_{K2} are linearly charged by the input voltage source Vin.

Stage B [t_1, t_2]: At $t=t_1$, the power switch S_2 is switched OFF, thereby turning ON diodes D_2 and D_4. The energy that magnetizing inductor L_{M2} has stored is transferred to the secondary side charging the output filter capacitor C_3. The input voltage source, magnetizing inductor L_{M2}, leakage inductor L_{K2}, and voltage-lift capacitor C_b release energy to the output filter capacitor C_1 via diode D_2, there by extending the voltage on C_1.

Stage C [t_2, t_3]: At $t=t_2$, diode D_2 automatically switches OFF because the total energy of leakage inductor L_{K2} has been completely released to the output filter capacitor C_1. Magnetizing inductor L_{M2} transfers energy to the secondary side charging the output filter capacitor C_3 via diode D_4 until t_3.

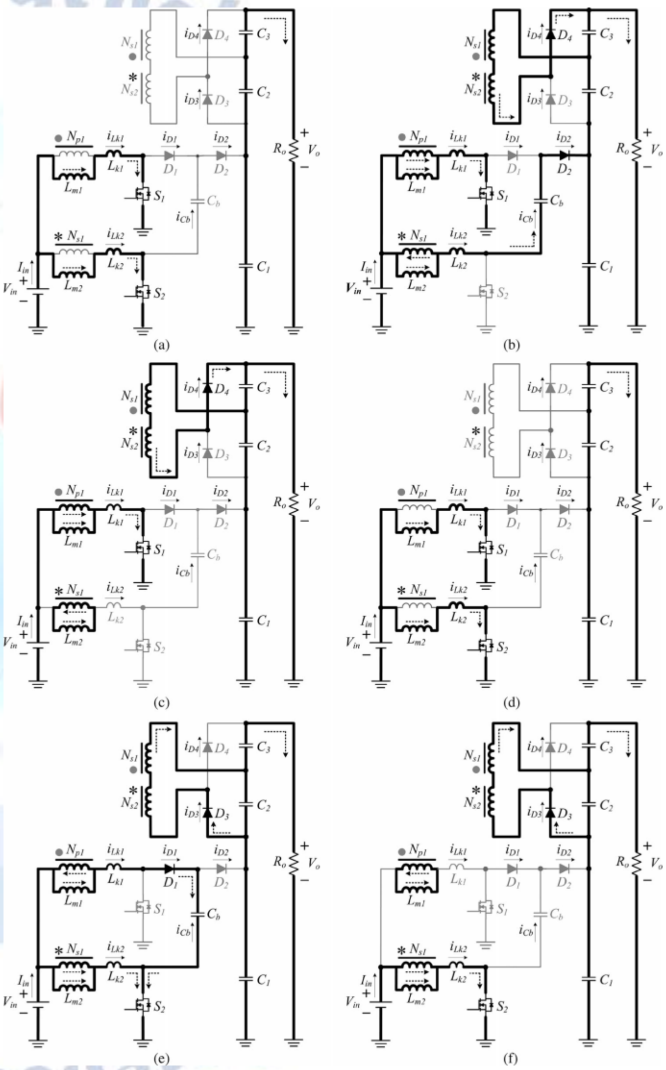

Figure 4 Operating Stages of the Proposed Converter

Stage D [t_3, t_4]: At $t=t_3$, the power switch S_2 is switched ON and all the diodes are turned OFF. The operating states of modes 1 and 4 are similar.

Stage E [t_4, t_5]: At $t=t_4$, the power switch S_1 is switched OFF, which turns ON diodes D_1 and D_3. The energy stored in magnetizing inductor L_{M1} is transferred to the secondary side charging the output filter capacitor C_2. The input voltage source and magnetizing inductor L_{M1} release energy to voltage-lift capacitor C_b via diode D_1, which stores extra energy in C_b.

Stage F [t_5, t_0]: At $t=t_5$, diode D_1 is automatically turned OFF because the total energy of leakage inductor L_{K1} has been completely released to voltage-lift capacitor C_b. Magnetizing inductor L_{M1} transfers energy to the secondary side charging the output filter capacitor C_2 via diode D_3 until t_0.

The operation principle analysis and the steady-state waveforms of the high step-up ZVT-interleaved boost converter have been discussed in [9]. Compared with the proposed converter, the full-bridge dc–dc converter is also employed commonly as a similar first stage in the PV system. However, for the high step-up gain applications, the large current ripples of the primary-side switches increase the conduction losses, and the secondary-side diodes need to sustain a high voltage stress. Moreover, as a buck type converter, a large turns ratio of the transformer is necessary to obtain a high step-up gain, which induces a large leakage inductance and large commutation energy on the primary-side switches. Therefore, the design of the transformer is difficult and the converter's efficiency is impacted. Furthermore, the resonant-mode converters such as LLC, LCC, and higher order element converters are studied and developed, which are attractive for potential higher efficiency and higher power density than PWM counterparts. However, most of resonant converters include some inherent problems, such as electromagnetic interference (EMI) problems due to variable frequency operation and reduced conversion efficiency due to circulating energy generation. Moreover, to make practical use of the resonant converters, the required precise control waveform and difficult over current protection increases the design complexity of the whole system [11].

IV. Design Considerations

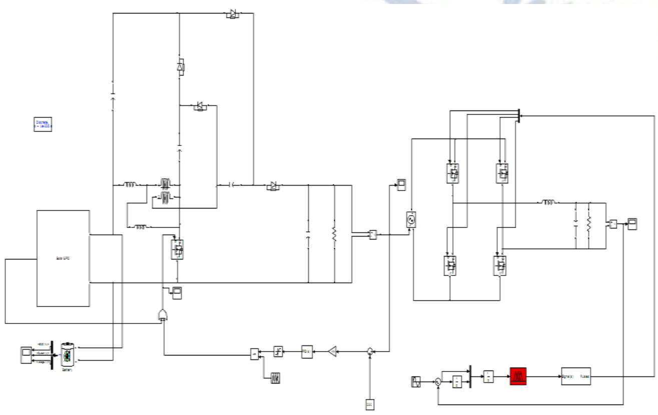

Figure 5 Simulink Diagram using FLC

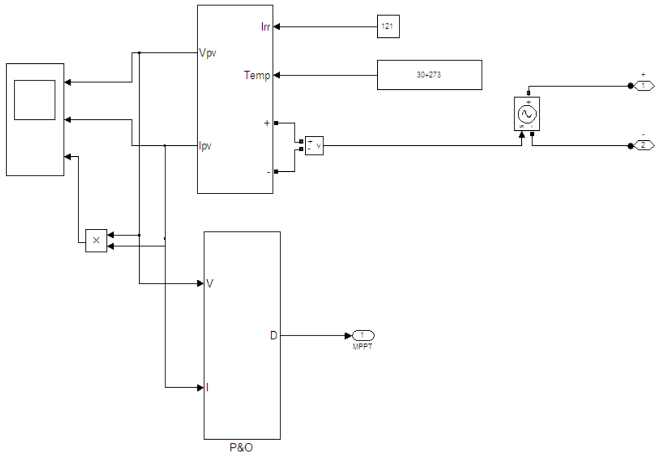

Figure 6 Solar Panel & MPPT (P & O)

V. Fuzzy Logic Controller

In this section, the fuzzy control fundamentals will be outlined first, and then, the key point of self-tuning PI-like fuzzy controller (STFC) will be briefly reviewed. Afterward, the modified design of the proposed STFC will be described in detail. A basic FLC system structure, which consists of the knowledge base, the inference mechanism, the fuzzification interface, and the de-fuzzification interface, is shown in Fig. 7. Essentially, the fuzzy controller can be viewed as an artificial decision maker that operates in a closed-loop system in real time.

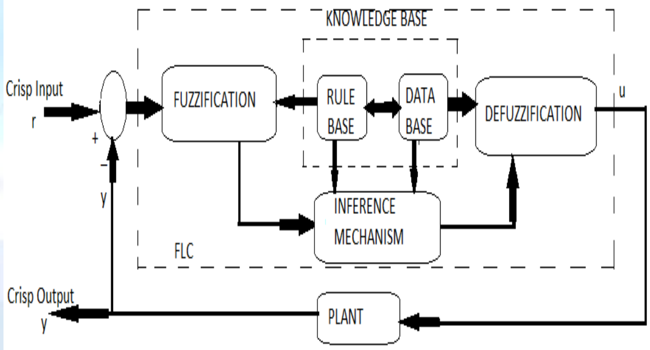

Figure 7 Basic Structure of Fuzzy Logic Control System

It grabs plant output $y(t)$, compares it to the desired input $r(t)$, and then decides what the plant input (or controller output) $u(t)$ should be to assure the requested performance. The inputs and outputs are "**crisp**". The fuzzification block converts the crisp inputs to fuzzy sets, and the de-fuzzification block returns these fuzzy conclusions back into the crisp outputs. Inference engine using if-then type fuzzy rules converts the fuzzy input to the fuzzy output.

Table 1 5x5 Based Rule

e \ Δe (o/p)	NB	NS	ZE	PS	PB
NB	NB	NB	NS	NS	ZE
NS	NB	NS	NS	ZE	PS
ZE	NS	NS	ZE	PS	PS
PS	NS	ZE	PS	PS	PB
PB	ZE	PS	PS	PB	PB

VI. Results

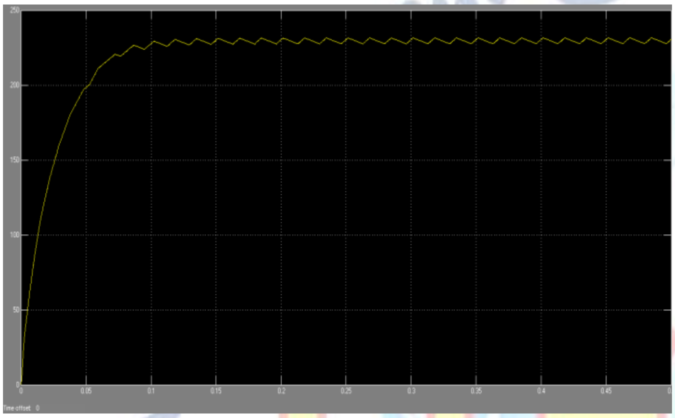

Figure 8 Boost Converter DC Output

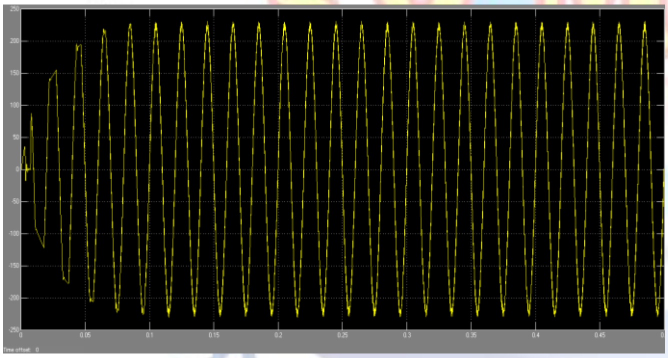

Figure 9 Inverted AC Output

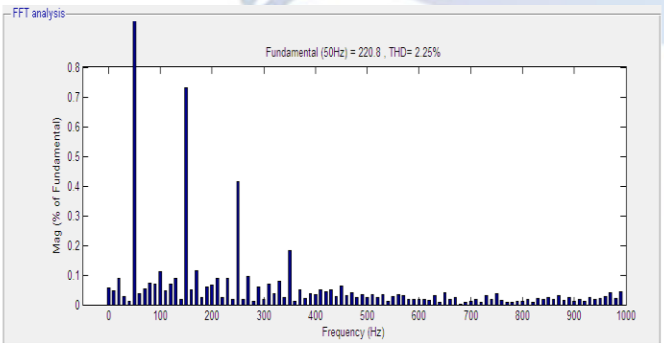

Figure 10 THD (2.25%)

VII. Conclusion

According to the proposed model using Fuzzy Logic Controller maximum harmonics has been reduced along with the minimization of the settling time as well as Total Harmonic Distortion of 2.25% with an efficiency of 97.75%. Thus, the proposed converter is suitable for PV systems or other renewable energy applications that need high step-up high-power energy conversion.

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