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Dual Step-Up Converter Fed with Single Stage CC-CSI with High Voltage Gain

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ABSTRACT— This work proposes a novel dual step-up converter fed with single stage capacitor commutated current source inverter with high voltage gain. In this context, power electronics performs important tasks making viable the connection of all these kind of clean power sources to the conventional grid and also to the load. This proposed system consists of two input sources, each one connected to two different inductor, being one fed by proton exchange membrane fuel cell and other fed by photovoltaic array. In this PEMFC act as storage system. The main feature of this capacitor commutated current source inverter is it can be switched between buck, boost, and buck-boost configuration. A modified carrier based modulation technique for the current source inverter is proposed to magnetize the dc-link inductor by shorting one of the bridge converter legs after every active switching cycle .This proposed system provide high voltage gain without use of a high frequency transformer which contribute to weight and size reduction in this proposed converter structure.

KEYWORDS—Capacitor commutated current source inverter, PEMFC, Photovoltaic array, Boost converter.

I. INTRODUCTION

Currently, alternative energy sources are seen as a matter of great importance in many countries. This is because of exhaustive carbon dioxide (CO2) emissions in the atmosphere reaching alarming levels contributing, therefore to global warming Sustainable development policies are being put into practice, through which the use of alternative and renewable energy sources have shown an increase in their growth over non-renewable resources such as coal, oil and alike. In this context of increasing renewable energy sources, the development of power electronics plays its part, more precisely in static power converters scene.

Due to the high growth rate of investments towards the development and use of alternative sources of energy, power electronics finds a broad market area, for example, in the development of static converters used in power generation systems using photovoltaic panels to capture solar energy and condition it into adequate energy [2]. It is worth noting that regardless of the type of alternative energy source used (fuel cell, photovoltaic panel, eolic energy, etc.), the use of static converters, depending on the application, is essential to make it possible to use these resources. Thus, the study of static converters for application in systems based on alternative energy is divided into two classes.

- Grid-Connected: systems where generated power is injected into the distribution network
- Stand-Alone: systems where generated power is supplied into a single load. This type of application is attractive in places of difficult access to energy distribution networks [2].

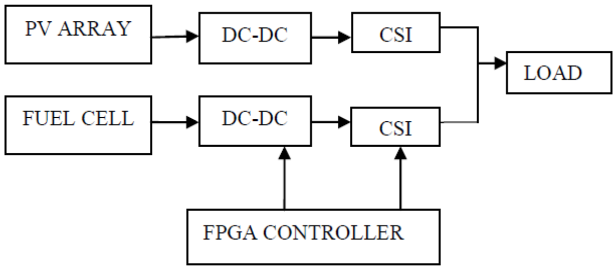


Fig.1.Block diagram.

Among the available renewable energy sources, the photovoltaic (PV) system is considered to be a most promising technology, because of its suitability in distributed generation, satellite systems, and transportation [3]. In distributed generation applications, the PV system operates in two different modes: grid-connected mode and island mode [4] -[8].

In order to evaluate the effectiveness of the proposed single stage high-voltage gain inverter structure fed by a fuel cell, this is a well-known source of clean energy that provides energy through the use of electrochemical processes [9], a proton exchange membrane fuel-cell (PEMFC) was utilized. The PEMFC presents an inherent characteristic which is the output voltage dependence of the load current. This happens owing to internal losses, that is, internal resistance ohmic losses, activation losses and concentration losses [10].

With this being the case, this paper, therefore sets as its main objective contribution through the development of static converters, which offers a reduction in size and weight through a control strategy applied to a step-down/ step-up DC–AC converter that operates with a totally controlled input current and output voltage. The analyzed proposed converter, portrayed in Fig. 2, consists of a single stage structure fed by a fuel cell and is basically a boost converter coupled to a current source inverter (CSI) targeted for stand-alone systems.

The main differentiable feature observed in the proposed structure is the ability to amplify voltage (24.48 VDC to 230VAC) without the presence of a pre-regulator stage or a transformer. The high-voltage gain is possible through the imposition of current in the input stage power source of the inverter for a reference signal generated by a FPGA controller. The use of a CSI structure arises from the possibility of achieving instant variations of output voltage as a function only of the energy stored in the input inductor. Moreover, the CSI structure has some advantages, such as the generation of sinusoidal voltage with low harmonic distortion, which makes its connection to the network viable [11, 14].

Although the proposed single stage inverter operates with a wide input voltage range (24–48 V), it is important to consider a power decoupling technique such as an ultra-capacitor or a battery connected to the input to match the oscillating output power to the constant input power supplied by the fuel cell, as observed in this paper. Thus, during transient load changes, the energy is provided by this storage element suppressing, therefore the slow fuel cell response and also avoiding the 'starvation phenomenon' [17–19], which can lead to permanent damage of the electro-catalyst of the fuel cell.

To achieve high voltage gain, this paper proposes a step-up converter fed with single stage cc-csi ,the main feature of this current source inverter is it has boosting ability it not only convert dc –ac but also it step up voltage .It also called as boost inverter .

This paper is organized as follows. The converter structures are explained in section II. The PV array model and PEMFC model is given in section III. Section IV describes Modified carrier-based pulse width modulation. section V represents the simulation results of the proposed system.

II. CONVERTER STRUCTURE

The structure of the proposed dual step-up converter fed with single stage cc-csi is represented in fig.2.As seen from the figure, the converter fed with two input power sources. Being one fed by PV array and other fed by PEMFC. The main feature of the proposed system was the simultaneous control of the input inductor current and output voltage and its effectiveness has been proved in an inverter system feed by a PEMFC. Thus, one can conclude that the main differentiable Feature observed in the proposed structure was the ability to amplify voltage (24–70 VDC to 230 VAC) without the presence of a dedicated pre regulator stage or a transformer. On the other hand, the main drawback of the proposed system is the high cost of hydrogen, which is inherent in a PEMFC system.

In order to overcome this drawback and make the proposed solution completely autonomous and reliable, parallel connection of two dc sources is investigated in this paper. In the converter structure, two inductors L1 and L2 make input power ports as two current type of input power sources, which results in drawing smooth dc currents from the input power sources, inductor L3 is connected in series with single stage capacitor commutated current source inverter to maintain a constant current flow control. The inverter has four metal oxide semiconductor field effect transistors (MOSFET) (S1–S4) and four diodes (D1–D4). Each diode is connected in series with an MOSFET switch for reverse blocking capability.

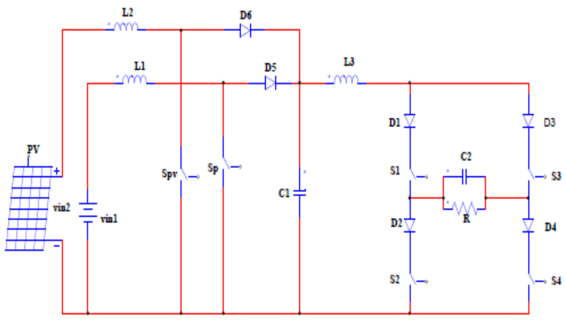


Fig.2. circuit topology of proposed system.

A. OPERATING PRINCIPLE

For one single dc source, as presented in [20], the operating principle is based on the imposition of two variables:

- IREF: Reference signal to the input current in the Inductor
- VREF: Reference signal to the output voltage of the Capacitor *C*.

For imposition of the variables *IREF* and *VREF* the converter operates under the Current Control, described in section II.*A*.1 cycle Control, described in section II.*A*.2, and voltage control described in section II.*A*.3 respectively.

1) Current Control

This logic of control is responsible for enforcing the desired current waveform across the inductor L and is shown in Fig. 4 being represented by the I signal. The ILV signal, sampled from inductor current, is compared to the reference signal IREF, which is a voltage signal generated from a microcontroller and converted to analog form. The signal is a rectified sinusoidal voltage. The result of the comparison between these two signals is the I pulse.

The logic of control is governed by the following

- IREF > ILV: I IS A HIGH VOLTAGE LEVEL
- IREF < ILV: I is a low voltage level

2) Cycle Control

This control is mainly intended to protect the switches of the inverter circuit. A circuit fed by current source has a characteristic such that an overvoltage occurs on the terminals of an element that disrupts current flow. The foreseen control always provides a way for the current of the inverter circuit eliminating the possibility of overvoltage across the terminals of the switches.

Another benefit occurs with the use of this control. The switches S1 and S3 operate at low frequency, 60Hz, reducing switching losses.

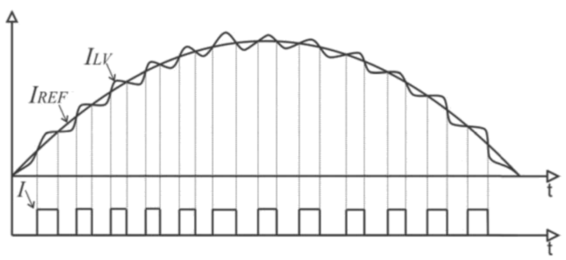


Fig.3. Imposition on the ILV current shape.

The control logic consists of the comparison between VREF and zero, generating two pulses that are complementary as follows:

The comparison results generates two complementary control pulses *V+* that activates *S1* and *S4* and *V-* that activates S3 and S2 working as follows:

- VREF > 0: Cycle+ is a high level of voltage, Cycle- is a low level of voltage;
- VREF < 0: Cycle+ is a low voltage level, Cycle- is a high voltage level

3) Voltage Control

This is done by comparing VREF which is a sinusoidal voltage signal, and VOV, sampled by a sensor. The VREF signal is generated by the FPGA controller and is synchronized with IREF.

Case: VREF < VOV:

- Cycle+ = 1,
- V- = 1;

Case: VREF>VOV:

- Cycle+ = 1,
- V + = 1;

B.MODE OF OPERATION

The proposed system has only two operating modes because of boost converter .The two modes of operation of proposed system are

- ON Mode
- OFF Mode

a) ON Mode

When power device is on, L1 is connected to supply Vdc and the inductor stores energy during on-time. The diode D5 is reverse biased and isolates the output stage, the inductor connected in series with current source inverter will be discharging .The energy from the inductor L3 will supply to the load. The switches Sp, S1, S2 and S4 will be on, although switch S4 is active, diode D4 is blocked by the capacitor and then the path of least impedance to the circuit is provided by switch S2.

b) OFF Mode

when power devices is off ,inductor L1 is discharging and the diode D5 is forward biased and the inductor L3 is charging. During off time the load will get energy from supply V_{dc} and inductor L1. The switch S2, S3, S4 will be on.

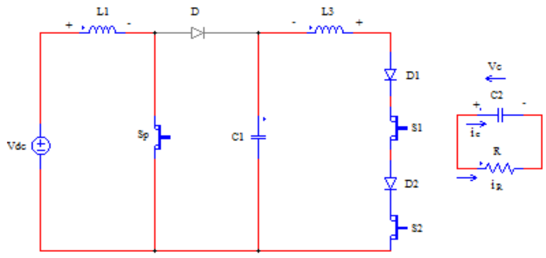


Fig.4.on mode

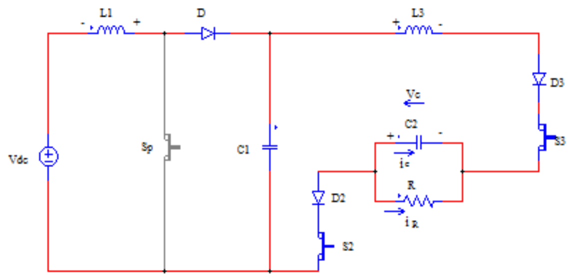


Fig .5.off mode

TABLE 1
SWITCHING STATUS OF PROPOSED SYSTEM

Case	V+	I	Sp	S1	S2	S3	S4	Mode
1	1	1	1	1	1	0	1	ON
2	0	1	0	0	1	1	1	OFF

III. Modified Carrier-Based Pulsewidth Modulation

Modified carrier-based pulse width modulation (CPWM) is proposed to control the switching pattern for the single stage CC- CSI. In order to provide a continuous path for the dc-side current, at least one top switch in either arm and one bottom switch must be turned ON during every switching period. In conventional sinusoidal pulse width modulation (SPWM), the existence of overlap time as the power devices change states allows a continuous path for the dc current. However, the overlap time is insufficient to energize the dc-link inductor, which results in increased THD. Therefore, CPWM is proposed to provide sufficient short-circuit current after every active switching action. CPWM consists of two carriers and one reference. Fig. 6 shows the reference and carrier waveforms, along with the switching patterns. The carrier with the solid straight line shown in Fig. 6 is responsible for the upper switches, while the dashed line carrier is responsible for the lower switches and is shifted by 180◦. To understand the switching patterns of the proposed CPWM, Fig. 6 is divided into ten regions (t1 − t10), and each region represents one carrier frequency period. CPWM operates in two modes, a conductive mode and a null mode, and the switching action of each MOSFET is equally distributed during every fundamental period. To validate the proposed CPWM, simulation results of a CSI operated by both CPWM and SPWM are shown in Fig.7.

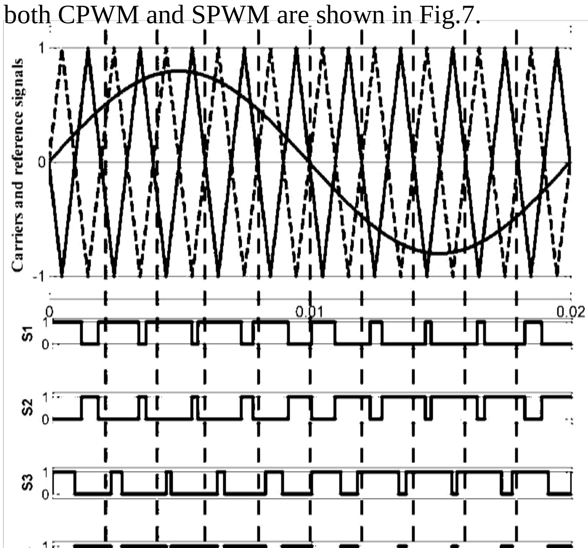
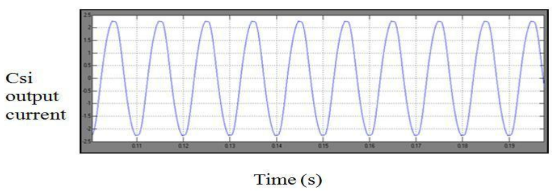
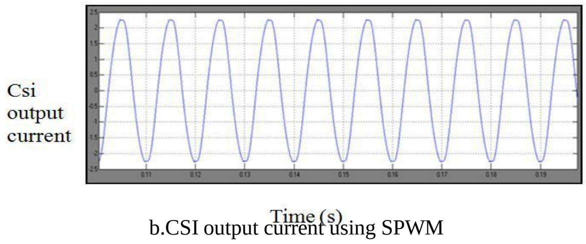


Fig.6. Proposed carriers-based PWM along with switching sequence for one fundamental frequency.



a.CSI output current using CPWM



b.CSI output current using SPWM

Fig.7.Comparison between the proposed CPWM and conventional SPWM:(a) CSI output current using CPWM and(b) CSI output current using SPWM

IV Simulation Diagram And Results

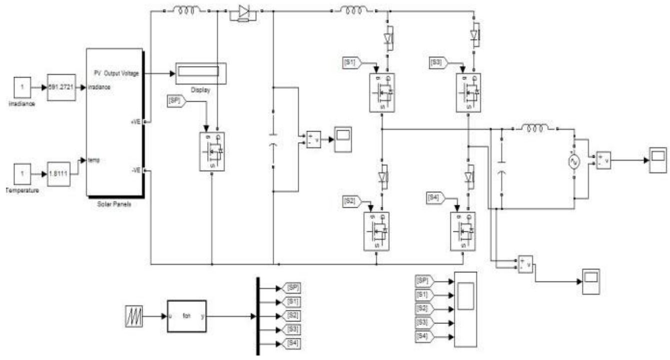


Fig.8. Proposed Converter with grid connected load

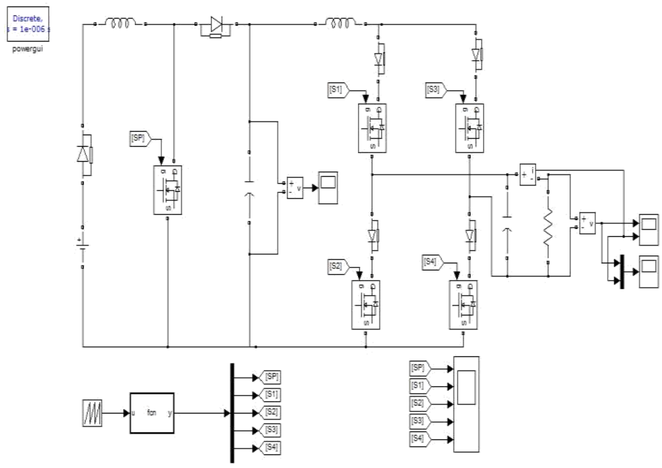


Fig.9. Proposed Converter with R load

Simulation specification

Output Voltage, VO RMS = 230v

Input Voltage - Fuel Cell System, VIN-1 = 22-50 VDC Input Voltage - PV Array System, VIN-2 = 65 VDC Input Inductor *L1*= 300μH, Core: 65-33-39

Input Inductor *L2*= 300μH, Core: 65-33-39 Input Inductor *L3*= 300μH, Core: 65-33-39

Input capacitor C1=20 μF

Output Capacitor *C* = 20 μF

Switches, IRFP264 Diodes, STTH200L04TV

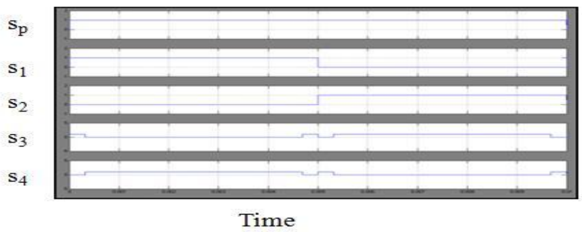


Fig.10.switching pulse of proposed converter

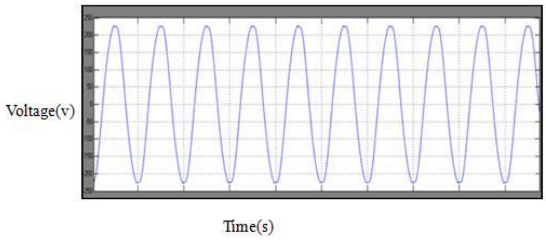


Fig.11.simulation response output voltage waveform

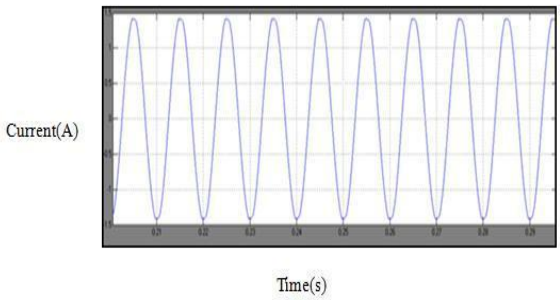


Fig.12.simulation response output current waveform

TABLE II
COMPARISON BETWEEN PROPOSED AND EXISTING SYSTEM

S.N0	Input voltage	Output voltage	
		Existing system	Proposed system
1	20	70	100
2	30	80	110
3	40	90	150
4	50	110	230

V.CONCLUSION

This project presented a novel single-stage inverter topology called dual step-up converter fed with single-stage capacitor commutated current source inverter and its feasibility has been tested using two alternative energy sources: a PEMFC and a PV array. High voltage gain and totally controlled output voltage can be achieved by using dedicated step-up dc–dc converter and not by using transformer. Comparing to other autonomous inverter structures, the proposed dual singles stage CC-CSI was achieved adding only one extra diode, one switch, and also one extra inductor. Despite the high cost of a PEMFC, like most new technologies, its application in this kind of study is justified since it is a well- known source of clean energy, contributing to the reduction of CO2 emissions. Therefore, the FC has been chosen as an energy storage system in substitution to battery banks commonly used in autonomous systems, eliminating the obvious drawbacks related to lifetime and maintenance issues.

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