Analysis and Performance of Grid/PV Hybrid Power System Based Fuzzy Logic Controller

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Abstract: This paper deals with an dual input converter for grid/PV based hybrid power system which is used by fuzzy logic controller. The proposed dual-input converter is operated either in single power supply mode or hybrid power supply mode. The PV power loss can be neglected by using this method and the proposed dual-input converter can obtain the complement power from the grid. Control is independent can provided to both PV power and grid power. The flow of power from both the sources is unidirectional and supplies the load individually. So overall efficiency of the system can be improved and produce high output power. Simulations are carried out by using MATLAB/Simulink and the results are verified to evaluate the validity and performance of the converter and controller.

***Keywords** -dual-input converter; hybrid power system; PV array*

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I. INTRODUCTION

Recently renewable energy systems have attracted a lot of attention due to global warming and fuel crisis. In tropical countries like India as well as other places where solar energy is available in abundance, photovoltaic (PV) has emerged as a major candidate for meeting the energy demand [3].

Power consumption of office lighting systems may take 20% to 60% of total energy consumption in daily life [16].

To meet these loads renewable energy resources can be used. Among the renewable energy sources PV is considered as stable and reliable, clean (pollution free) energy source, with almost no running and maintenance cost[1]. However the cost factor remains a major impediment.

In most of PV power systems, the battery is required to provide smoother electricity.

However, the costs of installing PV arrays and maintaining battery pack are still more considerable for consumers. Reducing the consumption of grid power by combining renewable resources is one of the major trends [5].

To decrease the overall cost of PV it is necessary to decrease the cost of other components. This can be achieved by minimizing the instrumentation involved for the MPPT [13]. Though it is difficult to compare the cost of MPPT, an extensive comparison of various MPPT schemes is available [14] from which a rough estimate of their relative cost can be made. With a view to minimizing the MPPT cost have discussed simple, economic, and, yet, fast efficient MPPT schemes, based on open-circuit voltage and short-circuit current values.

For grid-connected systems, the cost is further reduced due to the elimination of battery requirements, which is the second largest contributor to the cost of a PV system.

Grid power hybrid has been proposed. The dependence on grid power can then be reduced and the output power quality is also remained.

Basically, multi-input converters are classified into three types of topology. In first type, a multi-winding transformer is used to combine multi input power sources using single core [5]-[7]. In second type of converter, a pulsating voltage source cell (PVSC) is used as the power coupling component [2], [8]-[10]. Since the inductor is the major component in PVSC, the major design criteria of the PVSC-type converter are the continuity of inductor current and the copper loss in inductor winding. In the last type converter, a pulsating current source cell (PCSC) is used as the power coupling component [10], [11]. Since it uses capacitors, the copper loss is relatively much lower in this type.

The circuit diagram of the proposed dual-input converter for hybrid power system [17] is shown in Fig. 1. The system can be operated in single power supply mode or hybrid power supply mode.

When the PV power is not available, the converter could be operated in single power supply mode, which is the grid supply mode. If the PV power can only partly satisfy the load [11].

The converter could be operated in hybrid power supply mode for delivering the rest part of power from the grid to the load side and when the PV power is sufficient for the load demand and then the converter operates only in PV power supply mode [17].

II. PROPOSED DUAL-INPUT CONVERTER

For the proposed converter shown in Figure.1, the switch *S1* is provided to control the power flow from the grid to the load through the coupling capacitor *C1*. The other input terminal is connected to the photovoltaic panel (PV) and the PV output power is controlled by the switch *S2*.The PV power is delivered to the load side through the coupling capacitor *C1* as well. When the available power from PV array is lower than the load demand, the proposed converter would provide the complement power from the grid to the load side according to the feedback information about the load. Based on the supplying power sources, there are three power supply modes of the proposed converter. First, if the PV power is unavailable, the converter would be operated in the grid supply mode. Secondly the converter would be changed into the PV supply mode when the available PV power is higher than the load demand. Finally, if the PV power is available but not enough to supply the load demand, then the converter would be operated in the third mode which is the hybrid supply mode [8],[2].

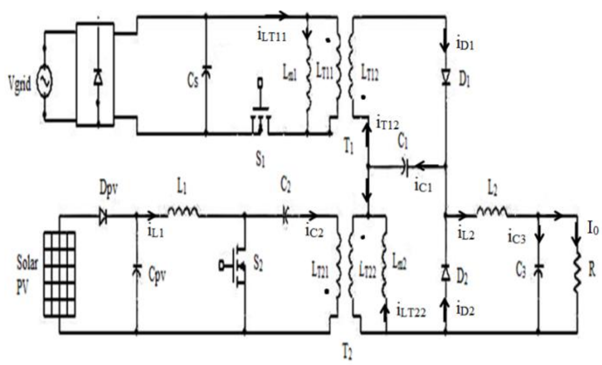

Figure 1 Circuit DiagramofProposed Dual-input Converter forHybrid Power System

When the two sources simultaneously deliver power that is during the hybrid power supply mode, there would be six operating modes in one switching cycle. The two switches are controlled with interleave phase shift technique to reduce the voltage and current ripple of the coupled capacitor. The corresponding operating principles in each mode are discussed as follows:

Mode 1—(t0≦t<t1): In this mode, the switch *S1* and diode *D2* are turned off and switch S2 and diode *D1* are turned on. The corresponding equivalent circuit is shown in Figure 2(a). As the switch *S2* is turned on, the input from panel magnetizes the inductor *L1* and capacitor *C2* discharges. The pre-stored energy in the magnetizing inductance of the transformer *T1* is released to secondary side [9]. The capacitor *C1* is charged with the difference (*iLT12*-*iL2*) and also magnetizes inductor L2 and supplies power to the load.

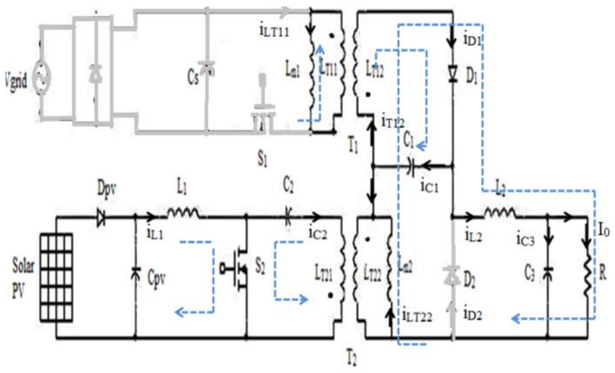

Figure 2(a) Mode1

Mode 2—(t1≦t<t2): During the second mode, the magnetizing current of *T1* on the secondary side, i.e. *iLT12*, is lower than the inductor current *iL2* and the coupled capacitor *C1* would discharge by the difference between these two currents. The corresponding equivalent circuit is shown in Figure.2 (b). The magnetizing current *iLT11* would continuously decrease and would become zero at the end of this mode [11].

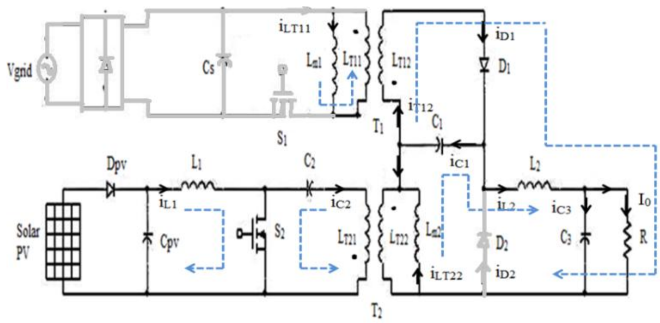

Figure 2(b)Mode2

Mode3—(t2≦t<t3): In this mode, the magnetizing current of *T1* at the secondary side is zero and the diode *D1* is turned off. The corresponding equivalent circuit is shown in Figure. 2(c).Since the switch *S2* is still on inductors *L1* and *L2* magnetizes and capacitor *C2* discharges [9].

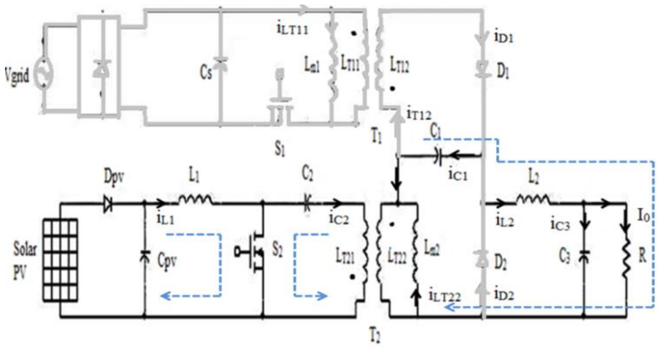

Figure 2(c) Mode3

*Mode4—(t3≦t<t4):*In this mode, the switch *S2* is turned off at *t=t3* and then the converter would operate in mode 4, as shown in Figure. 2(d). The switch *S1* is already in off condition. The diode *D2* is turned on for the pre-stored energy in inductor *L1* to charge the capacitors *C2* and *C1* and inductor *L2* is used to supply the load [4].

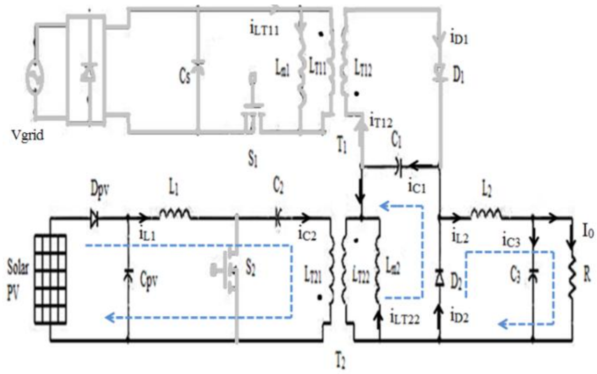

Figure 2(d) Mode4

Mode5—(t4≦t<t5): In this mode, the switch *S2* is still turned off and the corresponding equivalent circuit is shown in Figure.2(e). The diode *D2* is still turned on because the inductor current *iL2* is larger than the difference between the magnetizing current *iLT22* and the inductor current transferred to secondary side as *iL1/n2*. Therefore, the coupled capacitor *C1* would discharge by the current difference (*iLT22-iL1/n2 [12])*.

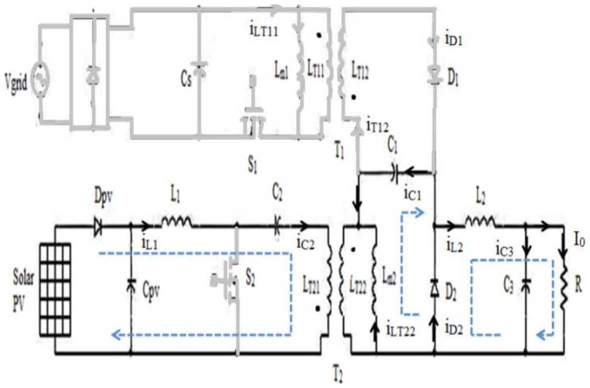

Figure.2 (e)Mode5

Mode6—(t5≦t<t6): In this mode, the diode *D2* is turned off, the active switch *S1* is turned on at $t=t_5$, then the operation mode of this converter would change into mode 6 as shown in Figure.2(f). The capacitor current *iC1* is equal the inductor current *iL2*. In this mode, the energy on the magnetizing inductance of transformer *T1* would be increased again by the grid source. This operation mode would come to end when the active switch *S1* is turned off and then the operating mode would be recycled to mode 1[8].

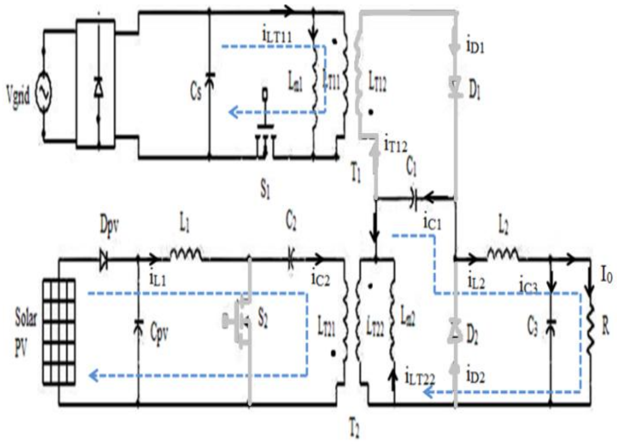

Figure 2(f) Mode6

III. POWER COMPLEMENT CONTROLLER

From the previous section, it is seen that the power drawn from the grid is controlled by the switch *S1* and firstly buffered in the coupling capacitor *C1*. Then, it would be transmitted to the load side through the inductor *L2*. The other input power, the PV power, is controlled by the switch *S2*. The operation is similar to an isolated Cuk converter.

The PV power would be delivered to the load side through the transformer *T2* and coupling capacitor *C1*. Obviously, the two power flows are both independent, unidirectional and transferred to the load side individually.

Usually, a maximum power point tracking (MPPT) could be adopted to fully utilize the renewable PV power and used to improve the efficiency of the solar panel. Hence, the gating signal of the switch *S2* is provided according to the adopted MPPT strategy.

The choice of the algorithm depends on the time complexity the algorithm takes to track the MPP, implementation cost and the ease of implementation. Incremental conductance is the MPPT strategy used in this paper. And the gating signal of the active switch *S1* is decided according to the amount of the complement power required for the load. For the control loop of PV power, the PV current can be regulated to the current command for extracting maximum PV power.

The switch *S2* is driven by gating signal VGS2 to control the input current from PV array. For the control loop of grid power, the primary objective is to deliver the complement power for remaining smooth current to the LED lighting module.

Therefore, the load current *Io* is fed back and needs to be regulated to the load current command which is decided by the normal operating current of LED module. Then the switch *S1* will be driven by the gating signal VGS1 to control the input grid power for complementing the power demand on the load side.

IV. FUZZY LOGIC CONTROLLER

The fuzzy compensator has the advantages of classical PI controller along with fuzzy control action. The inputs to the fuzzy controller are the error and change in error between reference voltage and output load voltage. The output from the fuzzy controller is duty cycle to the dc-dc converter.

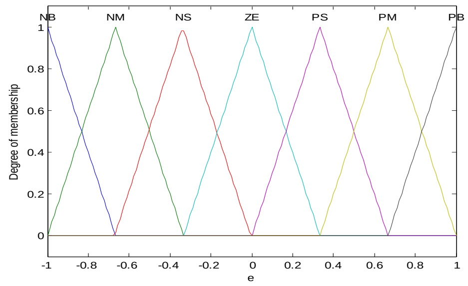

Figure 3 Membership Functions for Input Error e

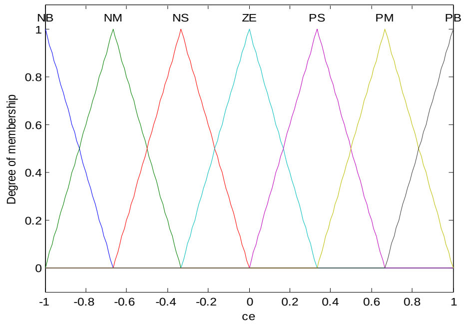

Figure 4 Membership Function for Input Change in Error ce

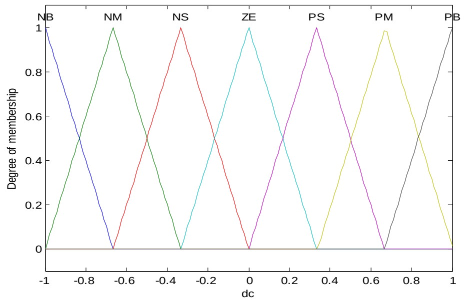

Figure 5 Membership Function for Output Duty cycle dc

There are seven triangular membership functions which are chosen due to simplicity and best control performance. The height of the membership function is unity [18].

An overlap of 50 % is provided for neighboring fuzzy subsets. Therefore at any point in the universe of discourse, no more than two fuzzy subsets will have non-zero degree of membership.

For inference mechanism, a linguistic rule table according to the dynamic performance of the converter is shown in Table 1. For example, if error in speed is ZE and change in speed error is NS then output is NS. The linguistic variables are transformed into crisp output by the process of defuzzification. Standard center of gravity method is used for defuzzification of obtain the crisp output [18].

ce/e	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NS	NS	ZE
NM	NB	NM	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PM	PB
PB	ZE	PS	PS	PM	PM	PB	PB

Table 1 Fuzzy Inference Rules for Fuzzy Controller

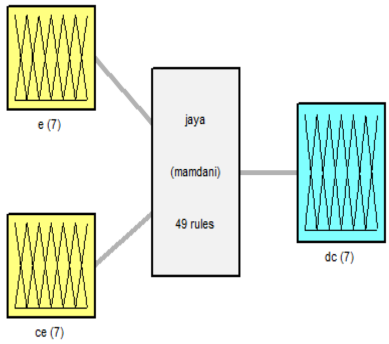

Figure 6FIS Evaluation

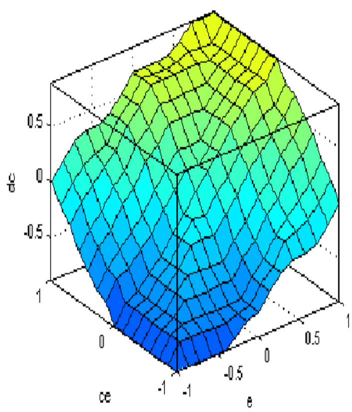

Figure 7Surface Plot between Two Input (error & change in error) and Output (voltage)

V. SIMULATION RESULTS

To evaluate the validity and performance of the proposed converter, simulations are carried out using MATLAB/Simulink. The TABLE I shows the simulation parameters for the proposed converter. The gate pulses are provided to the switches by comparing required value and actual value obtained in the converter.

TABLEI
SimulationParametersfortheDual-inputConverter

Parameters	Values
InputDCvoltage	21V
InputACvoltage	230V(rms)
Inductor(L1)	460µH
Inductor(L2)	200µH
Capacitor(C1)	6µF
Capacitor(C2)	220µF

The MATLAB circuit diagram of the proposed converter with solar panel and maximum power point tracking is shown in Figure. 8.

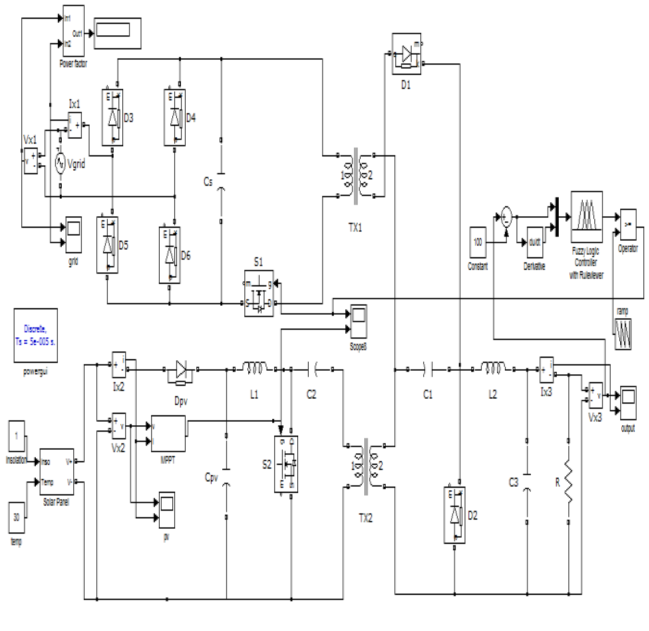

Figure 8MATLAB Simulation Diagram of the Proposed Dual- input Converter with Fuzzy controller

Figure. 9 shows the pulse waveforms for the switches S1 and S2 respectively. To reduce the dependence of power from grid, on time of grid is selected less than the on time of the solar panel. Pulse1 is given to the switch *S1*which is connected to grid and Pulse2 is given to the switch *S2* which is connected to solar panel.

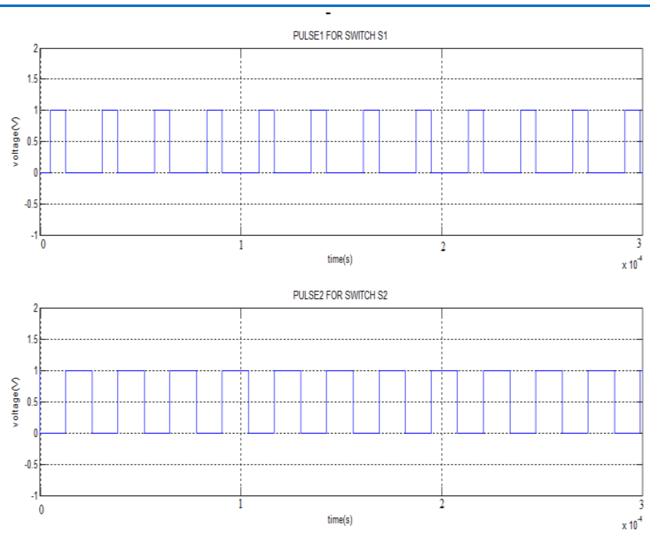

Figure 9 Pulse Input Waveforms to the Switches $S1$from fuzzy controller and S_2 from MPPT.

The solar panel output voltage which is given as input voltage to the converter is as shown in Figure. 10.

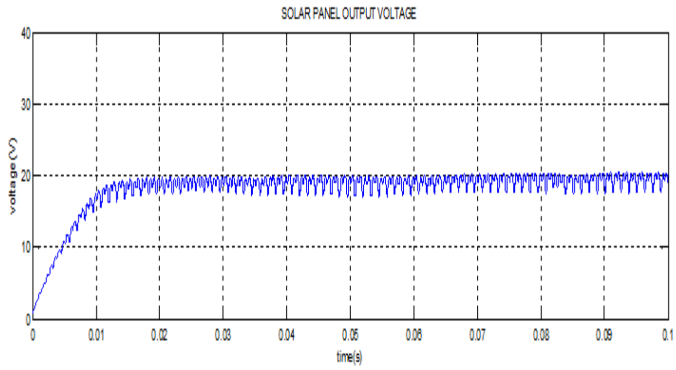

Figure 10 Waveform of Solar Panel Output Voltage

The solar panel output current is as shown in Figure. 11.

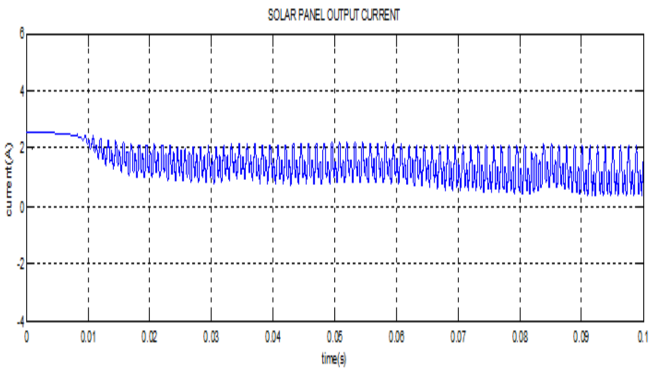

Figure 11 Waveform of Solar Panel Output Current

The grid input voltage and input current is as shown in Figure. 12 and Figure. 13.

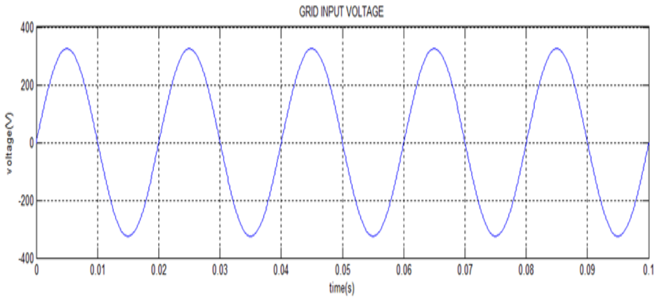

Figure 12 Waveform ofGridInput Voltage

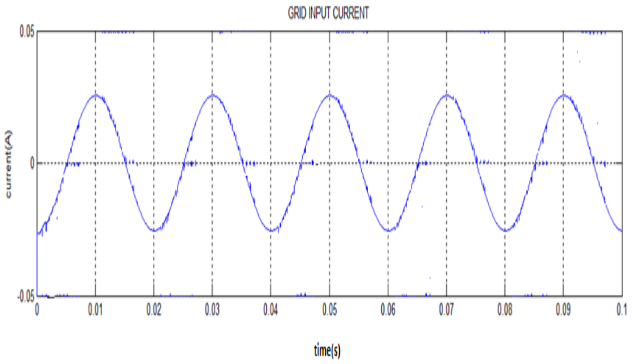

Figure 13Waveform of GridInput Current

The output voltage and output current waveforms of the proposed converter are as shown in Figure 14 and 15.The obtained output voltage and output current should be a constant continuous output in order to provide a smooth and reliable output to the load.

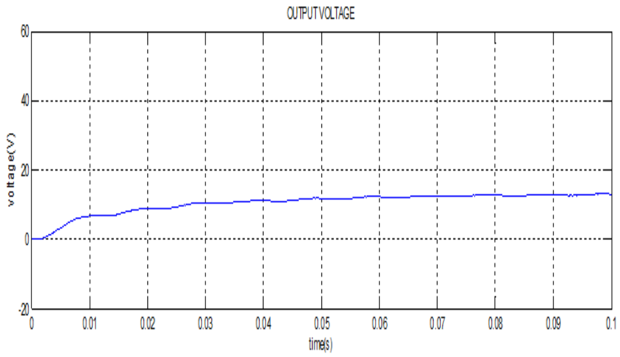

Figure 14Waveform of OutputVoltage of Proposed Dual-input Converter

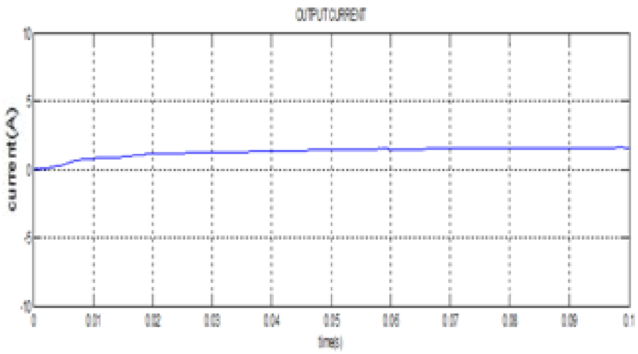

Figure 15 Waveform of OutputCurrentof Proposed Dual-input Converter

VI. CONCLUSION

The proposed converter uses Incremental Conductance algorithm for tracking maximum power from the PV panel. In the hybrid mode, when the PV power is insufficient for the load demand, the power flow from the grid would automatically be controlled using fuzzy logic controller to complement the output power. With the help of the hybrid converter, the PV panel installation capacity is reduced and the battery backup is eliminated which reduces the maintenance requirements. To evaluate the validity and performance of the proposed dual-input converter, simulations are carried out with resistive load using MATLAB and verified.

VII. ACKNOWLEDGEMENT

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REFERENCES

[1] T. F. Wu, C. H. Chang and Y. H. Chen, “A Fuzzy Logic-Controlled Single- Stage Converter for PV Powered Lighting System Application,” *IEEE TransInd. Electron*.,vol.47 no.2, pp. 287-296, April 2000.

[2] H. Patel and V. Agarwal, “MPPT Scheme for a PV-Fed Single-Phase Single- Stage Grid-Connected Inverter Operating in CCM with Only One Current Sensor,” *IEEE Trans. Energy Convers*. vol. 24 no. 1, pp. 256- 263, March 2009.

[3] X. Sun, L. K. Wong, Y. S. Lee and D. Xu, “Design and Analysis of an Optimal Controller for Parallel Multi-Inverter Systems,”*IEEETrans.Circuits Sys II, Exp.Briefs,* vol.26 no.1,pp.56-61,January 2006.

[4] R.J.WaiC.Y.Lin,L.W.Liu and Y.R.Chang,”High efficiency Single-stage Bidirectional with Multi-input Power Sources,”*IETTrans.Electr.Power Appl*.vol no.5.pp.763- 777,2007.

[5] Q.Wand,J.Zhang,X.Ruan and K.Jin,”Isolated Single Primary Winding Multiple-Input Converters,”*IEEE Trans. Power Electr*.,vol.26.12,pp.3435-3542,December 2011.

[6] Y.M.Chen,Y.C. Liu and F.Y.Wu,”Multi-input DC/DC Converter Based on the Multi-winding Transformer for Renewable Energy Applications,”*IEEETrans.Ind.Application*.,vol.38,no.4,pp.1096-1104.July/August2002.

[7] R.Maurya,S.P.Srivastava, and P.Agarwal, ” Design & Implementation of Transformer-less Multi Output DC Power Supply,” *Trans. International Review of Electrical Engineering*,vol.6,no.7,pp.2910-2918, November 2011.

[8] R. J. Wai, C. Y. Lin, J. J. Liaw, and Y. R. Chang, “Newly Designed ZVS Multi-Input Converter, *IEEE Trans. Ind. Electr.*, vol. 58 no. 2,pp. 555-566, February2011.

[9] R. Ahmadi and M. Ferdowsi, “Double-Input Converters Based on H-Bridge Cells: Derivation, Small-Signal Modeling, and Power Sharing Analysis*,” IEEE Trans. Circuits Syst. I*, Reg., vol. 59, no. 4, pp. 875-888, April 2012.

[10] Y. Yuanmao and K. W. E. Cheng, “Level-Shifting Multiple-Input Switched- Capacitor Voltage Copier,”*IEEE Trans. Power Electr*.,vol. 27 no. 2, pp. 828-837, February2012.

[11]Y. C. Liu and Y. M.Chen, “A Systematic Approach to Synthesizing Multi-Input DC-DC Converter,” *IEEE TransPower Electron*., vol.24, no.1, pp.116-127, January 2009.

[12]Kolhe M, “Techno-Economic Optimum Sizing of a Stand-Alone Solar Photovoltaic System*,”IEEE Trans. Energy Convers*., vol. 24,no.2, pp.511-519, 2009.

[13]Q. Li and P. Wolfs, “Hardware implementation and performance

analysis of a current-sensor-free single cell MPPT forhigh performance vehicle solar arrays," in Proc. *IEEE Power Electron. Spec. Conf.*, Jun 17– 21, 2007,pp.132–137.

[14]T. Esram and P. L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," *IEEE Trans. Energy Convers.*,vol. 22, no. 2, pp. 439–449, Jun. 2007.

[15]M. A. S. Masoum, H. Dehbonei, and E. F. Fuchs, "Theoretical and experimental analyses of photovoltaic systems with voltage and current based maximum power-point tracking," *IEEE Trans.Energy Convers.*, vol. 17, no. 4, pp. 514–522, Dec. 2002.

[16] Y. Uhm, I. Hong, G. Kim, B. Lee and S. Park, "Design and Implementation of Power-aware LED Light Enabler with Location-aware Adaptive Middleware and Context-aware User Pattern," *IEEE Trans.Consumer Electron.*, vol. 56 no.1, pp. 231- 239, January 2010.

[17]Yu-Lin Juan and Hsin-Ying Yang, Peng-Lai Chen, "An Isolated Dual-Input Converter for Grid/PV Hybrid Power System," Journal of Computers, vol. 8, no. 6,June 2013.

[18]Bhim Singh, A.H.N.Reddy, S.S.Murthy "Hybrid Fuzzy Logic Proportional Plus Conventional Integral-Derivative Controller for Permanent Magnet Brushless DC Motor"*IJETS*,vol 2(2),192-198,2011.

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