Rules based Functional Control of Bidirectional DC- DC Converter for Stand-Alone PV with Hybrid Energy Storage System

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Abstract-**This paper presents rules based functional control approach for bidirectional DC-DC converter with hybrid energy storage system. The proposed converter interface one unidirectional input power port and three bi-directional ports for storage elements in a unified structure. Battery act as the primary source and super capacitor act as a secondary source for transient load management. Non isolated bi-directional DC-DC converter with soft switching capabilities, which usually operates at a zero voltage switching (ZVS). The paper is focused on a comprehensive modulation strategy utilizing 27 rules based fuzzy logic control that satisfies the requirement of the PV system to achieve MPPT and output voltage regulation. The circuit analysis and design consideration are proposed by MATLAB modeling, simulation result has verified by closed loop design and power flow ability is achieved independently, the proposed converter reduces the component cost of losses for to harvest from the renewable energy.**

Key words: Multi-input converters, battery, super capacitor, ZVS, fuzzy controller.

1. INTRODUCTION

The developments in the field of power electronics and command have made it possible to increase the performances of such devices. The bi-directional converter has greater development to achieve high efficiency, simple structure(1). The power flow between two DC sources is improved in bi-directional converter, without changing the polarity of component the power can flow both the direction.
The major research is going on hybrid energy storage system to achieve the efficiency of the energy storage device. The drawback of the system is peak power sharing(4). To overcome this issue by placing a super capacitor as a storage device. By the hybridization of battery and super capacitor for steady state and peak power demand(4). Depending upon the application cost and safety various types of battery are chasing the main purpose of the battery are to provide power supply at the required period. The battery life will be affects when it serves the transient value of energy to the load. The interest on intelligent controller. Fuzzy logic controller (FLC) is becoming a popular controller. It is expert knowledge based control to regulate voltage to switches for boost and buck operation of the converter(13). The mathematical methodology of the converter is avoided by linguistic rules withy fuzzy controller.

Problem descriptor

- Without energy storage of this system should use less energy.
- This generation system cost to be lower than that of any other generation system.
- The load can be controlled independently of each other by the proposed system.

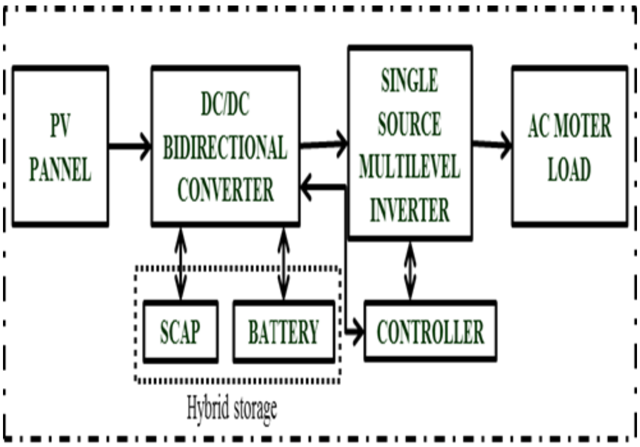


Fig 1 proposed block diagram

Maximum power point tracking (MPPT) is used in the system to generate more energy from the sun radiations, P&O algorithm is most commonly using nowadays. This paper is organized as follows. Section II structure of converter. RLC design in section III. Section IV operation of the converter Control analysis of the converter in Section V. Simulation and result in Section VI and Section VII this paper concludes.

II. STRUCTURE CONSIDERATION

The simple circuit of the bi-directional DC-DC converter is shown in the fig 2: The components which are placed are super capacitor, battery, solar panel. The main concept of this paper is hybrid storage system. This is already explained. The most available components are used in this circuit. To make the circuit simple, efficient, and also low cost.

According to the good performance the components are analyses of this proposed system. MOSFET and IGBT are the switches are suitable here MOSFET is used as a controller switch. A new technique is implemented in these converter topologies. They are canonical switching topology. This means the Tee shape connection. They are two components connected in serial in between those components a node or loop will be connected. By this connection the performance of the system is varied.

The canonical switching is implemented in this proposed converters are in storage operation. Each storage device is connected with the canonical switching topology. With the help of canonical switching buck and boost operation will be in the same leg. These switches are connected in battery are represented as S_{b1} and S_{b2}. The Super capacitor is connected switches are S_{c1} and S_{c2}.

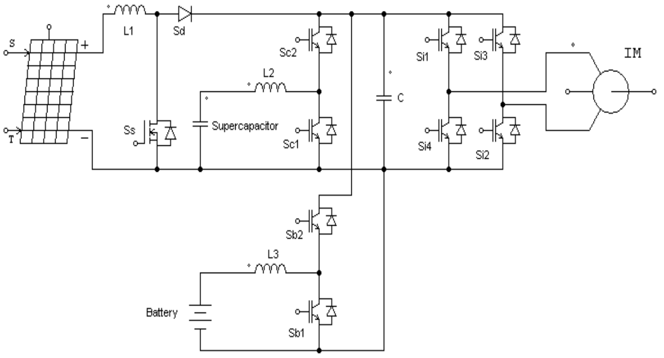


Fig. 2. Circuit of DC-DC, bidirectional converters

PV side only one switch is used because of only ON and OFF operation. The switch is S_s is connected with this and also diode is placed in it because of prevent the solar panel from the reverse power flow. MPPT is used in this system.

Load side full bridge inverter is used IGBT switches are used in the converter. The switches are denoted as S_{i1}, S_{i2}, S_{i3},S_{i4}, and induction motor is used. Mode of operation is determined by sensing the bus voltage. When bus voltage is minimum then it uses the storage charges.

III.R, L, C DESIGN

R, L, C values of the converter is specified as follows. To consider the output voltage ripple the proposed converter has designed the suitable L & C.

The voltage ripple of the proposed converter is given by

$$V_{ripple} = \frac{I}{2\omega c}$$

Where,

V is Output voltage

C is Capacitance

The calculated output current is $I = \frac{output\ power}{output\ voltage}$

$$I = \frac{500}{220}$$

I is 2.25 A

Let V_{ripple} is 0.7 V

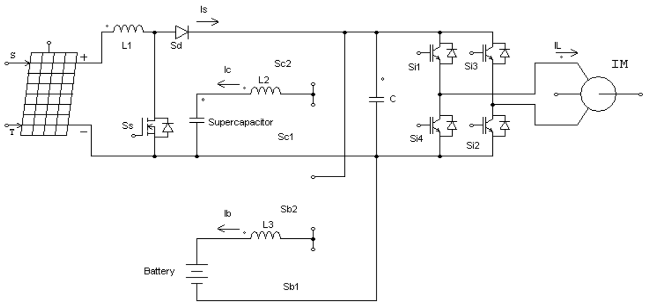
The value of C is calculated by substituting current and voltage ripple value in the equation.

$$C = \frac{I}{2\omega Vripple}$$

= 5mF

IV. OPERATION MODES OF CONVERTER

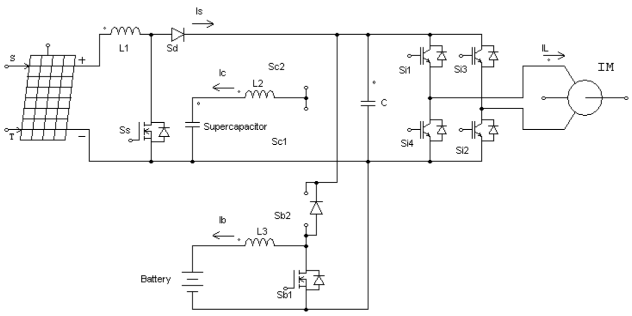
Mode 1; In this mode storage device is an ideal condition. So the switches in the mode are in OFF condition. We're the PV source is flowing in unidirectional from the source to the load.



Is=IL Ic,Ib=0

Fig. 3. Source to load

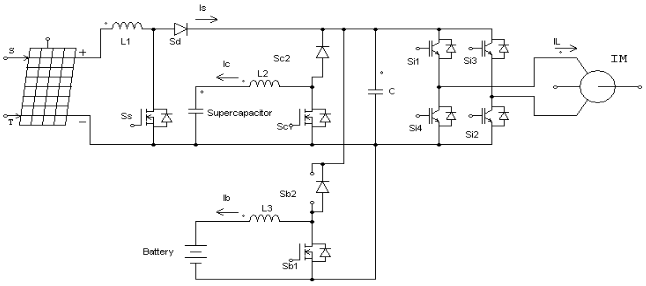
Mode 2; load voltage is greater than the source voltage then the stored battery energy is discharged. With the help of S_{b1} the inductor is used for boost operation. In this condition, super capacitor is in an ideal.



Is+ ib =IL Ic=0

Fig: 4 Battery discharging

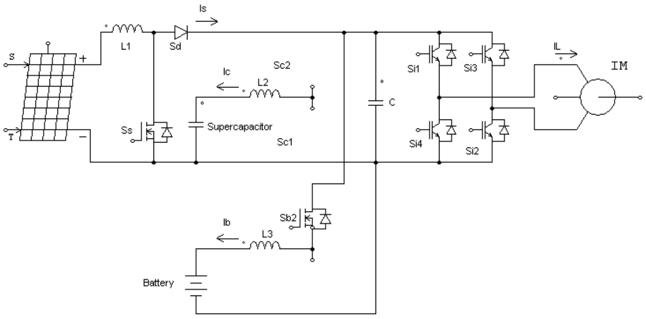
Mode 3; The stored energy in super capacitor and the battery is discharging. Because of source voltage is very low, then the transient supply is required for the load. In this condition the super capacitor also discharges.



Is+ Ib + Ic=IL

Fig. 5. Battery and super capacitor discharging

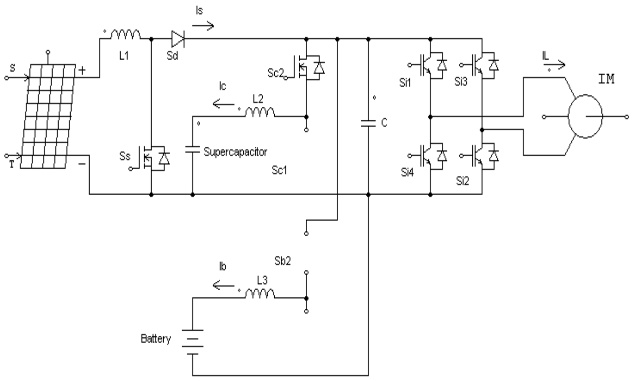
Mode 4; SOC of super capacitor is 100%, then the source voltage is greater than the load voltage. Then the energy will be stored in the battery by the buck operation. Switch S_{b2} is in ON condition.



Is = Ib + IL Ic=0

Fig. 6. Battery charging

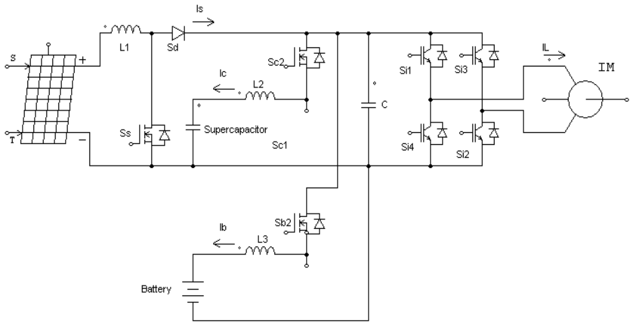
Mode 5; battery SOC is 100%, then the energy is stored in the super capacitor, by the switching operation of S_{c2} ON condition it also the buck operation is obtained. The source voltage is greater than the load voltage.



Is = Ic+ IL Ib=0

Fig. 7. Super capacitor charging

Mode 6; In this mode the no load condition takes place, then the generation can't be stopped so that condition the energy is stored in the storage device. The hybrid storage device will charge at a same time.



Is = Ic+ Ib IL=0

Fig. 8. No load condition

V. Control Analysis

In the PI controller methodology reference voltage of the DC bus u_0^* is compared with the DC bus voltage sensed voltage u_0. When error obtained is used by PI controller input and the output of the controller is I^* multiple by $\sin\omega t$. Input voltage is the instantaneous reference current command I_{ref} is sensed from PLL stage. Then the transfer function is

$$\frac{1 + Ki\,Ti\,S}{Ti\,S}$$

Where

$$Ki = \frac{RC}{2Ti}, \quad Ti = \frac{ARVsm}{8\pi FcvU_0^*}$$

Voltage close loop crossover function for a first order system is

$$\frac{U_0}{I^*} = \frac{U_{sm}}{4U_0^*}\,\frac{R}{1 + \frac{Rc}{2}S} = \frac{K_S}{1 + \tau_S S}$$

Since to avoid the steady state voltage error of the system pre-compensation voltage reference is obtained. The designed transfer function closed loop is given

$$\frac{U_0}{U_0^*} = \frac{K_S}{1 + \tau_S S}$$

These are the parameters of PI.

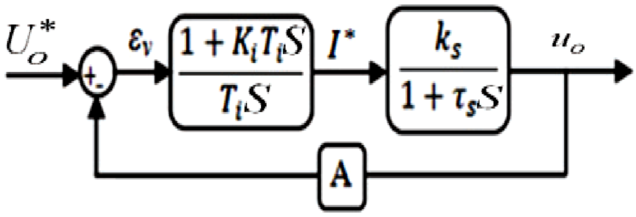


Fig. 9. PI-Controller

F_{cv} is the crossover frequency. The designed converter which doesn't follow this specification to overcome these issues fuzzy controllers is implemented it does not require any mathematical model of the system. The values of the fuzzy variables are defined by linguistic variables (fuzzy set and subset) such as low, medium, big, slow,….. It varies by the membership function. The shape of the fuzzy set is triangular, trapezoidal etc.

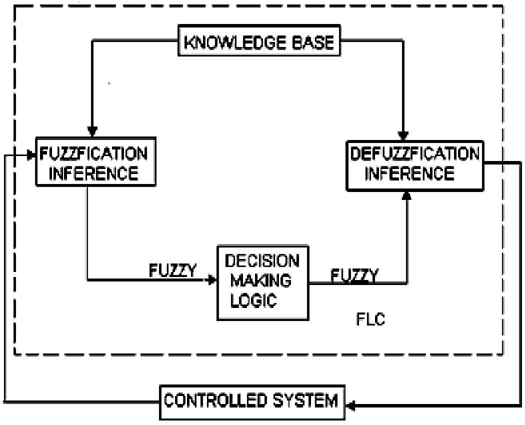
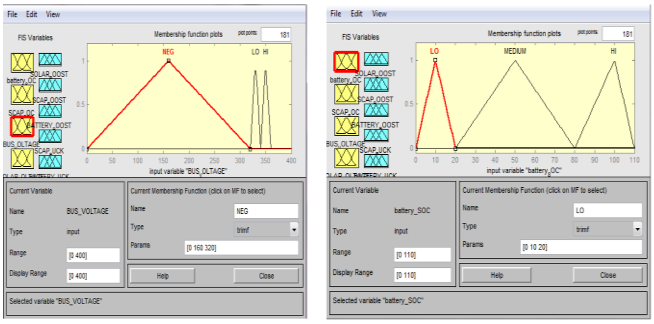


Fig. 10. Fuzzy Controller

The membership function of the proposed converter is shown in the fig solar voltage membership function and bus voltage membership function is given below.



(a) (b)

Fig. 11. Input membership functions, voltage (b) solar voltage

In this fig.12. Solar boost operation is controlled by the ON and OFF condition is shown below, all the output membership function is similar to this operation, they are battery boost, battery pack, super capacitor boost, super capacitor buck.

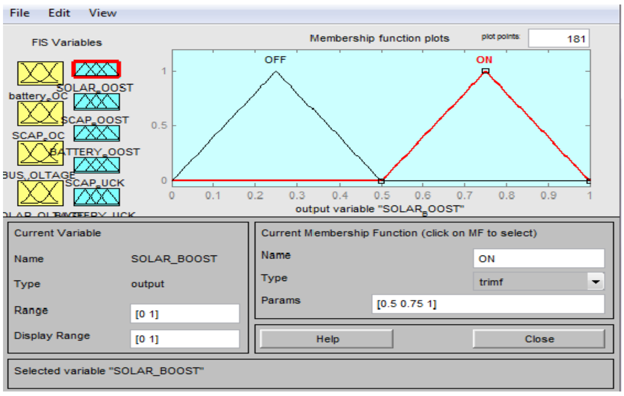


Fig. 12.Solar boost membership function

As explained before rules are the decision maker of the fuzzy total 27 rules are created to control this system the rule viewer is shown in fig. 13.

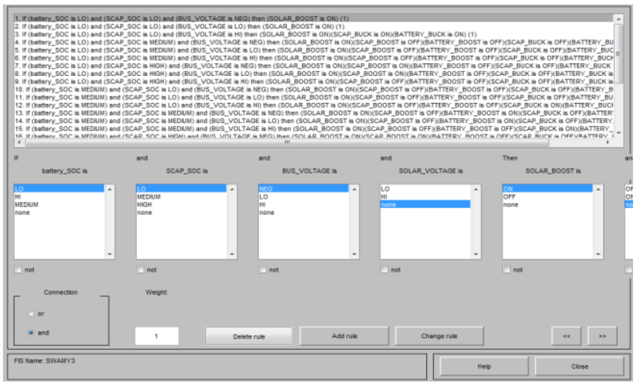
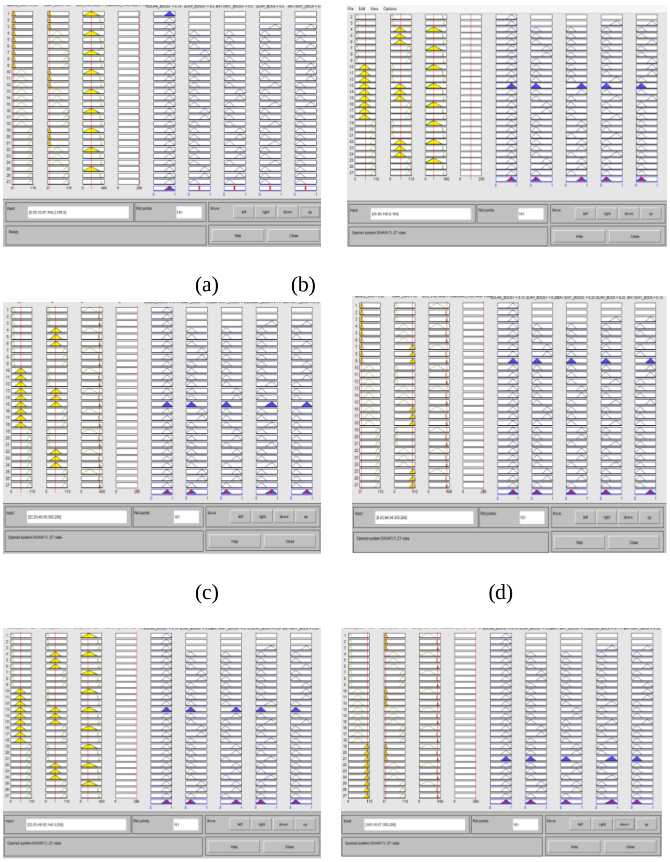


Fig. 13.Rule viewer

Shown fig. 14. The switching operation of the proposed converter is controlled by the fuzzy logic controller. Through this rule viewer switching operation are explained briefly. In this only two conditions are given they are “0” and “1”. On zero condition switch is in OFF condition, then in one switch is in ON condition. Each operation of the converter is controlled by this condition. When solar voltage is distributing the generated energy to the load at solar connected switch is in ON condition, and in OFF condition the generated energy is stored in an inductor.



(a) (b)

(c) (d)

(e) (f)

Fig. 14. Controller operation. (a) Solar to load, (b) battery discharge, (c) Battery and super capacitor discharge, (d) battery charge, (e) Super capacitor discharge, (f) super capacitor charge.

VI. SIMULATION RESULT

The advance components are employees to improve the performance of bidirectional converter while enhancing the flexibility of the design process and range of designs parameters is adjustable. The parameters are determined as solar voltage V_s, battery voltage V_b, super capacitor voltage V_c, and the bus voltage is V_{bs}, and output load voltage is V_l. PV cell is connected in series to create the PV model at the source voltage of 180V with the help of inductor source voltage is boosted into 310V. And the load side 500W induction motor is placed. For this full bridge inverter connection are given in the simulation. Battery and super capacitor parameters are 12V. The fuzzy logic control is inbuilt for the switch control. Fuzzy generate switch ON, OFF signal and the pulse generator is used to generate firing pulses. Depending upon the parameters given the parameters the result of the simulation are explained below.

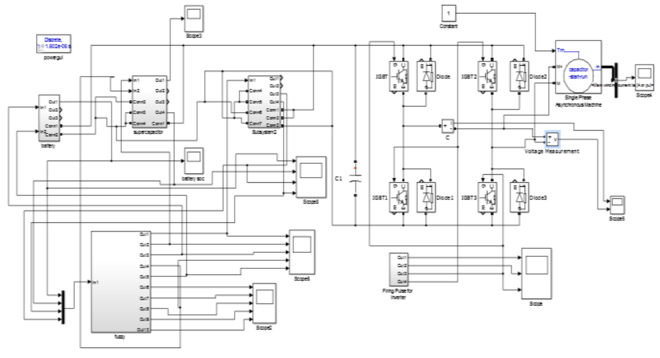


Fig. 15. Proposed converter simulation

MATLAB SIMULATION RESULT

SOURCE WAVEFORM: The source voltages of the proposed converter boosted solar voltage is shown in square waves value is 310V and current 0.8A. This is measured across the PV model using the scope. SOC of a battery is determined as 99.8%, which already fully charged voltage and current of the battery will never change. It will be 12V and 7.2A. Then SOC of super capacitor is shown here is 10% that mean it gating charging condition. When the super capacitor also has the same parameters. The given parameters will change according to the various modes of operation the values of the source varied. Mode of operation is determined by sensing the bus voltage. When bus voltage is minimum then its use the storage charges.

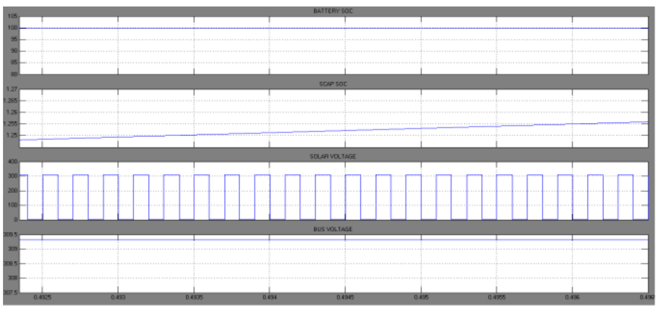


Fig. 16. Result of the Input

OPERATION WAVEFORM: In this simulation explains the operation of each port in waveform. The battery and solar is in boost and others are ideal condition were shown in the operation waveform.

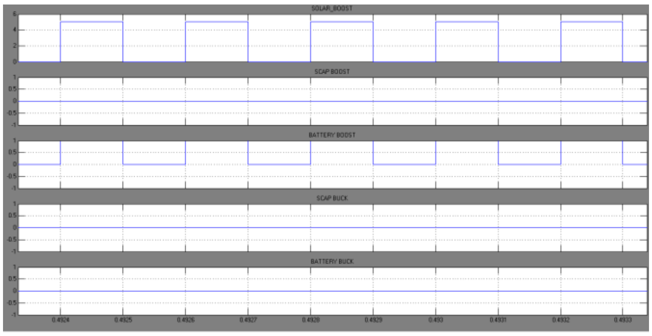


Fig. 17. Operation Waveform

MOTER LOAD WAVEFORM: The input voltage is 180V is converted into 220 V by non-isolated converter topology the output is simulated AC output is shown in the graph

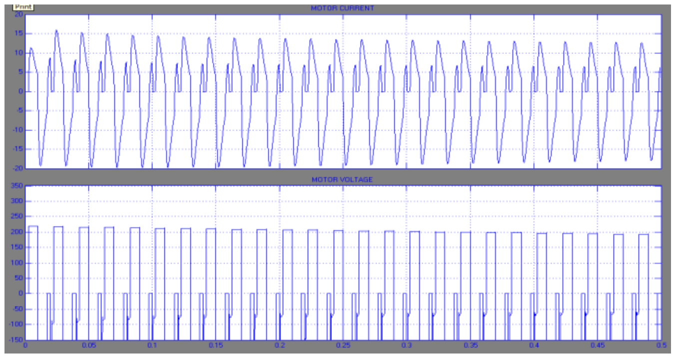


Fig. 18. Result of the Motor Load

INVERTER OUTPUT: The simulated output and input voltage, which is measured across the output of motor load by connecting a voltage measurement and current measurement with scope. The sin wave is generated using the multilevel inverter, the approximate sin wave is given in the fig. 19. And the current is in triangle waveform, firing pulse at 1 and 0.

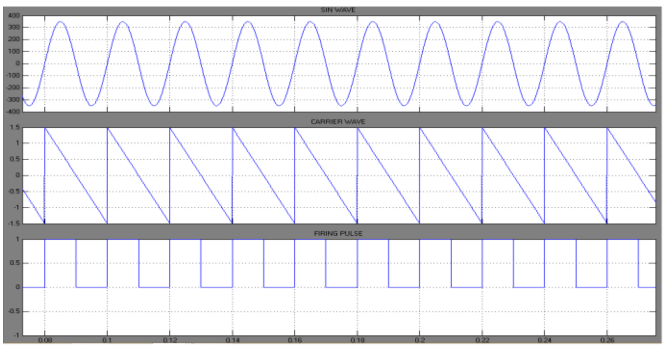


Fig. 19. Inverter Output

VII. Conclusion

The proposed Bi-directional DC-DC converter topology has utilized a hybrid energy storage system to increase the life of the battery, based on energy saving point of view hybrid energy storage are good choice. The size of the PV panel is reduced and to improve the performance of the system. The proposed converter output voltage is achieved by MATLAB @ Simulink simulation. The major advantage of the system is rule based functional controller was implemented for the all the modes of operation, by using the present rule to control the action of the switches. We also adopted a soft-switching technique for the bidirectional DC-DC converter, which enabled the main switch to exhibit a ZVS function during turning on and turning off and, thus, enhanced the converter's energy conversion efficiency.

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