

Asymmetrical Half Bridge DIC Converter with a Solar Panel and a Direct Control Incremental Conductance MPPT Algorithm

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ABSTRACT: During the past decades increased concern about the intensity of global energy shortage has led to a renewed interest in renewable hybrid power system. Renewable hybrid power system differs from traditional power system; the electricity they can deliver can be generated from a wide range of sources including PV energy, hydro energy, and wind energy, or any combination of these. In the renewable hybrid power system, multiple input converters (MICs) serve as the interface of several sources with a load, and provide the energy to the load simultaneously or individually. In this paper, an asymmetrical half-bridge double-input converter (DIC) adopting pulsating voltage source cells (PVSCs) for low power applications is simulated. Compared with available isolated DICs, the proposed converters have advantages of simple architecture and lower number of switches. In this paper the DIC converter with a solar panel as one of the source and a DC source as another is simulated. A solar panel is designed based on single diode model and Incremental conductance based MPPT is implemented for directly controlling the duty ratio of a switch related to the solar source of the double input Converter.

KEYWORDS: MPPT, Incremental conductance, Asymmetrical half bridge DIC

I. INTRODUCTION

Nowadays application of renewable energy has become a popular area for meeting the growing energy crisis. Renewable resources such as solar energy and wind energy have the advantages of non pollution and rich reserves, and they have been regarded as the alternative sources of the fossil energy. However, solar energy and wind energy are affected by some factors such as climatic conditions and they are unstable and discontinuous. So it is necessary to integrate the renewable energy resources to form a hybrid power system to provide continuous and stable electric power. Renewable hybrid power system differs from traditional power system in that the electricity they deliver can be generated from a wide range of sources, including PV energy, hydro energy, and wind energy, or any combination of these. Many of such sources are mutually complementary in the sense that they can be utilized simultaneously to maintain continuous delivery of power to the load. In the conventional hybrid power system, each energy source can be connected to the dc bus through a dc/dc converter. However, such configuration is complicated and the cost is high. In order to simplify the configuration and reduce the cost, multiple-input converter (MIC) could be used to replace the several single-input converters. MIC is capable of converting power from multiple power sources to a common load. DIC(double input converter) is one special case of MICs that consist of only two independent dc input sources. In this paper such Asymmetrical half bridge DIC synthesized by adopting various PVSCs is used, compared to other conventional DIC these have many advantages as simple configuration and lower number of switches. Among all the renewable sources available solar energy holds an important place due to its wide range of availability and easy method of tapping its energy using solar panels. But one of its demerit is its dependency on irradiation, during night the output voltage is zero thus, in order to maintain a constant voltage the DIC is used with its one source as solar panel and the other a DC source to provide uninterrupted power supply. It is also well known that output power of solar array changes due to different circumstances including temperature, solar irradiation and so on. In order to give out the

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maximum power of the cells under variable circumstances, the maximum power point tracking (MPPT) strategy is proposed [8,9]. There are many MPPT methods, In all existent MPPT methods, the Incremental Conductance method is a considerable one because of its excellent tracking ability for our entire energy crisis.

II. RELATED WORK

The conventional configuration of renewable hybrid power system consists of a number of independent single-input converters a common voltage dc bus with a provision for multivoltage level distribution and intelligent energy and load management. A number of renewable energy sources and the load are incorporated with each other by the numerous power converters [1]. Typically, this configuration may be complicated and the cost is relatively high due to multiple converters and the communication devices among the individual converters. As a prominent alternative, MIC can be introduced to replace the multiple individual converters, which can combine the converters into one topology and share the common components of original converters, therefore, partial power devices and magnetic components can be omitted [2][3]. As a result, the complexity and cost of the improved system can be reduced compared with conventional hybrid power system. Different MICs topologies have been proposed for the applications with isolated requirement. Based on the concept of the transformer flux additivity, a double-input current-fed full bridge converter was proposed [4], which combined input dc sources in magnetic form by adding up the produced magnetic flux together in the magnetic core of the coupled transformer, and the proposed converter features magnitude variation of dc input voltages and soft-switching realization. A time multiplexing control scheme was adopted in fly back and forward type MICs, where a switch should be put in series with each of the available dc input voltage sources to prevent the input voltage sources from being connected directly in parallel [5]. The flyback and forward type MICs have fewer switches and a simpler circuit configuration, however, only one power source is allowed to transfer energy to the load at a time, which decreases the utilization of energy sources. PSCs, including PVSCs and PCSCs were extracted from six basic nonisolated converters to derive various nonisolated MICs. Observing the fundamental combination rules, multiple isolated PSCs were combined in series or in parallel, cascaded with the suitable filter, and then a broad set of isolated MICs was derived. [6].

III. MATHEMATICAL MODELLING OF SOLAR PANEL

A solar cell is basically a p-n junction fabricated in a thin wafer of semiconductor. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor creates some electron-hole pairs proportional to the incident irradiation. [7,8]. The equivalent circuit of a PV cell is as shown in Figure 1.

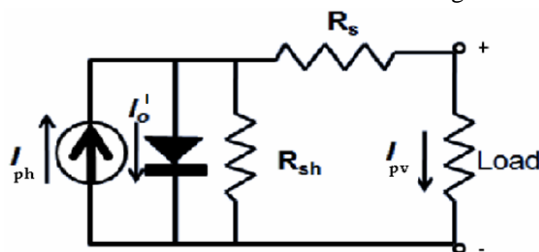


Fig. 1. The equivalent circuit of a solar cell.

The current source I_{ph} represents the cell photocurrent. R_{sh} and R_s are the intrinsic shunt and series resistances of the cell, respectively. Usually the value of R_{sh} is very large and that of R_s is very small, hence they may be neglected to simplify the analysis. PV cells are grouped in larger units called PV modules which are further interconnected in a parallel-series configuration to form PV arrays.

The photovoltaic panel can be modeled mathematically as given in equations (1)- (4)
Module photo-current I_{ph}

$$I_{ph} = [I_{scr} + K_i(T - 293) * l/1000] \dots \dots (1)$$

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Module reverse saturation current - I_{rs} :

$$I_{rs} = I_{scr} \left[\exp \left(\frac{qV_{oc}}{N_s k A T} \right) - 1 \right] \dots \dots (2)$$

The module saturation current I_o varies with the cell temperature, which is given by

$$I_o = I_{rs} \left[\frac{T^3}{T_r^3} \right] \exp \left[\frac{q * E_{go}}{B_k} \left\{ \frac{1}{T_r} - \frac{1}{T} \right\} \right] \dots \dots (3)$$

The current output of PV module is

$$I_{pv} = N_p * I_{ph} - N_p * I_o \left[\exp \left\{ \frac{q * (V_{pv} + I_{pv} R_s)}{N_s A k T} \right\} - 1 \right] - \left(\frac{V + I R}{R_{sh}} \right) \dots \dots (4)$$

- V_{oc} : Open circuit voltage
- A : Ideality factor(1.6)
- k : Boltzmann constant (1.38×10^{-23} J/°K).
- T_r : Reference cell operating temperature
- q : Electron charge (1.602×10^{-19} C).
- K_i : Short circuit current temperature coefficient at $I_{scr}=0.0017A/^{\circ}C$
- R_s : Series resistance of cell
- R_{sh} : Parallel resistance.
- E_{go} : Band gap for silicon=1.1ev
- N_s : Number of series cell = 36
- N_p : Number of cell in parallel = 1
- I : Insolation (W/m^2)

Table 1: Rating of solar PV module

Rated Power	100 W
Voltage at Maximum power (V_{mp})	25V
Current at Maximum power (I_{mp})	4A
Open circuit voltage (V_{oc})(per cell)	0.6V
Short circuit current (I_{scr})	4.75A
Total number of cells in series (N_s)	72
Total number of cells in parallel (N_p)	1

Note: The electrical specifications are under conditions : irradiance of 1 kW/m^2 , and cell temperature of $25^{\circ}C$.

IV. INCREMENTAL CONDUCTANCE MPPT TECHNIQUE

In order to increase the efficiency of solar array many MPPT methods have being formed. The MPPT algorithm operates based on the truth that the derivative of the output power (P) with respect to the panel voltage (V) is equal to zero at the maximum power point. In the literature, various MPP algorithms are available in order to improve the performance of photovoltaic system by effectively tracking the MPP. They differ in many aspects such as complexity, accuracy, sensors that are required, cost or efficiency and also speed at which they track the point. Based on the control variable it uses, each method can be separated from one another. There are different MPPT techniques such as Perturb and Observe, Hill climbing, Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Fuzzy Control, and Neural Network Control etc. Among all these methods Perturb and observe (P&O) and Incremental conductance are used commonly

The Incremental conductance(IC) is derived on the basis of perturb and observe technique but the disadvantage of perturb and observe method to track the peak power under varying atmospheric condition is overcome by IC method. It is based on the incremental and instantaneous conductance of the PV and track rapidly increasing and decreasing irradiance conditions with higher accuracy than Perturb & Observe

At MPP, according to P-V characteristic we have,

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$$\frac{dP}{dV} = \frac{d(V * I)}{dV} = 0$$

$$\frac{d(V * I)}{dV} = V * \frac{d(I)}{dV} + \frac{dV}{dV} * I = 0$$

$$\frac{dI}{dV} = -\frac{I}{V} \text{ is the condition at MPP}$$

In direct control method unlike the conventional method the output of the MPPT algorithm is the duty cycle of the converter and not the reference voltage V_{ref} . Hence the measured voltage is not tracked to the reference voltage using PI controller. Thus the control circuit made is made simpler and easier to implement and uses only one control loop, it performs the adjustment of duty cycle within the MPP tracking algorithm(Fig 2). The way to adjust the duty cycle is totally based on the theory of load matching.

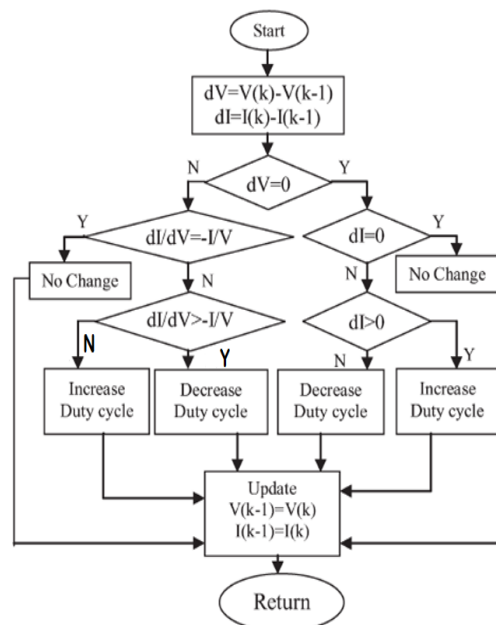


Fig. 2 :Direct control incremental conductance algorithm.

V. ASYMMETRICAL HALF BRIDGE CONVERTER

For all basic single-input isolated dc/dc converters, it is possible to decompose each of them into a few basic stages, namely, a PSC(Pulsating source cell), a transformer, an output rectifier, and an output filter. [6]The function of PSC is to provide an ac pulsating voltage or current, which is step-up or step-down by the transformer and further rectified and filtered by the output stage. Isolated DICs can also be divided into the same parts as single-input isolated converters,(Fig.3)[12] and this paper focuses on the basic non isolated PVSCs to derive the simplest DIC configuration. The voltage on the primary of the transformer has a dc component , so a blocking capacitor should be introduced in series with the primary winding to block the dc bias on the transformer as shown in Fig 3

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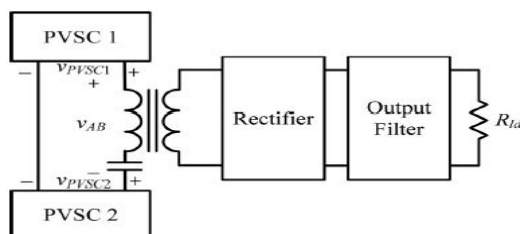


Fig. 3 : Circuit configurations of the DICs

A typical PVSC consists of a dc voltage source and a switch network. The dc voltage source is connected to the terminal of PVSC through the switch network, and the power conversion process is properly controlled. Fig.4 shows three simplest PVSCs extracted from basic non isolated converters, which are referred to as buck PVSC, Cuk PVSC, and Zeta PVSC.

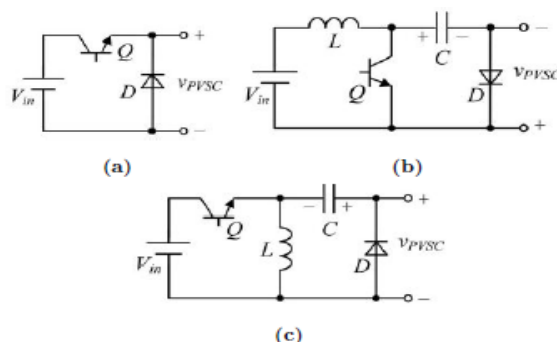


Fig. 4 : Circuit configurations of three nonisolated PVSCs (a) Buck PVSC (b) Cuk PVSC (c) Zeta PVSC

An asymmetrical half bridge converter can be synthesized using any combination of the above mentioned PVSCs thus forming a various types of configurations.[12] In this paper the converter was synthesized using two buck derived PVSCs There are two modes of operation for this converter SSSM and DSSM. In Single Source Supply Mode(SSSM) only one of the two sources supply the the load at a time whereas in Double Source Supply Mode(DSSM).The Sources can be connected both in Forward and reverse polarity this paper focus on reverse polarity as it has reduced dc components on the primary side of the transformer thus blocking capacitor required is small.

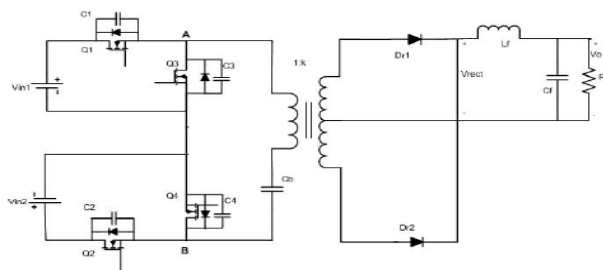


Fig. 5 : Buck Derived Asymmetrical Half Bridge Converter

Mode 1:From Fig 10,Up to t_0 Switch Q_1 is on and Q_3 is off whereas Q_2 is off and Q_4 is on. In this mode the source 1 is supplying the load for a duty ratio of D_1 ..Since the net voltage across secondary is positive diode D_{r1} conducts and D_{r2} is reverse biased.(Fig. 6)

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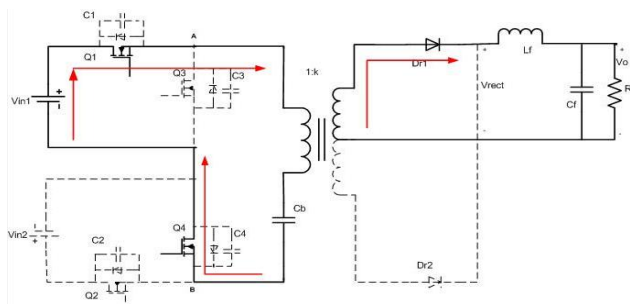


Fig. 6 : Mode 1

Mode 2: In this mode (t_0 to t_1) switches Q_3 and Q_4 are on, remaining two switches are off. The Diode D_{r2} starts to conduct due to polarity of C_b which appears across primary of the transformer at the same time diode D_{r1} continues to conduct. (Fig. 7).

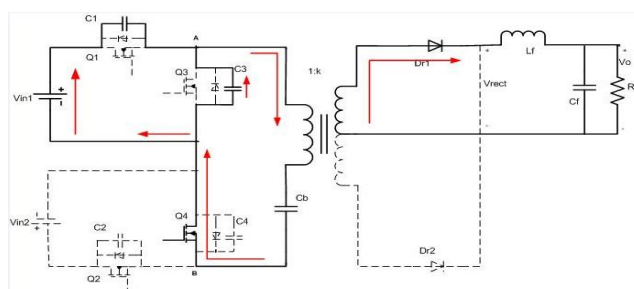


Fig. 7 : Mode 2

Mode 3: From t_1 to t_2 the switch Q_3 is conducting and Q_4 is turned off while Q_2 is turned on. In this mode D_{r1} stops conducting. Now the load is supplied from source 2 (V_{in2}), Fig. 8

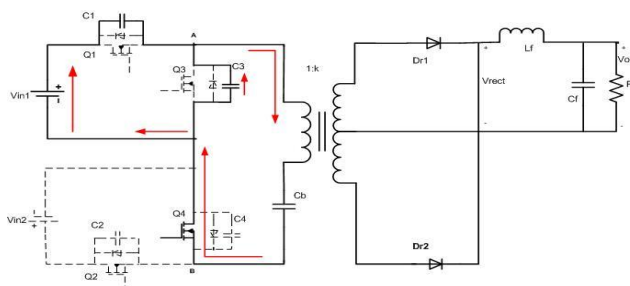


Fig. 8 : Mode 3

Mode 4: In this mode (t_2 to t_3) the switch Q_2 is turned off and Q_4 is made on, thus now C_b is supplying the primary of the transformer. During this the diode D_{r1} is off thus kV_{C_b} is the output across the secondary (Fig. 9)

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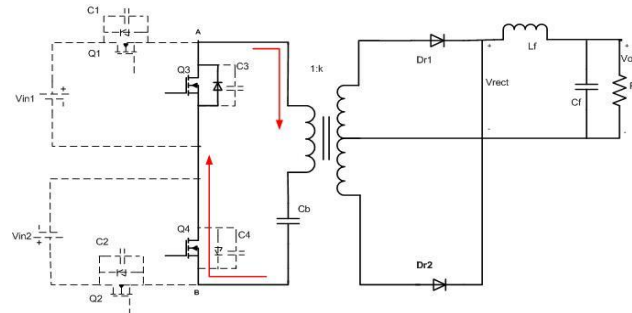


Fig. 9 : Mode 4

The modes of operation as explained above is shown in the below graph (Fig.10). The four switching pulses (Q_1, Q_2, Q_3, Q_4) are shown at a particular duty ratio are shown and the corresponding voltage waveform for different modes are also shown in the graph

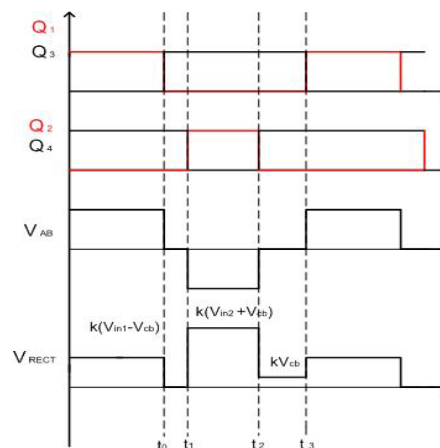


Fig. 10 : Modes of Operation

VI. SIMULATION RESULTS

The simulation was done in two steps, initially the asymmetric half bridge converter was simulated in MATLAB/Simulink by assigning two DC sources later on solar panel with rating given in the above discussion, was added with an MPPT as one of the source and DC as the other source.

Table 2. Simulation parameters of the DIC converter

DIC converter parameters	
Source 1(V_{in1})	290 V
Source 2(V_{in2})	200 V
Switching frequency(f)	100KHz
C_f	4.7 μ F
C_b	10 μ H
R_{load}	15 Ω
L_f	230 μ H
Transformer ratio	10:12
Duty Ratio (D_1)	0.3
Duty Ratio (D_2)	0.4

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Asymmetric Half Bridge Converter

The Buck derived Asymmetrical converter with the above values were simulated and output waveforms were obtained.

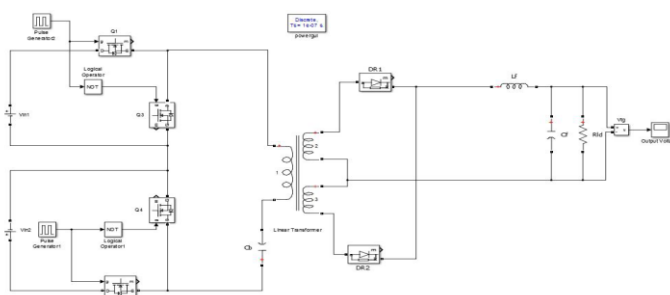


Fig.11 : Simulation model of the converter

The converter model was simulated in Simulink /MATLAB and the output obtained from the converter was analysed .The output voltage waveform were obtained at three stages of the converter. The three wave forms are shown below Fig. 12(a) to 12(c). Fig.12(a) shows the output at first stage i.e. at the primary side of the transformer. The second wave form shows the output voltage after the rectifier section(Fig.12(b)) and finally the output voltage across the load is shown(Fig.12(c)).

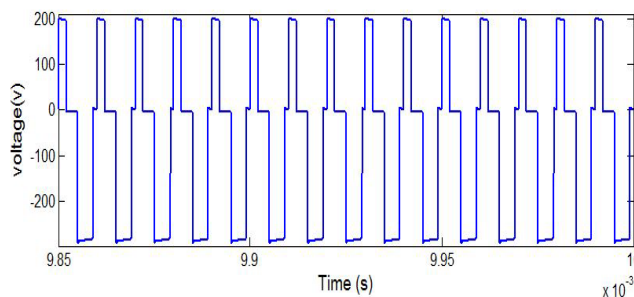


Fig.12(a) : Voltage across the primary of transformer

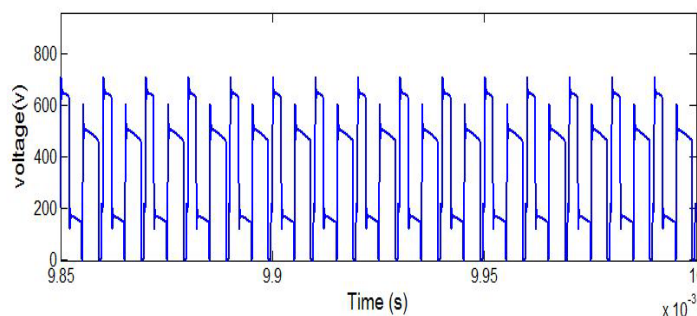


Fig.12(b) : Voltage across the rectifier section

The value of the output voltage obtained depends on the dutyratio of both the switches(Q_1 and Q_2) and the transformer turns ratio.The duty ratio of both the switches are limited to .5 value.As above this value of duty ratio the losses increases due to overlapping of voltages from both the sources

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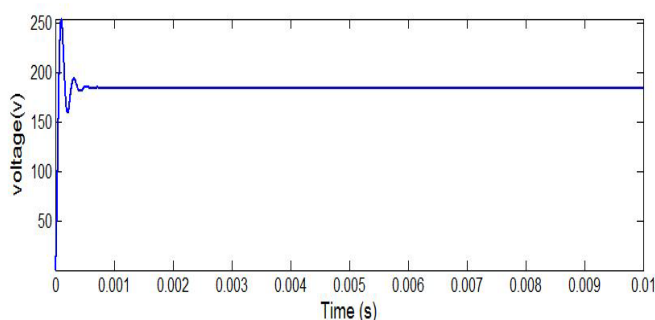


Fig.12(c) : Voltage across the load

Converter with Solar Panel and MPPT

Solar panel of 100W was simulated in Matlab and an incremental conductance MPPT algorithm was used to obtain maximum power from the solar panel. A closed loop control with PI controller was employed to control the output voltage to a constant value by controlling the duty cycle of the switch Connected in series with the DC source.

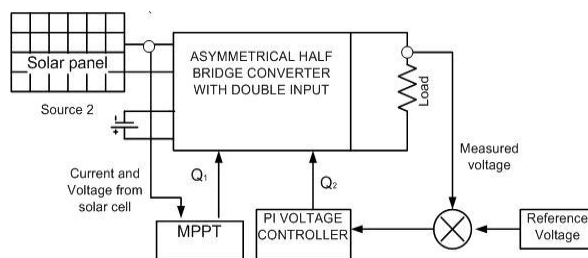


Fig.13 : Block diagram of the converter with solar panel and MPPT

The above block diagram(Fig.13) shows the converter system, one input of the converter is the solar panel and another is the DC source. The voltage and current of the panel is given as the input to the MPPT algorithm which tracks the maximum power that can be drawn from the solar panel. The output of the MPPT controls the switch connected to the solar panel source(Q_1) and the other closed loop control, employed using a PI controller controls the Switch (Q_2) to maintain the output voltage to a constant value.

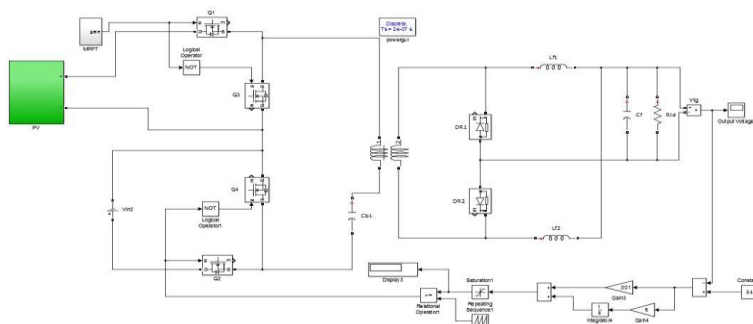


Fig.14 : Simulink model of the converter with solar panel

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The above Fig. 14 shows the Simulink model of the converter system explained in the above mentioned block diagram(Fig.13). In this a solar cell is modelled using simulink with the values mentioned in the above explanation of solar cell modelling. And an Incremental conductance MPPT technique is coded in Matlab and is used to track the maximum power of the solar panel at a given condition. And a closed loop control is also employed to maintain the output voltage constant.

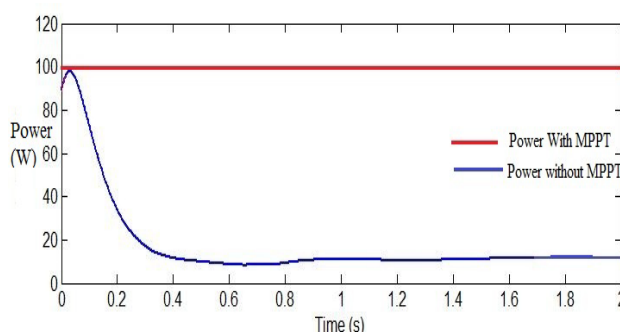


Fig.15 : Maximum Power tracked by MPPT from solar panel

The fig.15 shows the power drawn from the panel at two conditions. One without using a solar panel with MPPT and the other without MPPT. As shown in the graph power drawn without using an MPPT is very low compared to the maximum power drawn from the panel using an MPPT.

VII. CONCLUSION

The paper explains about the double input converter used to supply power continuously from two sources. These two sources can be any renewable sources of different voltages, thus the converter is termed as asymmetrical. The converter is synthesized using different PVSCs thus various combination can be obtained. In this paper a reverse polarity buck derived asymmetrical half bridge converter is explained. In this system one of the sources is a solar panel and an incremental conductance algorithm is used to track the maximum power from the source. And also PI controller is employed to control the output voltage by controlling the switch connected to a DC source. The DIC used in this paper has many advantages as compared to other DICs as it has less number of switches, simple structure and also it can power the load simultaneously from both the sources.

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