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Bidirectional DC-DC Converter with MPPT Controller Using PV Array

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Abstract - This paper proposes simulation of Bidirectional DC - DC converter with Maximum Power Point Tracking using Photo Voltaic cell with motor load in boost and buck mode respectively. The proposed two level converters have the advantages of transformer less operation. This converter can operate with steep conversion ratio, soft- switching, continuous inductor current and fixed switching frequency. In the proposed DC-DC converter topology, the switched coupled-inductor is used instead of coupled inductor. The proposed converter is carried out in MATLAB working platform and the output performance is analyzed. It shows that Bidirectional DC - DC converter with Maximum Power Point Tracking using Photo Voltaic cell gives more efficiency.
***Keywords*: Maximum Power Point Tracking, Photo Voltaic, Perturb and Observe.**

I. INTRODUCTION

The market for residential photovoltaic (PV) converter is becoming highly competitive. PV manufacturers are competing to increase the efficiency for every 0.1%. From the Maximum Power Point Tracking (MPPT) algorithm point of view, the existing methods, such as Perturbation and Observation (P&O) and incremental conductance (IncCond), can track the maximum power point properly and the dynamic response is good enough to deal with changes in temperature and irradiation. The topology used in [1] raises the efficiency for the DC/DC converter of the PV Power Conditioning System (PVPCS), and it minimizes switching losses by adopting a resonant soft-switching method. Inverter technologies for connecting photovoltaic (PV) modules to a single-phase grid is given in [2]. P&O is simple to implement and thus can be implemented quickly. The concept behind the "Perturb and Observe" (P&O) method is shown in Fig.1 to modify the operating voltage or current of the photovoltaic panel until you obtain maximum power from it is in [3]-[5].

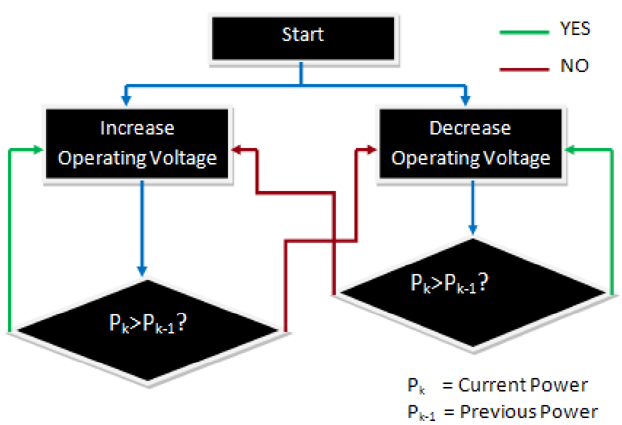

Fig.1 Perturb and Observe algorithm

Zero-Voltage Switching (ZVS) techniques that may be suitable for unidirectional coupled inductor converters or for bidirectional non-coupled inductor converters are generally not suitable for bidirectional coupled inductor converters. The nature and characteristics of these converters make it very difficult to implement ZVS in them with very few exceptions. A soft-switched bidirectional dc-dc converter with coupled inductors is implemented in [6]. In [7] the inductor in the classical boost converter is replaced by a Switched-Coupled-Inductor (SCL) configuration in order to achieve high gain with moderate duty cycles. An enhanced cascaded bidirectional DC DC converter with SCL mode of operation discussed in [8]. The bidirectional converter find applications in hybrid vehicles and Uninterrupted power Supply [9].

In this paper, a three-port bidirectional DC-DC converter is given for grid-interactive Photovoltaic (PV) system application. The three-phase topology is suitable for residential power requirement. The control of battery and PV are naturally decoupled. The maximum power of the PV cell is tracked with an adjusted P&O MPPT algorithm based on Boost DC/DC converter. A DC/AC inverter has been used to connect the PV cell to the grid and regulate the output voltage of DC/DC converter. The given model can work under sudden change of environment temperature or solar.MPPT method is able to considerably increase the efficiency of the PV system during rapidly changing irradiance is given in [10] & [11].

The DC-DC converter is used for boosting a low voltage of the PV array up to the high dc bus voltage, which is not less than grid voltage level is given in [12]. The Perturb and Observe (P&O) method operates by periodically perturbing (i.e. incrementing or decrementing) the array terminal voltage or current and comparing the PV output power with that of the previous perturbation cycle. The proposed Perturb and Observe control algorithm is a software program with a self-tuning function which adjusts the array reference voltage and step size of the voltage to achieve maximum power point. When the external environment changes suddenly the system can track the maximum power point quickly. Both buck and buck-boost converters have succeeded to track the MPP due the use of P&O technique [13].

A Thermo Electric Generator (TEG) is a low voltage, high current DC power source with a linear V-I characteristic. The linear V-I characteristic produces a P-I characteristic with a flatter peak relative to other sources. This can result in large operating point variations while performing Maximum Power Point Tracking (MPPT). A novel high step-up DC/DC converter topology operating with a fractional short-circuit MPPT algorithm is given in [14].

Bidirectional DC-DC converter with MPPT controller and motor load is proposed. This topology has less components than other topology and it also improves the voltage conversion ratio of the circuit and its performance. The two level cascaded circuit which operates on both boost and buck mode is explained in section.2. The proposed circuit is implemented in the MATLAB platform is given in section.3.

II. TWO LEVEL BIDIRECTIONAL DC-DC CONVERTER

Fig.1 shows the proposed two level non isolated dc-dc converter with inductor current control. In the bidirectional circuit, while the current flowing through the positive terminal of L_1 inductor is considered as positive. Similarly the current flowing through the positive terminal of L_2 inductor is considered to be positive. The current flows through the switches T_{11} and T_{12} are positive, while the current flows through their respective switches to drain. The current flows through the T_a switch is positive, if it is flowing from the source to drain. The current flowing into the positive terminal of the capacitors (C_1, C_2) are considered to be positive and the drain-source voltage is considered to be positive for all the switches. The diodes (D_1) are added to the proposed cascading circuit, which allows the current in one direction. The capacitors and the diodes are used for improving the performance of the converter. The modes of operation of the proposed circuit for both the modes like buck and boost operation is given in the next section A.

A. Motoring And Regenerative Modes Of Operation

In boost mode of operation switch T_{11} is acting as a main power switch and the T_{12} acting as the freewheeling diode, similarly for the buck mode of operation switch, T_{12} acting as the main switch and the T_{11} acting as the freewheeling diode. The proposed cascaded topology gives an enhanced performance for the converter which have series connection of the capacitors and the diode. The addition of the switched coupled inductor provides the high conversion ratio. From fig.2 the overall output voltage in boost mode is given by,

$$V_{boost} = V_i\left[1+\frac{T_{on}}{T_{off}} * N\right] + \sum_{m=1}^{2} L_m \frac{di_m}{dt} + \sum_{m=1}^{n} \frac{1}{C_m}\int i_2(t)dt + \sum_{m=1}^{n} \frac{kT_m}{q} + \frac{V_{low}}{1-D_1} \quad (1)$$

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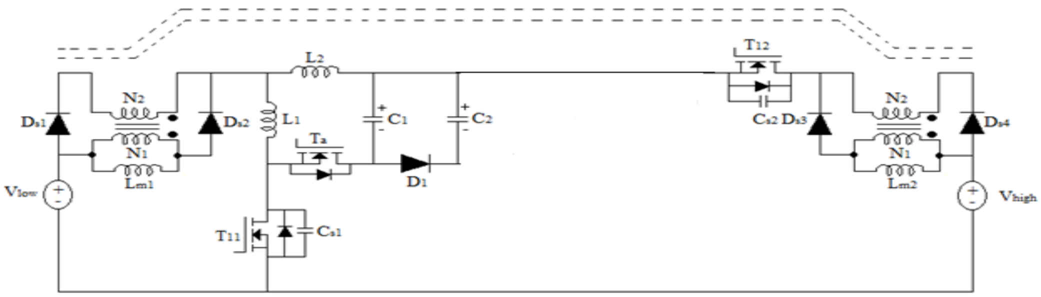

Fig. 2 Two level non isolated dc-dc converter with inductor current control

where, $N = \frac{N_2}{N_1}$ turns ratio for boost mode, for this mode N_2 windings must be greater than N_1 windings, V_i is the input voltage, L_m is the mutual inductors $m = 1,2$, C_m is the capacitors, $m = 1,2 ...... n$, k is the Boltzmann constant, T_m absolute temperature of the P-N junction $m = 1,2 ...... n$, q is the magnitude of charge on electron, D_1 is the duty ratio of the switch T_{11} . Similarly for the buck mode operation over all voltage is given in equation (2).

$$V_{buck} = V_i\left[1 + \frac{T_{on}}{T_{off}} * K\right] + \sum_{m=1}^{2} L_m \frac{di_m}{dt} + \sum_{m=1}^{n} \frac{1}{C} \int i_2(t)dt + \sum_{m=1}^{n} \frac{kT_m}{q} + V_{high} + \frac{nV_{low}}{1-D} \quad (2)$$

where, $K = \frac{N_2}{N_1}$ turns ratio for boost mode, for this mode N_2 windings must be less than N_1 windings, V_{high} is the high voltage side.

III. SIMULATION CIRCUIT & RESULTS

A. Discrete DC Machine

1) Boost Mode: Motor Parameters: Armature parameter:Ra=0.78 Ω, La=0.016 H, Rf=50 Ω, Field parameter: Lf=26 H, Inductance between armature and field: Laf=1.234 H, Total inertia: J=0.05 kg.m^2, Viscous friction coefficient: Bm=0.01 N.m.s, Voltage : Vin=18 , Vout=42 V, Io=1.8 A .

The simulation of proposed two stage non isolated bidirectional DC-DC converter with MPPT controller is done using MATLAB and results are presented. Fig.3(a) shows the converter with controller circuit in boost mode. The photo voltaic power is given as input to converter with Maximum Power Point controller. The controller decides duty cycle of converter with P&O algorithm. The output of two level non isolated bidirectional DC-DC converter is given to DC motor. Fig.3 (b) shows solar input voltage as 18 V. Fig.3(c) shows output voltage as 42 V. Fig.3(d) shows the armature speed of 510 rpm. Fig.3(e) shows the motor torque. Fig.3(f) shows the ZVS operation of main switch. Fig.3(g) shows the output power of DC-DC converter without and with MPPT controller for different input voltage. Fig.3(h) shows the efficiency comparison between with and without MPPT controller of proposed system.

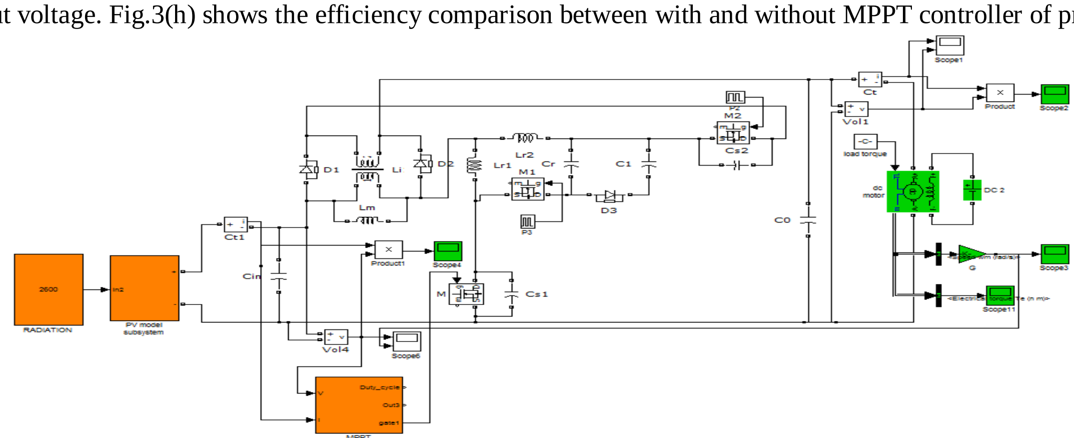
Fig.3(a) DC /DC converter with MPPT controller in boost mode

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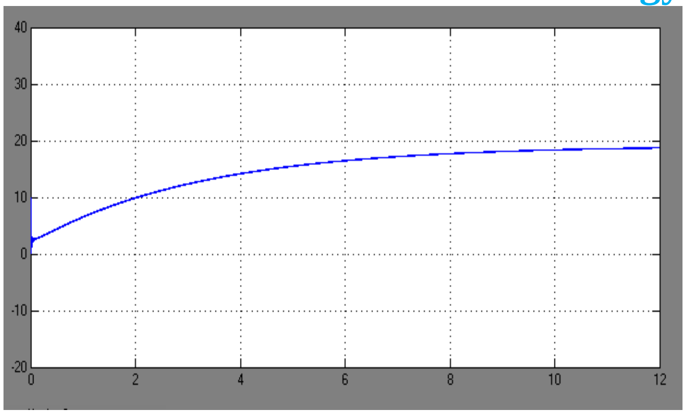

Fig.3(b) Solar input Voltage

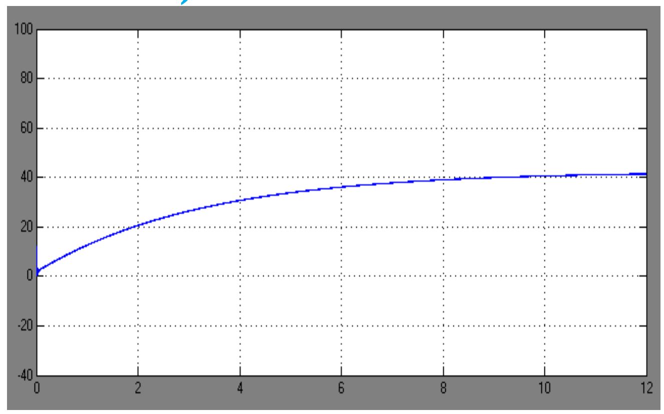

Fig.3(c) Output voltage

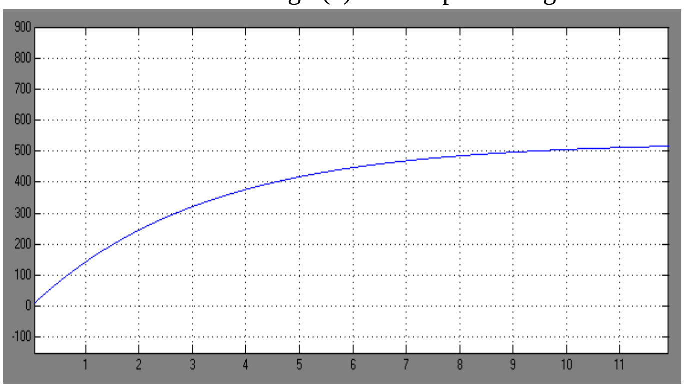

Fig.3(d) Armature speed

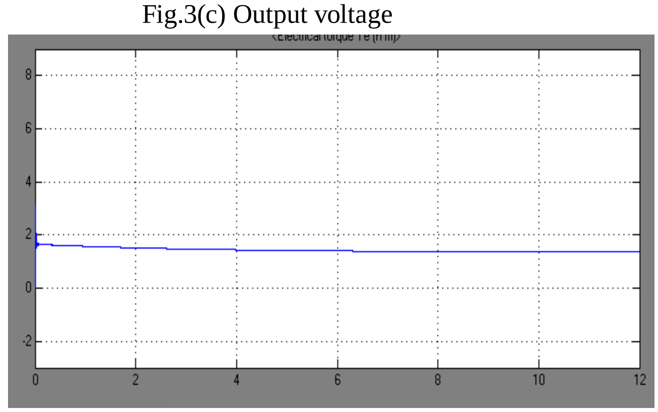

Fig.3(e) Motor Torque

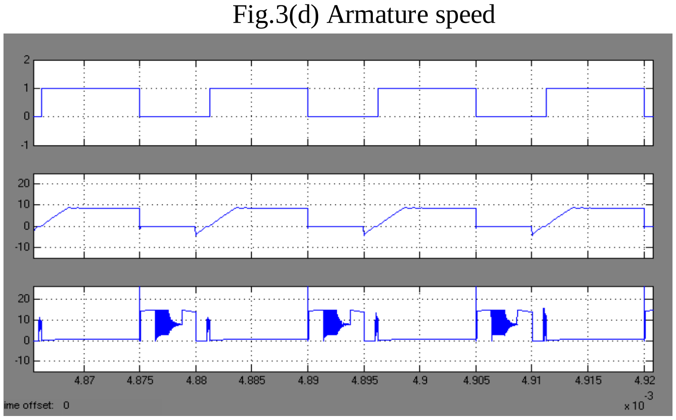

Fig.3(f) ZVS operation across switch

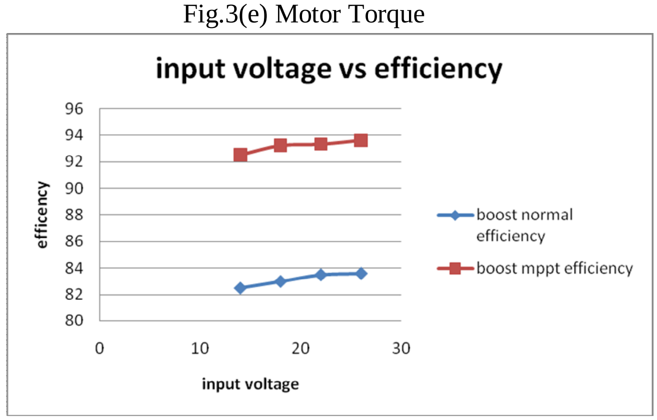

Fig.3(g) Efficiency comparison

Input voltage (V)	Output power (w)	Output power with MPPT(w)	Boost normal efficiency	Efficiency
14	49.5	50	82.5	92.5
18	71	76.3	83	93.2
22	95.3	100.3	83.5	93.3
26	122.7	127.4	83.6	93.6

Fig.3(h) Output power without and with MPPT

2) Buck Mode

Motor Parameter: Armature parameter: Ra=0.78 Ω, La=0.016 H, Rf=50 Ω, Field parameter: Lf=26 H, Inductance between armature and field: Laf=1.234 H, Total inertia:J=0.05 kg.m^2, Viscous friction coefficient: Bm=0.01 N.m.s, Voltage: Vin=42 V , Vout=18 V, Io=1.5 A .

Fig.3(i) shows the converter with controller circuit in buck mode. The photo voltaic power is given as input to converter with Maximum Power Point controller. The controller decides duty cycle of converter with P&O algorithm. The output of two level non isolated bidirectional DC-DC converter is given to DC motor.

Fig.3(j) shows Solar input voltage as 42 V. Fig.3(k) shows the output voltage as 18 V. Fig.3(l) shows the armature speed as 250 rpm. Fig.3(m) shows the motor torque. Fig.3(n) shows ZVS across switch. Fig.3(o) shows the output power of DC-DC converter without and with MPPT controller and Fig.3(p) efficiency comparison between without and with MPPT controller. It shows that by the use of MPPT controller more efficiency is achieved.

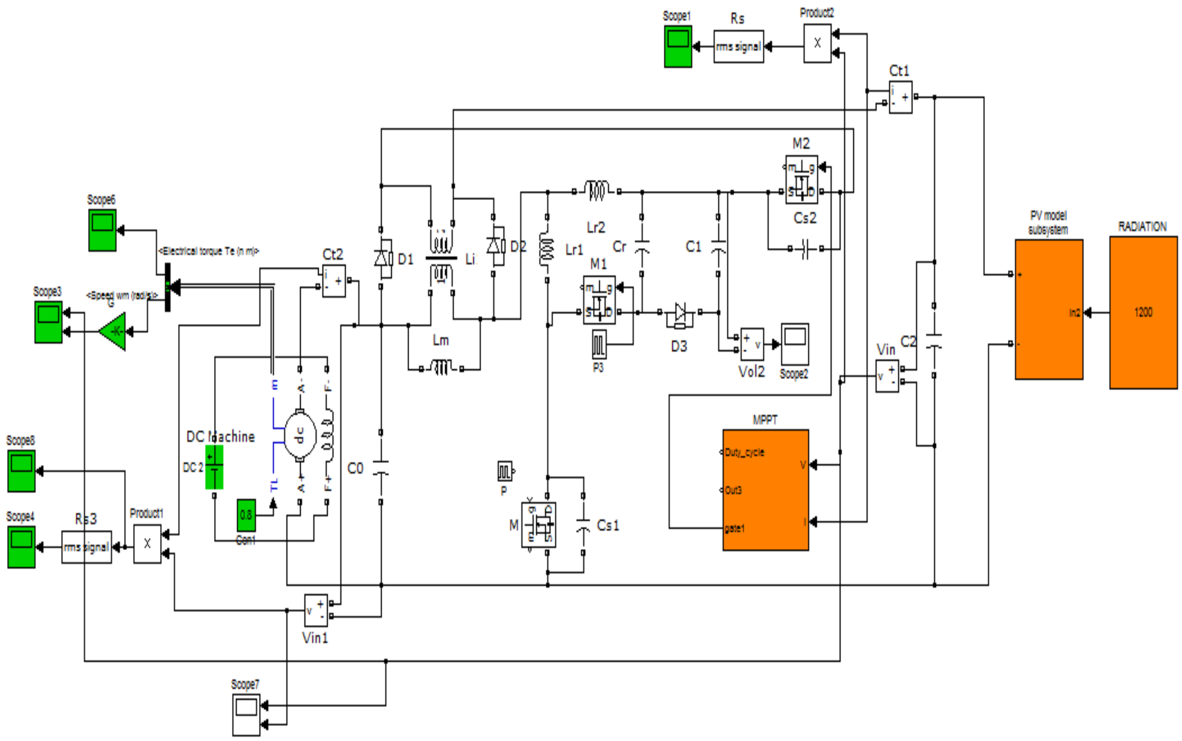

Fig.3(i) DC/DC Converter with MPPT controller in buck mode

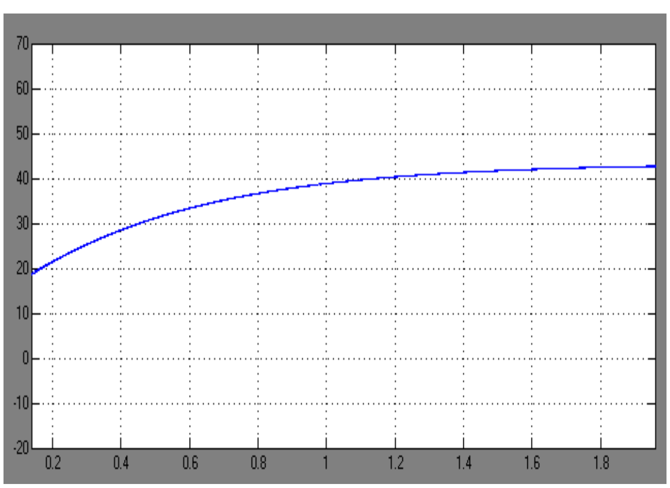

Fig.3(j) Input voltage

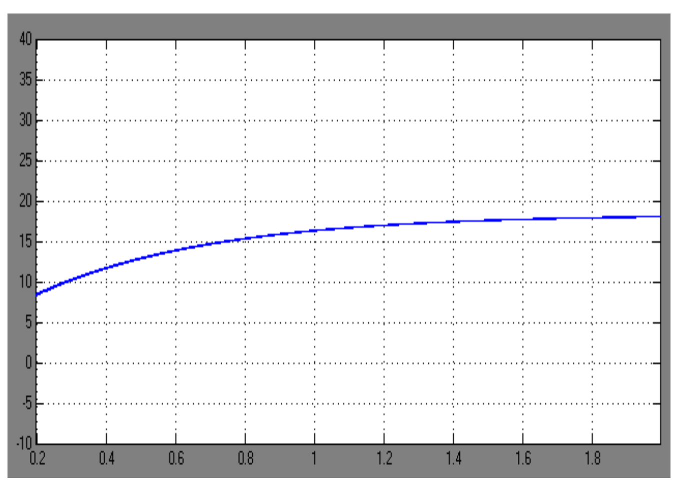

Fig.3(k) Output voltage

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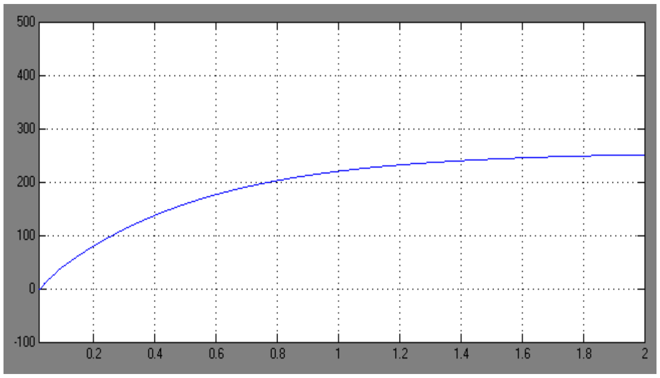

Fig.3(l) Armature speed

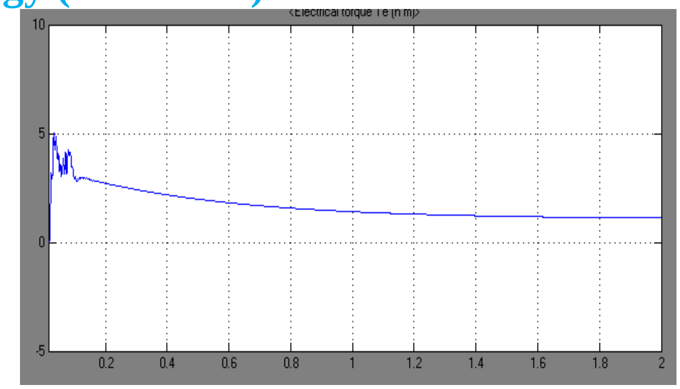

Fig.3(m) Motor Torque

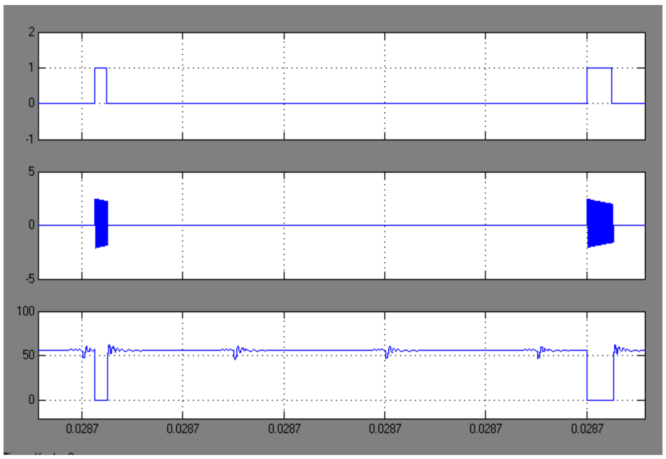

Fig.3(n) ZVS operation across main switch

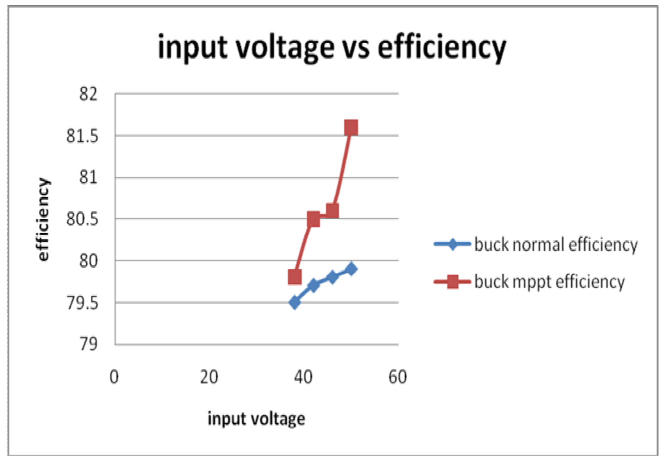

Fig.3(o)Efficiency with and without MPPT controllers

Input voltage(V)	Output power(w)	Output power with MPPT (w)	Buck normal Efficiency	Buck MPPT Efficiency
38	26	27.7	79.5	79.8
42	29.5	31.8	79.7	80.5
46	33.2	35.5	79.8	80.6
50	37.1	40	79.9	81.6

Fig.3(p) Output Power without and with MPPT

IV. CONCLUSION

This paper proposes simulation of Bidirectional DC - DC converter with Maximum Power Point Tracking using Photo Voltaic cell with motor load in boost and buck mode respectively. The proposed two level converter has the advantages of transformer less operation. This converter can operate with steep conversion ratio, soft- switching, continuous inductor current and fixed switching frequency. In the proposed DC-DC converter topology, the switched coupled-inductor is used instead of coupled inductor. The proposed converter is carried out in MATLAB working platform and the output performance is analyzed. It shows that Bidirectional DC - DC converter with Maximum Power Point Tracking using Photo Voltaic cell gives more efficiency.

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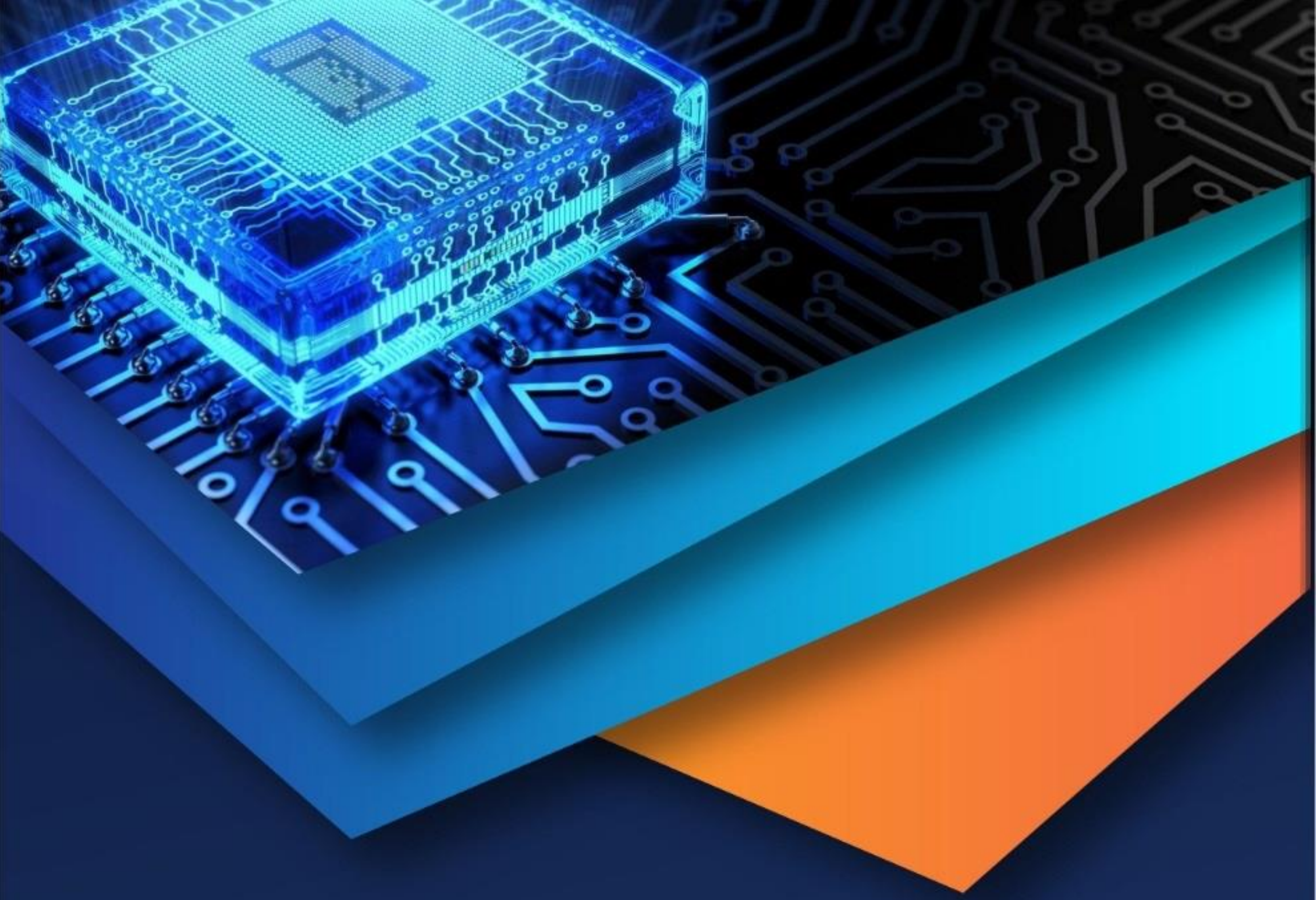

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