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Design of Dual Input Single Output High Gain Step up DC -DC Converter with modified Deer Hunting Optimization based MPPT Controller

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Abstract
This paper proposes a high-efficiency hybrid electric vehicle (HEV) power system powered by solar photovoltaic (PV) and battery sources. A high gain Dual Input Single Output (DISO) converter is designed for HEV applications. It regulates solar PV output voltage under source and load side disturbances. To ensure that the solar panels always deliver maximum power to load, Modified Deer Hunting Optimization (MDHO) algorithm has been used to generate switching pulses to DC-DC converter under various conditions. Simulation results obtained from MATLAB/R2024a Simulink under various load and variable solar irradiance conditions assess the converters ability to maintain a constant output voltage and demonstrate its accuracy compared to conventional methods. The system achieves a peak efficiency of 94.6% highlighting its effectiveness for sustainable transportation applications.

Keywords: evergreen; *High gain step-up, DC-DC converter, MPPT, MDHO, optimization, Hybrid electric vehicle.*

1. INTRODUCTION

Solar is the most promising energy source to supply the load throughout the year. As the people aware the adverse effects of fossil fuels, they started to use renewable energy sources for their day to day applications. As per International Energy Agency, the fossil fuel contribution towards transportation is maximum compared to all other sector, hence it is much needed to use renewable energy in transportation sector. Though solar PV will be obvious choice to supply power to EV, it is not capable of providing constant DC voltage at all the time. To extract constant power from solar PV, the role of power electronics converter is inevitable. The following section elucidates, the various power converters designed by pioneers in this research and their significant contribution.

Mohammadi, F et.al (2024) proposed a DC-DC converter capable of transferring power in either direction and could effectively handle two inputs simultaneously. In the proposed converter, a switched capacitor technique had been implemented to improve voltage gain. The discontinuity load current issue had been effectively addressed by having a large inductor in the input side. It reveled that the efficacy of proposed converter if any one of the port failed to supply the load. Sivaram, N. V et.al (2024) stressed the importance of dual input DC-DC converter for various applications. They designed a high gain DC-DC converter to supply power to DC micro-grid with solar PV and battery for the sources of input. It was proved that the proposed converter could effectively handle two sources at its input port and deliver power with high voltage gain and efficiency.

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Danyali, S et.al (2024) implemented a medium gain DC-DC converter with ZVS capable to address switching loss issue. To further more increase, the voltage, a voltage multiplier cell has been connected at its output port. It has been observed that the switches were triggered at ZVS condition because of third inductor component and being switched off with ZCS condition. It could take two current inputs from separate sources and delivers power to load with minimum number of power switches and circuit components efficiently. Karthikeyan, B et.al (2022) designed a high gain DC-DC converter capable of handling DC inputs from solar PV and fuel cell simultaneously to feed power to drive motor of hybrid electric vehicle. A single inductor across both the sources could reduce circuit size and complexity but retains high voltage conversion ratio. A 200W scaled down experimental prototype proved the efficiency of proposed concept with minimal circuit components.

Suresh, K et.al (2021) emphasized the importance of high voltage gain non-isolated multifunctional DC-DC converter with bidirectional capability for DC micro-grid and hybrid electric vehicle applications. They proposed a four port DC-DC converter with minimal components and simple control strategy to perform both step-up and step-down operation. They verified both steady state operation and dynamic performance of proposed converter in handling four ports effectively. Nayak, P.S. R et.al (2021) hassled the importance of wireless charging of EV during its running condition. This could be accomplished by suitably designing on-road charging along the pavement and usage of solar PV roof-top for EV. They proposed a DC-DC converter which could perform both step-up and step-down operations based on requirement and capable of handling both solar PV and EV battery charging effectively though they possess different electrical characteristics.

Dhananjaya, M & Pattnaik, S (2020) proposed a novel single input and dual output DC-DC converter, considering its importance over a decade in the literature. Though it feeds dual output port, common grounding problem has been eliminated. It could customize the both the output voltage according to the requirement without having cross-regulation issue. Kumar, G.G. & Sundaramoorthy, K., (2020) felt that conventional converter made under utilization of solar PV mounted on roof-top of EV when battery gets fully charged. The proposed converter could effectively handle two input sources and perform six various mode of operations based on status of battery and vehicle running conditions. A 500W scaled down model of experimental set-up built in laboratory proved the efficacy of proposed converter in handling power sources and operating under six modes.

Dam, S. and Mandal, P et.al (2020) proposed a dual output DC-DC converter for low power applications. In the proposed converter, MOS based capacitance used in the circuit for addressing the issues of high conduction losses. An inductor based boost converter operation and switched capacitor based step down operation were realized in the proposed converter. Jalilzadeh, T et.al (2020) implemented a four-port non-isolated DC-DC converter with voltage gain capability. This converter was designed to power drive motor and auxiliary appliances with different voltage levels. Some notable features of proposed converter were high voltage gain, continuous current at low duty cycle, reduced voltage stress across the switches and diodes.

R.Nisha et.al (2024) implemented a combination of both bio-inspired algorithm and one cycle control technique to track maximum power from solar-PV under partial shading condition. The output from the controller in turn operates KY-converter under dynamic duty cycle with resistive load. The performance analysis was being carried out using MATLAB simulation tool and compared the results against other bio-inspired algorithms. It was proven that the proposed methodology could yield better results in terms of power tracking efficiency, settling time and accuracy of power tracking. Aguila-Leon, J et. al (2023) used a novel Grey Wolf Optimization (GWO) technique to effectively track optimum power from solar

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PV. In this study, root mean square error and global efficiency of tracking maximum power have been considered as performance parameters. It was evident that the proposed scheme performance was better compared to conventional control scheme. Rojas-Galván, R et.al (2024) trained Artificial Neural Network using four different optimization algorithms to trace maximum power from solar PV under partial shading condition. Among four different bio-inspired optimization techniques, GWO proved its efficacy compared to all other techniques.

Pathy, S et.al (2019) had some experiences in using conventional MPPT techniques as it could track maximum power if there were multiple peaks present in solar power. They compared the performance of five different control techniques and it was proven that Bacterial Foraging Optimization (BFO) yielded better results than others. Priyadarshi, N et.al (2021) used Chicken Swarm Optimization (CSO) method to trace maximum power from fuel cell used in Hybrid Electric Vehicles. In this study, a natural clamp ZCS bidirectional converter used at the output port of fuel cell instead of having conventional step up converter to increase conversion efficiency by reducing switching losses. The proposed bio-inspired algorithm yielded maximum power under different atmospheric and disturbing load condition with good tracking accuracy.

The challenges posed by the depletion of fossil fuels, the phenomenon of global warming, and the increasing global demand for energy underscore the urgent need for the advancement of clean energy sources. Using data at several sites to guide operating choices, Basaran et al. (2017) created a hybrid wind-PV system for effective power management, showcasing an innovative method to power management. A BAT-Fuzzy control approach is put out by Ge, X., Ahmed et al. (2020) for a hybrid energy system that integrates a PV panel with BES. The best parameter values for maximum power point tracking are found using the fuzzy controller and the BAT method. Simulations demonstrate improved stability and quick reaction in transient situations. An experimental investigation on a freestanding hybrid micro grid system using renewable energy sources as wind turbines, solar arrays, fuel cells, and batteries was carried out by Benlahbib et al. (2020). The hybrid system, designed for distant applications, utilizes speed controllers for wind and SIFL controllers for solar subsystems, and an energy management strategy based on battery state of charge. Nasef et al. (2022) explore optimal design, power management, and control strategies for hybrid photovoltaic and battery energy storage systems in grid-connected wind energy conversion systems. This research aims to maintain stable DC-link voltage, smooth stator and rotor currents, and steady active power output using a moth-flame optimized fuzzy logic controller. A hybrid system that combines biomass, PV, WT, and battery storage is suggested by El-Sattar et al. (2021). For the suggested hybrid setup, four optimization techniques are employed to maximize performance, guaranteeing that energy demands are satisfied while lowering COE. Abou Houran et al.2023, improve CNN-LSTM hyper parameters using Coati optimization method in enhancing performance and learning rate in solar and wind power forecasting.

II.PROPOSED SYSTEM:

The proposed system consists of solar PV and battery as energy sources for the hybrid electric vehicle as shown in figure 1.

These input sources feeding the proposed converter and Modified Deer Hunting Optimization -MPPT controller is supposed to generate switching pulses to the switches of proposed converter as it is fed from solar PV which is highly dynamic in providing constant voltage to the system. The output of DC-DC converter is fed to three-phase inverter which drives BLDC motor which in turn accelerate/decelerate the wheels of hybrid electric vehicle.

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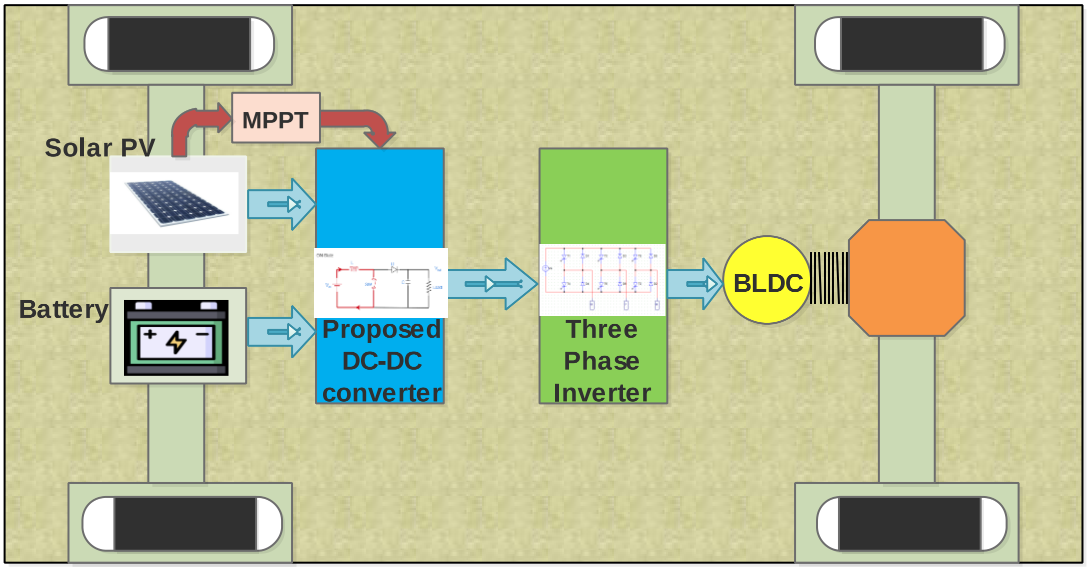

Figure 1. The proposed hybrid electric vehicle system.

III. DISO HIGH GAIN STEP-UP CONVERTER:

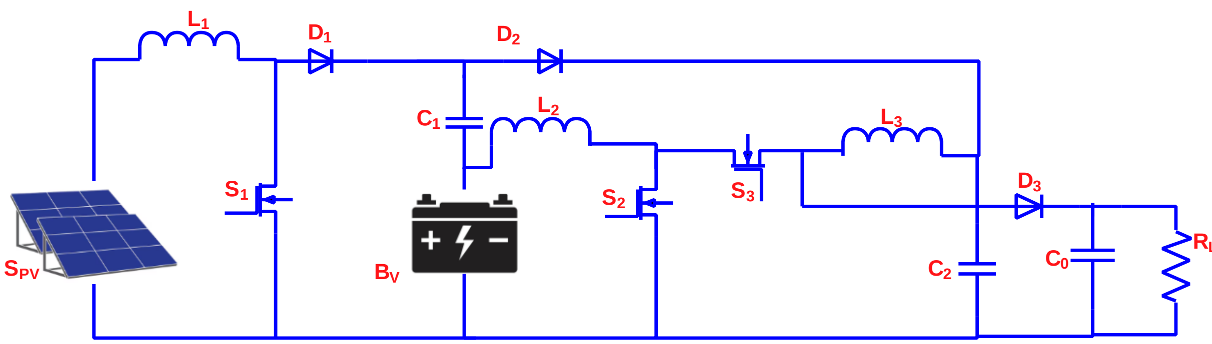

Figure 2. DISO converter

The proposed converter is excited by two energy sources such as solar PV and battery as shown in figure 2. It has passive components such as three inductors L_1,L_2,L_3 , three capacitors C_1, C_2,C_o. It consists of three semiconductor switches S_1,S_2,S_3 and three diodes D_1,D_2,D_3. To validate the results a resistive load R_L is connected across the output terminal. The mode of operation is explained in the following section. The expected key-waveforms are given in following section.

Mode I:

In this mode of operation, Switch S_1 is in off condition whereas switches S_2 and S_3 are in on condition which makes current flow as shown in figure 3. Solar PV is supplying to the battery and load is disconnected during this mode, however load is supplied from output capacitor. The inductor current IL_2 is increasing whereas IL_1 and IL_3 are decreasing as shown in figure 4. The steady state equations for this mode are given in this section.

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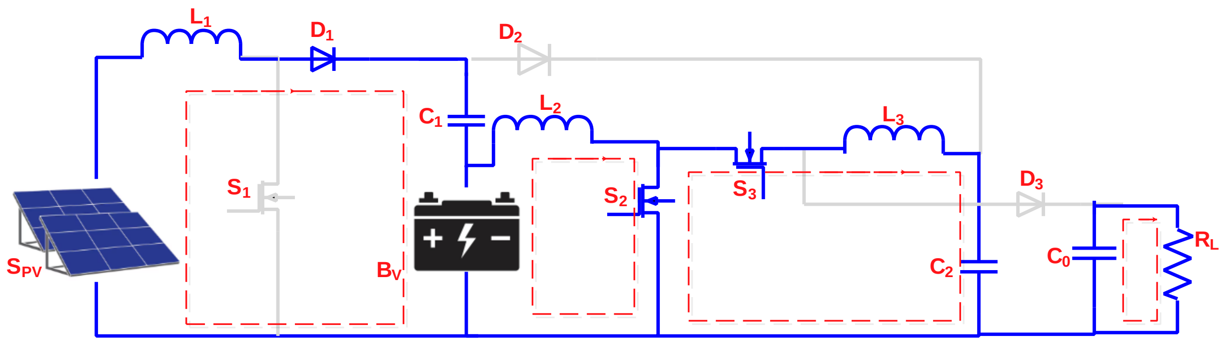

Figure 3. Mode I operation.

$$V_{L1} = V_{Spv} - V_{C1} \quad (1)$$

$$V_{L2} = V_{Bv} \quad (2)$$

$$V_{L3} = -V_{C2} \quad (3)$$

$$I_{Co} = -I_L \quad (4)$$

$$I_{L1} = I_{C1} \quad (5)$$

Mode II:

In this mode of operation, switch S_1 is getting charged and switches S_2 and S_3 are in off condition as shown in figure 4. Inductor 1 is getting charged during this mode and current IL1 is increasing whereas other inductor currents are decreasing as shown in figure 5. The output capacitor Co is made to charge during this mode. The steady state equation of this mode is given in this section.

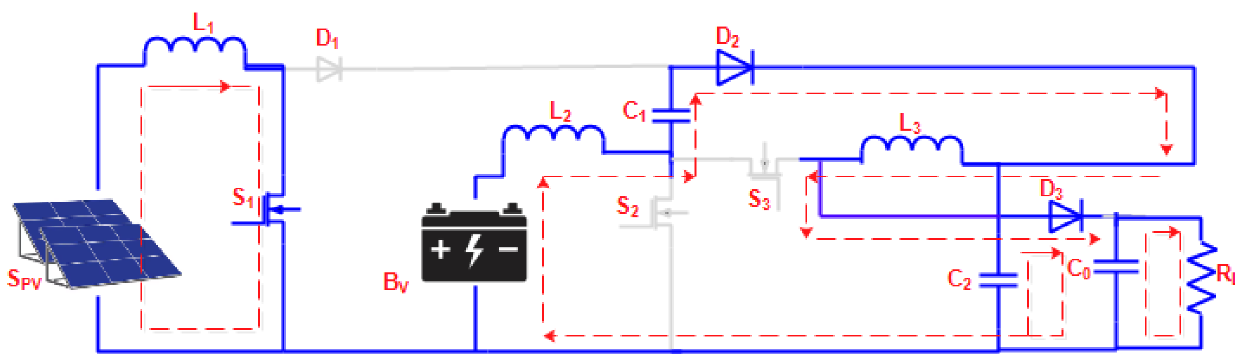

Figure 4. Mode II operation.

$$V_{L1} = V_{Spv} \quad (6)$$

$$V_{L2} = V_{Bv} + V_{C2} - V_{C1} \quad (7)$$

$$I_{C2} = I_{L2} + I_{L3} \quad (8)$$

$$I_{L2} = -I_{C1} \quad (9)$$

$$I_{Co} = I_{L3} - I_L \quad (10)$$

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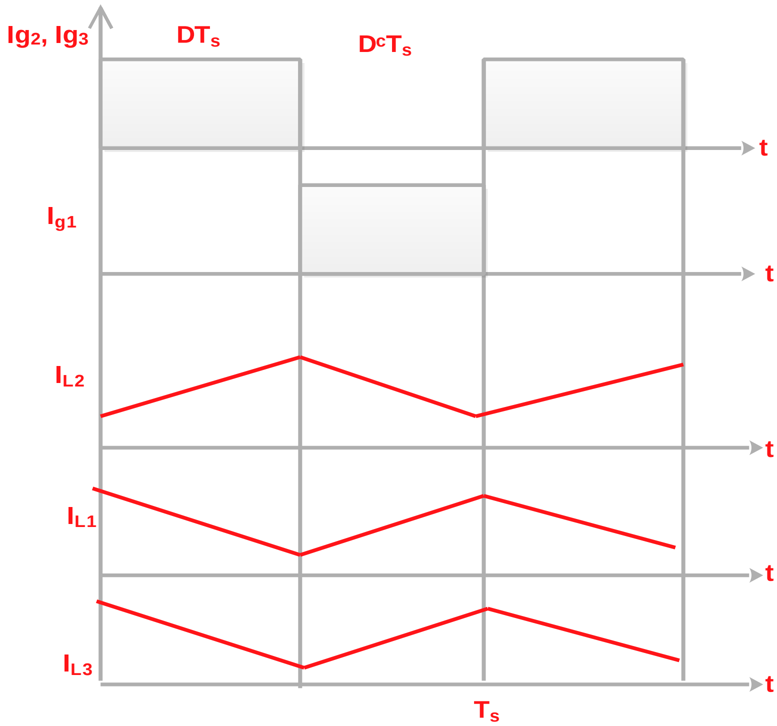

Figure 5. Steady-state waveform of proposed converter.

IV. MODIFIED DEER HUNTING OPTIMIZATION ALGORITHM:

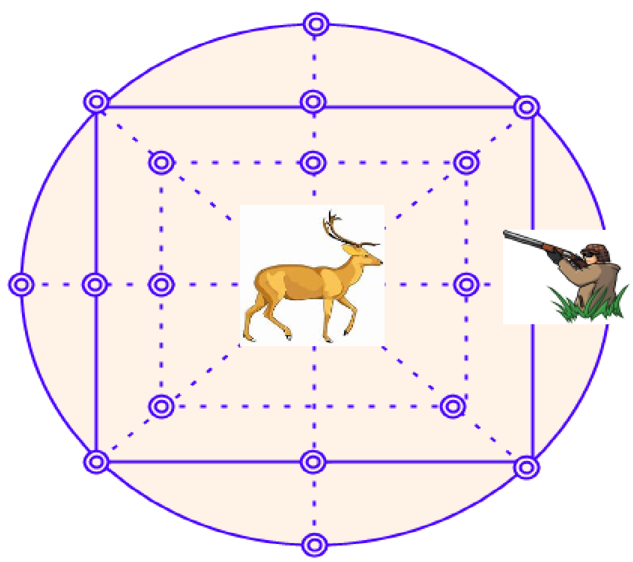

Figure 6. Position of deer in hunting process.

This algorithm is written by imitating the process of deer hunting process. Usuaally deers are inherently clever to escape from any dangerous environmnet. They smell the hunters if they start attacking and alters others to encape. The entire process is elucidated in the following section and its

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flow chart is shown in figure.7. Initially the number of predators, population, wind angle is initlaized. The best poision of deer has been obtained by using the following equation.

$$\theta_p = 2\pi\gamma + \pi \tag{11}$$

γ-is the random variable assumed in the range of [0,1]

There are two positions assumed in position update phase such as pioneer's position and follower's position. The pioneers position is updated based equation (12) and followers are supposed to follow pioneers signal for best position to hunt the deer at its best position.

$$p^{b}_{i+1} = p^{b} - T * R_s * \left|L * p^{b} - p_i\right| \tag{12}$$

$$T = \frac{1}{4}\log\left(\frac{1+(i*i_{max})}{i_{max}}\right) * K \tag{13}$$

The hunting process gets repeated until predators attain their best position i.e the value of 'L' becomes greater than or equal to one. The step by step process is given in flowchart.

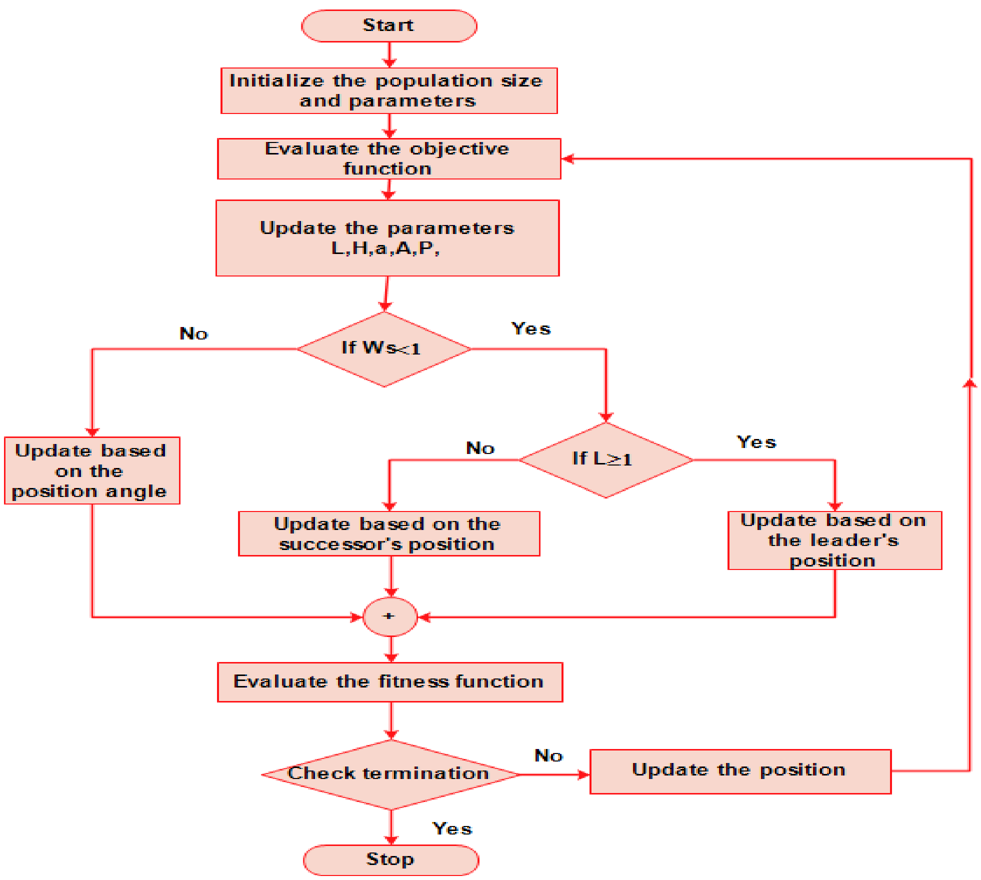

Figure 7. Flowchart of MDHO algorithm.

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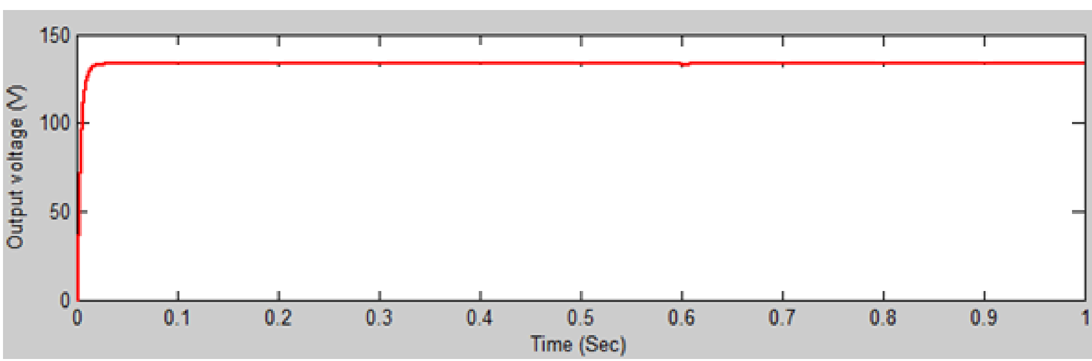
V. RESULTS AND DISCUSSION:

In order to validate the results, the proposed converter is simulated in MATLAB/R2024a simulink environment. The performance of converter is tested under steady state and dynamically varying solar irradiance condition and its results are discussed in this section. The components used in this converter are listed in Table.1. All the components listed in table 1 assumed to behave ideally for simulation study purpose.

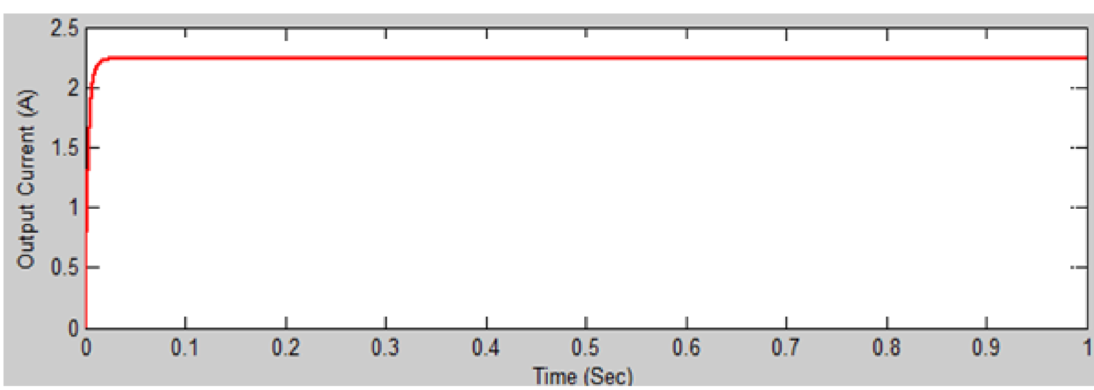
Table 1. components used in converter

.No	omponents Description	omponents specifications
.	.ctive switches	IOSFET (rds_{on}=30mΩ)
.	)iodes D_1,D_2,D_3	ast Recovery diodes
.	apacitor C_1, C_2,C_o	0µF
.	ıductors L_1,L_2,L_3	$_1$,L_2=,150µH, L_3= 1000µH

I. Steady state- simulation results:



(a)



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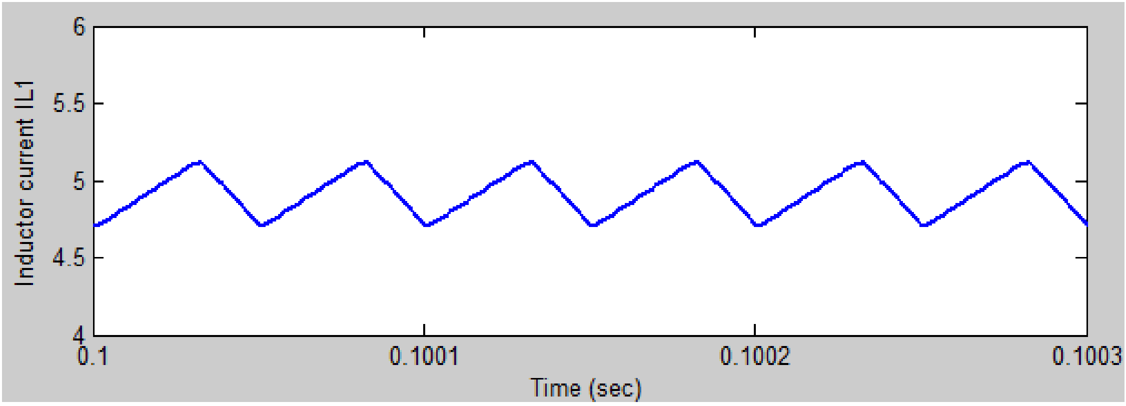
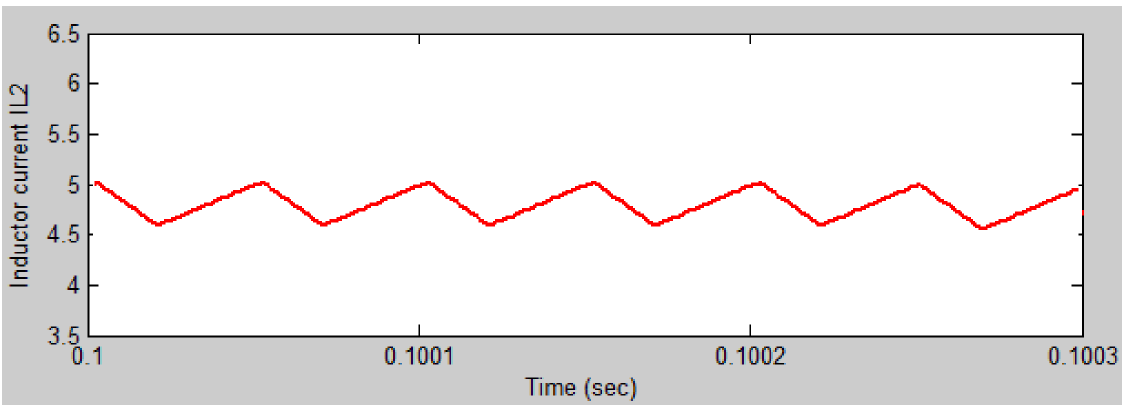
(b)



(c)



(d)

Figure 8. Steady state results of proposed converter. (a). output voltage (b). Output current (c).Inductor current I_{L1} (d).Inductor current I_{L2}=I_{L3}

The performance of the proposed converter under steady state condition was simulated in MATLAB/R2024a Simulink environment. The switching frequency was maintained at 100 kHz. The waveforms were obtained by keeping the duty ratio at 0.6 and input voltage from both the sources as 12 V each ideally. The output voltage and current obtained from the converter was 125V and 2.3A respectively. The inductor current being oscillated between 5A to 4.5A as shown in figure 8.(c) and (d). The approximate current ripple in inductor current estimated as 11%.

II. Dynamic –simulation results:

To validate the dynamic performance of the converter under various conditions, the MPPT controller is designed to generate switching pulses to the converter in order to give constant voltage at the output terminal. The solar irradiance varied as follows: (0 to 1 sec)-1000 W/m^2, (1-2sec)-500 W/m^2, and (2-3sec)-1500 W/m^2 as shown in figure 9(a). The maximum power tracing capacity of conventional P&O algorithm and MDHO algorithm is shown in figure 9 (b) which is evident that the proposed MDHO based MPPT controller could yield maximum power during variation of solar irradiance condition. The load current varied as follows: (0 to 1 sec)-5A, (1-2sec)-3A, and (2-3sec)-4A as depicted in figure 9. (c). However the load voltage maintained constant at 180V due to dynamic pulse generation by MPPT

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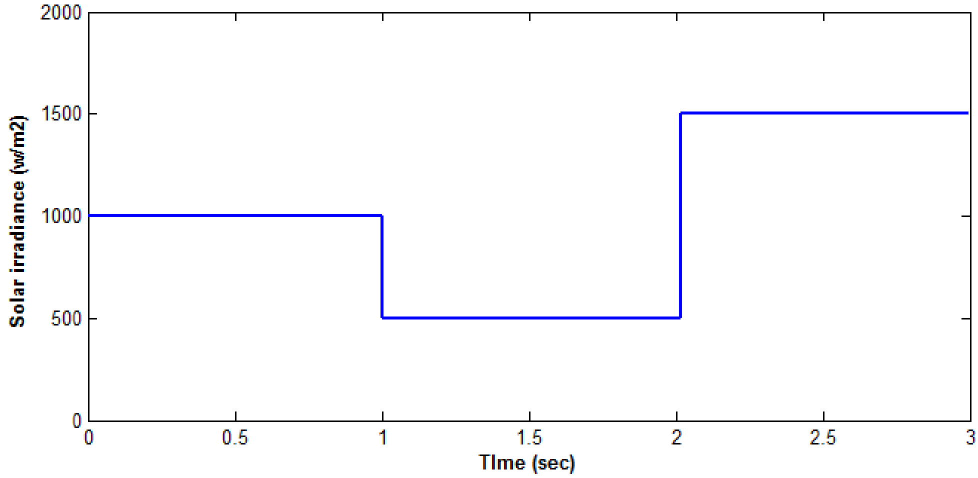
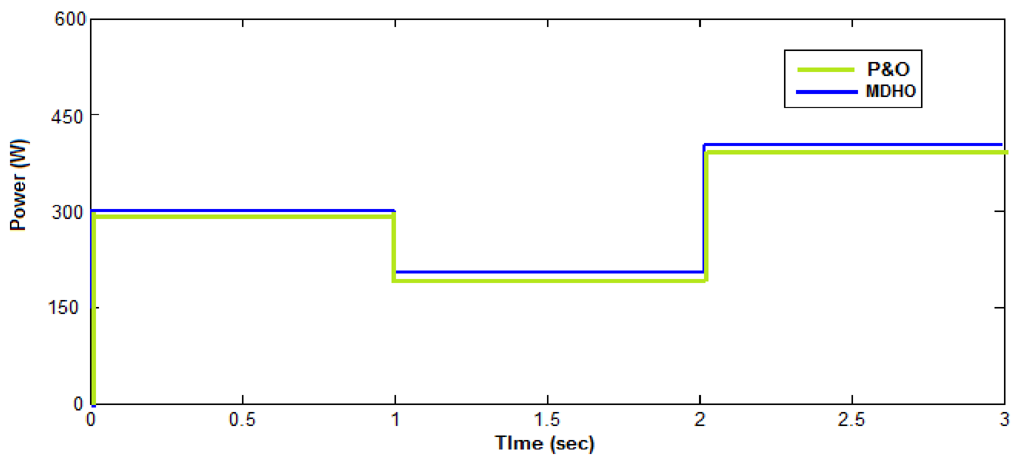
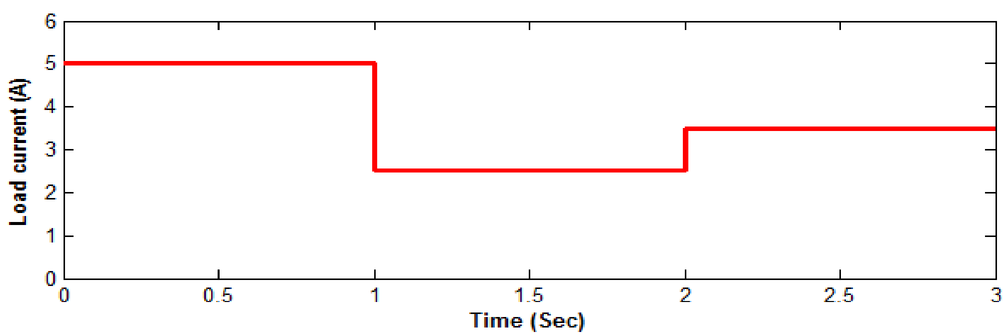
controller as depicted in figure 9.(d). the power conversion efficiency tested under various load condition by suitably adjusting the value of load resistance. the maximum efficiency achieved was 94.6% at 103 W output power as depicted in figure 10.



(a)



(b)



(c)

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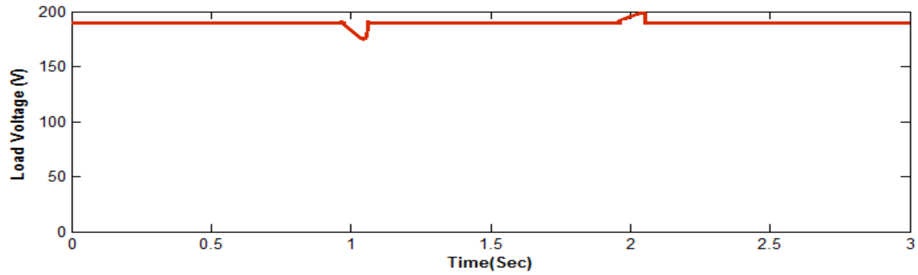

(d)

Figure 9. Dynamic performance of the proposed converter (a). Variation of solar irradiance (b). maximum power tracing ability of proposed MPPT controller. (c). Variation of load current (d). Constant output voltage under variable load condition.

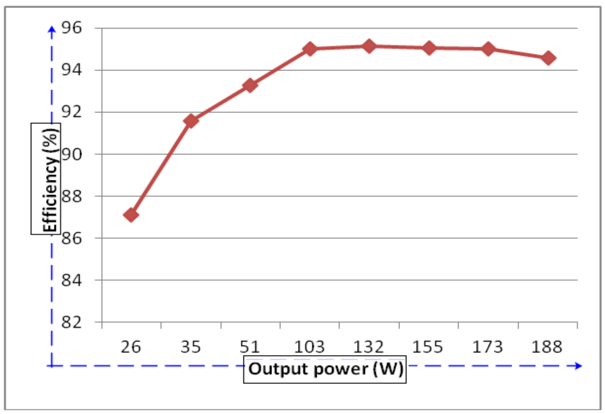

Figure 10. Conversion efficiency

VI.CONCLUSION

A Dual Input Single Output (DISO) high step up converter was designed to regulate the power fed to hybrid electric vehicle applications in this research work. A detailed steady state analysis has been carried out and dynamic performance of the converter under various solar irradiance condition and load conditions was tested. To yield maximum power from solar PV, a Modified Deer Hunting Optimization algorithm used to generate dynamic switching pulses to DC-DC converter and its performance tested. The proposed control algorithm could overcome the performance of conventional P&O algorithm under variable load condition and variable solar irradiance. A detailed simulation study has been carried out using MATLAB/R2024a Simulink environment to validate the results.

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