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Optimized Intelligent Controller Based DC-DC Converter for EV Application

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ABSTRACT:

A lot of interest has recently been shown in Electric Vehicles (EVs), which promote eco-friendly transportation while reducing carbon emissions. By using EVs powered by Photovoltaics (PV), the amount of carbon dioxide released into the sky is greatly reduced. Due to the intermittent nature, low voltage is obtained from the PV, which is the main drawbacks of this system. Therefore in this work, a DC-DC Single-Ended Primary Inductance-Capacitor (SEPIC) is used to extract high power from the PV panel during changes in ambient conditions and it has the ability to charge an electric vehicle's battery by using PV source. The proposed converter is regulated by the Grey Wolf Optimization based Radial Basis Function Neural Network Maximum Power Point Controller (GWO-RBFNN MPPT) controller for extract the optimal power from the Photovoltaic system. The performance of proposed method and PV module is enhanced by using the GWO-MPPT, because it is a fastest and most dependable optimization algorithm. The output is simulated by utilizing the MATLAB software. As a consequence, the proposed technique achieves high efficiency and high voltage gain when compared to the other conventional approaches.

Keywords: : Electric vehicle, PV system, SEPIC converter, GWO-RBFNN MPPT controller, MATLAB software

1. INTRODUCTION:

The rise of electric vehicles for transportation is facilitated by the growing concern over greenhouse gases [1-2]. To overcome the constraint in battery storage capacity, EVs require widely dispersed charging stations. This type of distributed charging station is grid-dependent and runs on fossil fuels. When a large number of EVs are connected to a rapid charging station, the grid experiences a number of power quality problems, including voltage sag, an increase in peak demand, and power gaps [3]. However, using the power grid to charge the EV adds to the burden on the utility, particularly during peak usage times. One way to reduce the harm caused by the grid is overcome by using renewable energy sources. [4-5]. the renewable energy is now being used more and more as a source of electrical energy. Solar energy is one of the renewable resources, which is used to transform sunlight into electricity and it is necessary for using solar energy as a source of electrical energy [6].

Solar energy is an eco-friendly and does not produce noise pollution as well as air pollution, which interfere with daily activities. A battery stores solar power from the sun and uses it to power a vehicle. Such vehicles produce a silent operation and a pollution-free environment [7]. However, the solar radiation and surrounding temperature have a significant effect on the utilisation of photovoltaic. The amount of electrical energy produced rises with increasing the sun irradiation. In order to continually supply the load, photovoltaic has to be access to sun radiation and a suitable temperature. A photovoltaic system is unable to connect directly to the load because the voltage generated is insufficient for the load. Therefore it require a converter to extract high power from the Photovoltaic system [8-9].

In [10] the DC-DC boost converter is employed, which produce a high output voltage as well as gives a low operating duty cycles. However, because of the limitations imposed by power switch and diode losses, the conversion efficiency and step up voltage gain are constrained. To overcome this limitations, the buck converter is implemented in [11], which has the ability to give high efficiency and low output voltage ripple. But in can’t be used in step-up applications. In [12] used buck-boost converter, which works in both step-up and step down applications. However, high gain is not achieved by this converter due to its poor efficiency. The Cuk converter is utilized in [13], which produce constant current at the input and output of the converter. But it has the limitation for generating high current stress on switch. Therefore, to overcome those drawbacks the proposed work utilizing the SEPIC converter, which gives high efficiency and low switching loss.

To track high power from the Photovoltaic system, for that intelligent MPPT control approaches is essential. In [14] perturb and observe (P&O) and the incremental conductance (INC) are employed to perform well under uniform radiation and enhancing the accuracy level. However this approaches has low accuracy for tracking MPP. To overcome this limitation Fuzzy logic controller (FLC) and Artificial Neural Network (ANN) controllers are used in [15-16], which has the ability to quickly track changing conditions than the P&O and incremental conductance. FLC is employed to obtain the high power from the Photovoltaic by handling the non-linearity conditions but it has the drawbacks that the membership functions as well as the extract rules are difficult.

The ANN has the capable of learning and modelling the complex and nonlinear relationships. However, for operation in the actual world, they require a wide variety of training samples. The limitation from the conventional approaches are overcome by the proposed GWO-RBFNN based MPPT technique.

In this work, the optimized intelligent controller based DC-DC converter for EV applications is proposed. The SEPIC converter is boost the voltage from the Photovoltaic system. The Grey Wolf Optimized RBFNN based MPPT controller is employed to track the maximum power from the PV system. The effectiveness of the proposed method is simulated by the MATLAB software. As a result, the developed method achieves high efficiency, high voltage gain when compared to the other existing methods.

2. PROPOSED METHODOLGY:

The block diagram of proposed work is illustrated in figure 1. The voltage obtained from PV is low due to varying climatic conditions such as irradiance and temperature. The voltage from PV system is given to the SEPIC converter to boost the voltage. To obtain maximum possible power out of PV and to achieve stabilized converter voltage MPPT technique is utilized. The voltage (V_{PV}) and current (I_{PV}) obtained from the PV panel is fed as input to the GWO-RBFNN based MPPT controller to track the maximum power from PV system.

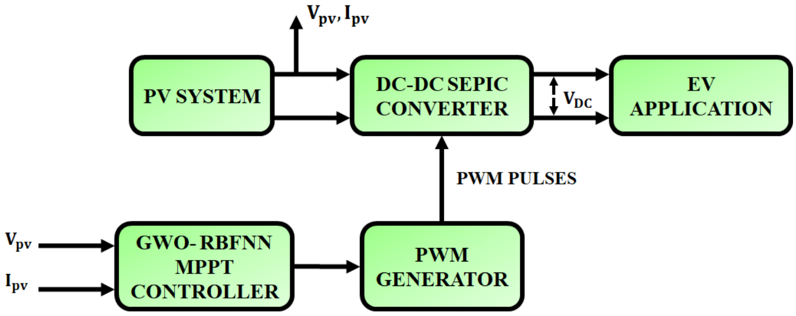


Fig 1 Block diagram of the proposed work

The output from the controller is fed to the PWM generator, which generate the required PWM pulses for better working of SEPIC converter. The constant DC link voltage is then given for the EV application.

2.1 PV Modelling

The proposed work utilizes PV as primary source which converts solar energy into DC electricity. There are many cells in PV panel, which is placed in shunt R_{sh} or R_s series. Figure 2 illustrates a current source connected in parallel with a diode according to shunt and series resistors.

Equation (1) illustrates the output current,

$$I = I_{ph} - I_D \quad (1)$$

$$I = I_{ph} - I_0 \left[\exp\left(\frac{q(V+R_s I)}{AK_B T}\right) - 1\right] - \frac{V+R_S I}{R_{sh}} \quad (2)$$

Where, I_0 specifies the saturation current, I denotes the cell current, K_B represents the Boltzmann's constant, R_s shows the series resistance and R_{sh} illustrates the shunt resistance.

Generally, the series resistance R_s is very small and shunt resistance R_{sh} is very large. Therefore, to shorten the solar cell model such resistances are used to eliminate commonly. As a consequence Equation (3) yields the optimal voltage-current characteristic for a solar cell.

$$I = I_{ph} - I_0 \left[e^{\left(\frac{qV}{KT}\right)} - 1\right] \quad (3)$$

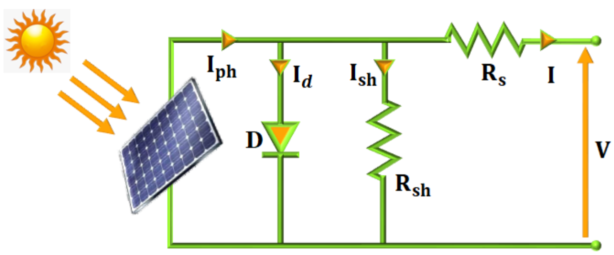


Fig 2 Circuit diagram for the PV array

2.2 Modelling Of DC-DC Sepic Converter

This SEPIC converter is based on DC-DC converter, which is employed to sustain the continuous output voltage. This converter consists of 2 inductors $\boldsymbol{L_1}, \boldsymbol{L_2}$, 2 capacitors$\boldsymbol{C_s}, \boldsymbol{C_0}$, load resistor and a diode as represented in Fig 3. No current is flowing in any of the components, capacitor has charged to $\boldsymbol{V_{in}}$ and the output voltage is zero. The timing diagram for the SEPIC converter is represented in Fig 4.

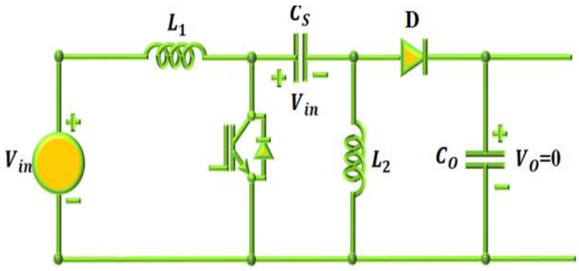
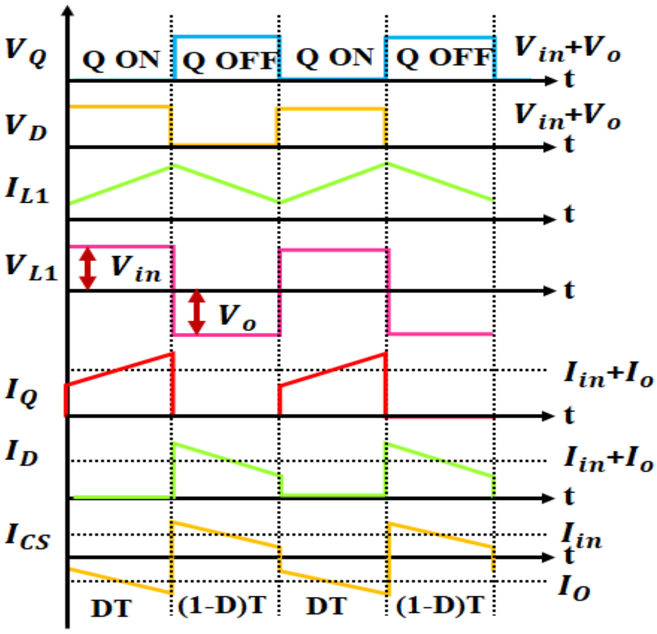
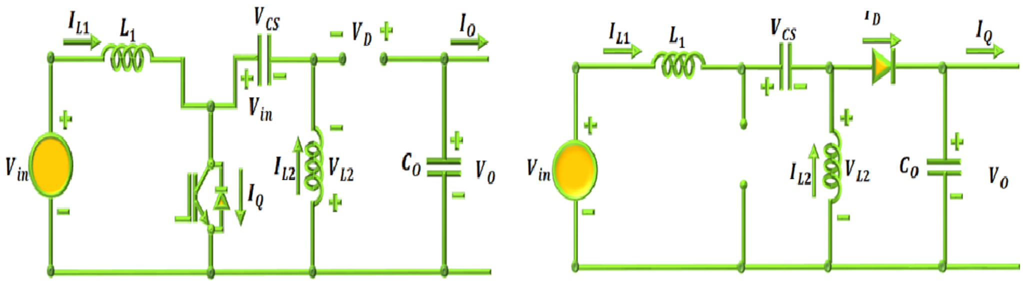


Fig .3 Circuit diagram for SEPIC converter



As shown in Figure 5(a), when the switch closes, current ramps up across the first inductor i_{L1} as well as the current i_{L2} ramps up like the similar way of L_1. Across the second inductor, Voltage V_{in} applied over the capacitor. The output capacitor is left to supply the load current when the diode is reverse biased. When the switch is turned ON, L_1 and $L_2$are charged up, detached from the load, and it is discharged. Due to the forward bias of the diode, the current passing through L_1 is only flow through $C_s$to the load when the switch is OFF condition.



(a) Mode 1

(b) Mode 2

Fig 5 Modes of Operation (a) ON state and (b) OFF state

Shunt inductor L_2 receive current from the output. Current flows through both inductors to the capacitor and load. Fig 5(b) illustrates this converter circuit switching state. The energy balance volts-hertz is expressed in equation (4) at average voltages across L_1 it corresponds to 0 for a full cycle.

$$V_{L1} = D.V_{in} + (1 - D).(-V_o) = 0 \quad (4)$$

$$V_o = \frac{DV_{in}}{1-D} \quad (5)$$

The SEPIC converter's ideal output is given as,

$$I_o = \frac{1-D}{D} I_{in} \quad (6)$$

Compared to the typical buck-boost converter, the SEPIC operate from an input voltage which is more or lower than the regulated output voltage without polarity reversal, as shown by the aforementioned voltage as well as current relation.

2.3 RBFNN Based MPPT Technique

RBFNN developed a simple neural network design model, which has one hidden layer and is applied in numerous different fields. Three layers make up the RBFNN. The input layer is the top layer and it only matches the input signal. There might be several variables, each of which relates to a different neuron. Fig 6 illustrates the construction of the MPPT technique using RBFNN, which includes an input, output, and a hidden layer to carry out data processing tasks. An equation (7) denotes the net input as well as output of the input layer.

$$\left.\begin{aligned} net_j^1 &= x_i^1 \\ y_{1j}^1 &= f^1(net_j^1) = (x_i^1) \end{aligned}\right\}_{j=1..n;i=1,2} \quad (7)$$

Where, $f(x_j^1)$ denotes the net sum of nodes, which is given to the hidden layer, x_i^1 specifies the input layer.

Gaussian functions are utilised in the second layer, which is a hidden, nonlinear layer. Large numbers of neurons are contain in this layer.
The choice of neurons for this layer is a challenging task. So that it suggested a method of choosing neurons for the hidden layer which preserves the data structure. According to the complexity of the input/output variables, each neuron in the hidden layer is composed of an RBF, which is centred at a point. The hidden unit activations are determined by the fundamental functions, which depend on the variables $\{w^1 1j, b^1 j\}$, and input activations $x^1 j$.The RBF function's radius is vary for each dimension. The radius of RBF function may vary for each dimension. The centres and spreads of the network are chosen during the training phase. The net input as well as output of the hidden layer are displayed in below.

$$\left.\begin{aligned} net_j^1 &= \textstyle\sum_j w_{1j}^1 y_{1j}^1 \\ y^2 1j &= f^2(w_{1j}^1 y_{1j}^1 + b_j^1) \end{aligned}\right\}_{j=1...n} \quad (8)$$

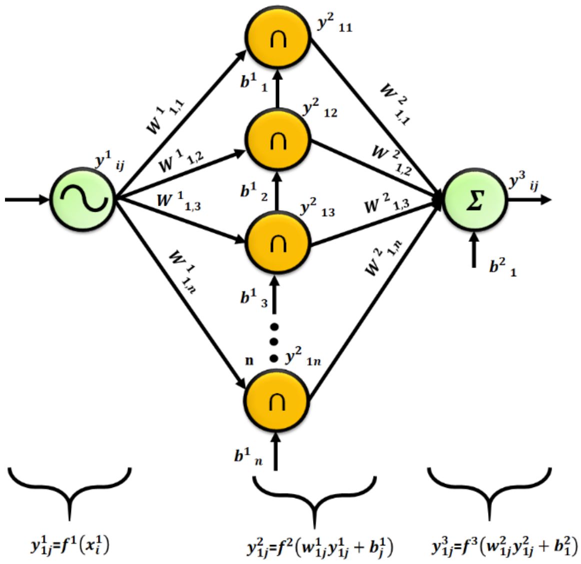


Fig 6 Structure of MPPT technique using RBFNN

Where, the bias terms of hidden layer is denoted as b_j^1, w_{1j}^1 specifies the weights that connect to the hidden and input layer. The linear layer combines the outputs from the Gaussian function. Only the weights among the hidden as well as output layers are altered and computed during training.

The input and output of overall RBFNN is expressed as,

$$\frac{d\omega_r}{dt} = b + \sum_{j=1}^{n} v_j \, exp\left(-\frac{\|x - C_j\|^2}{\beta^2 j}\right) \quad (9)$$

Here, bias term and weight over the hidden layer is represented as b andv_j, n specifies the number of RBF units. Nevertheless, tuning method is needed to achieve high PV power. Therefore the GWO algorithm is utilized in this study

2.5 Gray Wolf Optimization technique

In 2014, the GWO algorithm emerged [23]. This optimisation method takes information from the way grey wolves pursue their prey in the wild. Grey wolves always live in packs of five to ten people. Four levels of leadership are present in their group. Depending on where they are in the leadership pyramid, sub leaders are referred to as beta (β), delta (δ), and omega (ω), while the leaders are referred to as alpha (α). Where wolves become more dominant from top to bottom. The wolves hunting methods are illustrated as the mathematical expression as follows,

$$\vec{E}=|\vec{C}.\vec{d}_p(i)-\vec{d}(i)| \quad (10)$$

$$\vec{d}(i+1)=\vec{d}_p(i)-\vec{A}.\vec{E} \quad (11)$$

Where, $\vec{d}_p$ termed as a position of prey, $\vec{d}$ represents the position of grey wolf and i denoted as the current generation, $\vec{A}.\vec{E}$ are utilized to sustain the balance over exploration as well as exploitation, which is explained as equation (12 and 13),

$$\vec{A}=2\vec{a}.\vec{r}_1-\vec{a} \quad (12)$$

$$C=2.\vec{r}_2 \quad (13)$$

The prey is encircled by the grey wolves. The commands of the group's leader (Alpha wolf) should always be obeyed before those of the beta and delta wolves, in order of decreasing priority. Fig7 is a flowchart, which explains the GWO when a PV system uses it as an MPPT.

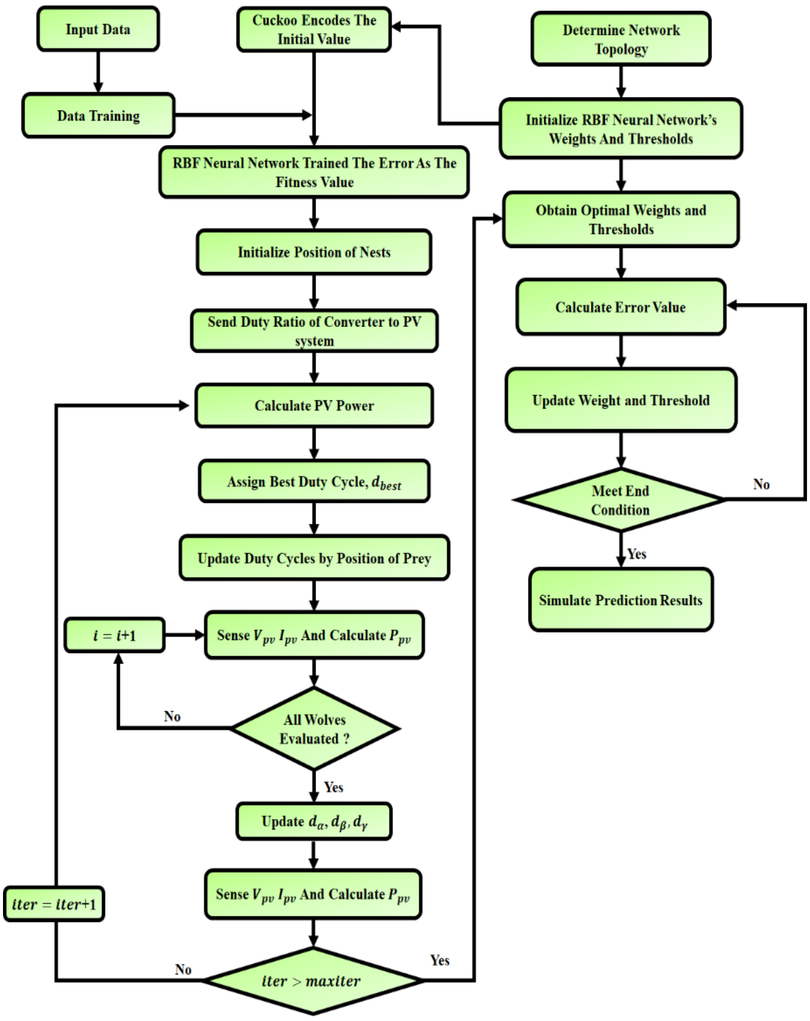


Fig. 7 Flowchart for the GWO based MPPT system

3. RESULTS AND DISCUSSION:

In this work, the proposed technique is developed for constant power supply to the EV application. The SEPIC converter extract high power from the Photovoltaic system. The GWO-RBFNN based MPPT technique is used in this work, which has the ability to track maximum power from the Photovoltaic system. The output of the developed method is simulated by the MATLAB software, which shows the result that proposed technique attain high voltage gain and high efficiency when compared to the conventional approaches. Table 1 represented the parameters specification.

Figure 8 represents the temperature and intensity waveform, from the figure it is analysed that the temperature is initially fluctuated and constantly maintained at 35C and the intensity is constantly maintained at 1000(W/Sq.m).

Parameters	**Specifications**
PV panel	
No. of Panels	20 $panels$
Peak power	10 kW
Open circuit voltage	22.6V
No.of PV cells	36
Short circuit voltage	12V
SEPIC converter	
C_s	4.7μF
C_0	2200
L_1,L_2	1mH
Switching frequency	10KHz

Table. 1 Parameter specifications

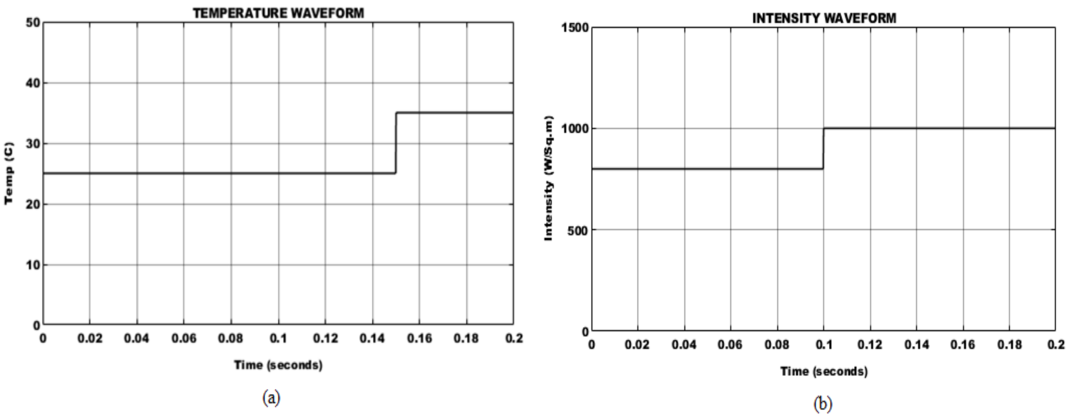


Fig 8 (a) Temperature and (b) Intensity waveform

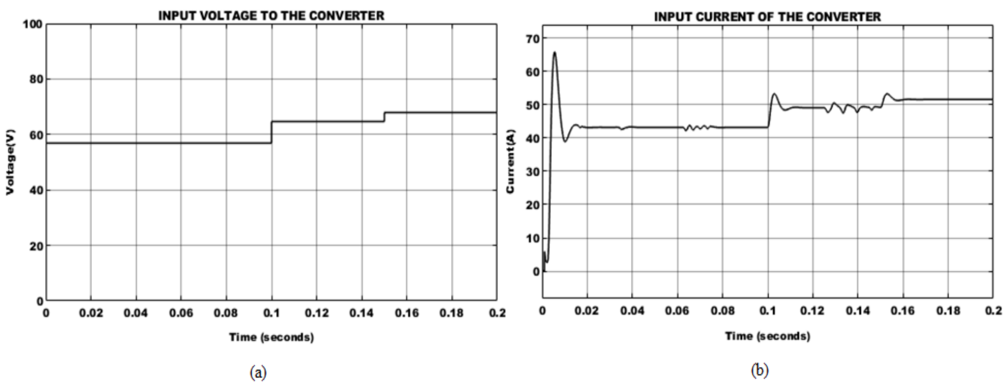
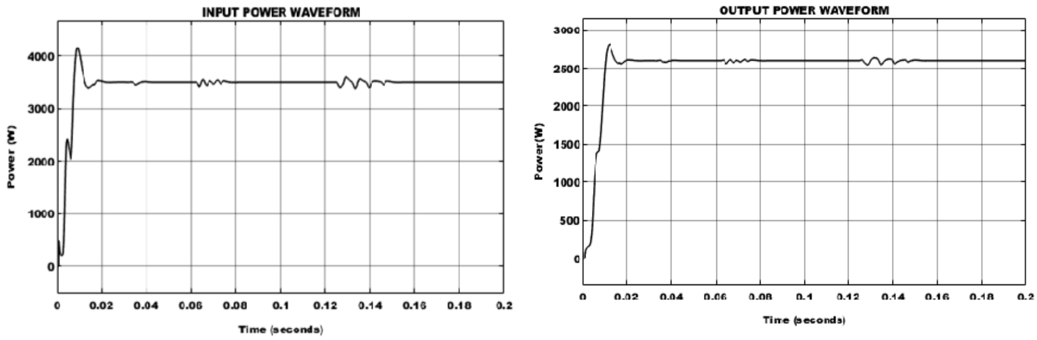


Fig 9 (a) voltage and (b) current waveform for the converter

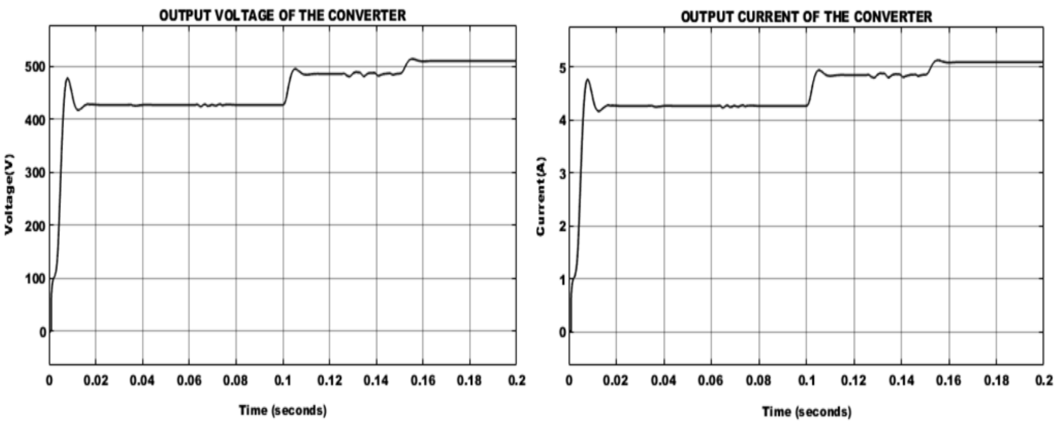
Fig 9 specifies the voltage and current waveform for the converter, which is analysed that the voltage is initially fluctuate, after 0.16s it constantly maintain without any distortion at 70V and the initially current fluctuated, after 0.16s it is constantly maintained at 51A.



(a) (b)

Fig.10 (a) Input and (b) Output power waveform

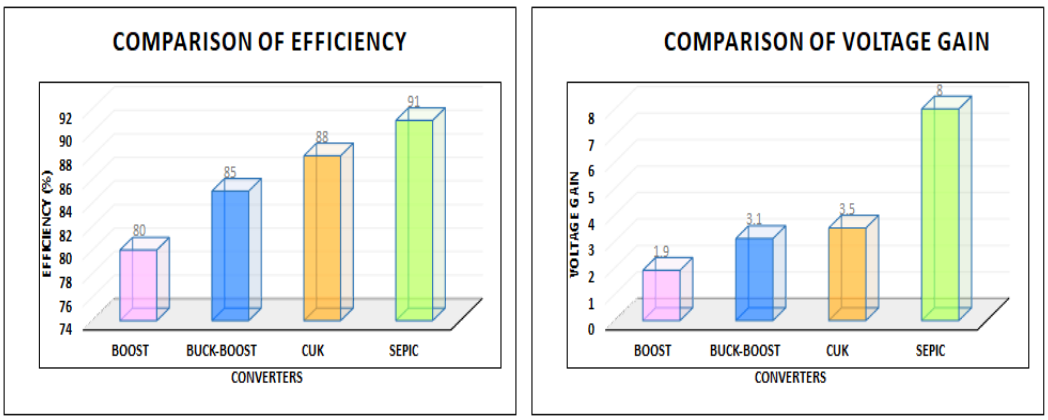
The input and output power waveform is illustrated in fig10, the input power is initially the power is fluctuated and attain constant supply at 3500W after 0.15s. The output power is constantly maintained at 2600W.



(a) (b)

Fig .11 Waveforms illustration of converter output (a) voltage and (b) current

The output voltage and current waveform for the converter is illustrated in fig 11, from the figure it is analysed that the voltage is initially fluctuated and after 0.16s it is maintained constant at 510V. The current is constantly maintained after 0.16s at 6A.



(a) (b)

Fig. 12 Comparison of (a) efficiency and (b) voltage gain

Comparison of efficiency and voltage gain is illustrated in figure 12, which is observed that the proposed SEPIC converter attains high efficiency of 91% and it achieves high voltage gain of 1:8 ratio, which is higher than the other conventional converters.

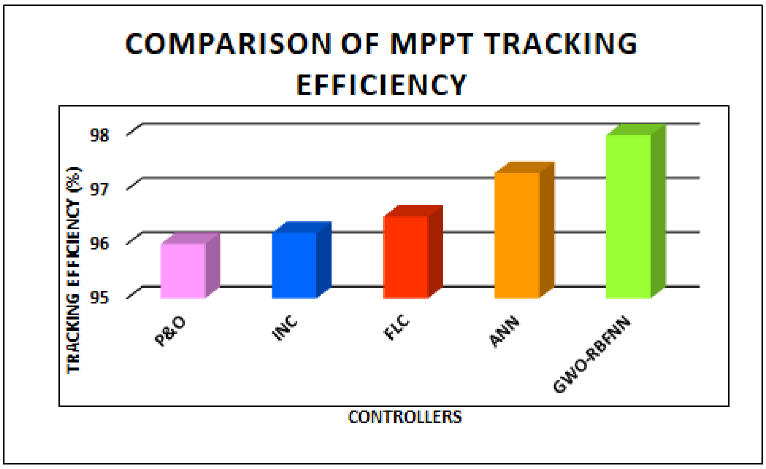


Fig. 13 Comparison of MPPT tracking efficiency

Comparison of MPPT tracking efficiency is represented in fig 13, from the figure it is analysed that the proposed GWO based RBFNN achieves high tracking efficiency of 98% when compared to the other controllers like P&O, INC, FLC, ANN as specified in above figure.

5. CONCLUSIONS

This research proposed the optimized intelligent controller based dc-dc converter for EV application. The PV system gives the low voltage due its intermittent nature, to attain high voltage the SEPIC converter is utilized in this technique, which has the capacity to extract high power from the PV systems. To control the converter GWO-RBFNN based MPPT controller is employed, which track the high power from the PV. The performance of the developed work is simulated by the MATLAB software. The obtained results shows that the proposed SEPIC converter achieves high voltage gain by the ratio of 1:8 and high efficiency of 91% when compared to the other techniques like boost, buck-boost Cuk converter by the efficiency of 80%, 85% and 88%. The proposed GWO-RBFNN achieves high tracking efficiency of 98% compared to the existing controllers like P&O, INC, FLC, ANN

References:

- Chakir, Asmae, Meryem Abid, Mohamed Tabaa, and Hanaa Hachimi. "Demand-side management strategy in a smart home using electric vehicle and hybrid renewable energy system." Energy Reports 8 (2022): 383-393.
- Nadeem, Anam, Mosè Rossi, Erica Corradi, Lingkang Jin, Gabriele Comodi, and Nadeem Ahmed Sheikh. "Energy-Environmental Planning of Electric Vehicles (EVs): A Case Study of the National Energy System of Pakistan." Energies 15, no. 9 (2022): 3054.
- Castro, José FC, Davidson C. Marques, Luciano Tavares, Nicolau KL Dantas, Amanda L. Fernandes, Ji Tuo, Luiz HA de Medeiros, and Pedro Rosas. "Energy and Demand Forecasting Based on Logistic Growth Method for Electric Vehicle Fast Charging Station Planning with PV Solar System." Energies 15, no. 17 (2022): 6106.
- Alrubaie, Ali Jawad, Mohamed Salem, Khalid Yahya, Mahmoud Mohamed, and Mohamad Kamarol. "A comprehensive review of electric vehicle charging stations with solar photovoltaic system considering market, technical requirements, network implications, and future challenges." Sustainability 15, no. 10 (2023): 8122.
- Huang, Zhiyu, Zhilong Xie, Caizhi Zhang, Siew Hwa Chan, Jarosław Milewski, Yi Xie, Yalian Yang, and Xiaosong Hu. "Modeling and multi-objective optimization of a stand-alone PV-hydrogen-retired EV battery hybrid energy system." Energy conversion and management 181 (2019): 80-92.
- Kou, Gang, Serhat Yüksel, and Hasan Dinçer. "Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects." Applied Energy 311 (2022): 118680.
- Maka, Ali OM, and Jamal M. Alabid. "Solar energy technology and its roles in sustainable development." Clean Energy 6, no. 3 (2022): 476-483.
- Haider, Zeeshan, Abasin Ulasyar, Abraiz Khattak, Haris Sheh Zad, Alsharef Mohammad, Ahmad Aziz Alahmadi, and Nasim Ullah. "Development and Analysis of a Novel High-Gain CUK Converter Using Voltage-Multiplier Units." Electronics 11, no. 17 (2022): 2766.
- Dr. Balaji. V, Dr. Nethravathi. P.S, Dr. E. Maheswari(2023), RBFNN Machine Learning Based BLDC Motor Driven PV Fed Electric Vehicle, International Journal of Scientific Research and Engineering Development, Vol. 6, No. 4, pp. 14- 22.

- Al-Baidhani, Humam, and Marian K. Kazimierczuk. "Simplified Nonlinear Current-Mode Control of DC-DC Cuk Converter for Low-Cost Industrial Applications." Sensors 23, no. 3 (2023): 1462.
- Kiran, Shaik Rafi, Ch Hussaian Basha, Abhishek Kumbhar, and Nikita Patil. "A new design of single switch DC-DC converter for PEM fuel cell based EV system with variable step size RBFN controller." Sādhanā 47, no. 3 (2022): 128.
- Awada, Emad, Eyad Radwan, And Mutasim Nour. "Robust Sliding Mode Controller For Buck DC Converter In Off-Grid applications." Bulletin of Electrical Engineering and Informatics 11, no. 5 (2022): 2425-2433.
- Dr. Balaji. V, Dr. Nethravathi. P.S,(2022) Optimization And Intelligent Techniques For Electrical Vehicle,JETIR, Vol. 9, No. 10, pp. 523-537.
- Alajmi, Bader N., Mostafa I. Marei, Ibrahim Abdelsalam, and Nabil A. Ahmed. "Multiphase interleaved converter based on cascaded non-inverting buck-boost converter." IEEE Access 10 (2022): 42497-42506.
- Şehirli, Erdal. "Examining the Design of Different Types of DM EMI Filters and Their Effect on EMI Noise and Control Characteristics for Cuk DC-DC Converter." International Transactions on Electrical Energy Systems 2023 (2023).
- Basha, Chakarajamula Hussaian, and Matcha Murali. "A new design of transformerless, non-isolated, high step-up DC-DC converter with hybrid fuzzy logic MPPT controller." International Journal of Circuit Theory and Applications 50, no. 1 (2022): 272-297.
- Dr. Balaji. V, Dr. Nethravathi. P.S, Dr. E. Maheswari July(2023), Fuzzy Controlled Cuk Converter For Grid Connected EV Applications, Journal of Interdisciplinary Cycle Research,Vol.15, No 7, pp. 354- 364.
- Subramanian, Vasantharaj, Vairavasundaram Indragandhi, Ramya Kuppusamy, and Yuvaraja Teekaraman. "Modeling and analysis of PV system with fuzzy logic MPPT technique for a DC microgrid under variable atmospheric conditions." Electronics, Vol. 10, no. 20, pp: 2541, 2021.
- Tsai, Ming-Fa, Chung-Shi Tseng, Kuo-Tung Hung, and Shih-Hua Lin. "A Novel DSP-Based MPPT Control Design for Photovoltaic Systems Using Neural Network Compensator." Energies, Vol. 14, no. 11, pp: 3260, 2021.
- Maheswari Ellappan, Kavitha Anbukumar, Comparative Analysis of ACM and GPWM Controllers in Continuous Input and Output Power Boost PFC Converter, Journal of Control Engineering and Applied Informatics, Vol. 22, No. 4, 2020
- E. Maheswari, Dr. A. Kavitha (2016) Bifurcation analysis in continuous input output buck boost PFC converter, IEEE, ICCPEIC, 2016, 10.1109/ICCPEIC.2016.7557284.
- Dr. Balaji. V, Dr. Nethravathi. P.S, (2023), A Bio-Inspired optimizer Based ANN Controller for EV charging station with grid tied PV system, IJARIIE, Vol. 9, No. 4, pp. 144-159