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Article Title: PV Connected Grid System Using Modified Boost Converter with AI Based Controller

PV Connected Grid System Using Modified Boost Converter with AI Based Controller

M. Nivedha

Assistant Professor, Department of Electrical and Electronics Engineering, Arasu Engineering College, Kumbakonam, Tamil Nadu, India. nivedha.manivel12@gmail.com

ABSTRACT

Grid connected solar Photovoltaic (PV) system has a fast growing rate and rapidly becoming an essential part in power distribution systems. Solar energy generated through PV array completely depends on atmospheric conditions, changes in weather affects the amount of output energy, and hence the system needs to be improved according to changes in climate. Thereby, this work focuses on Modified Boost Converter (MBC) with AI based controller for optimizing the performance of grid connected PV module. Moreover, Artificial Neural Network (ANN) based Maximum Power Point Tracking (MPPT) is used in extracting maximum output power from PV system. The single-phase Voltage Source Inverter (1ϕ VSI) is utilized in converting the DC supply into AC. For verifying the performance of grid connected PV, it is implemented in MATLAB. The results demonstrates that the proposed converter results with higher voltage gain compared to the other conventional converters.

Keywords: Grid connected PV system, Modified Boost Converter, Artificial Neural Network, Maximum Power Point Tracking system, (1ϕ VSI), Proportional Integral controller.

1 Introduction

Gradual increase in economic development and population has prompted high energy demand and the main focus on Renewable Energy Sources (RES), moreover it is considered important in fulfilling the present and future energy needs. Among all the RES, PV is apparently considered as the substantial innovations because of its perpetual and non-polluting nature [1-2]. Recently, significant amount of research has been organized in this sources. Considerably, grid associated with PV system is efficient in utilizing the PV power, subsequently it fascinated the consideration of researchers. Generally in the scientific society, human action affects environment and the major impact comes from fossil fuel combustion. Thus, adapting grid-connected PV system gets beneficial in reducing greenhouse emissions which generates more power to the grid [3-4]. On the other hand, PV systems are clean renewable source of energy. The output voltage of PV module is low, thus, it is necessary to employ an effective DC-DC converter to obtain boosted output voltage.

Boost converters are widely used for DC-DC conversion in PV applications, which has the capability in performing voltage boosting functions, meanwhile, it is not ultimate in stepping down voltage conversion applications which has a high ripple current and leads to higher losses

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[5].The implementation of Buck-Boost converter performs by both increasing and decreasing the voltage conversion, but output voltage has been lower or higher than the input DC voltage as well as it possess a discontinuous input current. The Cuk converters has continuity in input current, but its output voltage is reversed, as with the Buck-Boost converter [6].

MPPT algorithms plays an important role in improving the efficiency for PV system. [7]. Perturb and Observe (P&O) belongs to a conventional MPPT method, has the ability in increasing or decreasing PV array voltage, also the power converter in a duty cycle gets tuned and finally checks the changes in the PV output power, but fluctuation occurs near Maximum Power Point (MPP) and dynamic response is slow, which leads to higher losses in the PV [8]. Hill Climbing (HC) is utilized in tracking the efficiency of the solar system, while tracking, PV voltage gets adjusted and it is ineffective for rapidly changing environments. Incremental Conductance (IC) is a variant of HC, used in improving accuracy of tracking and dynamic performance of the PV under various circumstances, but it is less effective in changing solar radiation conditions. [9-10]. As a result, ANN based MPPT controller is enhanced in this system which tracks maximum power under different shading conditions [11-12]. ANN has more advantages than conventional methods. To obtain maximum output of a solar PV module, ANN based MPPT controller is utilized [13-14]

The aim of this work is to improve voltage level of the PV system by using an MBC and through ANN based MPPT, the maximum power is obtained, which helps in reducing the fossil fuel consumption. Moreover to convert the DC supply into AC supply, (1ϕ VSI) is used.

2 Proposed System Description

A grid connected PV is developed in this work for producing renewable energy and also aims in reducing the fossil fuel consumption by using RES under various environmental circumstances. The benefits gained through RES prompts the interest in adopting PV based grid system. Figure 1 demonstrates the solar connected grid system.

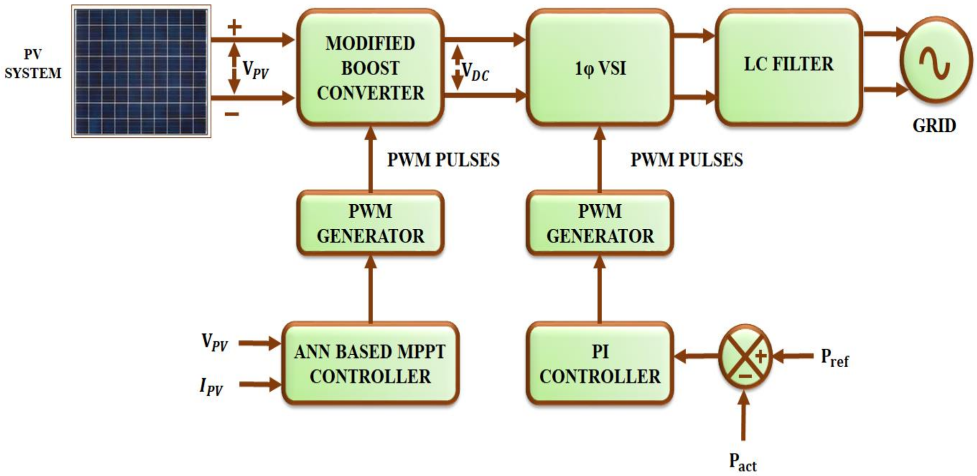

Figure 1: *Proposed Grid connected PV system*

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The solar panel generates DC from RES and pours through an inverter which converts DC into AC power. The performance of PV depends on the basis of solar irradiance and temperature. For improving PV output voltage, MBC is designed and by using ANN based MPPT controller, the maximum power is obtained. Moreover, MBC obtains power through inverter and the mechanism gets regulated. Using a 1ϕ VSI helps in converting DC supply into an AC, which is controlled by a PI controller. Thereafter voltage and current filtered into an LC, which produces a stable output voltage, after applied in the grid.

3 Proposed System Modelling

3.1 Modelling of PV System

To attain higher current or voltage, PV cells are connected in series and parallel within a PV module. The equivalent circuit model of PV array is shown in figure 2

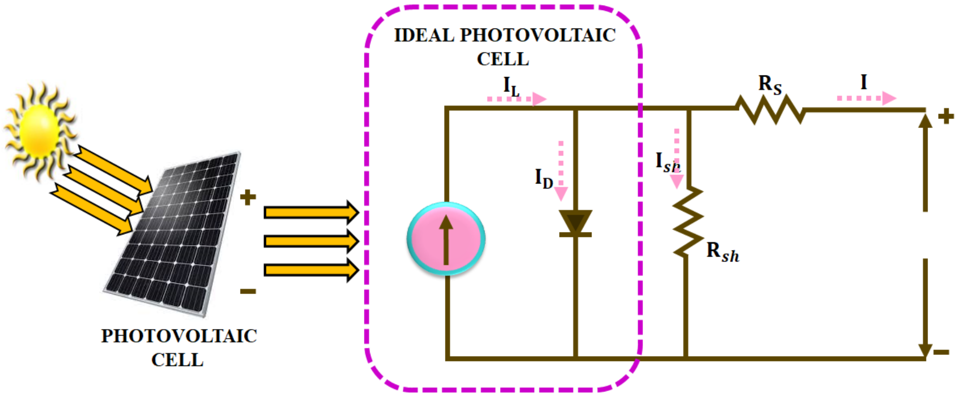

Figure 2: *The equivalent circuit model of solar PV*

The connection between current and voltage of the PV module equation is written as,

$$I_{Pv} = I_{Ph} - I_r\left[\exp\left(q\left(\frac{V_{Pv} + R_s\, I_{Pv}}{n_s\, kTa}\right)\right) - 1\right] - \frac{V_{Pv} + R_s\, I_{Pv}}{R_{sh}} \qquad (1)$$

Whereas, PV module current and photon generated current are represented as I_{Pv} and I_{Ph} respectively. The term I_r symbolizes the reverse current and the voltage of PV is signified as V_{Pv}. The series and shunt resistance are symbolized as R_s and R_{sh} and the ideality factor of the diode is demonstrated as a respectively. Boost converter plays a significant role in boosting up the voltage from PV which is explained as follows.

3.2 Modelling Of Modified Boost Converter

The proposed converter includes one inductor, three diodes, and three capacitors, along with a single power controlled semiconductor device. Figure 3 demonstrates the circuit diagram of the proposed MBC.

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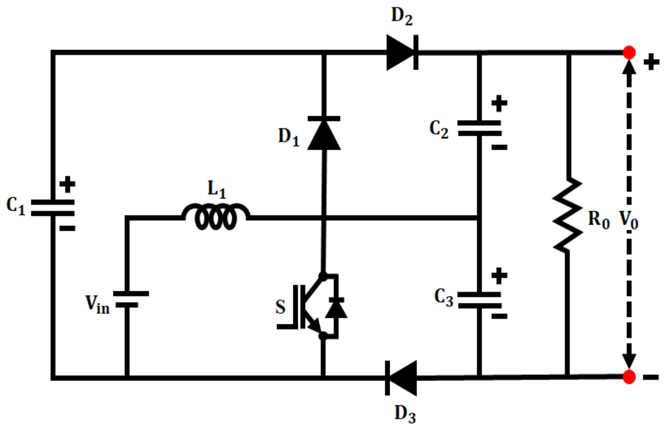

Figure 3: *Proposed MBC*

The working of MBC is based on the condition of controlled device, ON and OFF and it has two parts, Mode I and Mode II.

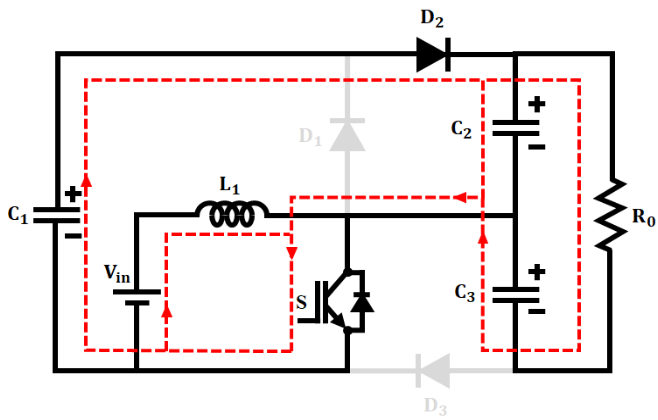

Figure 4(a): *Operating mode of MBC when switch is ON*

Mode I:

Figure 3 (a) demonstrates the switch S is on, between $0\ to\ DT_s$. While processing in a continuous mode, the inductor current I_L remains positive and never drops to zero. Through input voltage supply V_{in}, the inductor L_1 gets charged. The capacitor $C_1$and C_3 moves the stored energy to the load$R$, simultaneously capacitor C_1 chargesC_2. Diode D_2 is in the state of forward bias condition, diode D_1 and D_3 operates in a reverse bias condition. When the capacitors $C_1$and C_3 are not charging, the capacitor C_2 gets charging, which is shown in figure 3 (a).

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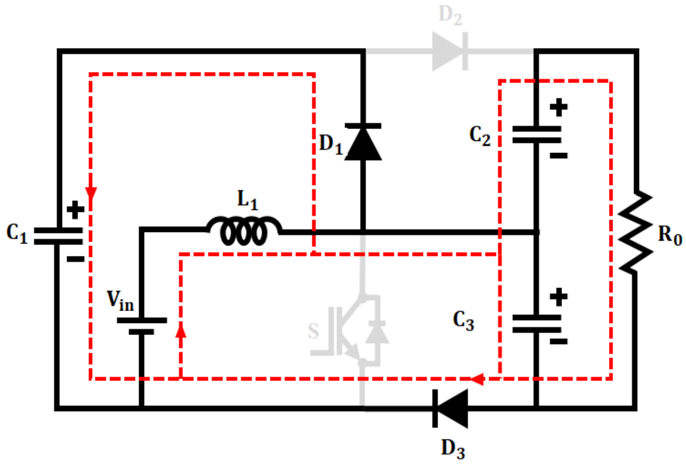

Figure 4(b): *Operating mode of MBC when switch is OFF*

Mode II:

Figure 3 (b) demonstrates the switch S is off, between DT_s and T_s. During the switching process in non-conducting mode, the inductor current I_L drops to zero. Through input voltage V_{in} and inductor $L_1$the capacitor C_3 and C_1 gets charged. At the same time, load R gets energy from input voltage V_{in} and capacitor C_2. By utilizing inductor L_1 and input supply V_{in} the capacitors C_1 and C_3 receives energy respectively. When the diode D_1 and D_3 are in a state of forward bias condition, diode D_2 gets reversed, which is seen in figure 3 (b).

When controlled device S is ON, the voltage emerged beyond the inductor in mode I is written as,

$$V_{L1} = V_{in}$$
$$V_{C3} = V_{C2}$$
$$V_0 = V_{C1} + V_{C3} \tag{2}$$

In mode II, controlled device S is OFF, whereas voltage emerged beyond the inductor is written as,

$$V_{L1} = V_{in} - V_{C1}$$
$$V_{L1} = V_{in} + V_{C2} - V_0$$
$$V_{L1} = V_{in} - V_{C3} \tag{3}$$

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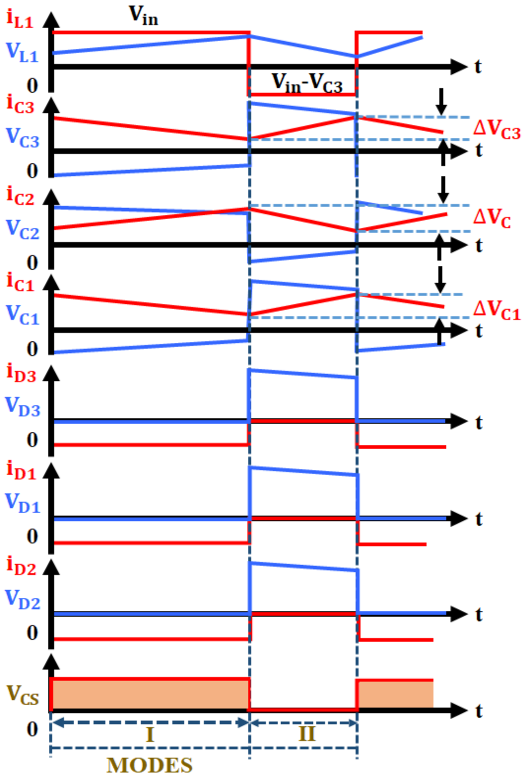

Figure 5: *Characteristic waveform of MBC*

According to Inductor Volt Second Law (IVSL),

$$(V_{in})D + (V_{in} - V_{C1})(1 - D) = 0$$

$$V_{C1} = \left[\frac{V_{in}}{1-D}\right] \tag{4}$$

Equation 5 demonstrates the voltage capacity of C_2,

$$(V_{in})D + (V_{in} + V_{C2} - V_0)(1 - D) = 0$$

$$V_{C2} = -\frac{V_{in}}{1-D} + \frac{2\,V_o}{1-D} \tag{5}$$

The voltage capacity of C_3 is shown in equation 6,

$$(V_{in})D + (V_{in} - V_{C3})(1 - D) = 0$$

$$V_{C3} = \frac{V_{in}}{1-D} \tag{6}$$

Load voltage is equal to capacitor C_1 and C_3 voltage, which is shown in equation 7,

$$V_O = V_{C1} + V_{C3} \tag{7}$$

The output voltage and input current of the proposed MBC is shown in equations (8) and (9).

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$$V_O = \frac{2}{(1-D)} V_{in} \tag{8}$$

$$I_{in} = \frac{2I_O}{(1-D)} \tag{9}$$

Moreover, to extract the MPP on PV panel, ANN based MPPT is implemented which is detailed in the following section.

3.3 Artificial Neural Network (Ann) Based MPPT Controller

ANN based MPPT controller is proposed in this work in order to extract maximum power from the PV modules in respect to solar irradiance and temperature. The proposed controller performs well under variable temperature conditions, resulting in fast tracking speed with optimum output voltage. The architecture of ANN based MPPT controller is illustrated through Figure 5.

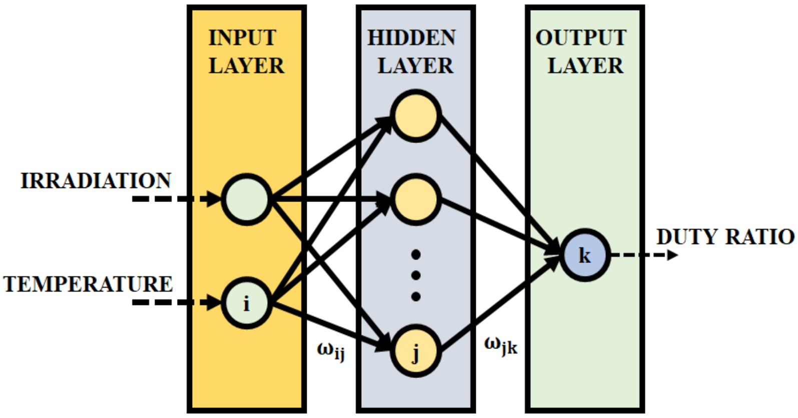

Figure 6: *ANN based MPPT controller*

For changing the resistance permitted by PV system, ANN based MPPT is implemented. It has a three-layer neural network architecture that are an input, output and hidden layer. PV parameters such as irradiation, temperature are the input variables whereas, duty cycle is the output variable generally used in controlling the converter to operate most efficiently. This network gives a particular value of duty cycle for every changes occurs in solar temperature value by obtaining maximum power from the PV array. By using Mean Squared Error (MSE), the performance of ANN is measured. Throughout this process, weights gets adjusted in tracking the particular values with minimum error. The MSE is calculated in the below equation:

$$F = \frac{1}{N} \sum_{i=1}^{N} (t_i - a_1)^2 \tag{10}$$

Whereas, target is signified as t_i and output is defined as a_1 respectively.

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MSE is used in evaluating the average squared difference in between the predicted and target values within the dataset. In order to minimize harmonics, a 1ϕ VSI is used which is described as follows.

3.4 Modelling Of Single Phase VSI

A grid connected 1ϕ VSI is used in this work to convert DC supply into AC supply which is shown in figure 6.

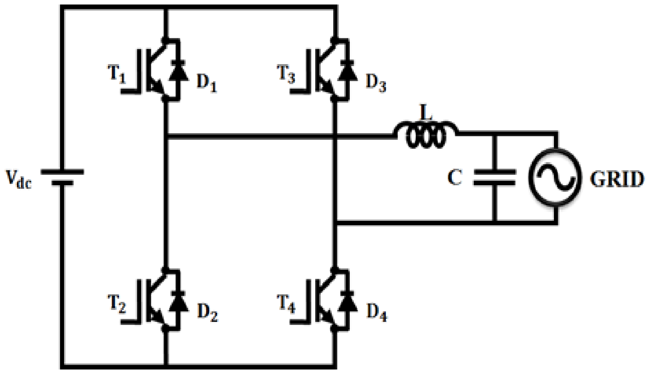

Figure 7: Single phase VSI

In a grid connected inverter, high frequency switch is required to reduce output current of the inverter. It consists of four diodes $D_{1,}\,D_{2,}\,D_{3,}$ and D_4 along with four power switches $T_{1,}T_{2,}T_{3,}and\ T_4$. For maintaining the sinusoidal waveform and minimizing the harmonics, output of the inverter is connected to the grid through an LC filter.

4 Results and Discussion

A grid connected PV system using ANN based MPPT controller with MBC converter is discussed in this work. Using MATLAB, the proposed control strategy is examined and the results are presented as detail. The parameters utilized to design the proposed research is shown in Table 1.

Table 1: *Design Parameter*

Parameter	description
Solar PV System	
Open circuit Voltage	37.25V
Short circuit Current	8.95 A
Series Connected solar PV cell	3
Parallel Connected solar PV cell	15.35
Maximum Voltage	29.95V
Maximum Current	8.35 A

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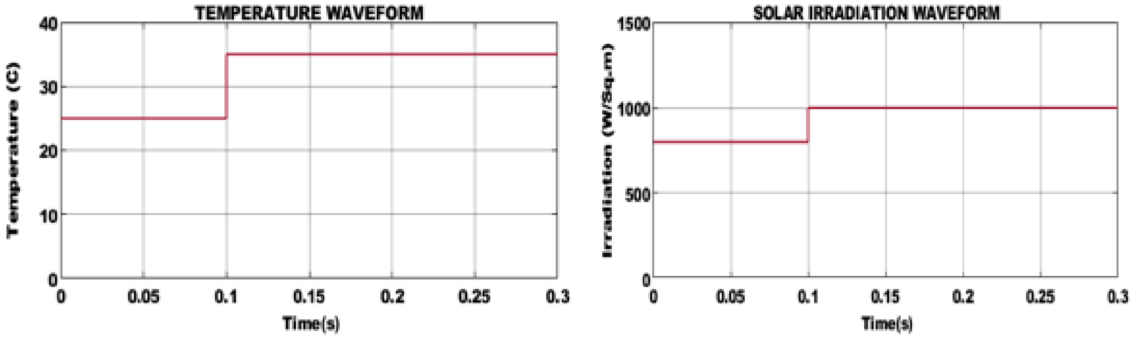
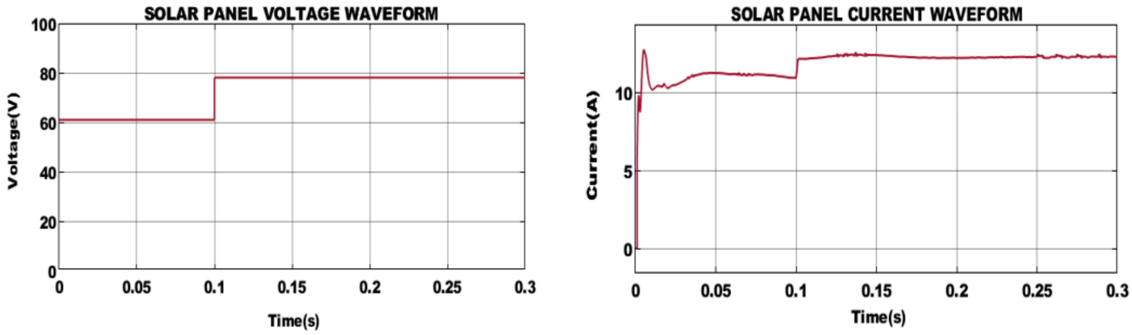


(a) (b)

Figure 8: *PV panel (a) Temperature waveform and (b) Solar Irradiation waveform*

Figure 7 illustrates the temperature and solar irradiation of the PV panel. The temperature maintains at a constant level until 0.1s after that initial rise occurs in temperature from 25℃ to 35℃ and a sudden rise occurs in solar irradiation which increases to 1000 W/Sq.m at 0.1s thereafter a constant irradiance is maintained.



(a) (b)

Figure 9: PV panel waveforms representing (a) Voltage (b) Current

Figure 8 illustrates the waveform of PV panel which represents current and voltage. Initially solar panel waveform maintains a constant voltage till 0.1s after that a sudden increase occurs in voltage level from 60 V to 80 V and the current gets fluctuated till 0.1s and a constant level is maintained with minor distortion as seen in Figure 8 (b).

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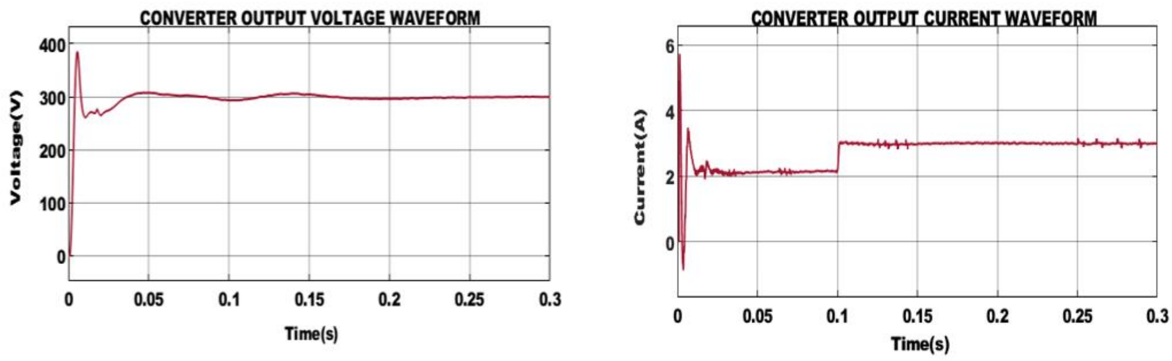
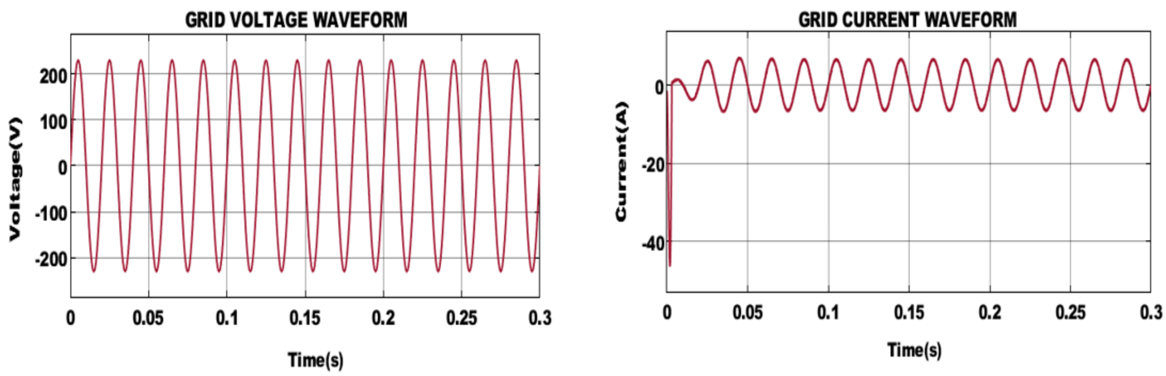


(a) (b)

Figure 10: *Output of Modified Boost converter (a) Voltage waveform and (b) Current waveform*

Figure 9 illustrates the output voltage and current waveform of boost converter. Following certain variations, voltage output attains 300 V at 0.2 s and output current variances until 0.1s, and thereafter a constant value of 3A is sustained, which is shown in the above Figure.



(a) (b)

Figure 11: *1ϕ connected VSI (a) Voltage (b) Current*

Grid connected 1ϕ VSI of current and voltage is illustrated in the Figure 10. The obtained value of grid current is 230 V and value of grid voltage is 8 A. The real and reactive power waveforms demonstrates in Figure 11.

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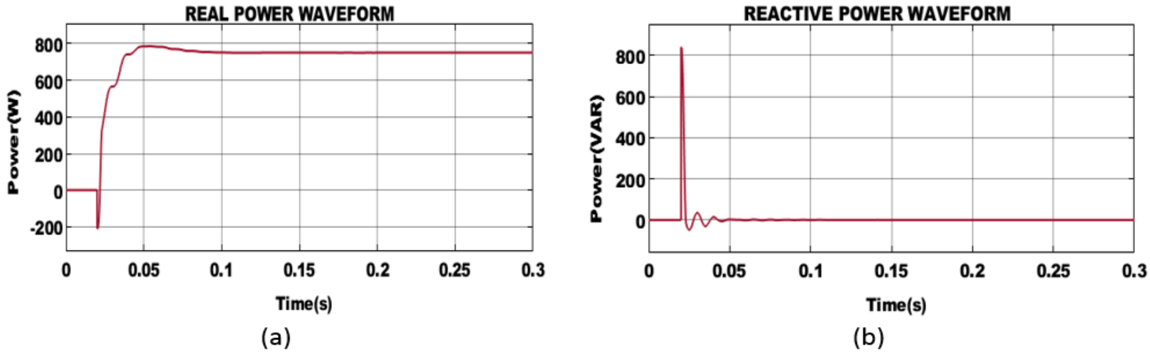

Figure 12: (a) Real power waveform (b) Reactive power waveform

Figure 11 shows the obtained real power value is about 780 W and the magnitude of reactive power is found to be low. Through resistive load, Real power (P) is consumed and through inductive load, Reactive power (Q) is attained. THD waveform is symbolized in Figure 12.

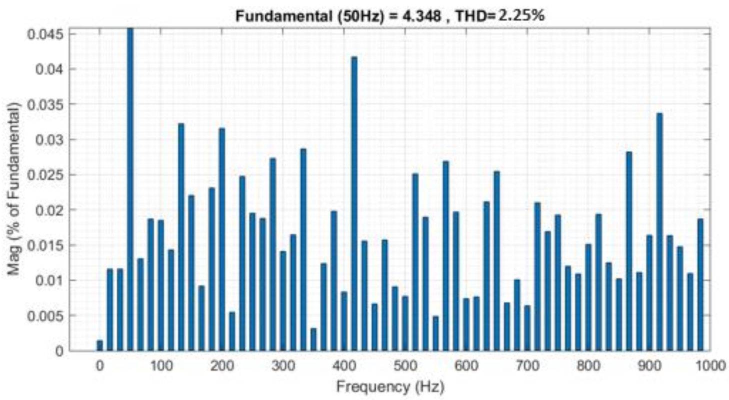

Figure 13: *THD waveform*

THD waveform illustrates a THD value of 2.25% with reduced harmonics is obtained for the proposed methodology.

Table 2: *DC-DC converter efficiency and Voltage gain comparison.*

Converter	Efficiency	Voltage gain
Boost	86%	1.1
Buck-Boost	89.3%	1.3
Cuk	91.2%	1.6
Modified Boost	93.4%	1.8

Table 2 demonstrates the comparisons and voltage gain ratio of the DC-DC converters, for determining the performance of the proposed MBC with the conventional converters. MBC achieves an efficiency of 93.4% and voltage gain of 1.8. Comparing with Buck-Boost and Cuk

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converters, the proposed converter has numerous advantages including high output voltage and low operating duty cycles.

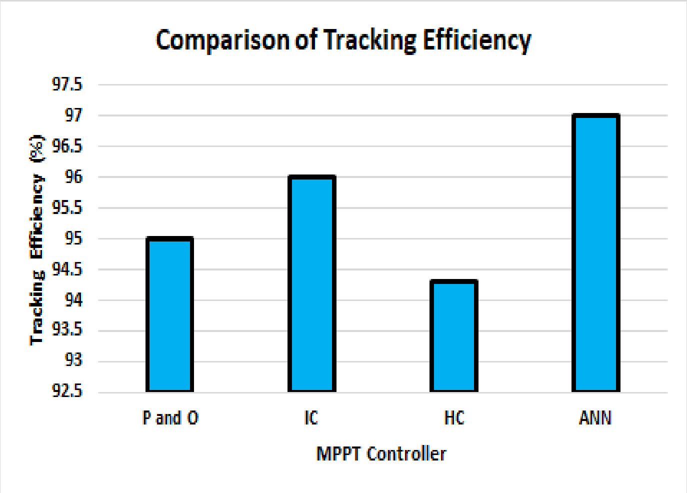

Figure 14: *Comparison of tracking MPPT controller Efficiency*

Compared to P&O, HC, and IC controllers, ANN based MPPT controller is stable in response with an efficiency of 97% as seen in Figure 13, and also efficient in comparing with other conventional controllers.

5 Conclusion

In this proposed work a grid connected solar PV system has been developed to reduce greenhouse gas emissions and to substitute fossil fuel based energy resources. This model has been utilized in predicting maximum power voltage for changeable atmospheric circumstances. For reducing harmonic distortion, LC filter is used in the inverter. Comparing with other MPPT controller, the proposed ANN based MPPT controller resulting in fast response towards suddenly changing solar temperature and irradiance which gives less steady state error and moreover it is less in time consuming. The proposed method indicates a high tracking speed under changes in irradiance and temperature, therefore power loss is prevented and the tracking accuracy gets increased. MPPT algorithm is implemented in MATLAB which shows excellent results of the proposed method. Furthermore, it is simple to implement in numerous PV model.

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