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Hardware Realization of Conventional MPPT Techniques

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***Abstract*:This paper presents a comparative study on the conventional MPPT techniques used in the solar photovoltaic system. These techniques have been implemented in a hardware environment and their performance has been studied for variations in environmental conditions. It can be observed from analysing of PV array that, the P-V & I-V characteristics are highly influenced by the environmental factors leading to low conversion efficiency. Thus, the significance of maximum power point tracking controller is very high. The analysis and comparison of various existing technique has to perform to aid in selecting the appropriate method for implementation hardware results are being analysed to examine the feasibility, cost and efficiency obtained for the existing techniques. The MPPT technique included for study are perturb & observer algorithm (P&O), incremental conductance algorithm (INC), constant voltage method (CVM) the simulation studies were carried out in the MATLAB/Simulink environment. The DSPIC30F4011 has been used to implement the MPPT control**.

***Keywords:*MPPT (Maximum Power Point Tracking), P&O (Perturb & Observe), INC(IncrementalConductance), CV(Constant Voltage).**

I.INTRODUCTION

Owing to the unavailability of appropriate resources to meet the power demand in developing countries like India, the quest for finding suitable ways of harnessing power from renewable sources of energy is intensifying. The prime energy sources stand out to be solar energy and wind energy. The abundance of solar energy and the intermittent nature of wind energy makes solar energy receive higher importance. The advantage of solar power generating units is that it can be used as a standalone or even a grid connected system based on the availability of grid. The drawback of using solar energy power system is that the solar cell efficiency is low and it is also effected due to fast climatic changes and wide variations in the ambient temperature. Power electronic conditioners have helped in tracking the problem of low efficiency by helping the PV panel to operate at its maximum power. The MPPT controller makes the power output of the solar panel maximum by matching the Thevenin impedance of the system to the load impedance.

The entrenched technique for MPPT are:-

1. Perturb & Observe algorithm
2. Incremental conductance algorithm
3. Constant voltage method

These algorithms force the PV panel to operate at the maximum power point under corresponding irradiation and temperature conditions. It has been observed from the papers archived in the literature that the implementation of the MPPT techniques in mundane. Thus, it is very important to select the appropriate controller for hardware implementation. The setup can be further utilized for integration to standalone and grid connected PV system.

II. SYSTEM DESCRIPTION

The figure 1 shows the block diagram of the solar photovoltaic system incorporating MPPT control. It consists of PV panel connected to the load through a boost converter. The firing pulses to the boost converter are given by the MPPT controller. The switch is operated such that the PV panel delivers maximum power.

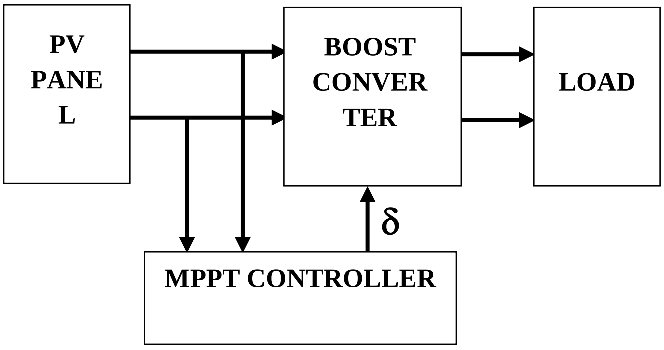

Figure 1.Block diagram of overall system

2.1 Modelling of PV panel:-

Conversion of light energy to electrical energy is the basic function of the photo voltaic cell. The PV panel needs to be modelled mathematically to analyse the characteristics. The PV cells can be realized as a current source in parallel to a diode as in figure 2. The internal resistance is represented by a series resistance R_s in the equivalent circuit. The mathematical equations of the PV panel can be in equation [1-3]

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$$I = I_{PV} - I_O\left[e^{\frac{q(V+IR_s)}{akT}} - 1\right] - \left[\frac{V+IR_s}{R_p}\right] (1)$$

Where,

I_{pv}= photo voltaic current

I_o=saturation current of the diode

q=electron charge in coulombs

$=1.602*10^{-19}$C

K=Boltzmann constant

$=1.380*10^{-23}$J/K

a=diode ideality factor

R_s=series resistance

R_p=parallel resistance

T=Temperature in kelvin

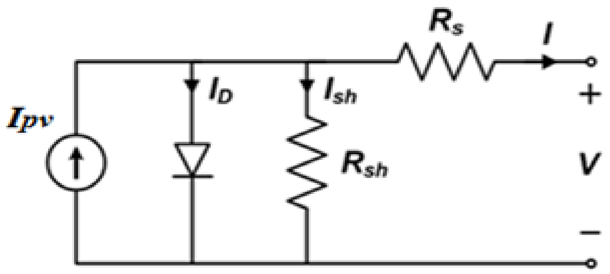

Figure 2.Equivalent Circuit PV cell

The photo voltaic current Ipv is a function of the irradiance (G) and is formulated as:

$$I_{PV} = \left[I_{PV\_STC} + K_i \Delta T\right] \frac{G}{G_{STC}} (2)$$

Where;

I_{PV_STC}=light generated current under standard test conditions (STC)

ΔT= T-T_{STC} (in kelvin)

G= surface irradiance of cell (W/m^2)

G_{STC}=1000W/m^2

Irradiance under STC

K_i= short circuit current coefficient

The diode saturation current I_o is given as:

$$I_o = I_{O_{STC}} \left(\frac{T}{T_{STC}}\right)^3 exp\left[\frac{qE_g}{ak}\left(\frac{1}{T_{STC}} - \frac{1}{T}\right)\right] (3)$$

Where;

$I_{o,stc}$= normal saturation current under standard test conditions (STC)

T_{STC}= temperature under standard test conditions

E_g= band gap energy of the semiconductor

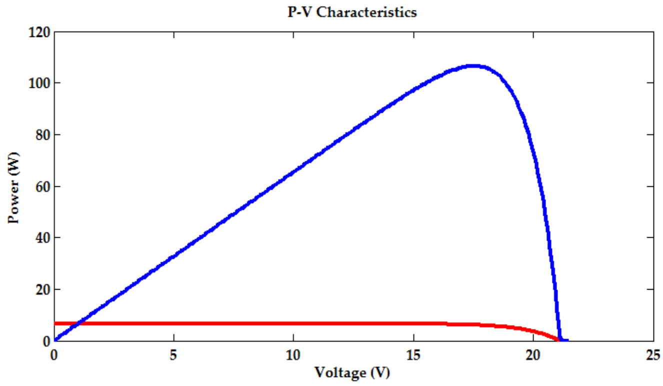

Figure 3.PV characteristics of panel

TABLE 1.PANEL SPECIFICATIONS

SPECIFICATIONS	PARAMETERS
MAXIMUM POWER	100W
VOLTAGE AT MAX	17.5V
CURRENT AT MAX	5.71A
OPEN CIRCUIT VOLTAGE	21.50V
SHORT CIRCUIT CURRENT	6.28A

2.2 Boost Converter:-

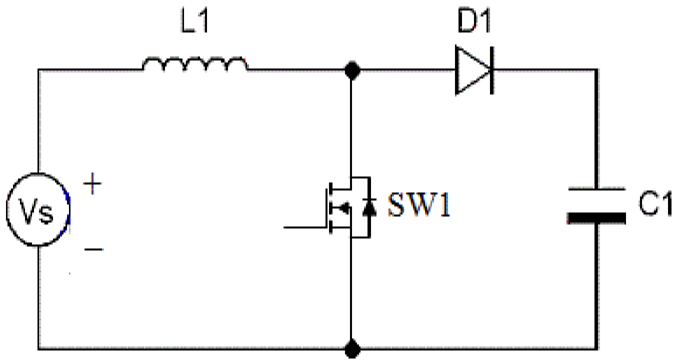

Figure 4.Circuit Diagram of Boost Converter

The function of a boost converter in a solar photovoltaic system aided with MPPT is to step up the voltage required by the load. By stepping up the voltage, the maximum power from the PV panel is extracted. The source side impedance can be matched with the load side impedance.

Mode1:-

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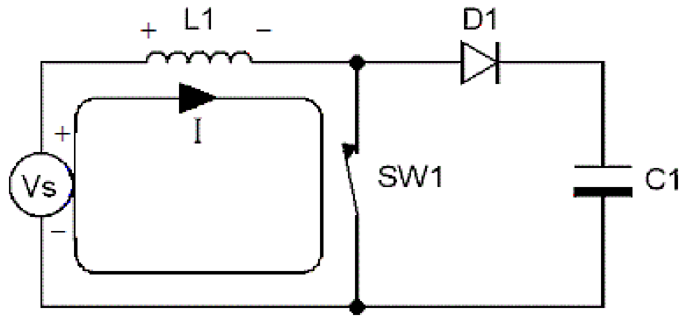

Figure 5.Boost converter Mode1 operation

$$\begin{pmatrix} L\frac{di_l(t)}{dt} \\ C\frac{dV(t)}{dt} \end{pmatrix} = \begin{pmatrix} 0 & -1 \\ 1 & -\frac{1}{R} \end{pmatrix}\begin{pmatrix} i_l(t) \\ V(t) \end{pmatrix} + \begin{pmatrix} 1 \\ 0 \end{pmatrix}\begin{pmatrix} V_g(t) \\ 0 \end{pmatrix} \quad (4)$$

$$y = \begin{pmatrix} 1 & 0 \end{pmatrix}\begin{pmatrix} i_l(t) \\ V(t) \end{pmatrix} y = \begin{pmatrix} 1 & 0 \end{pmatrix}\begin{pmatrix} i_l(t) \\ V(t) \end{pmatrix} \quad (5)$$

Mode2:-

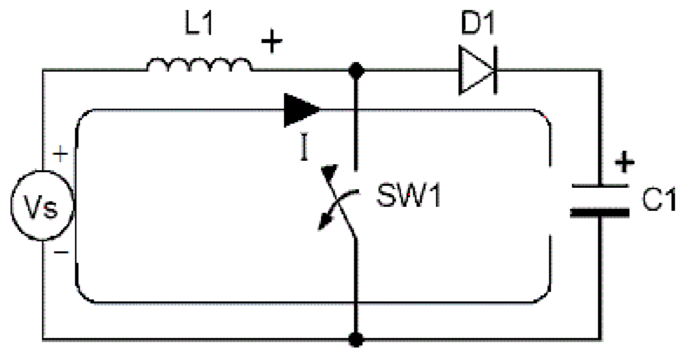

Figure 6.Boost converter Mode2 operation

$$\begin{pmatrix} L\frac{di_l(t)}{dt} \\ C\frac{dV(t)}{dt} \end{pmatrix} = \begin{pmatrix} 0 & 0 \\ 1 & -\frac{1}{R} \end{pmatrix}\begin{pmatrix} i_l(t) \\ V(t) \end{pmatrix} + \begin{pmatrix} 1 \\ 0 \end{pmatrix}\begin{pmatrix} V_g(t) \\ 0 \end{pmatrix} \quad (6)$$

$$y = \begin{pmatrix} 1 & 0 \end{pmatrix}\begin{pmatrix} i_l(t) \\ V(t) \end{pmatrix} y = \begin{pmatrix} 1 & 0 \end{pmatrix}\begin{pmatrix} i_l(t) \\ V(t) \end{pmatrix} \quad (7)$$

Boost Converter Specifications**:-**

TABLE 2.BOOST CONVERTER SPECIFICATION

SPECIFICATIONS	PARAMETERS
CAPACITOR C_1	50e-6
CAPACITOR C_2	22e-6
INDUCTOR L	410e-6

III. MPPT Techniques

The conventional MPPT technique employed to the PV system under uniform insolation conditions are:

(1)Perturb & Observe Method
(2)Incremental Conductance Method
(3)Constant Voltage Method
The growing prominence of these methods is the economic feasibility, easy installation etc...

3.1 Perturb & Observe Method:-

The Perturb & Observe Method is a very popular method due to its simple implementation, few measured parameters and low cost. The location of maximum power point is found by perturbing the voltage of panel as the duty cycle of the boost converter. The basic idea of the algorithm is to periodically perturb the duty cycle of the converter and measure the module current and voltage to determine the power. Based on the difference of the present & past values of voltage, the direction of perturbation is decided. The flow chart of the Perturb & Observer method is shown is that, the system oscillate around the MPP due to perturbations. This leads to a significant loss in power. When there is a change in the uniform insolating the operating voltage cannot change immediately and thus it takes time for the system to converge to the MPP.

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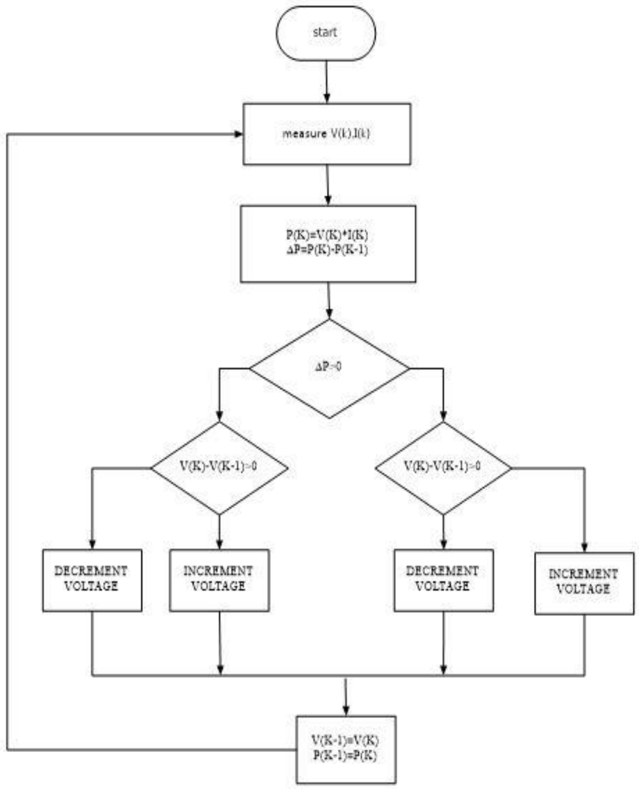

Figure 7.Flowchart of Perturb and Observe Technique

3.2 Incremental Conductance Method:-

The basic principle for formation of the incremental conductance algorithm is the fact that the slop of the PV array curve is zero at the peak, negative on the right side and positive on the left side.

$$P = V * I \qquad (8)$$

$$\frac{dP}{dV} = \frac{d}{dV}(V * I) \qquad (9)$$

$$\frac{dV}{dV} * I + V * \frac{dI}{dV} = 0 \qquad (10)$$

$$I + V * \frac{dI}{dV} = 0 \qquad (11)$$

$$\frac{dI}{dV} = \frac{-I}{V} \text{ at MPP} \qquad (12)$$

it can be concluded that

$$\frac{dP}{dV} = 0 \rightarrow \frac{dI}{dV} = \frac{-I}{V} \text{ at MPP}$$

$$\frac{dP}{dV} > 0 \rightarrow \frac{dI}{dV} > \frac{-I}{V} \text{ at left side of MPP}$$

$$\frac{dP}{dV} < 0 \rightarrow \frac{dI}{dV} < \frac{-I}{V} \text{ at right side of MPP}$$

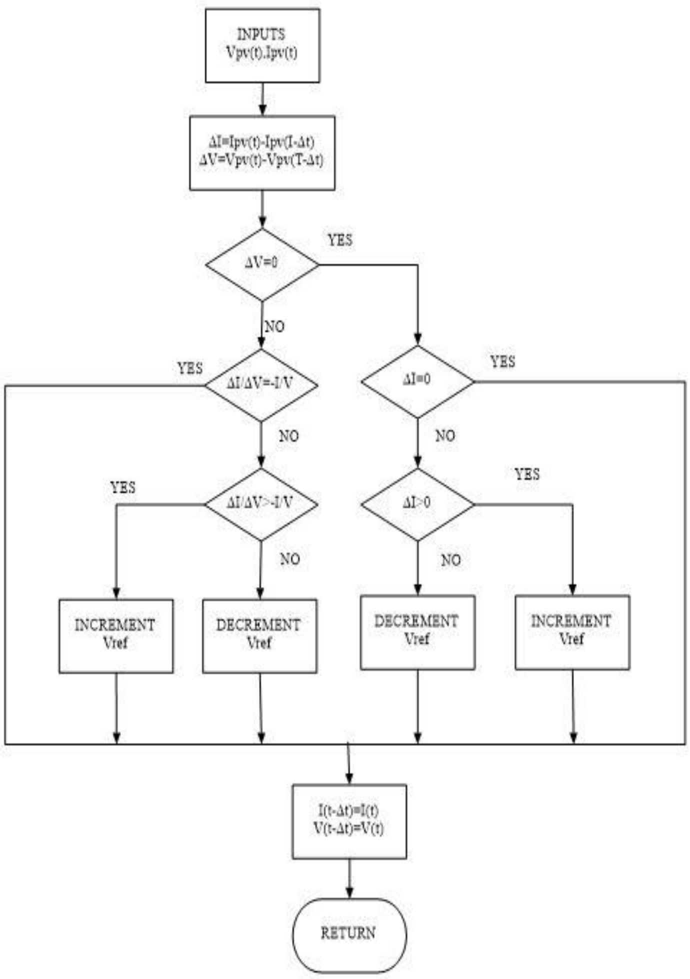

Figure 8.Flow Chart of Incremental Conductance Method

The advantage of the incremental conductance MPPT over the P&O algorithm is that, there are less number of steady state oscillations. In the Perturb & Observe algorithm, varying the perturbation size is not very feasible. But, in the INC, the step size can be selected for faster dynamics and reduction in steady state oscillations.

3.3 Constant Voltage Method:-

The idea behind the constant voltage tracking method is that, for a fixed temperature & irradiation conditions the voltage is fixed to a close value. If the MPPT controller operates such that the voltage is fixed to that maximum value, maximum power can always be extracted from a PV array. It can be observed from the I-V characteristics that the ratio of the maximum power point voltage to the open circuit voltage is approximately constant and less than 1.

$$\frac{Vmpp}{Voc} = k$$

The value of K is noted be between 0.8 & 0.9 for majority cases

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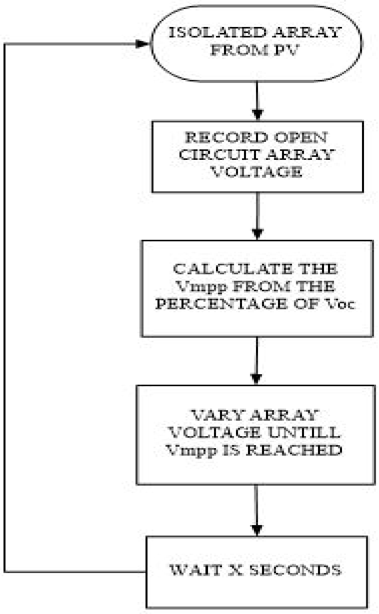

Figure 9.Flowchart of Constant Voltage Control

The advantage of the method is the simplicity in the algorithm, reduction in the number of sensors etc. But this method holds a huge drawback of low accuracy especially in varying environmental conditions. Due to the varying environmental conditions, significant effect is observed on the characteristics and voltage of the PV array. Simulation and hardware results have been analysed to choose the appropriate algorithm.

IV. SIMULATION RESULTS

4.1 Perturb & Observe:-

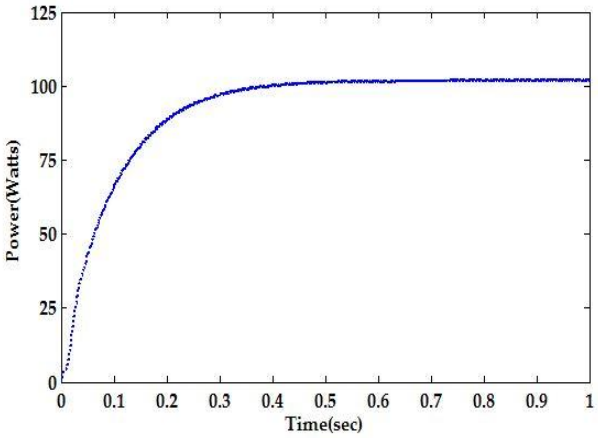

Figure 10.Output Power of Perturb & Observer Technique

4.2 Incremental Conductance Technique:-

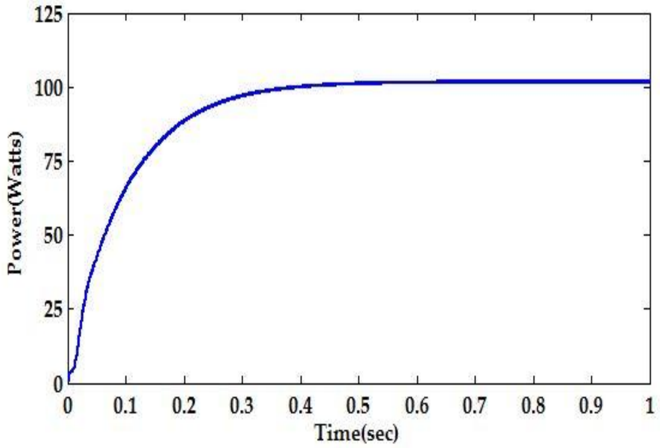

Figure 11.Output Power of Incremental Conductance Technique

4.3 Constant Voltage Method:-

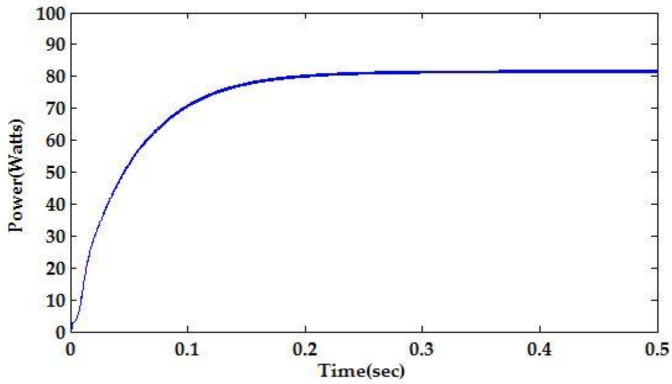

Figure 12.Output Power of Constant Voltage Method

From the results obtaining the following comparison table can be drawn

SPECIFICATIONS	P&O	INC	CVC
Efficiency	Medium About 95% depending on how method is optimized	High About 98% depending on how method is optimized	Low About 90%
Complexity	Easy but complex when site conditions vary	Difficult	Very simple but very difficult to get optimal K1
Realization	Easy to implement as few measured parameters	More complex hence microcontroller/ DSP is needed	Easy to implement with Analog hardware
Cost	Relatively lower	Involving higher cost	Relatively lower

TABLE 3.COMPARISON OF VARIOUS MPPT TECHNIQUES

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V. HARDWARE IMPLEMENTATION & RESULTS

The hardware implementation of the system shown in figure 13

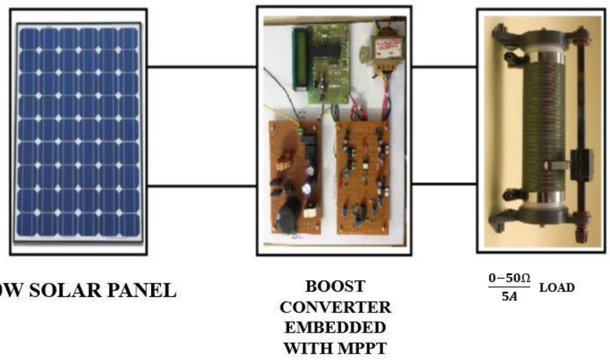

Figure 13.Blockdiagram of the Hardware Setup

The Hardware prototype of the system is shown in figure 14

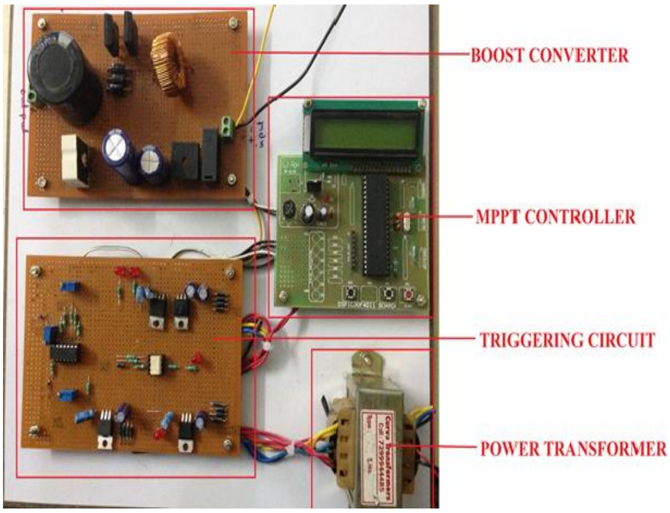

Figure 14.Hardware Implementation

The parameters of the system for hardware implementation are given in the following table

TABLE 4.HARDWARE SPECIFICATIONS

PARAMETERS	**SPECIFICATIONS**
C1	1000µF, 63V
C2	4700µF, 50V
C3	470µF, 450V
DIODE	IN540
L	1mh

The following results were noted during experimental validations of the conventional technique

Perturb & Observe:-

TABLE 5.TABULATED OUTPUTS OF P&O

WITH OUT MPPT			WITH MPPT				
TIME	V_{OC}	I_{SC}	V_{MP}	I_{MP}	V_O	I_O	P_{MAX}
10 AM	17.5	3.36	17.54	3.03	23.05	2.30	53.1
11 AM	17.5	4.92	17.22	4.47	27.8	2.78	77.3
1 PM	17.5	5.32	17.44	4.84	29.06	2.90	84.4
2:30 PM	17.5	4.67	17.43	4.25	27.23	2.72	74.1
3 PM	17.5	4.01	17.8	3.63	25.45	2.54	64.8
5 PM	17.5	3.00	17.5	2.73	21.87	2.18	47.8

Incremental Conductance Technique:-

WITH OUT MPPT			WITH MPPT				
TIME	V_{OC}	I_{SC}	V_{MP}	I_{MP}	V_O	I_O	P_{MAX}
10 AM	17.5	3.36	17.3	3.07	23.07	2.30	53.2
11 AM	17.5	4.92	17.52	4.41	27.77	2.77	77.1
1 PM	17.5	5.32	17.12	4.91	29.07	2.90	85.5
2:30 PM	17.5	4.67	17.13	4.31	27.33	2.72	74.1
3 PM	17.5	4.01	17.56	3.68	25.42	2.54	64.6
5 PM	17.5	3.00	17.3	2.77	21.99	2.19	47.9

TABLE 6.TABULATED OUTPUTS OF INC

Constant Voltage Control:-

TABLE 7.TABULATED OUTPUTS OF CVC

TIME	VOLTAGE (V)	POWER(P)
10 AM	8	18
11.30 AM	12	40.2
1 PM	19	67
2.30 PM	14	55.5
3 PM	11	29.7
5 PM	7	13.65

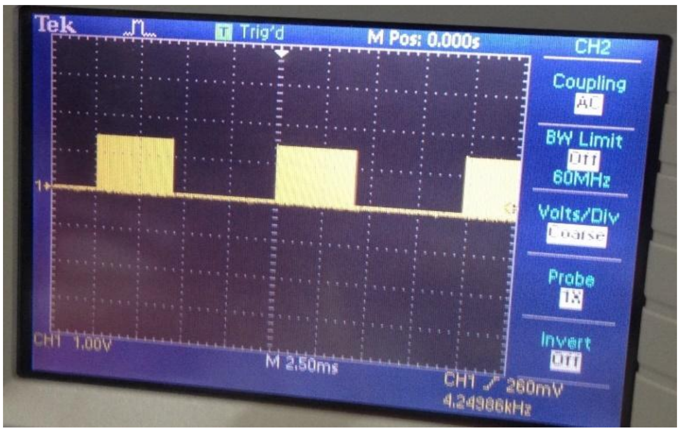

Figure 15.Duty cycle to boost converter

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VI. CONCLUSION

It can be noted that the incremental conductance method gives the most satisfactory results when compared with the other two techniques. The constant voltage method needs a reference voltage to be set based on the open circuit voltage of the panel. The method is highly inefficient and doesn't give satisfactory results under varying environmental conditions. The perturb and observer method gives oscillation leads to significant loss in the system

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