ARDUINO UNO CONTROLLED DC WEAVING MACHINE POWERED BY SOLAR ENERGY

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ABSTRACT - The use of solar energy to run a weaving machine motor has been presented in this work. Since the solar energy is of fluctuating nature, the DC motor is run by feeding power from photovoltaic module using Maximum Power Point Tracking method for obtaining maximum power at any instant. By adjusting the duty cycle of the charge controller using MPPT technique the DC motor is being run at desired output. The MATLAB/SIMULINK model is first presented to verify the design of the model then a hardware experimental verification using ARDUINO UNO has been done with a 12-15V 200RPM DC motor to confirm the results.

KEYWORDS: Arduino UNO, MATLAB/SIMULINK (Software), MPPT (maximum power point tracking), P&O (Perturb and Observe method), Weaving Machine.

1. INTRODUCTION

The demand for sustainable energy utilization is increasing day by day as industrial, domestic and other sectors are utilizing solar energy as their source of energy. Most of the problems related to eco-friendliness, harmful emissions, etc. can be avoided using solar energy. Hence to utilize this solar energy maximum power point trackers are installed along with boost converters to step up voltage obtained to required values and hence motor of weaving machine can be run accordingly. A MATLAB model of the above described design is made and experimental verification of this model is also done using a hardware prototype.

1.1 Literature survey

Manual weaving is a traditional method of earning for livelihood in rural areas. Utilization of solar energy using MPPT techniques has been presented in [1], here a mathematical model is presented to extract power. Similar work has been done in [2], where MPPT technique is used to run an induction motor used for pumping water. A CUK converter analysis for the MPPT technique used for solar power extraction is given in [3], and a buck-boost converter analysis for MPPT technique is given in [4]. In all these works the duty cycle of converters are adjusted based on MPPT techniques to provide desired outputs based on solar input. To overcome the disadvantages of the less production rate of manual weaving, costly weaving machines and unavailability of electricity in villages the proposed method can solve a lot of these problems. The proposed method hence uses a boost converter analysis and utilizes MPPT technique to adjust the duty cycle in order to run the motor of weaving machine using solar energy.

2. PROPOSED METHODOLOGY

Here the block diagram in Fig.1, shows that the PV module is being fed by various values of irradiance and temperature which changes depending upon the intensity of solar radiation received at any instant of time. The output of PV module is given to the boost converter which helps to step up the voltage of PV module as required by the load. The voltage and current sensors are used to sense the PV module output and MPPT algorithm is applied to these outputs in-order to generate the PWM pulses to give to the gate of the switch of the boost converter. The duty cycle of PWM pulse is also varied depending upon MPPT algorithm.

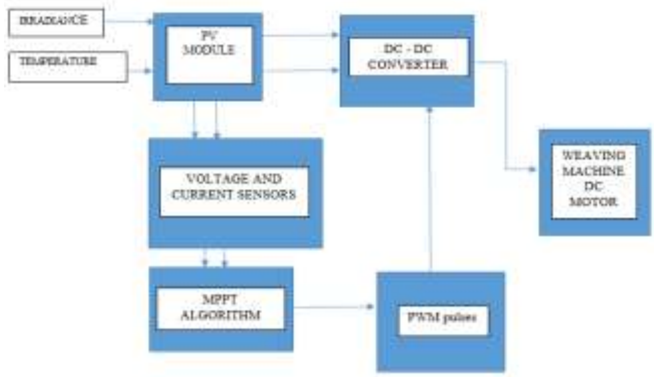

Fig-1: Block diagram of proposed method

3. COMPONENTS OF PROPOSED MODEL.

3.1 PV Module

The Photovoltaic cells connects together to give rise to the module which helps in extracting maximum solar energy and converting it into electricity. The current produced by the cell is proportional to the irradiation falling on it. Power of solar modules decreases with decrease in solar radiation and increase in temperature.

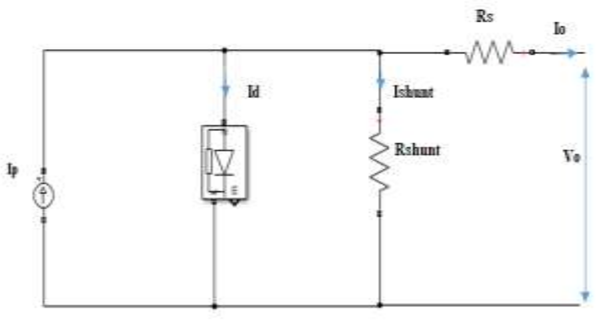

Fig-2: Equivalent circuit of solar cell

In the Fig.2, an equivalent solar cell circuit is shown which can be modelled by using equations. The output current I_o is given as,

$$I_o = I_p - I_d - I_{shunt} \qquad (1)$$

where

I_o = output current (Ampere)

I_p = photo-generated current (Ampere)

I_d = diode current (Ampere)

I_{shunt} = shunt current (Ampere)

The voltage across the shunt resistance and diode will be,

$$V_e = V_o + I_o R_s \qquad (2)$$

Where

V_e = voltage across elements (Volts)

V_o = output voltage (Volts)

I_o = output current (Ampere)

R_s = series resistance (Ω)

The diode current can be calculated as,

$$I_d = I_r \left\{ \exp \left[\frac{V_e}{n\, V_t} \right] - 1 \right\} \qquad (3)$$

Where

I_r = reverse saturation current (Ampere)

n = diode ideality factor

V_t = thermal voltage (Volts)

By using (1), (2) and (3) we can model a PV cell in the MATLAB environment and simulate it by giving irradiance and temperature as inputs. The solar module used in this work is generating 200 Watts. The corresponding V-I and P-V characteristics at 1500W/m² and 25°C is given in Fig. 3 and Fig. 4. As the value of irradiance decreases to 1000W/m² or even lower the characteristics also has lower values of voltage, current and power. Practically we select a value of 950W/m² at which the maximum power point will be 120Watts as in Fig 5 and Fig 6.

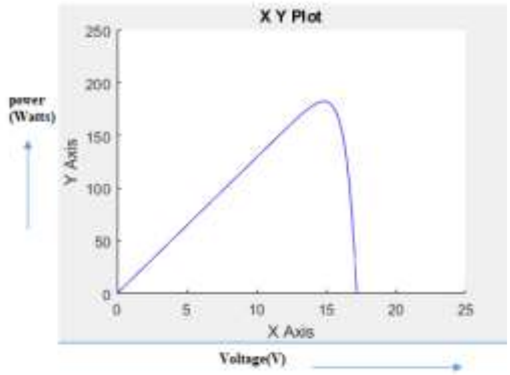

Fig -3: P-V graph of solar module at 1500W/m² and 25°C

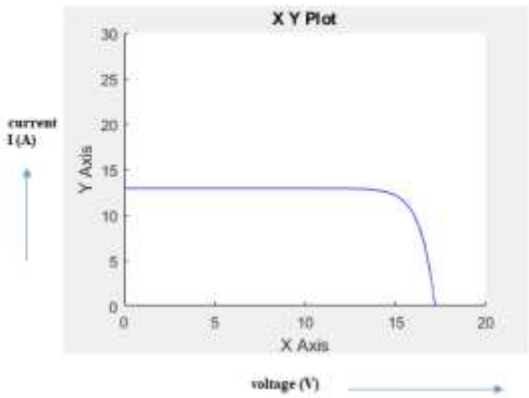

Fig-4: I-V graph of solar module at 1500W/m² and 25°C

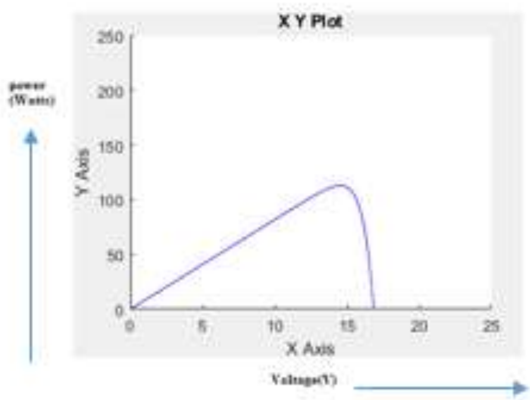

Fig -5: P-V graph of solar module at 950W/m² and 25°C.

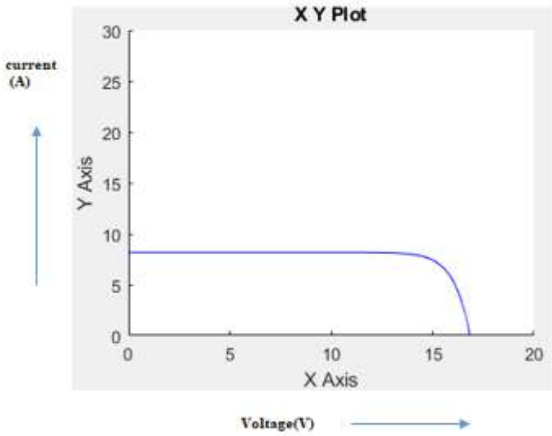

Fig -6: I-V graph of solar module at 950W/m² and 25°C.

The specifications which has been used in this work has the following specifications developed as shown in table 1.

Table-1: Design of solar PV array

PARAMETERS	VALUES
Voltage at Pmax	27.20 V
Current at Pmax	7.30 A
Open circuit voltage	30.80 V
Short circuit current	6.35 A
No. of cells in series	60
No. of cells in parallel	1

3.2 Maximum Power Point Tracking

The charging methods sends energy from PV output to converters. The maximum power point tracking is used to extract maximum power from the given solar irradiance in order to produce desired output. Here Perturb and observation technique [2] is used to extract maximum power. The output power changes with change in voltage across it.

The algorithm shown in Fig. 7 senses the PV voltage and PV current and does perturbation which may result in either increase or decrease of power output. Once the maximum power point is reached the system starts to move to and fro about the point. To decrease this movement step size or duty ratio is decreased. The duty ratio of DC to DC converter is controlled to give optimum voltage corresponding to maximum power point at PV array.

When the source and load impedance equalizes maximum power is delivered by load. The charge controller used here is a DC –DC step up converter which matches both impedances [2]. This algorithm cannot be used for high values of solar irradiances as variables fluctuates at high values.

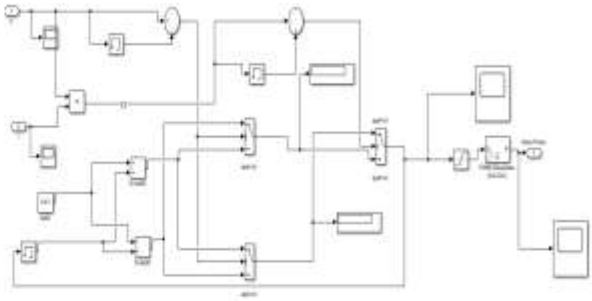

Fig-7: MATLAB model of Perturb and observation technique.

3.3 Boost Converter

There are many converters which are used to either step up, step down or both step up and step down voltages depending upon our need. For regulating the widespread range of output of solar module the DC –DC converter is employed [5]. The solar module voltage at maximum power point will be 17V. But the DC machine is fed with 42V hence boosting of 17 V to 42 V using this converter is preferred [5].

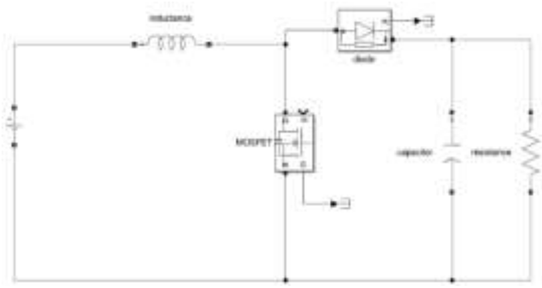

Fig-8: Boost converter circuit

The DC voltage from the PV is stepped up depending upon our need to required value in order to run the motor of weaving machine. The circuit diagram of boost converter is given in Fig.8. The output voltage and duty cycle of boost converter can be calculated by following equations.

$$V_o = \frac{V_i}{1-\Delta} \quad (4)$$

$$\Delta = 1 - \frac{V_o}{V_i} \quad (5)$$

Where

V_o = output voltage of boost converter (Volts)

Vi = input voltage of boost converter (Volts)

Δ = duty cycle.

The working of boost converter at switch on condition has the inductor current rising, and during switch off condition this inductor gets discharged to the load or the weaving machine motor. The values of boost converter used are tabulated in table 2 [5].

Table-2: Boost Converter Design

Sl No.	COMPONENTS USED	RATINGS OF COMPONENTS
1	Load resistance	10Ω
2	Capacitor	1µF
3	Inductor	1mH
4	Input voltage	17V
5	Output voltage	42V
6	Duty Ratio	0.6

3.4 DC Motor of Weaving Machine.

The DC motor is being fed with a voltage of 42V DC and it is running at 120 rpm for irradiance of 1500W/m^2. At an irradiance of 950W/m^2 the value may slightly deviate to 37V DC at 117rpm. Due to MPPT algorithm the maximum power is being extracted at every irradiation value. The armature coil and field windings are separately energized for separately excited DC motor, armature is energized by solar PV module while the field is energized by separate dc source of 230V. A load torque of 5 Nm is applied for the weaving machine. For further speed regulation consider speed regulation feedback [5]. The table 3 shows the parameters of weaving machine DC motor used for simulation.

Table-3: Weaving Machine Motor Design

Sl No.	DC MOTOR PARAMETERS	VALUES
1	Resistance value for Armature	0.784Ω
2	Inductance value for Armature	0.02H
3	Field Resistance	180 Ω
4	Field Inductance	112.5H
5	Mutual Inductance	1.234H
6	Initial current	1A
7	Initial speed	1rad/s
8	Total Inertia	0.05kgm^2
9	Back EMF	230V
10	Load torque	5Nm

3.5 ARDUINO UNO

Here in this work is done using Arduino UNO shown in Fig .9, which helps to follow the MPPT algorithm and PWM controller produces the pulses to be fed to the boost converter. The output PWM signal (output Pin_D9) is a square waveform of maximum voltage of amplitude 5 V, constant frequency of 31.2 kHz, and variable duty cycle D (0% - 100%). ATmega328p microcontroller forms the basic development board of Arduino UNO. It consists of 6 pins ADC of 10 bits resolution, output digital to analog converter (DAC) of 8 bits resolution, several digital input/output pins (6 pins dedicates as PWM outputs), and several analog input/output pins. The USB port connects to computer to exchange data [6]. The characteristics of a typical Arduino UNO board is mentioned in table 4. The main limitation is it do not have a lot of SRAM that limits memory. Power supply of 9-12V at 2A is fed to the microcontroller. Table 4 gives the specification list of ATmega328p microcontroller.

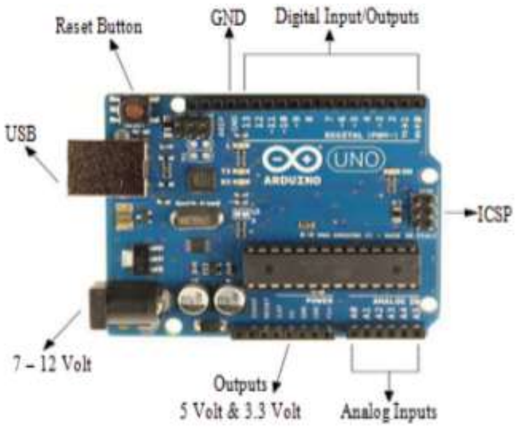

Fig -9: ARDUINO UNO board

Table-4: Specification of ARDUINO UNO board

CHARACTERISTICS OF ATMEG328P	RATINGS
Operating Voltage	5V
PWM Digital I/O Pins	6
Input Voltage	7-12V
Digital I/O Pins	14
Analog Input Pins	6
DC Current for 3.3V Pin	50 mA
DC Current per I/O Pin	20 mA
Clock Speed	16 MHz

4. SIMULATION RESULTS AND ANALYSIS

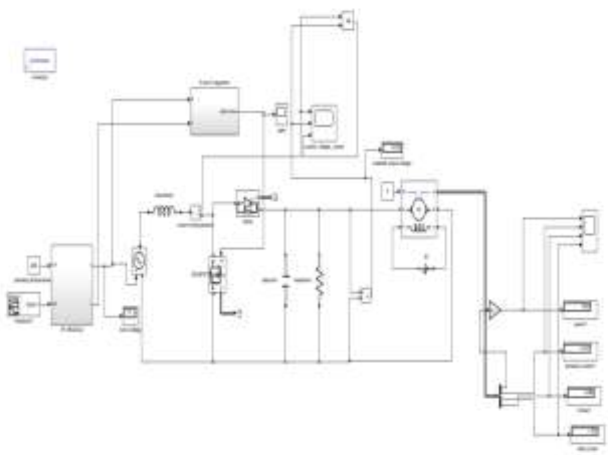

Fig -10: Simulation of whole model.

The overall MATLAB simulation obtained is shown in Fig 10. Here the solar module output is sensed by MPPT to adjust duty cycle and produce pulses for the switch of boost converter which boosts the voltage to be fed to the DC weaving machine.

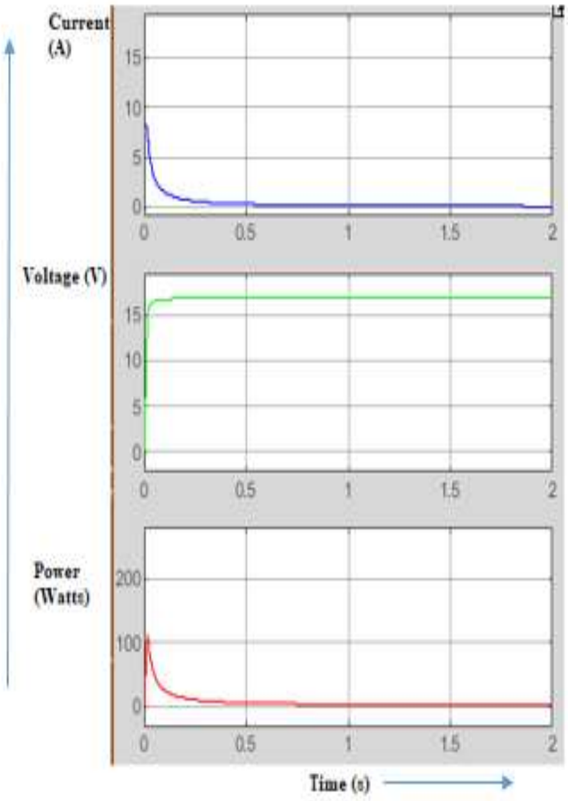

Fig-11: At irradiance of 950W/m^2 solar module output waveforms

The simulation output of solar module at 950W/m^2 is given in Fig 11, where the current, voltage and power of the module is given. The Fig 12, shows the gate pulses with 55% duty cycle calculated by MPPT algorithm, for achieving maximum output at this irradiation level. For a 950 W/m^2 irradiation at 25^{o}C the input to DC machine changes to 37V as shown in Fig 13. Hence the motor speed also reduces to 117rpm. At this time the power produced by DC motor is 81.4Watts. Hence the weaving machine uses MPPT algorithm to adjust the duty cycle of the boost converter to such a value that the maximum output is obtained at any irradiation value. For feeding the output voltage of the PV to the boost converter a controlled voltage source is used.

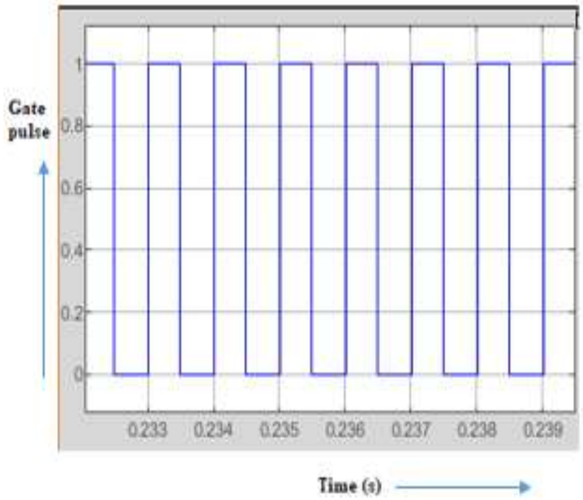

Fig -12: Gate pulse with 55% duty cycle at 950 W/m^2

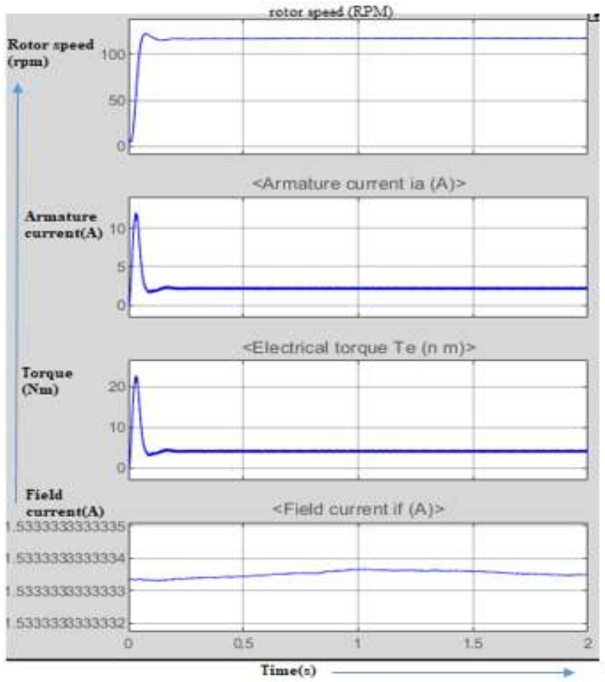

Fig-13: DC motor of weaving machine waveforms at 950W/m^2 and 25^{o}C (a) rotor speed in rpm (b) armature current in Amperes (c) Electrical Torque in Nm (d) field current in Amperes.

The output waveforms of PV module and the corresponding pulse to be fed to the switch of the boost converter for an irradiation of 1500W/m^2 is given in Fig .14 and Fig. 15 respectively.

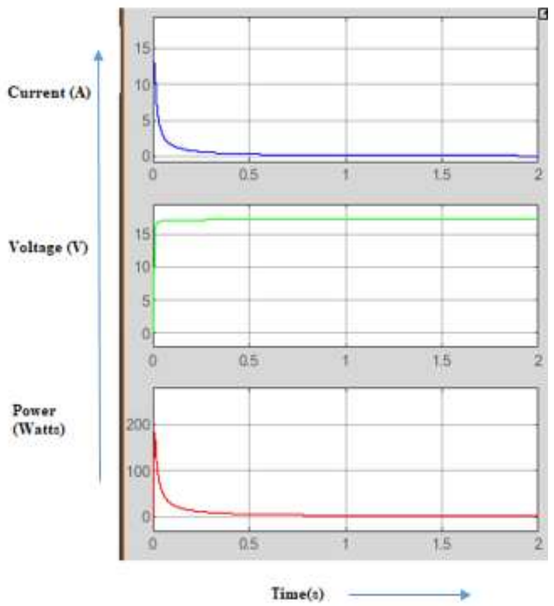

Fig-14: At irradiance of 1500W/m^2 solar module output waveforms

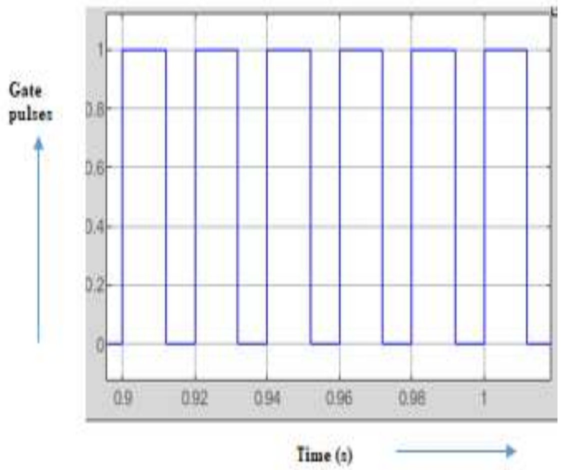

Fig-15: Gate pulse with 60% duty cycle at 1500 W/m^2

The waveforms of DC motor of weaving machine at 1500W/m^2 and 25^{0}C input to PV panel is shown in Fig .16. The input of the DC motor is varying depending on irradiation values. At 42V DC input to motor the speed of rotor will be 120rpm. The current at this time will be 2.5 A. Hence a weaving machine of 105 Watt, 200rpm is chosen for the work. For compensating all the possible losses of the system the solar module is chosen to supply 180 Watts.

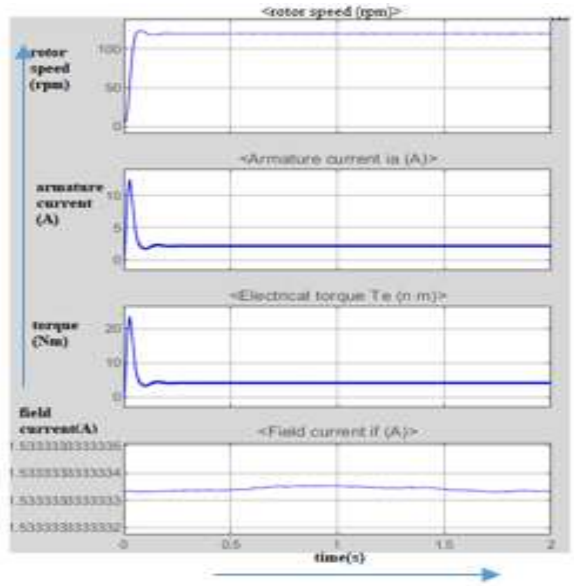

Fig-16: DC motor of weaving machine waveforms at 1500W/m^2 and 25^{o}C (a) rotor speed in rpm (b) armature current in Amperes (c) Electrical Torque in Nm (d) field current in Amperes

A comparison of simulated outputs obtained in both the cases of irradiations are tabulated in table 5. As the value of irradiation decreases the speed of machine also decreases.

Table-5: Comparison of simulated results.

PARAMETERS	CASES	
Irradiation (W/m^2)	1500W/m^2	950W/m^2
PV VOLTAGE (V)	17.14	16.18
PV CURRENT (A)	13	8
PV POWER (WATTS)	190	120
DUTY CYCLE (%)	50	55
BOOST VOLTAGE (V)	34.14	37
MOTOR SPEED (RPM)	119.2	117
MOTOR ARAMATURE CURRENT (A)	2.41	2.2
MOTOR TORQUE (Nm)	4.02	4.61

5. HARDWARE RESULT AND ANALYSIS

For this work the use of Arduino was preferred for doing three main operations

1. Provide frequency for PWM signal generated.
2. Calculate the power by reading voltage and current of boost converter to be fed to motor.

3. Modify the duty cycle of PWM to track the maximum power point by implementing 'Perturb and Observe' algorithm that compared the previous power to new power.

The hardware implementation can be explained using Fig .17.

Fig-17: Hardware implementation

The components used for the hardware implementation are listed in table 6.

Table -6: Components of Hardware

COMPONENTS	SPECIFICATIONS
PV PANEL	6V,5 Watts
OPAMP	741
RESISTOR	100Ω, 1KΩ, 0.1Ω 5W, 10KΩ, 100Ω 5A
CAPACITORS	33.33 µF
INDUCTOR	5mH
AMMETER	2A
DC VOLTAGE SUPPLY	15V
MOSFET	IRFZ44
DIODE	1N4148, DB258
DC MOTOR	12-15V ,200RPM

A current to voltage converter will produce a voltage proportional to the given current. This circuit is required while measuring PV current and the measuring instrument is capable only of measuring voltages and the need is to measure the current output. This is implemented using an OPAMP circuit. The table 7, shows the final analysis of the hardware, the output voltage of boost converter increased until it reached the maximum value with the increase of duty ratio. Here two sets of values are manually fed and chosen as current from PV source and also voltage of PV source is also manually fed to ARDUINO UNO pins A0 and A3 respectively. The pulse from ARDUINO pin 9 fed to switch in the boost converter. By MPPT the duty ratio is varied and we see that boost output voltage increases for the fed input voltage. Hence the MPPT algorithm is executed and it is seen to work properly and give results. This boost output voltage is then fed to a DC motor of 24V 200rpm rating which runs at highest speed at maximum voltage while speed decreases as the voltage fed decreases.

The table 7, can be analyzed by considering two sets of current from PV being considered. At the first three values of PV output the PV current is set to 0.8A while in the next three sets of value PV current is 0.2A. The first three cases has a boosted output along with their duty cycles changing due to MPPT shown in Fig 18. Since we consider a PV output of 6V and DC motor input to be 12-15V we design a boost circuit with (4), (5). Here we take the switching frequency as 14 KHz.

Table -7: Final analysis of Hardware implementation

SL No.	V_ pv (V)	I_pv (A)	I_pv (in terms of voltage) (V)	Boost input voltage (V)	Boost output voltage (V)	Duty ratio (%)
1.	1.8	0.8	1.2	8.7	9.06	10.14
2.	2.0	0.8	1.2	9.1	12.50	43.26
3.	2.4	0.8	1.2	11.2	15.61	64.81
4.	1.8	0.2	0.9	5.7	8.48	11.12
5.	2.1	0.2	0.9	9.2	13.63	50.6
6.	2.3	0.2	0.9	12.4	16.10	80

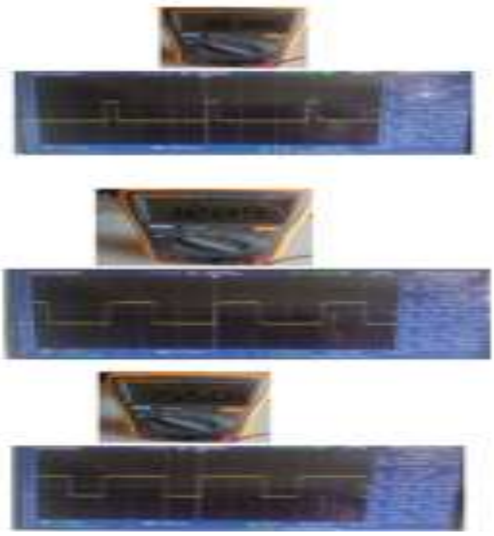

Fig-18: Boosted output for PV current of 0.8A

6. CONCLUSION

The prototype successfully locates the maximum power regardless of what the solar panel voltage production may be, as long as it is within the range of the 0-6V, since 6V is the limitation of the available laboratory equipment. Hence, this prototype can be used to track the maximum power point of different solar panels and help customers determine the most efficient solar panels available out there in the market, reliably.

The Arduino UNO uses a language that is very simple to program and there are many available resources, however, the actual chosen hardware was not very compatible with our circuit. So choosing a different microcontroller that better fits the circuit would help improve the accuracy of measuring and calculations as well as simplifying the overall circuit and the code, as mentioned in design modification section. These are all possible improvement points that can be accomplished in the future.

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