Designing a Maximum Power Point Tracking System for a Monocrystalline Silcion Solar Module Using the Arduino Microcontroller and Synchronous Buck Converter

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Maximised power output and efficiency in a photovoltaic (PV) system for specific conditions can be obtained by using a maximum power point tracking technique (MPPT). Many tracking algorithms have been developed for this purpose. This paper presents the design and methodology used to create a photovoltaic charge controller that uses the algorithm developed for maximum power point tracking. The charge controller presented in this work is not only designed to maximise the power from the solar module but also contains added features that make the system beneficial to the researcher. The suggested system has used Perturb and Observe (P&O) MPPT method for the design and implementation. In this technique, the controller delivers the PWM (pulse-width modulation) signal using the Arduino microcontroller to regulate the voltage. A DC-DC (direct current-direct current) synchronous Buck converter is used to interface the PV module with the load. The results are gained for two systems:- using a microprocessor controlled MPPT operating from a PV module, and a PV module connecting directly to the load. It is found that the MPPT is effective, providing the highest power to the operating load under changing outdoor conditions. The experimental results indicate that for cloudy days, it is suitable to use MPPT control, which that will enhance the PV production power compared to situation in which the PV module is directly connected to a fixed resistance.

Keywords: *photovoltaic MPPT system, P&O algorithm, DC-DC converter, Arduino microcontroller, tracking techniques.*

1. INTRODUCTION

Research is concerned with increasing solar module efficiency and lowering it is costs due to fact that solar energy has increasingly good potential. Many countries have begun to understand solar energy's potential to economically offset part of total energy needs economically. Solar energy is the cleanest energy used on Earth, so it can help to reduce greenhouse gas emissions and it will play an important role in climate-friendly scenarios in the coming decades [1, 2].

"Abundance" and "zero emission" factors are the conventional power generators that are the main benefits of solar energy. However, there are limitations because this energy is not available in the night and it is not constant even during the daytime. The atmosphere and the surface of the Earth together absorb 71% of incoming solar radiation, so they must radiate that much energy back to space for the planet's average temperature to remain stable. The efficiency with which solar energy is harvested and used, is this the basic limitation of solar energy use. Despite the availability of many technologies in solar panels and solar cell manufacturing, the highest efficiency of these panels transforming solar energy into electricity does not exceed 30%. This factor (solar panel efficiency) is one of the reasons why harvesting solar energy is not used as a way of producing energy [3, 4]. Many researchers [5-9] have studied the effects of operating temperature on the performance of free-standing PV panels and simple semi-empirical explicit correlation, including the environmental conditions. They have also studied grid- connected PV/wind energy stations, irradiance effect and other climatic conditions on silicon solar cell.

Researches found that, the power depends linearly on panel temperature. Solar cells experienced significant seen fabulous development since the first issue of the Journal Solar Energy Materials in 1979. There are still many problems that solar panels suffer from, however, such as the effect of temperature, light absorbing efficiency and electron-hole recombination rate. To make up for low levels of solar radiation, there are a few ways to improve the performance of solar panels, including direct methods such as solar tracking and concentration of light, and indirect methods like the one covered in this research, the maximum power point

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tracking techniques (MPPT). The solar module tracking method keeps the solar modules face the sun at any point of the day. This can be done by maintaining the solar modules on a single or double axis; this controlled mechanism uses a sensor to track sunlight intensity, while concentration of light using mirrors or lenses can be arranged above or around the solar array to increase the amount of radiation that hits the panels [10, 11].

One of the indirect methods to maximise solar module efficiency involves the use of MPPT, in which solar panels provide electricity to an on-grid or off-grid connection such as charging batteries. The MPPT charge controller creates a balance between the output voltages of the panel to match the voltage level of the battery.

A current versus voltage (I-V) characteristic curve under constant uniform solar irradiance is an electric property for every photovoltaic (PV) module (see Figure 1). There is a unique point on the knee of this curve, known as the maximum power point (MPP). In this way, the panel produces maximum power and operates with maximum efficiency. If the solar module is connected directly to a load, via a so-called "direct-coupled" system, the I-V curve and load line intersection are the operating point of the systems. Generally, this operating point is not at the PV module's MPP, as can be clearly seen in Figure 1.

PV module is frequently oversized to ensure that the load's power requirements can be supplied in a direct-coupled system. This leads to a more expensive system [12, 13]. To overcome this problem and find an efficient and inexpensive solution, the MPPT technique can be used to validate the PV module's operating state at the MPP. The working principle of MPPT is to control the voltage and current of the solar panel output, regardless of the load tied to it. The MPPT can identify and track the MPP of the PV module if properly controlled by MPPT algorithm. However, the MPP site in plane I-V is unknown a priori. It should be located, either through model calculations, or by a search algorithm.

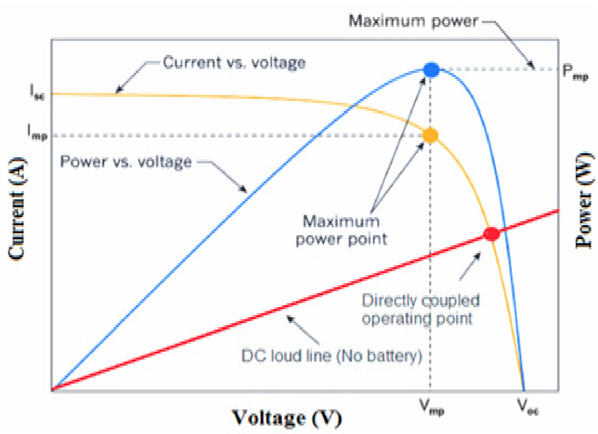

Figure 1. PV module I-V characteristic curves [14]

This is more complex in reality of the fact that the MPP depends on a nonlinear solar irradiance and temperature, as shown in Figure 2. This figure shows a family of solar module I-V curves under increased radiation, but at a constant temperature. The Perturb and Observe (P&O) algorithm is used in this work because the hardware required is simple and the implementation cost is low. The algorithm introduces the variable of perturbation as a reference value for the terminal current of the PV panel, a terminal voltage of the PV panel, or the duty cycle of the MPPT converter.

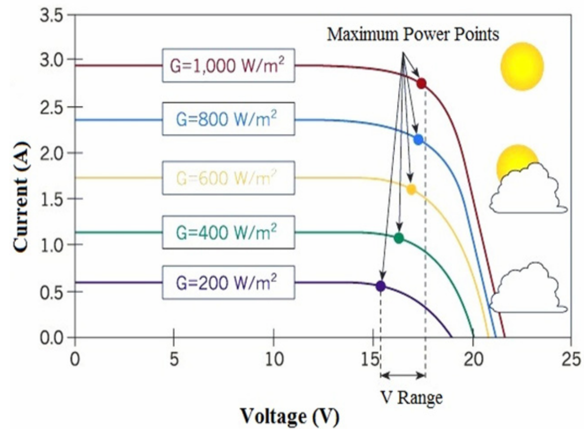

Figure 2. Solar module voltage-current at different solar irradiance levels [14].

2. MPPT SYSTEM OVERVIEW

The overall system block diagram is exhibited in Figure 3. The electricity generates when sunlight incident encounter the solar panel via the photoelectric effect. The MPPT charge controller is fed by this unregulated output power from the solar panel, using the sensors of the charge controller to measure the voltage and current of both the PV module and the battery. Next, a regulated output is supplied to the battery. The goal is to make the PV module operate efficiently using the MPPT algorithms implemented in microcontroller software.

The MPPT charge controller is made up of two basic parts: a microcontroller to track the MPP and a converter to convert the generated voltage into a suitable level for the load. An algorithm runs on the microcontroller to track the MPP. Input and output processing of the photovoltaic system is one of the microcontroller tasks. These tasks involve analysing values from the sensors, controlling the converter duty cycle, monitoring system performance and anomalies, transmitting data via the internet and outputting data to an LCD (liquid crystal display).

The heart of the MPPT charge controller hardware is the DC-DC converter. The converter is usually used in DC power supplies and DC motor drives. MPPT uses the DC-DC converter for the same purpose mainly for regulating the output voltage from the PV module at MPP and to transfer the maximum power it providing load matching.

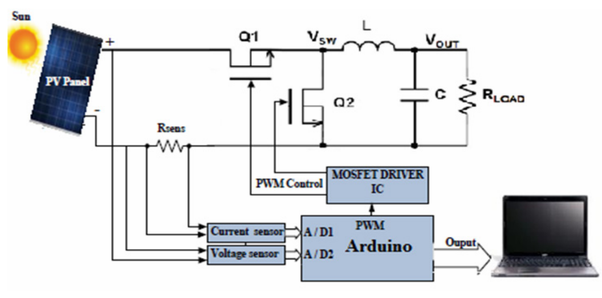

Figure 3. Hardware of the proposed MPPT.

A step-down synchronous Buck converter is used in this research to step the voltage down from a PV model to a lower desired level. The microcontroller changes the duty cycle of the basic converter switch and the input impedance of the converter implicitly until the system reaches the MPP.

3. MPPT CONTROL ALGORITHM

MPPTs control the output of the photovoltaic outlet power systems because they lead to the highest performance of the PV system output power for a given set of conditions, and they therefore maximise the performance of the solar module. Consequently, an MPPT can minimise the system cost. Using an MPPT algorithm and MPPTs is entails finding and maintaining the operation of the system at the maximum power point. P&O is used and described in the following subsection because this method requires less hardware complexity and low-cost implementations.

MPPT operate at frequencies ranging between 20 and 80 kHz. The benefit of high-frequency circuits is that they can be operated with small components [15].

Due to its simple structures and easy implementations, the Perturb and Observe algorithm is widely used in MPPT systems. This technique is known as the perturbation and observation algorithm because it works by continuously varying the operating set point of the solar module. Consequently, it discovers the corresponding fluctuation of the outlet power in order to find the next change to approximate to MPPT [16].

The principal of the P&O algorithm is that the perturbation variable may be assumed as a set point for the terminal voltage of the PV panel, a terminal current of the PV panel, or the duty cycle of the MPPT converter. Thus, the operating voltage of the PV panel is perturbed by a small increment, determining the resulting change in power. Figure 4 shows a clarification of the solar module outlet power against the module voltage at a specific irradiance and constant temperature; the spot indicated represents the MPP [17].

If it is assumed that dual operating states are point A (dP/dV □ 0) and point B (dP/dV □ 0), as highlighted in Figure 4, it is clear that the operation point is on the left side of MPP if the voltage at point A is perturbed and (dP/dV □ 0). This algorithm will then increase the photovoltaic module voltage and move the operating point towards the MPP. It is clear that the operating point is on the right side of the MPP at point B when (dP/dV □ 0). The mentioned algorithm will then decrease the photovoltaic module voltage [14].

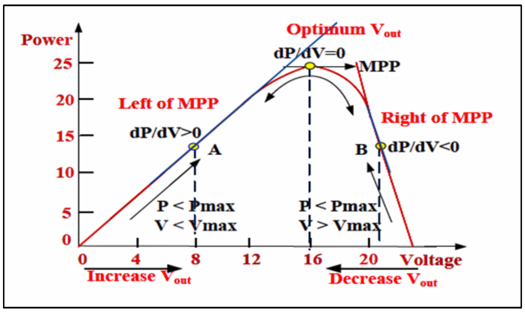

Figure 4. The operation region on the power characteristic curve [14].

4. DC-DC REGULATORS

In any solar module system the MPP varies with the variation of ambient conditions. For each solar irradiance and temperature there is one optimum output voltage for the PV module to operate with.

A DC-DC regulator is required to make the PV panel operate at its MPP and maintain an optimal battery charging process (i.e. desired battery level). The process will be done up or down the outlet volt value of the solar module. Switch mode DC-DC converters are utilised to render the unstable DC input into stabilized DC output at the set point voltage level. The basic MPPT system hardware is a DC-DC current converter and without it, the maximum power cannot be achieved [18].

A different type of DC-DC converter can be made from basic components of the DC converter (power switch, inductor, capacitor and diode). To stabilise the solar module voltage at MPP and match them, the MPPT system uses a DC converter by providing maximum power transfer. The most efficient way to permit a pulse width modulation to frequency control and the switch duty cycle is MOSFET (metal-oxide-semiconductor field-effect transistor). The amount of power transferred from the input to output depends on the high duty cycle. There is no need for analogue to digital signal conversion from the microcontroller to the MOSFET because the signal remains digital from the source and this is one of PWM advantages [16].

There are various different types of DC-DC converter such as the Buck/Boost, Cuk and Single Ended Primary Inductor Converter (SEPIC). In the Buck converter, the input voltage is higher than the output voltage, while the Boost converter works on a higher output voltage since it has less input voltage. The Buck/Boost and Cuk converters have the same characteristics: the input voltage is higher or lower outlet voltage, and the polarity of voltage between input and output are reversed. However, the SEPIC converter can have a low or high input voltage with maintaining the polarity between input and output. The main type of DC-DC converter in this project is the synchronous Buck converter [19]. The synchronous Buck converter is used to reduce voltage level from a higher to a lower voltage.

Today high-efficiency solutions to portable electronics are made using synchronous buck converters. This gives a stable voltage that is lower or equal input and can minimise power loss by supplying high currents. Figure 5 shows that the synchronous Buck converter has two power MOSFETs, an output inductor, and an output capacitor [20, 21].

For direct connection of the circuit input voltage with the high side MOSFET (Q1) and when Q1i is turned on, current is given to the load through the high side MOSFET. Within this time, the low side MOSFET (Q2) is turned off and the inductor current increases, charging the LC filter. When Q1i is turned off, Q2i turns on and the current is delivered to the load through the low side MOSFET. Consequently, the inductor current decreases, discharging the LC filter. Q2- the low side MOSFET- presents an added function when both MOSFETs are turned off. This locks the voltage of the switch node through the body diode to avoid VSW from going too far negative when the high side MOSFET is first turned off [21, 22].

Figure 6 illustrates the synchronous Buck converter and its basic waveforms in continuous conduction mode. The total change in the inductor current is due to peak to the peak inductor current. The LC output stage which supplies a regulated DC voltage at the output adds smoothing to the switch mode output voltage. A direct short to the ground occurs by shooting both MOSFET high side and low side. Equal values of input and output voltage are available when the duty cycle, D is equal to one and then the high side MOSFET is on 100% of the time. A duty cycle of 0.1, leads to the high side MOSFET being on 10% of the time and output voltage on approximately 10% of the input voltage.

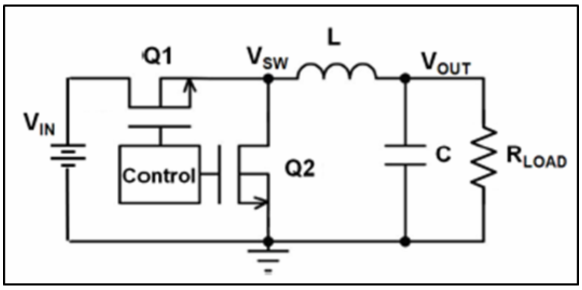

Figure 5. Synchronous Buck converter [21].

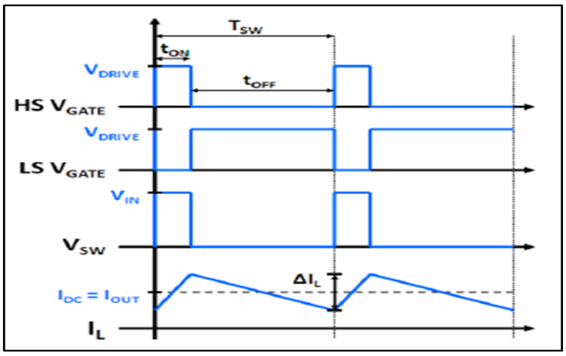

Figure 6. Synchronous Buck converter waveforms [21].4

5. MPPT SYSTEM COMPONENTS

5.1 Solar Module

A 50W PV module consisting of 36 single-crystalline solar cells is used as the power source to test the MPPT system. The module's electrical characteristics are supplied by the manufacturers at reference conditions: solar irradiance (G) = 1000 W/m^2, air mass ratio (AM) 1.5 solar spectrum, and solar module temperature (T) = 25 ^{o}C). These electrical characteristics data are: V_{oc} = 21.8V, I_{sc} = 3.25 A, IMPP = 2.9 A, and VMPP = 17.2 V. Sunlight is used as a natural irradiance source in the proposed work.

To obtain maximum power from the solar module, the operating point should coincide with the MPP at different atmospheric conditions. The process of extracting maximum power from a module is performed by the maximum power point tracker. The MPPT charge controller dynamically adjusts to these changing conditions, which makes it more efficient than other static charge controllers.

5.2 Charge Controller Hardware

The charge controller is designed and manufactured on a prototype printed circuit board (PCB) (see Figure 7). This PCB will house the microcontroller and DC-DC synchronous Buck circuitry in addition to the sensors, Wi-Fi module, and display peripherals. Table 1 shows the MPPT charge controller components.

In order to make the overall system more user-friendly, an LCD screen will be included to display various sensor data. The serial enabled LCD specifically chosen. The fact that this device uses I2C (inter-integrate circuit) communication allows for easy integration with the ATmega328P and reduces the number of pins required to communicate with the screen to only 4 pins. The LCD has an adjustable backlight features and is monochrome. It will provide sufficient detail for the system while consuming little power to maintain the best efficiency, drawing only 60 mA during normal operation (see Figure 8).

Table 1. Components of MPPT charge controller

No.	Components
1	Synchronous Buck converter
2	The inductor
3	ESP8266 WiFi module
4	LM2596 step-down voltage regulator
5	Battery current sensor
6	5A safety fuses for battery
7	Output power connector to the battery
8	Output power connector to the load
9	Input power connector from the solar panel
10	5A safety fuses for battery
11	Solar current sensor
12	Arduino Nano
13	AMS1117 3.3V step-down voltage regulator

The microcontroller selected is the ATmega328P with an Arduino boot loader. The hardware functions of the design charge controller and all the digital and analogue pins needed by the sensors are available through microcontroller offers.

The 16 MHz clock speed, I2C communications, TTL serial, and the programming language are robust and they are deciding factors in this decision. Figure 9 shows the ATmega328P connection to the peripheral devices. The ESP8266 WiFi module is joined to the hardware of microcontroller UART ports. The LCD screen uses a digital I/O pin to communicate with the microcontroller. The voltage and current sensors use four analogue input pins, and a voltage between 0 and 5V is read in. Delivering the right charging voltage to the load will be the task of the microcontroller controlling the Buck converter.

A one pulse width modulation (PWM) line and one additional digital output are needed to stabilise switches that turn the buck converter of the MPPT circuit on or off [24, 25].

Standard voltage divider techniques are implemented to sense the voltage of the solar module. The resistor values are chosen so that the designated pin is fed an analogue voltage between 0 and 5V so the microcontroller can interpret and extrapolate the actual voltage value.

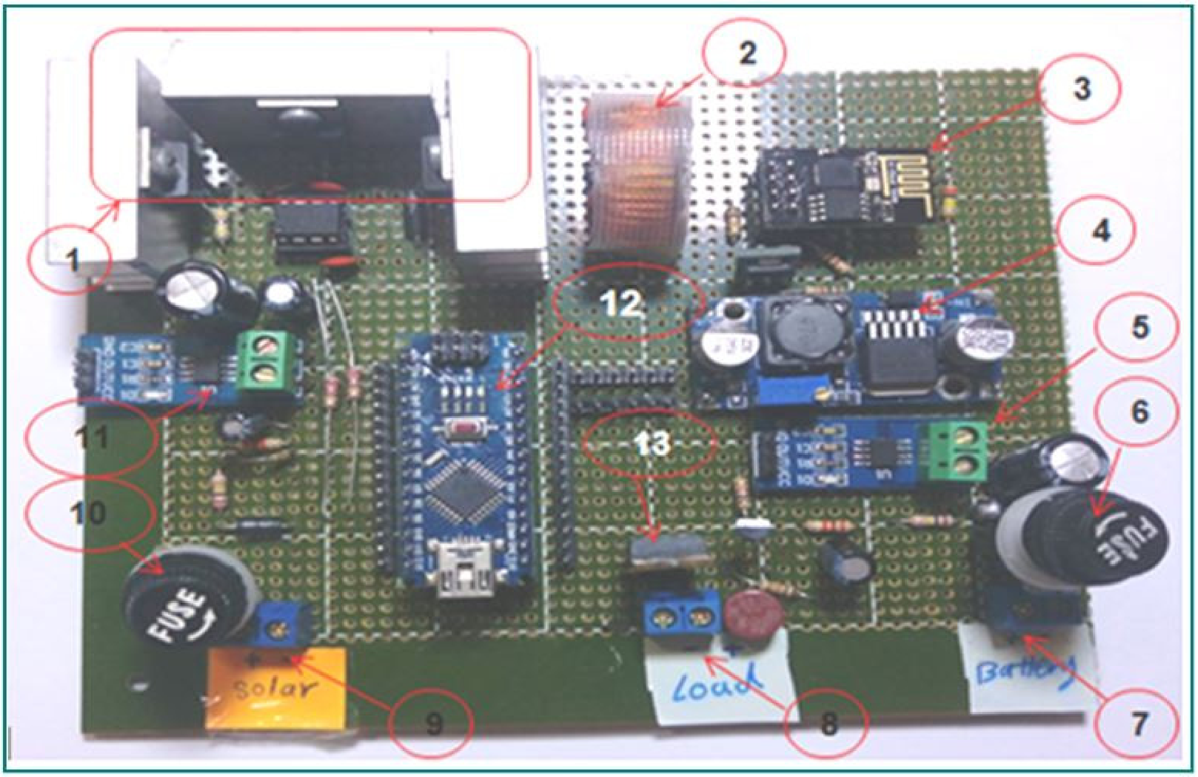

Figure 7. Configuration of MPPT charge controller.

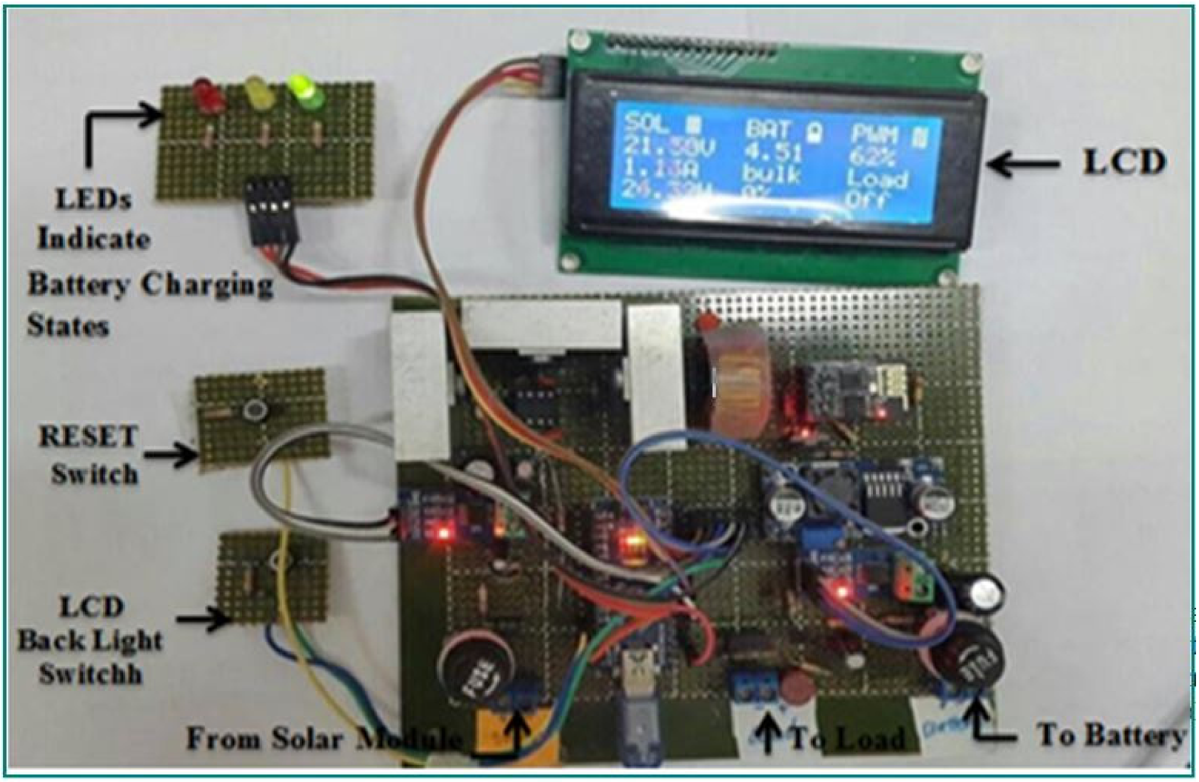

Figure. 8 MPPT charge controllers with peripheral devices.

Similarly, the current sensors send an analogue voltage value to the microcontroller, which determines the nominal value of the current. The current sensors function alongside the voltage sensors to sense the current coming into and out of the charge controller. The ACS712 Allegro -5A current sensor is chosen because it is rated up to 5A. The advantage of the design of this specific model is that it is a very accurate and low power circuit.

The DC-DC converter is a 50W synchronous Buck converter working at a switching frequency of 50 kHz. It is used to interface the PV panel output to the load and to track the maximum power point of the PV panel. The parameters of the converter are given in Table 1. The system output parameters and their load determine the first step design in the Buck converter circuit. The operation frequency, the size of the inductor and the output capacitor size are very important since they determine the ripple size of current and voltage. It is preferred to have as smaller a ripple of current and voltage as possible [21, 22].

The PWM of higher frequencies reduces the efficiency of the system because of losses in MOSFET switching, so a trade-off has to be achieved. Calculating the value of the inductor is critical in a step-down switching converter design that meets the design constraints of the end system [21, 23].

For this research, the inductor has a toroidal core and it is hand-wound from an old computer power supply. To reduce the voltage overshoot and the step-down converter output, a ripple in the output capacitance is required. The suitable MOSFET for a particular design includes reducing the switching losses and finding out how to rely on the switching frequency, current, duty cycle, and shift time ups and downs of these losses. The half-bridge driver is an IC designed specifically for driving MOSFETs outputs. The driver takes the PWM signal coming from the microcontroller then drives high and low-side MOSFET. The driver used is IRS2104, a half-bridge driver manufactured by International Rectifier. This driver allows 2- PWM signals to be connected to high- and low-Side MOSFET outputs, and it also provides the opportunity for MOSFET's dead band switching fine tuning.

5.3 Charge Controller Hardware

The main loop of the program consists of the following four functions:

- Read_sensor_data
- Charge controller
- Print_data_LCD
- Transmit_data_ESP8266

The software program is implemented in The ATmega328P microcontroller. The ATmega328P microcontroller is pre-loaded with the Arduino boot loader. Arduino has a USB cable allowing for easy chip programing and directly eliminating the need for an external programmer.

The Arduino has an internal development environment (IDE). This IDE is entirely free and open source. The Arduino language is easy and simple and it is very simple than the famous C++ language. This makes learning it fast in. Using the digital and analogue pins make use of the various protocols of communication. Arduino community easy interfaces are available in many libraries.

6. EXPERIMENTAL WORK

A testing plan was developed to ensure that all of the features of the MPPT system work as expected. First, during initial prototyping, each part was tested at the component level to confirm that it works individually before integrating it into the system. Each of the current sensors, voltage divider circuits and LCD screen were connected to the Arduino development board and checked for accuracy. The DC-DC regulator circuitry was also replicated on a solder less breadboard to demonstrate its functionality before its layout into the PCB.

Figure 9. Arduino microcontroller interfacing with peripherals.

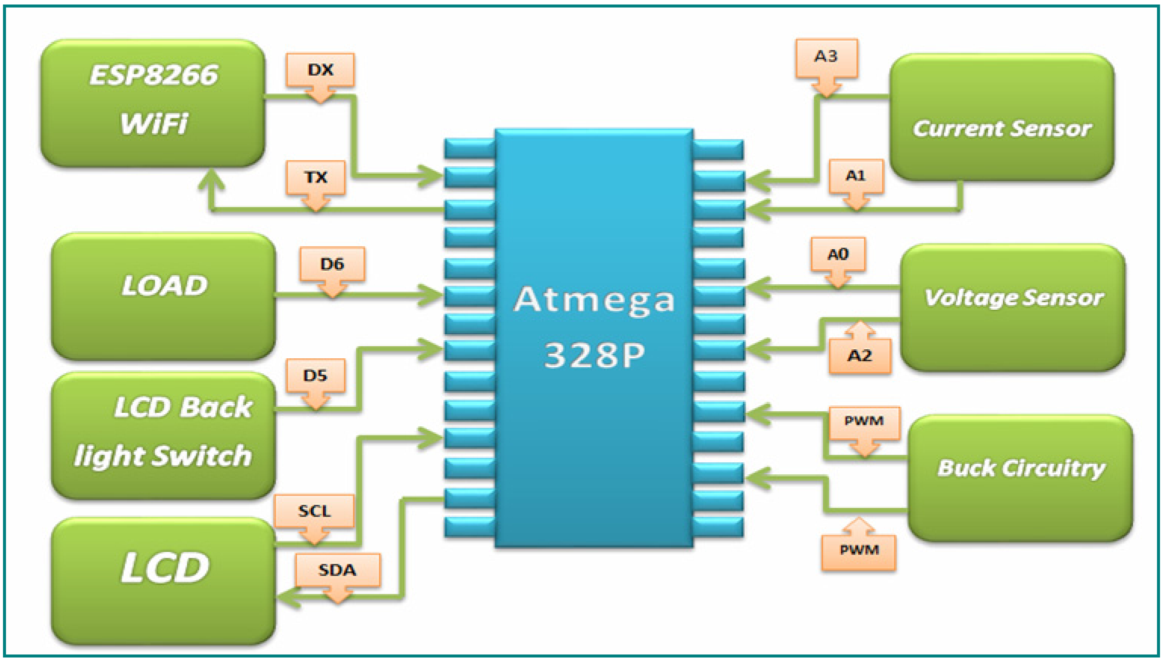

Figure 10. Setup of the experimental work.

Figure 10 shows the experimental system setup that will be mounted onto a custom designed aluminium frame with caster wheels on the bottom for easy movement. The performance of the MPPT charge controller was tested for 65 days from 15th September to 20th November 2016 under different solar radiation fluxes and temperature values. The tests were performed in outdoor conditions in Baghdad city. The results obtained from the proposed design were compared with corresponding results of the solar module connected directly to the resistive load. The value of this resistance was set so that the panel was able to output the maximum power.

7. RESULTS AND DISCUSSIONS

The MPPT system was constructed and tested with a 50 W maximum output power solar module. Figure 11 shows a comparison between the calculated and measured voltage regulation, as well as the validity of the proposed design. This includes the solar module, the charge controller (containing a DC-DC converter) and an Arduino microcontroller in which the MPPT algorithm was implemented. These tests were carried out to measure the characteristics of the Buck converter and the MPPT charge controller.

The first aspect of the converter is to verify the voltage regulation. The voltage regulation was found by measuring the input and output voltages at different duty cycle levels. The output voltage was divided by the inlet voltage to obtain the regular voltage. Figure 11 summarises comparisons between the measured voltage regulations of the converter and the corresponding expected voltage regulation values that were calculated from the following equation

$$D = t_{(ON,HS)} \Big/ \left(t_{(ON,HS)} + t_{(OFF,HS)} \right) \cong V_{OUT} / V_{IN} \quad (1)$$

The experimental results were measured with the converter connected to the PV panel as an input source, and at fixed input voltage.

Figure 11 summarised a linear relationship for the voltage regulation results of the actual converter with the calculated ones up to an 80% duty cycle. From the proposed results there are two important points: firstly, for the regulation ratios 0.05 up to 0.75, it is found that the converter is acting as expected; secondly, something can be learned from the results of a duty cycle of 75%, where the calculations do not take into account real-world parameters and physical limits on components. The results from the equation were considered with the assumption that the converter connected to an ideal voltage supply at 17 volts. This voltage supply was said to be able to supply an unlimited current while staying at the 17-volt level. The PV panel, however, is not an ideal source. This contributes to the limiting factor on the voltage regulation of the circuit during the higher duty cycles. As previously presented a PV panel has a finite limit on the amount of voltage, current and power it can output.

When the converter is running at higher duty cycle values the PV panel is outputting very high currents, close to the short-circuit value. Since the panel has a finite amount of power it can produce, this high current causes the panel's output voltage to become much lower. This high current, low voltage output characteristic effectively limits the voltage regulation of the converter. These output characteristics don't allow the circuit the necessary power; it needs to properly step-down the output voltage to the expected level.

Another attribute of the converter that needed to be tested was the circuit's efficiency. Testing of the efficiency was performed with the converter connected to the output of the PV panel. The input current and voltage were measured using solar module analyser PROVA 200. The output current and voltage were measured using a multi-meter. The test was performed on the converter alone without any of the current and voltage sensing technologies in place. Figure 12 illustrates the results of the efficiency test. It can be seen that the effective result for a duty cycle of 95% is not included in the graph. This is simply because the result is so much lower than the others it makes the graph difficult to view. It's also clear the graph that the efficiencies are highest when the duty cycle is lowest. This was expected due to the large inductance values. The final and most compelling aspect of the graph is the almost uniform efficiency over the band of duty cycles that the MPPT system will use on most normal days. This band covers the duty cycles from 5% to 75%. Over this area, there is a minimum efficiency of 92.4% and a maximum of 95.4%.

A first MPPT test performed on a cloudy overcast day for the solar module is available in Figure 13. For cloudy days is better to use the MPPT algorithm than the fixed resistance for the best power output. This behaviour is due to that the fixed resistance was set to obtain the most power on a sunny day as recommended by the PV panel manual. When clouds are present the fixed resistance cannot compensate for them in this way the algorithm is able to. The algorithm was able to adjust slightly to compensate for the differing thickness of each passing cloud in order to obtain the highest power output at any point in time. The solar module connected to the MPPT system clearly has an advantage over the system with a fixed resistance. The fixed resistance panel's output is dependent on how much sunlight is getting through the clouds and only that. The fixed resistance cannot change the power point that the panel is currently operating at to ensure maximum power point output. The converter can be adjusted by the algorithm to compensate for the clouds.

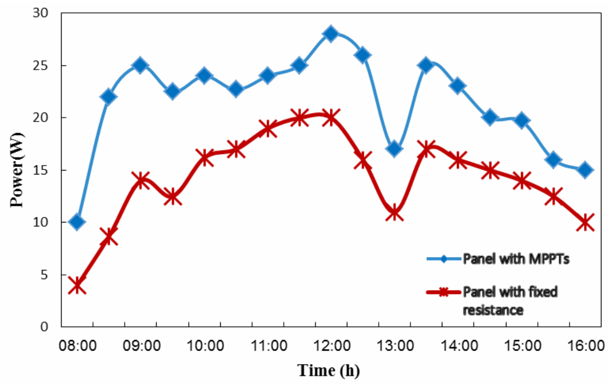

Figure 11. Calculated and measured results of voltage regulation.

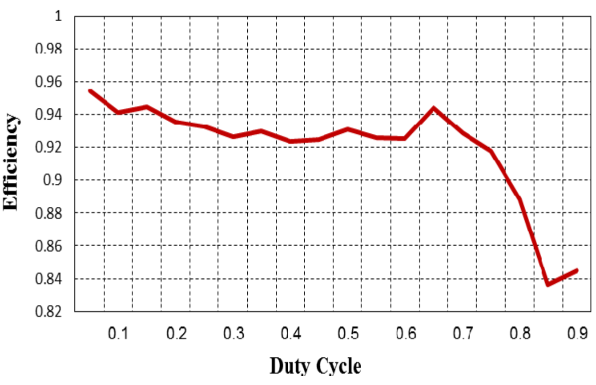

Figure 12. Efficiency of the buck converter.

Figure 14 summarises the next MPPT test for the time just after sunrise, when the sun was high in the eastern sky. This test showed the effectiveness of the algorithm and its speed. The power of the solar module steadily increases as the sun goes up. It was found that the power output by the panel connected to the converter and controlled by the algorithm was rising higher and faster than the power output by the panel with a fixed resistance. The most noticeable thing from Figure 14 that the power is initially lower at 0.5W when the controller is first turned on; however, the algorithm quickly searches for the MPP and allows the panel to operate there (about 3.8W). This is because of the transition from low to the highlight condition as the sunlight reaches the solar panel and the panel begins to generate power. This increase in power value happens when the converter is operating at a duty cycle of 5% and it tries to climb higher. As a protection for the converter, the algorithm is never allowed to set the duty cycle higher than 95% or lower than 5%. When the duty cycle tries to exceed one of these values it is reset to a value of 50%. When the reset occurs, the algorithm again searches for the MPP of the PV panel. When the system finds the MPP it will be able to hold there for a short period of time, before being reset again. Over the same time frame, the panel with fixed resistance output increases from 0.25 to 2.05W.

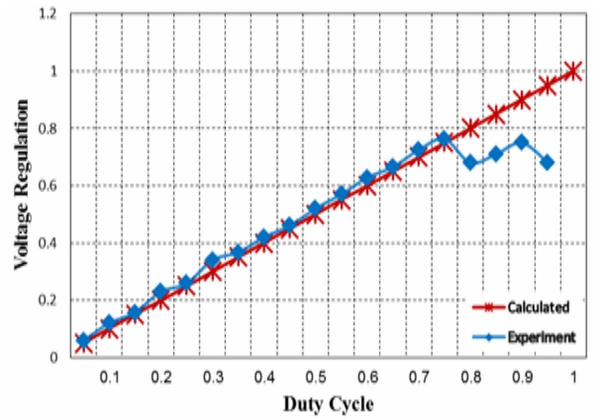

Figure 13. Output power of solar module with the proposed MPPT system. which directly connected to a fixed resistance on a cloudy day.

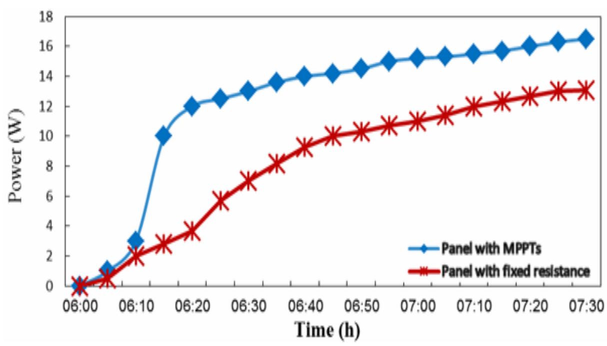

Figure 14. Output power of solar module with the proposed MPPT system that directly connected to a fixed resistance at sunrise.

Figure 15 summarises the final MPPT test. In this figure, the system is run for almost a full sunny day (no clouds in the sky). The figure shows the same results as those presented in Figure 14, where there is a significant improvement found when using the system compared to using a fixed resistance.

A notable aspect of this figure is how much of an improvement is achieved when the system is at maximum power output because the sun is at its maximum point in the sky. This large improvement is due to the test being performed during a winter month. In the winter months, the sun is at a lower angle in the sky so it is not hitting the PV panel straight on. This causes less light to be absorbed within the panel than would be absorbed during a summer month. The lower light absorption due to the angle can also be seen in that the maximum power output barely exceeds 28 watts when the panels are rated at 50 watts.

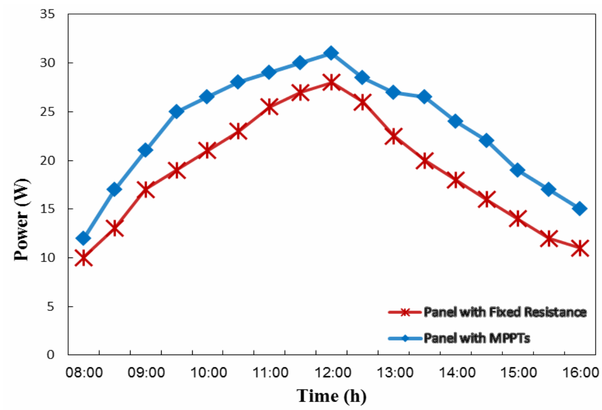

Figure 15. Efficiency of the Buck converter.

8. CONCLUSION AND REMARKS

This work presented the design for a MPPT charge controller based on the Arduino microcontroller. The control algorithm performs the Perturb and Observe MPPT function, which allows, to get the highest power produced by the solar module to the load for a given solar irradiance. This method improves the power performance as compared with systems that work without the MPPT technique. This procedure led to a reduced cost and size in the PV solar module. The results showed that the PV module output power using MPPT is much better than a direct connection with fixed resistance under variable weather conditions. Although this resistance was chosen to make the PV module operate at MPP, the results indicate that on cloudy days, the PV power output increased with the use of the proposed MPPT control as compared to the case where the PV module is directly connected to a fixed resistance.

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NOMENCLATURE

D	Duty cycle
G	Solar radiation, W/m^2
IMPP	Current at maximum power point tracking, A
I_{sc}	Short circuit current, A
$t_{(OFF,HS)}$	Time off, s
$t_{(ON,HS)}$	Time on, s
T	Temperature, ^{o}C
V_{IN}	Input voltage, V
V_{MPP}	Voltage at maximum power point tracking, V
V_{OUT}	Output voltage, V
V_{oc}	Open circuit voltage, V
AM	Air mass ratio
IDE	Internal development environment
I-V	Current-voltage
I2C	Inter-integrate circuit
PV	Photovoltaic
MPPT	Maximum power point tracking
MPP	Maximum power point
PCB	Printed circuit board
P&O	Perturb and Observe
PWM	Pulse-width modulation

ДИЗАЈН MPPT СИСТЕМА ЗА МОНО-КРИСТАЛНИ СИЛИЦИЈУМСКИ СОЛАРНИ МОДУЛ КОРИШЋЕЊЕМ АРДУИНО МИКРОКОНТРОЛЕРА И СИНХРОНОГ STEP-DOWN КОНВЕРТЕРА

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Максимална излазна енергија и ефикасност фотонапонског (PV) система за одређене услове може се остварити применом стратегије максималне снаге (MPPT). У ту сврху развијени су бројни алгоритми праћења. Рад приказује дизајнирање и методологију израде фотонапонског контролера напуњености у циљу постизања максималне снаге. Контролер напуњености није дизајниран само да максимизира снагу из соларног модула већ има и додатне карактеристике које чине систем корисним за истраживаче. Предложени систем користи P&O MPPT метод за дизајн и имплементацију. Код ове технике, контролер испоручује PWM сигнал помоћу Ардуино микроконтролера у циљу регулисања напона. Синхрони DC-DC step-down конвертер се користи за спајање PV модула са оптерећењем. Резултати се добијају за два система: - MPPT контролисана микропроцесором ради из PV модула а PV модул је спојен директно са оптерећењем. MPPT је ефикасна стратегија, обезбеђује највећу снагу за оптерећење у променљивим временским условима спољашње средине. Експериментални резултати показују да је у условима облачног времена употреба MPPT погодна јер побољшава снагу PV продукције у поређењу са ситуацијом када је PV модул повезан са фиксном отпорношћу.