MPPT-based Power Management System For Remote Areas

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Abstract—**Maximum power point tracking (MPPT) controller is commonly used in photovoltaic (PV) power generation systems to maximize energy harvested. It is usually more efficient by 15-20% compared to Pulse Width Modulation (PWM) controllers making it perfect for locations with varying weather conditions. In this paper it is proposed to improve the commercially available MPPT controller by adding a power management system that will utilize more energy during low solar radiation like cloudy, sunset and sunrise conditions. Power management system was designed using a DC-DC converter which is controlled by the generated PWM of the Arduino. Since the MPPT controller has a required solar panel input voltage depending on the voltage of the battery, the algorithm tracks if the output from the solar panel is lower than the required input voltage of the MPPT controller and continuously adjust the PWM to regulate the output voltage from the solar panel. The results showed that the transfer efficiency of the designed power management system during low radiation condition is about 94% and the overall system has an increased value of the average power harvested per day.**

Keywords—DC-DC converter,Maximum Power Point Tracking controller, Photovoltaic, Power management system, transfer efficiency

I. INTRODUCTION

Usage of electricity have made our life much more convenient. The use of geothermal energy, fossil fuels and natural gasare the main source of electricity distribution here in the Philippines. But due to the requirement of power lines to distribute electricity, most remote places here in the Philippines cannot have access to the electricity. With the discovery of Photovoltaic (PV) Systems, even the remote areas can have access to the electricity since PV system offer advantages such as ease of installation, minimal maintenance, and it produces zero waste.

In recent years, usage of controllers to improve the efficiency of power harvested by the PV panels are continuously developed by the researcherss. In a research conducted by BishwajitSwarnaka and Anupama Datta, the researcherss used the Pulse Width Modulation (PWM) controller to disconnect the battery from electrical loads when the battery reaches low state of charge and automatically connect and disconnect an electrical load at a specified time overdischarge and provide load control functions [1]. In another research conducted by Dr.Anil S. Hiwale, Mugdha V.Patil and Hemangi Vinchurkar, the researcherss used MPPT controller to operate at the Maximum Power Point (MPP) and produced its maximum power output thus it maximizes the array efficiency, thereby reducing the overall system cost [2].

Since these two controllers each have their own advantages and disadvantages, combining these two controllers can provide higher efficiency.

The general objective of this study is to create a Power Management system that can utilize the PWM controller to regulate the required input voltage needed by the MPPT controller since MPPT controller requires a higher input PV voltage than the battery input. Specifically this research aims: (1) To design a PWM controller to detect and regulate the PV input voltage. (2) To compare the difference in efficiency of the system with a MPPT controller and the proposed power management system.This study aims to use the power management system in places with varying weather conditions.

In a normal condition using a normal controller setup can give you significant amount of power in a day.

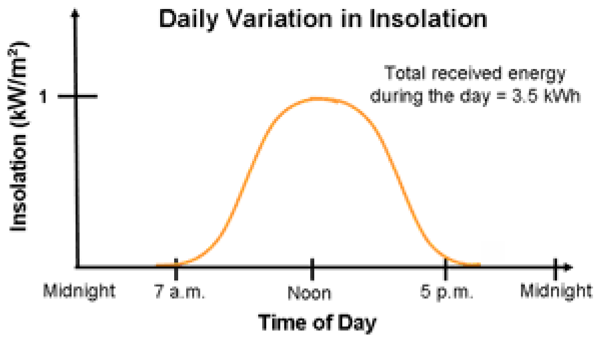

Fig.1 Normal Insolation Condition

The block diagram shows the graph of insolation if the condition in a day is normal [3]. But there are instances that the condition is cloudy or rainy where the sun is not fully visible therefore the voltage produced by the solar panels become lower than the required input voltage of the MPPT and the power during that time is not utilized. These conditions are most suitable for the power management system because it can easily adjust the required voltage needed by the battery even if the weather is cloudy or rainy. By adding a Microcontroller controlled DC-DC Converter in the system even low voltages can be adjusted to the required input voltage of the MPPT.

II. REVIEW ON RELATED STUDIES

A. *Design and Implementation of Maximum Power Point Tracking Solar Charge Controller*

Maximum Power PointTracking system has a high capability of power extraction from solar panel. This study showed an improved design of MPPT solar charge controller using Arduino. The proposed technique significantly reduces the system power loss and increase the efficiency. Experimented highest efficiency 97.75% is recorded from the proposed system. Additionally, some new features are added like smart device charging, wireless data logging and protections from high voltage disconnect (HVD), low voltage disconnect (LVD), over current protection, short circuit protection and reverse polarity protection[4].

B. *Fuzzy Logic Controller of DC to DC DC-DC Converter for Energy Harvesting Applications*

This paper describes the design of a fuzzy logic controller (FLC) of a DC-DC converter used to charge a battery. The FLC functions are used to maintain the output of the converter at a constant level regardless of variations in the input voltage. The output of the FLC was also used as input to a controller which functions is to prevent overcharging and over discharging of the battery. The converter input and output voltages were used as input membership functions for the FLC; while, the duty cycle applied to the switch of DC-DC converter was used as the output membership function [5].

III. METHODOLOGY

A. *Block Diagram*

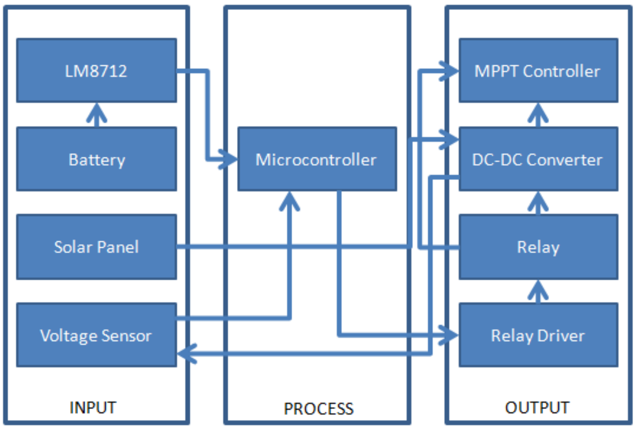

Fig.2 Block Diagram of the System

The system has three major parts: input, process and output. The input part are composed of Battery Supply which is 24V, LM7812 which regulates the 24V to 12V to be able to supply the Microcontroller, Solar panel which is the one to be regulated with the required input voltage in the MPPT and the Voltage Sensor which tracks the output voltage of the DC-DC Converter to be processed if it is the same with the required input voltage of the MPPT. The process part is composed of the Microcontroller which process the voltage if it is below the required the input voltage and switches the path of the solar panel through the DC-DC converter using a relay and continuously adjust the duty cycle of PWM which will be sent to the DC-DC Converter. The output part are composed of Relay Driver which enables the relay coming from the 5V of the Microcontroller, Relay which switches the path of the solar panel, MPPT Controller which is the one that receives the input voltage from the DC-DC converter and the DC-DC converter which is the one that continuously adjust the voltage based on the PWM coming from the Microcontroller.

B. *Flowchart of the algorithm for the Power Management System*

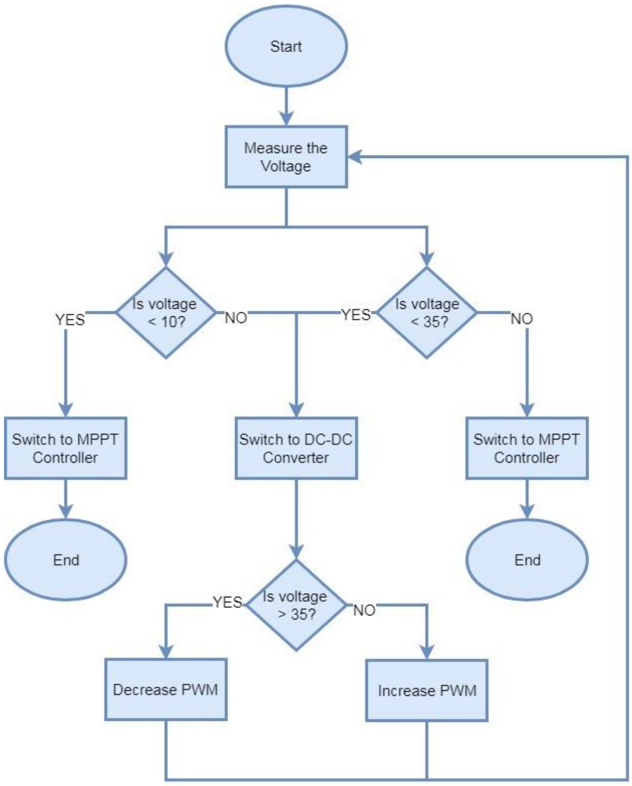

Fig. 3 Flowchart for the Power Management System

The figure shows the flowchart of the algorithm for the testing. First the voltage sensor will measure the voltage coming from the solar panel. If the voltage is greater than 10V and less than 35V the relay will switch the path of the solar panel to the DC-DC converter then if the voltage is not equal to 35V the microcontroller will either increase or decrease the PWM to regulate the voltage to 35V. If the voltage of the solar panel is greater than 35V or less than 10V the relay will switch the path of the solar panel to the MPPT Controller. The DC-DC converter will stop working if it is lower than 10V because the voltage lower than that is harvested during sunset where the sun is not visible anymore.

C. *Hardware*

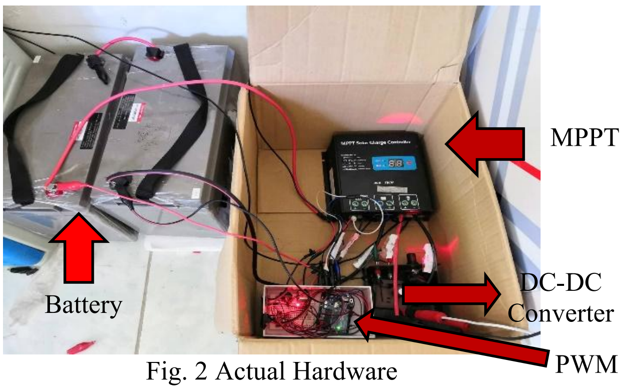

Fig. 2 Actual Hardware

The prototype shown on Figure 2 shows the actual wiring of the MPPT to DC to DC converter connected to a DC Refrigerator as a load

IV. TESTING

A. *Verification for the System*

Before implementing the Power Management System, the researcherss run some test if it really produce the desired output that are processed through the microcontroller based on the input voltage.

TABLE I. VERIFICATION FOR THE SYSTEM

Trial	Vin	Vout
1	6	5.9
2	8	8
3	10	35
4	14	35
5	18	35.3
6	22	34.9
7	26	34.9
8	33	35.2
9	35	35
10	36	36.1
11	37	37
12	39.6	39.6
13	40	40

Table I shows the acquired output voltage based on the input voltage supplied through the Power Management System. Based on the results, voltages below 10V gives output based on the given input, the DC-DC Converter starts to work when the input voltage reaches 10V and stops to work again when it reaches 36V and input voltages greater than 35V gives output based on the given input.

B. *Transfer Efficiency of the Power Management System*

TABLE II. COMPARISON OF TRANSFER EFFICIENCY BETWEEN DIFFERENT VOLTAGE INPUTS

Power Management System Through a 50Ω Load			
Vin (V)	**Power w/o the system (W)**	**Power w/ the system (W)**	**Transfer Efficiency (%)**
10	1.86	1.74	93.55
14	3.77	3.55	94.16
18	6.32	5.98	94.62
22	9.5	8.93	94
26	13.34	12.5	93.7
33	19.12	18	94.14
35	21.5	20.08	93.4

Table II shows the transfer efficiency of the system using a 50Ω load. Based on the table the average transfer efficiency acquired through the system is 94%.

V. RESULTS AND DISCUSSION

TABLE II. COMPARISON OF POWER OUTPUT OF SYSYEM WITH AND WITHOUT THE DC-DC CONVERTER

TIME	MPPT only	w/ DC-DC Converter
8 AM	42.35 W	47.07 W
9 AM	66.11 W	80.93 W
10 AM	107.98 W	112.47 W
11 AM	134.23 W	130.43 W
12 NN	137.47 W	144.15 W
1 PM	122 W	133.42 W
2 PM	100.93 W	117.17 W
3 PM	87 W	98.06 W
4 PM	49.07 W	57.34 W
5 PM	10.87 W	12.25 W

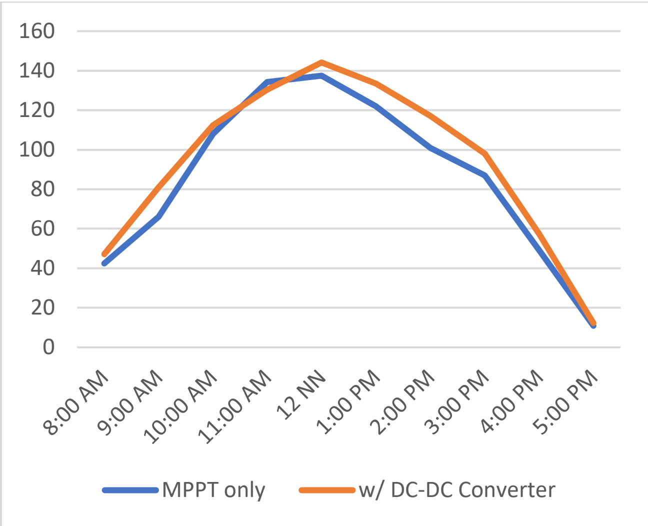

Fig. 4 Power Output vs. Time Comparison Graph

Table II and figure 3 shows the daily average comparison of power output of the system for MPPT only and with DC-DC converter with respect to time. It can be seen that the average power per hour involve is quite higher for the system with DC-DC Converter compared to the system with MPPT only. The average power for system with MPPT only is 85.801 watts and for system with MPPT and DC-DC Converter is about 93.329. Thus the system gives an average gain percentage of 8.77% by adding DC-DC converter the MPPT system.

t-Test: Paired Two Sample for Means		
	MPPT Only	*With Boost Converter*
Mean	85.85130105	99.0985518
Variance	1728.007549	2246.171525
Observations	121	121
Pearson Correlation	0.962019159	
Hypothesized Mean Difference	0	
df	120	
t Stat	-10.75492075	
P(T<=t) one-tail	1.33089E-19	
t Critical one-tail	1.657650899	
P(T<=t) two-tail	2.66178E-19	
t Critical two-tail	1.979930405	

Fig. 5 Statistical Analysis

The figure 5 shows the statistical analysis of the data of system with MPPT only and system with the DC-DC converter. Since the p value (1.33089E-19) is less than the alpha value (.05), we reject the null hypothesis that there is no difference between the two data and we accept that there is significant difference between them.

VI. CONCLUSION

After conducting the study and tests about"MPPT-based Power Management System", the researcher/s were able to design, build and implement a higher efficiency power managementment system that can be use for remote areas where the weather is constantly changing throughout the day. The researcherss came up to a design that will prolong the energy harvesting hours of a normal MPPT system by adding a DC-DC converter and switching circuit that will operate at lower irradiance where the MPPT is not functional but the energy that can be harvested is still significant

VII. REFERENCES

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