MPPT based Auto Integrated Dust Control and Efficient Cooling Mechanism for Improving the Efficiency of Photovoltaic based System

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Abstract

Background/Objectives: It is necessary to keep the photovoltaic panels cleaned regularly to gain the maximum power output. It is inexorable that things like bird droppings, dust, pollen, leafs and mud will collect and deposit on photovoltaic modules that reduces the efficiency of these panels, by as much as 30%. This research paper presents a design and development of an automatic cooling and dust control mechanism for increasing the conversion efficiency of photovoltaic panels. **Methods/Statistical Analysis:** The design consists of a wiper and water sprinkler mechanism connected to the solar panel through relay driver circuit and is interfaced with PIC16F72 microcontroller. The tracking of maximum power is done through incremental conductance MPP algorithm and the duty cycle of PWM output is controlled through Cuk Converter. Wiper and water sprinkler were run through motors and the driving source for motors is battery that is charged from the solar panel connected. The operation is controlled by programming PICF72 using PIC C-compiler. The experimental method involved finding the voltage and current readings of the panel output and comparing the efficiency in the power output before and after cleaning on timely basis. **Findings:** The experimental method involved finding the voltage and current readings of the panel output and comparing the efficiency in the power output before and after cleaning on timely basis. The wiper is programmed to move for every hour and water is sprinkled for every six hours. The results prove that by adopting Cuk Converter compared to other converters. The design also aims on providing an automatic mechanism which reduces a huge human effort and is cost effective. Results have proved that the conversion efficiency is improved up o 45%. **Application/Improvement:** The design also aims on providing an automatic mechanism which reduces a huge human effort and is cost effective. Results have proved that the conversion efficiency is improved up to 45%.

Keywords: Cuk Converter, Maximum Power Point Tracking, PIC16F72 Controller, Sprinkler Interface, Wiper Interface

1. Introduction

The increasing demand for energy, the continuous reduction in existing sources of fossil fuels and the growing concern regarding environment pollution, have push mankind to explore new technologies for the production of electrical energy using clean, renewable sources such as solar energy, wind energy etc. Extracting usable electricity from sun is by photoelectric mechanism and development of solar cell where a semi conductive material that converts visible light into direct current[1]. There are inherent problems with photovoltaic modules like rapid change in insulation conditions, high initial establishment cost and low conversion efficiency. To overcome the problems it is necessary to optimize the design of photovoltaic system components. Maximum Power Point Tracking (MPPT) is used in photovoltaic systems to maximize the photovoltaic array output power, irrespective of the temperature and radiation conditions. Many researchers have proposed various algorithms

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for tracing the exact MPP point[2,3]. In our proposed system we have considered the technique of incremental conductance algorithm to track the MPP point and then focused on the auto cleaning mechanism. There were several considerations taken into account when designing this system. Firstly, in the case of use, solar panels are usually placed on the roof to receive the maximum amount of sunlight. Manual cleaning at regular intervals includes high risk and it is not cost effective. However, considering a typical set up with 40 panels, a rate of $ 5 to $ 10 and cleaning every three months would result in an annual cost of $ 800 to $ 1600[4]. Furthermore, if we then estimate that the panels will remain clean enough to maximize the output for 4 days after they are cleaned, then the remaining 86 days until the next cleaning, the solar panels will be operating at a reduced efficiency. This essentially means that the solar panels will only be operating at its maximum efficiency for about 4% of the time. As a result of this, it only made sense that the system being designed should be autonomous to prevent having to climb up onto the roof and save money by allowing for the solar panels to be cleaned often. The U.S. Department of Energy figures have shown that panel efficiency may be reduced by up to 7% from airborne dust particles alone[5]. Adding in other factors such as falling leaves and water streaking, the efficiency of these panels can be further reduced to as much as 15%–30%[6]. Some studies have linked this reduction in output to as much as $ 10,000 of lost value[7]. In the case of a commercial installation, this would be a significantly higher cost. Hence our concentration of work is to increase the efficiency and reduce manual effort.

The block diagram of proposed system is shown in Figure 1. The PIC microcontroller (PICF72) is connected to wiper motor and sprinkler through relays. It is also interfaced with LCD to display the status of wiper and sprinkler. Battery is connected to solar panel. It charges from the solar panel. When a direct connection is carried out between the source and load, the output of PV module is seldom maximum and the operating point is not optimal. To overcome this problem it is necessary to add an adaption device, an MPPT controller with a converter between source and load. In designing the MPPT controller we have used the principle of existing incremental conductance algorithm[8] to track the exact optimal MPP point and a Cuk Converter[9,10] has been designed and placed. The power that is outputted by the PV array is given as input to the Cuk Converter circuit. The parameters of PV array like Current (I) and Voltage (V) are given as input to the MPPT controller. Based on those parameters the MPPT system generates the output pulses. These pulses are used for switching purpose in the Cuk Converter, which controls the output power at the Cuk Converter thus controls the output power of the whole system. The Pulse Width (PWM) generator is required to maintain the switching mechanism because only when the desired output of current is attained then only the battery should be allowed to charge. A 40 W lamp is connected as a resistive load. Programming was done in embedded – C and has been compiled using PIC-C compiler. The details of hardware components chosen were discussed later in the paper.

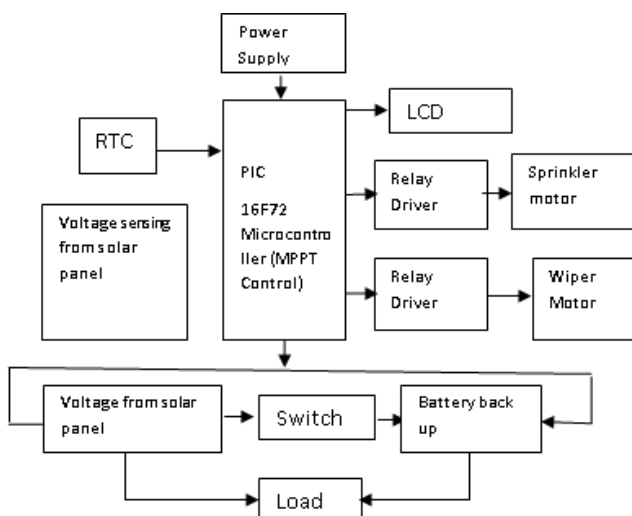The specifications of the solar panel used for experimentation are listed in Table 1.

Table 1. Specifications of PV module considered for experimentation

Rated power (Pmax)	20 W
Open circuit voltage	21.60 V
Short circuit current (Isc)	1.39 A
Rated voltage (Vmax)	17.00 V
Rated current (Imax)	1.20 A
Tolerance	±3%

2. Design Details of Hardware and Software Components used in the System

The digital data in the form of 0's and 1's are received at the base terminal of relay circuit. When logic 1 (+5 V) is received, the circuit behavior is given below:
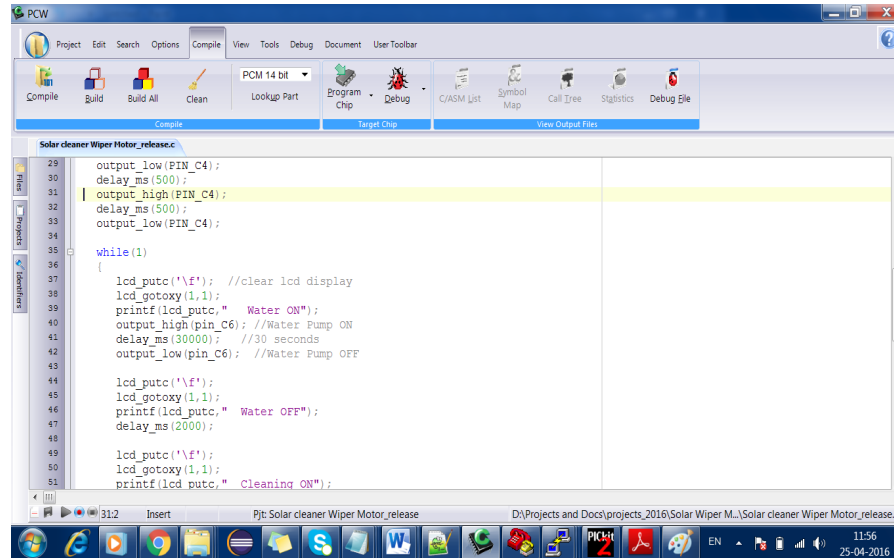

Figure 1. Block diagram of the proposed algorithm.

Applying KVL at input side of Figure 2.

Figure 2. Relay driver.

$5 = I_b (4.7 \text{ K}) + 0.7$
$I_b = 4.3/4.7 \qquad I_b = 0.91 \text{ mA}$
$I_c = ß (I_b) \qquad I_c = 50*(0.91) \text{ mA} \qquad I_c = 45.5 \text{ mA}$

This implies transistor is in active region. This in turn magnetizes the primary coil of relay circuit, produces magnetic field thereby load is connected and operated. For logic 0 (0 V) the transistor is in off condition. Therefore load is not connected to relay. This time duration is called delay. The delay is generated with the help of PIC microcontroller. This type of relay circuit with different delay programming is used for both wiper motor and sprinkler. The current needed to operate the relay coil is more than can be supplied by most chips (op. amps etc.), so a transistor is usually needed. A resistor of about 4.7 K is used. The diode is needed to short circuit the high voltage back EMF (Electro Magnetic Field) induced when current flowing through the coil is suddenly switched off.

The battery specifications are 12 V, 7.6 AMPH and lithium ion made battery. The wiper motor specifications are 12 V, 0.6 A rated current, 7.2 W, 15 ohm resistance. The sprinkler motor specifications are 12 V, 0.2 A rated current, 2.4 W flow rate 300 L/hour. The wiper and sprinkler motors used are shown in Figure 3.

Figure 3. Wiper motor and sprinkler motor used in the system.

3. Circuit Implementation

The schematic structure of all the hardware components connected has been done in Proteus software and it is shown in Figure 4. With the help of solar panel, solar

Figure 4. Schematic structure of the proposed system in Proteus software.

Figure 5. Source code written for programming the microcontroller.

energy is converted into electricity and is stored in 12 V, 7.6 AMPH battery. Since we use a 20 W panel, it is beneficial to choose a battery having a current rating less than 20 AMPH. This helps the battery to take less time for charging. This battery is connected to wein bridge rectifier to provide reverse polarity protection. This in turn is connected to capacitor to protect from current dip. It acts as tank circuit. PIC16F72 microcontroller needs +5 V supply. To extract this, a voltage regulator LM7805 is connected to capacitor. To examine the proper working of circuit, a LED and resistor is placed in series with +5 V supply. The microcontroller is provided with a crystal oscillator of frequency 20 kHz. Normally reset pin is low. It is connected to +5 V supply with a series resistance. Once the pin is pressed, it is connected to ground. A 2*16 LCD display is used to indicate various activities such as cleaning on, cleaning off and wiper on, wiper off. An 8 pin connector is used to interface the LCD with the PIC microcontroller.

The program code written is shown in Figure 5. The delay subroutine specifies the clock at which the CPU runs. LCD_init function must be called to initialize the LCD module. LCD_putc ('\f') function is used to clear display and set cursor to upper left. LCD gotoxy (x, y) function is used to set cursor position. Delay_ms function will create code to perform a delay of the specified length. Sprinkler is turned on by making pin C6 as high with a delay of 30 seconds. Sprinkler and wiper motor are connected to pins C6 and C7 of the microcontroller respectively. Then

wiper motor is turned on by making pin C7 as high for one minute. Next a delay of one hour is set. This entire operation is placed in a while (1) loop which makes the circuit work indefinitely as long as the supply is on.

The above screenshot shows whether dumper is recognized by the microcontroller. Import the program which is '.hex' file format as shown in Figure 6. This figure also shows that program has been successfully burned into the microcontroller. This process has been done using PIC-C compiler.

4. Details of Working Model of the Proposed System

The stepwise working model of the proposed system is shown in Figure 7. The first block is the initial position of setup just after switching on the circuit. LED indication shows 12 V has been obtained at voltage regulator. In the second block sprinkler connection is established and LED indication of the relay corresponding to the sprinkler is observed. This operation is indicated on LCD display in the third block. In the fourth block wiper motor connection is established and LED indication of the relay corresponding to the wiper motor is observed. This operation is indicated on LCD display in the fifth block. In the sixth block LCD indication "wait for 1 hr" is observed. This operation gets repeated for every one hour.

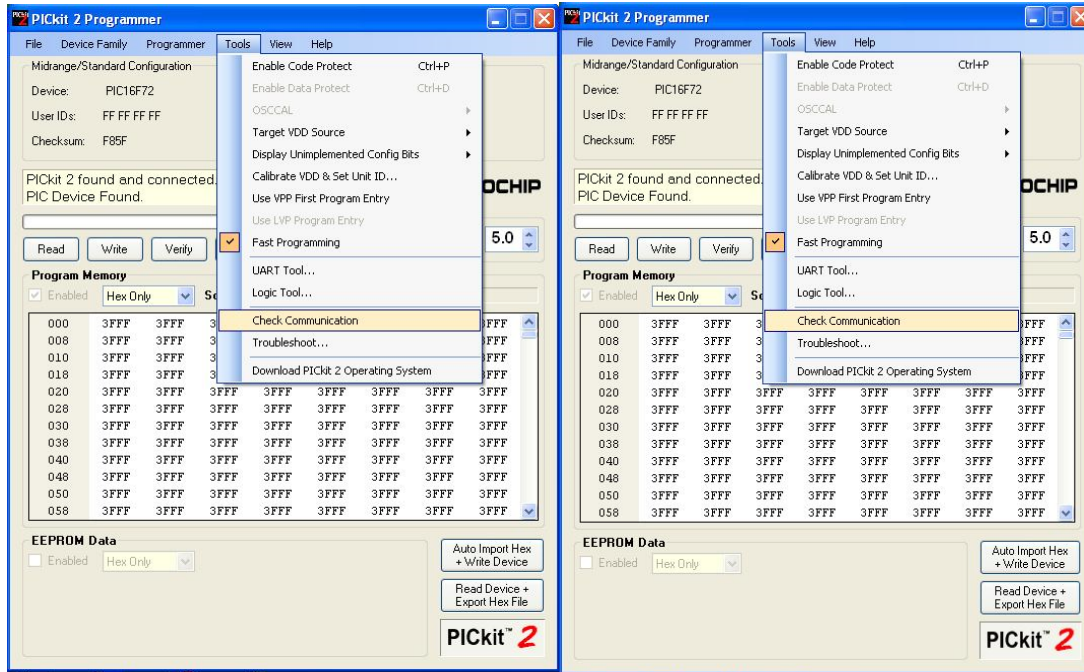The various positions of the wiper during operation

Figure 6. Compilation process of source code using PIC-C compiler.
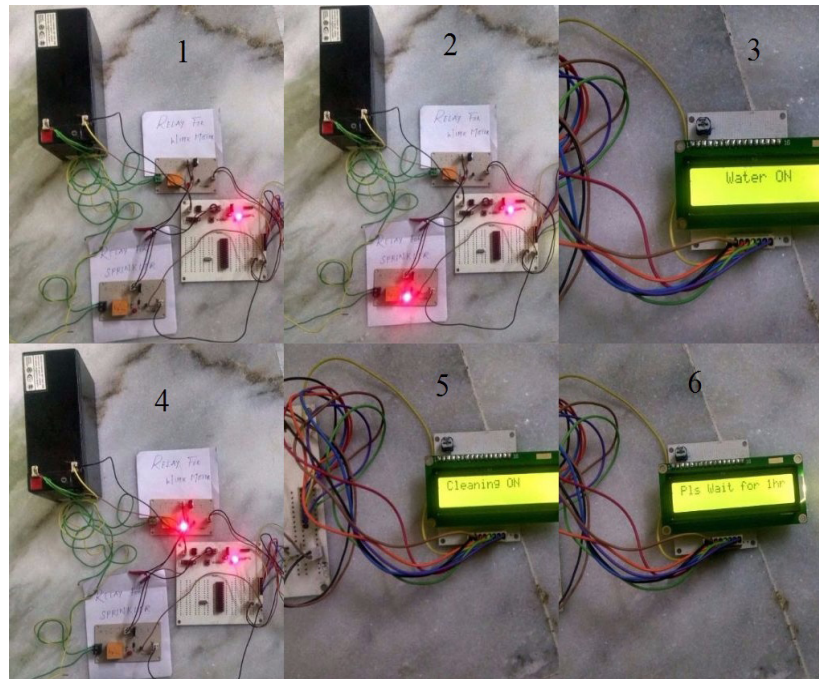

Figure 7. Working model of the proposed system.

are shown in Figure 8. The battery specifications are given as 12 V, 7 AMPH. The solar panel power rating is 20 W, Vmp is 17 V, Imp is 1.2 A. The minimum charging time is given as T (charging) = [V*AMPH] battery/(Vmp)*(Imp) = (12*7.6)/(17*1.2) = 4.47 hrs. T (discharging) =

[V*AMPH] battery/Applied load wattage = (12*7.6)/(12*0.6) = 12.66 hr {Here the load is wiper motor. Its rated current is 0.6 amps}. Wiper motor wattage = 12*0.6 = 7.2 W.

In this application it is used for 1 minute per hour. So

in total 24 times per day Wiper motor usage per day = (24*7.2)/60 = 2.88 W/day.

Sprinkler motor wattage =12*0.36 = 4.32 W.

In this application it is used 30 seconds per hour. Sprinkler motor usage per day = (24*4.32)/(60*2) = 0.864 W/day.

We considered a 40 W bulb as resistive load and we have noticed that apart from using the stored energy for running the motors and the entire cleaning and cooling system the load can be driven up to 2.18 hours as per the calculation done below:

Wattage of battery used for end application = 12*7.6 = 91.2 W.

Battery usage for end application = [91.2-(2.88+0.864)]/40 = 2.18 hours. So the proposed system is able to drive a load inspite of using the stored energy for working of the cleaning system.
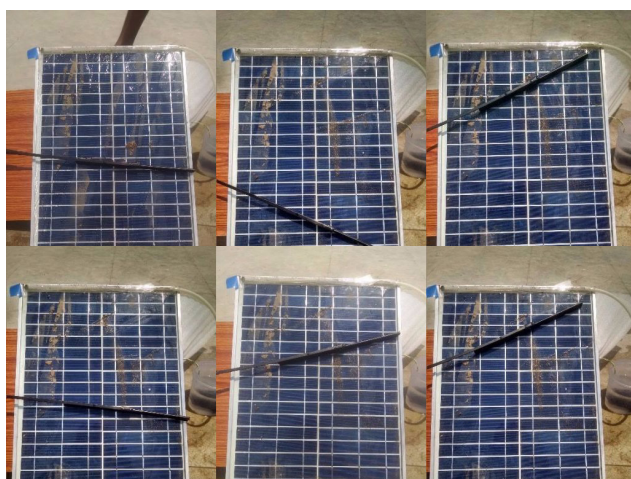

Figure 8. Various positions of wiper during cleaning.

5. Results

The effect of accumulation of on the solar panel is quantified by tabulating the voltage, current and power at different time intervals as shown in Tables 2 and 3. The dust was dropped by us for experimentation which includes 25 gram of leaves, 10 gram of talcum and 35 gram of husk.

Table 2. Voltage, current and power readings before cleaning

Time	Voltage(V)	Current(A)	Power(W)
9.00 AM	18.59	0.29	5.39
10.00 AM	18.78	0.29	5.44
11.00 AM	18.70	0.23	4.30
12.00 PM	18.88	0.25	4.72
1.00 PM	19.00	0.35	6.65
2.00 PM	19.34	0.51	9.86
3.00 PM	18.56	0.35	6.49
4.00 PM	18.50	0.21	3.88

Table 3. Voltage, current and power readings after cleaning

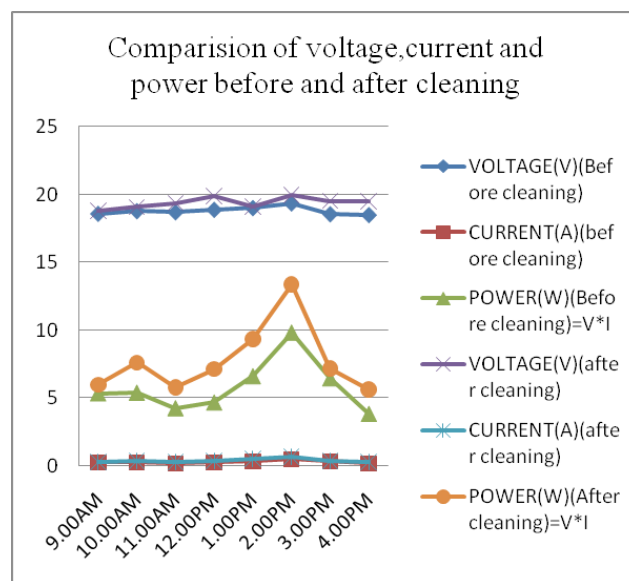| TIME	Voltage(V)	Current(A)	Power(W)
9.00 AM	18.80	0.32	6.01
10.00 AM	19.09	0.40	7.63
11.00 AM	19.40	0.30	5.82
12.00 PM	19.90	0.36	7.16
1.00 PM	19.11	0.49	9.36
2.00 PM	20.00	0.67	13.4
3.00 PM	19.55	0.37	7.23
4.00 PM	19.50	0.29	5.65

Figure 9. Various positions of wiper during cleaning.

From Figure 9 it is observed that there is a gradual increase in the output parameters during the time when the sun intensity is high and it is slowly reduced. Comparatively at all point s of time there is a considerable increase in power after adopting the cleaning system.

6. Conclusion

The intensive use of energy from the solar cell is essential for providing solutions to environmental problems like pollution and global warming. As per the proposed model we have been succeeded in integrating all the hardware components and have interfaced with the source code that has been programmed in PIC C compiler. Presence of every module has been reasoned out and placed carefully, thus contributing to the best working of the unit. It is observed that there is a significant increase of up to 45% of output power by adopting the cleaning mechanism. The other aspect considered is the water used for cleaning may be impure so to avoid salt deposits a piece of potassium aluminum sulphate $KAl (SO_4)_2$ has been placed on the interior side of water supply tank. When the water gets in contact with $KAl (SO_4)_2$ the contaminants precipitate and clean fresh water is supplied to the sprinkler. The system developed is easy to maintain in less cost and moreover it completely reduces the human effort. We are also working towards an emulsion coating over the panel which resists accumulating the dust on the panel and does not affect the transparency of the panel. We also suggest a roller type of cleaning mechanism instead of using a wiper.

7. References

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