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Research Article

Microcontroller Based DC Motor Control With Fuzzy Maximum Power Point Tracking of PV System

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Abstract

Photovoltaic (PV) energy conversion is now recognized to be the most widely accepted method of harnessing renewable energy sources to benefit communities, especially in developing countries. PV arrays provide direct conversion of solar energy into electrical energy without inducing environmental pollution. Recognizing these facts, extensive research and development efforts are devoted to photovoltaic. Especially in countries like India where the government is facing oil crunch, the tapping of PV energy which is available in abundance throughout the year is considered to be very important. The main encumbrance for the reach of PV systems is their low efficiency and high capital cost. The present work, intends to examine a schematic to draw out maximum obtainable solar power from a PV system to be used in DC application. The concept of Maximum Power Point Tracking (MPPT) is implemented by using Fuzzy Logic, which results in appreciable increase in the voltage level required. The MPPT algorithm thus proposed will identify the suitable duty ratio in which the DC/DC converter should be operated to obtain maximum power output. The obtained maximum power can be used to charge the battery, as well as to run the DC motor. The proposed scheme also focuses in developing a microcontroller based closed loop scheme for the speed control of a DC motor fed from PV array. The microcontroller keeps on tracking the determined speed by varying duty cycle in a closed loop control system.

Keywords: *DC/DC converter, MPPT, PV system, Fuzzy logic control, Microcontroller, DC motor.*

1. Introduction

Energy is the most basic and essential of all resources. All the energy we use on Earth comes from fission or fusion of atomic nuclei or from energy store in the Earth (Shakil Ahamed Khan et al,2010). The problem with both fission and fusion is that, they have dangerous radioactivity and side effect. Therefore, most of the generation of energy in our modern industrialized society is strongly depending on very limited non-renewable resources such as petroleum. As the world's energy demands rise and resources become scarce, the petroleum is getting more and more expensive. The search for alternative energy resources has become an important issue for our time. The people seek for new green and unlimited energy sources, e.g. wind energy, water energy, solar energy, etc. The most effective, reliable and harmless energy source is probably solar energy. Solar energy can be harvested by the use of PV array. PV array has an optimum operating point to extract the maximum power called the Maximum Power Point (MPP), which varies depending on cell temperature and insolation level.

Many industrial applications require rotating drives and DC source. The versatile control characteristics of DC motor and DC drives have contributed a lot to industrial application. The drivers are normally capable of speed control and often require an equipment to attain a versatile and smooth speed control characteristics and make the motor to operate on a desired specific speed-torque characteristic. The speed can be varied by varying the applied voltage to armature or by varying the field current. Today's industries are increasingly demanding process automation in all sectors. Automation results into better quality, increased production and reduced costs. The variable speed drives, which can control the speed of AC/DC motors, are indispensable controlling elements in automation systems. Depending on the applications, some of them are fixed speed and some of them are variable speed drives. However, AC motors have definite advantages in cost, size and weight, and require much less maintenance compared with DC motors. Even then the DC motor was taken as a favorable choice for high performance adjustable speed drives because they are easily controllable and provide fast response to speed control commands.

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Recent developments in science and technology provide a wide range of scope in the field of applications in high performance DC motor drives. It includes the areas such as rolling mills, chemical process, electric trains, robotic manipulators and the home electric appliances. All these require speed controllers to perform tasks.

The speed control is one of an important parameter in DC motor operation (S. Krithiga et al,2011). The control includes a regulating circuit that has an output for controlling the armature voltage of the motor. The speed of the motor is directly proportional to the input armature voltage. A speed signal proportional to armature voltage is feedback to the regulating circuit to establish an error signal for operating the controller to regulate the armature voltage of the motor and there by the motor speed.

The use of power electronics for the control of electrical machines not only offers better performance caused by precise control and fast response but also provides better maintenance and ease of implementation. In parallel with the advances in power electronics there have been great developments in microcontroller based control systems due to their flexibility and versatility. Hence all the control algorithms are implemented in software.

2. Proposed Scheme

The block diagram of the proposed scheme is shown in Fig. 1. This scheme consists of PV array, boost converter, voltage sensor, current sensor, battery, battery charger, keypad, LCD, DC motor and Atmega8535 microcontroller.

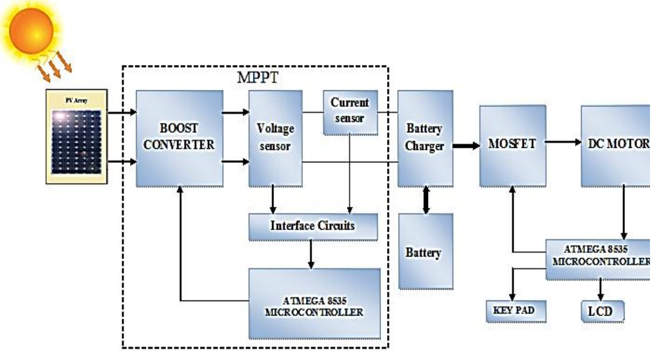

Fig. 1: Block diagram of the proposed scheme.

The PV array converts the solar radiation into electrical power. The boost converter is used to step up the voltage from the PV panels. A boost converter (step-up converter) is a DC-DC power converter with an output voltage greater than its input voltage (Y. S. Ettomi et al,2003). The switching element used here, is MOSFET and it is kept in heat sink to avoid over temperature. A low cost, high performance ATMega8535 microcontroller has been used for generating the gate pulses to the MOSFET in the boost converter.

The ATmega8535 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega8535 achieves Up to 16 MIPS Throughput at 16 MHz allowing the system designed to optimize power consumption versus processing speed. The feedback circuit consists of a voltage sensor and a current sensor. The sensors provide analog data as an output.

For further processing of these data, A/D conversion is needed. Since ADC module contained in ATMega8535 microcontroller and can work on voltage up to 5V, so it is an added advantage which reduces the cost of two A/D converters IC. The analog output of two sensors is connected to ADCO and ADC1 pin of ATMega8535 microcontroller and the A/D conversion is completed by using software program.

Battery charger is used to charge the Lead-acid battery. It typically has two tasks to accomplish. The first is to restore capacity, often as quickly as practical. The second is to maintain capacity by compensating for self-discharge. It also indicates the state of charge of battery through LED.

The DC Motor used is a 12V PMDC motor. The specification of this motor is shown in Table 1.

Table 1: Specifications of the PMDC motor.

Voltage rating	12V
Armature current	2.5A
Speed	2550 R.P.M.
Power	30W

The control system shown in Fig. 1 implements several control functions to perform the following tasks:

1. Implementation of microcontroller based Fuzzy Logic controller for MPPT of a PV system. The Atmega8535 microcontroller is programmed to automatically vary the duty cycle of the Boost converter.
2. The obtained maximum power from the PV system can be used to charge the battery, as well as to run the DC motor.
3. Implementation of a microcontroller based closed loop scheme for the speed control of a DC motor by using PWM technique.

3. Implementation of MPPT

Over the past decades many methods have been developed to find the Maximum Power Point (MPP) and published. These techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking when irradiation and/or temperature change, hardware needed for the implementation or popularity.

As the characteristics of a PV system vary with temperature and insolation, the MPPT controller is also required to track the new modified maximum power point in its corresponding curve whenever temperature and/or insolation variation occurs. The MPPT algorithm employed based on Voltage and Power feedback control approach, with the step size being dependent on the slope of the Power v/s Voltage (P-V) curve as shown in Fig. 2. Conventionally with this methods,

$$\frac{dP}{dV} = \frac{P(n)-P(n-1)}{V(n)-V(n-1)} \quad (1)$$

MPP is defined by, $\frac{dP}{dV}(n) = 0$

When, $\frac{dP}{dV}(n) > 0$ (or $\frac{dP}{dV}(n) < 0$)

Then the operation point is on the left (or right) of the MPP and should be tuned towards the opposite direction.

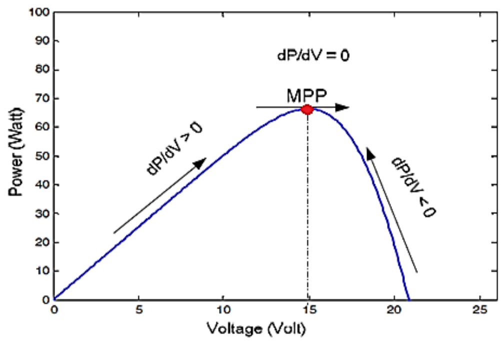

Fig. 2: P-V characteristics of a PV module.

We have proposed a scheme as shown in Fig. 1, based on the use of conventional DC-DC converter, where combination of voltage and power feedback control system is implemented with the use of artificial intelligence algorithm which results in tracking response faster and maximizes the power extracted from the solar module and the power delivered to the load. MPPT is assured by varying duty cycle of the PWM signal to control MOSFET switch applied to a boost converter. The control logic is implemented to a microcontroller (ATMega8535) with the use of fuzzy logic algorithm (Timothy J. Ross).

A. Fuzzy Logic control (FLC)

The use of fuzzy logic control has become popular over the last decade because it can deal with imprecise inputs, does not need an accurate mathematical model and can handle nonlinearity, can provide fast convergence and minimize oscillations around the MPP . Furthermore, they have been shown to perform well under step changes in the irradiation. The disadvantage is that their effectiveness depends a lot on the skills of the designer, not only on choosing the right error computation, but also in coming up with an appropriate rule base. Microcontrollers have also helped in the popularization of fuzzy logic control.

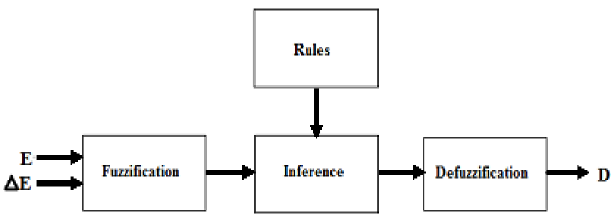

Fig. 3: General structure of the Fuzzy controller.

Fig. 3 shows the general structure of the FLC, which consists of three stages: fuzzification, inference, and defuzzification.

➢ *Fuzzification*

The inputs to a MPPT FLC are usually an error (E) and a change of error (ΔE) as given in equation (2) and (3) respectively.

$$E(n) = \frac{P(n)-P(n-1)}{V(n)-V(n-1)} \quad (2)$$

$$\Delta E(n) = E(n) - E(n-1) \quad (3)$$

E and ΔE are calculated and converted to the linguistic variables during fuzzification. Five linguistic variables are considered, they are PB (Positive Big), PS (Positive Small), ZE (Zero), NS (Negative Small), and NB (Negative Big).

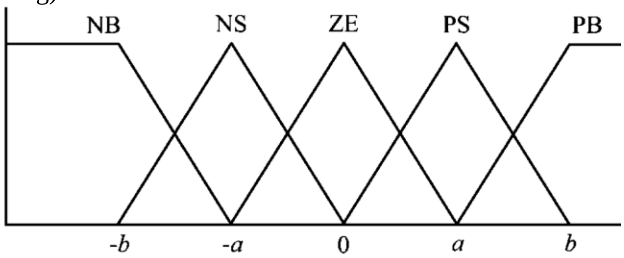

Fig. 4: Membership functions for E and ΔE.

At some point the error is PS and at some point the error is PB the space between PB and PS indicates an error. The vertical axis describes the degree to which a linguistic variable fits with the crisp measured data.

Table 2 Fuzzy Rule Base Table.

E \ ΔE	NB	NS	ZE	PS	PB
NB	ZE	ZE	NB	NB	NB
NS	ZE	ZE	NS	NS	NS
ZE	NS	ZE	ZE	ZE	PS
PS	PS	PS	PS	ZE	ZE
PB	PB	PB	PB	ZE	ZE

➢ *Inference method*

The FLC output is typically a change in duty ratio (ΔD) of the power converter. The linguistic variables assigned to ΔD for the different combinations of E and ΔE as shown in Table 2, which is based on a boost converter. If, for example, the operating point is far to the left of the MPP as shown in Fig. 2, that is E is PB, and ΔE is ZE, then we want to largely increase the duty ratio, that is ΔD should be PB to reach the MPP.

➢ *Defuzzification*

The final step in the FLC is to combine the fuzzy output into a crisp system output. The result of the defuzzification has to be a numeric value which determines the change of duty cycle of the PWM signal used to drive the MOSFET. There are various methods to calculate the crisp output of the system. Centre of Gravity (COG) method is used in our application due to better results it gives. The flowchart of Fuzzy MPPT is shown in Fig. 5.

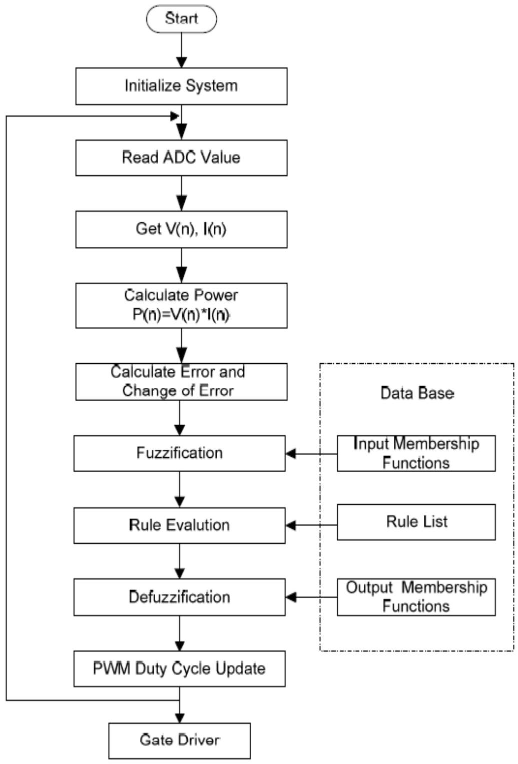

Fig. 5: Flowchart of Fuzzy MPPT.

The drawbacks of this technique are mainly two. The first and main one is that they can easily lose track of the MPP if the irradiation changes rapidly. In case of step changes they track the MPP very well, because the change is instantaneous and the curve does not keep on changing. However, when the irradiation changes following a slope, the curve in which the algorithms are based changes continuously with the irradiation, as can be seen in Fig. 6, so the changes in the voltage and current are not only due to the perturbation of the voltage. As a consequence it is not possible for the algorithms to determine whether the change in the power is due to its own voltage increment or due to the change in the irradiation.

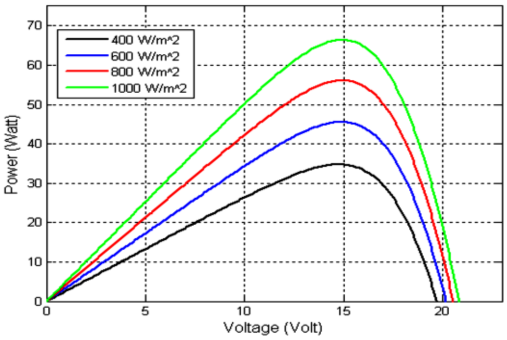

Fig. 6: P-V curve depending on the irradiation.

4. Speed Control of DC Motor

From the obtained Maximum Power the DC Motor is run. Here the keypad is provided to set the speed of the motor and this keypad in turn interfaces with the Atmega8535 microcontroller for speed control. Furthermore an LCD display was also provided to display the inputs in alphanumeric form, this kind of set up provides a complete user interface unit. Data can be input via the keypad and it can be observed on the LCD display. Hence the system is complete stand-alone and user friendly.

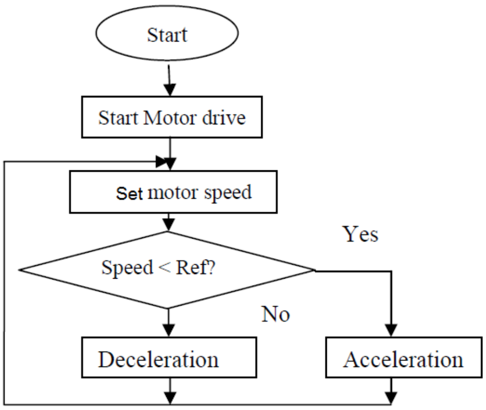

Fig. 7: Flowchart of DC motor speed control.

Microcontroller accepts this input and signals the driver circuit to delivers the actual voltage required for running the motor. Since Back emf (E_b) is directly proportional to speed, E_b is taken as actual speed and compares with the desired speed which set through the keypad. Then microcontroller generates the control signal to control the speed of DC motor. The flow chart for the speed control of the DC motor is illustrated in Fig. 7. It indicates that, if the speed is less than the reference speed, then motor accelerates and if the speed is greater than the reference speed, then motor decelerates.

5. Experimental Results

The hardware setup for testing the proposed scheme is shown in Fig. 8. This includes a solar panel with a voltage rating of 12V and power rating of 10W. The boost converter consists of an inductor (L=24μH) and a capacitor (C=2200μf). The switching element used here is IRFZ44N MOSFET and it is placed inside a heat sink to avoid any damage due to rise in temperature. The Atmega8535 microcontroller is used to generate a suitable control signal that controls the Duty cycle. The 12V PMDC motor is employed for the speed control.

The results obtained from MPPT of PV system are shown in Table 3. It shows that the output of the solar panel continuously varies as the temperature and insolation of sun varies. Boost converter output also varies proportional to the solar panel output.

The output voltage and current of boost converter is measured by using multi meter and corresponding power is calculated. The graph of Power v/s Voltage is plotted, as shown in Fig. 9.

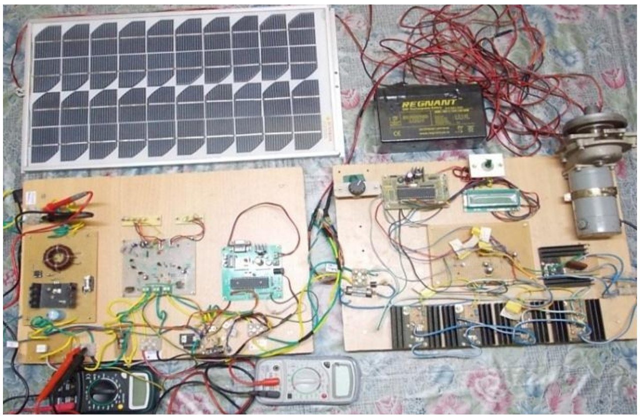

Fig. 8: Overall system setup for experimental testing.

Table 3: Results of MPPT of PV system.

Solar panel Output Voltage	Boost converter Output Voltage	Boosted voltage	Output Current	Output Power
0	0	0	0	0
0.12	3.70	3.58	2.97	11
0.15	4.38	4.23	2.96	13
0.26	7.37	7.11	2.98	22
0.28	8.26	7.98	3.02	25
0.35	10	9.65	3	30
0.37	11.12	10.75	2.24	25

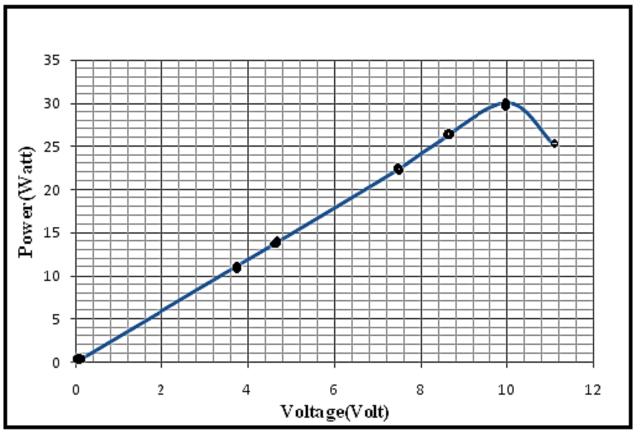

Fig. 9: The Voltage v/s Power curve of the MPPT system.

The above graph indicates that up to 10V the power increases and then decreases gradually. The MPPT system improves the output power of the module. It is observed that Maximum output Power of 30W is obtained during 12:00 noon. Output power of about 10W is obtained during early morning and evening. The Maximum Power is affected by temperature variation.

Table 4: Results of Speed control of DC Motor

Set speed in %	Set speed in RPM	Back EMF	Obtained Speed in RPM
0	0	1.45	0
25	625	0.70	611
50	1250	0.27	1228
75	1875	0.12	1848
100	2500	0.00	2478

The results obtained from speed control of DC motor are shown in Table 4. It shows that the speed can be set as 0, 25, 50, 75 and 100 in terms of % through keypad. Microcontroller takes it as reference speed. Since the back emf is directly proportional to speed, it is taken as actual speed and the microcontroller generates a suitable control signal to vary the duty cycle of MOSFET. Obtained speed is measured using tachometer.

Conclusion

This paper has demonstrated the implementation of FLC to a microcontroller for MPPT of a PV module under variable temperature and insolation conditions. The FLC is easy to implement and require a small amount of inexpensive components in compact size. The designed controller is capable of rapidly locking into the MPP for a PV panel. With MPPT, there is no need to input the duty cycle. The algorithm itself iterates and decides the duty cycle. When there is change in the solar irradiation the MPP changes and thus the required duty cycle for the operation of the model also changes. If MPPT is not used, then the duty cycle is to be set manually. Thus with the above advantages Fuzzy based MPPT is considered to be one of the best methods for tracking solar energy. Further, to predict the maximum power of the module, automatic recording and monitoring of the temperature and insolation level can be incorporated.

References

Shakil Ahamed Khan and Md. Ismail Hossain (Dec 2010), Design and Implementation of Microcontroller Based Fuzzy Logic Control for Maximum Power Point Tracking of a Photovoltaic System, *6th International Conference on Electrical and Computer Engineering, ICECE*, 18-20, Dhaka, Bangladesh.

S. Krithiga and N. Ammasai Gounden (Aug 2011), A Microcontroller based Power Electronic Controller for PV assisted DC motor Control *6th International Conference on Industrial and Information Systems, ICIIS*, Sri Lanka.

Y. S. Ettomi, S. B. Noor, S. M. Bashi and M. I. Hassan 9(2003), Micro Controller Based Adjustable Closed-Loop DC Motor Speed Controller, *Student Conference on Research and Development (SCOReD), 2003 Proceedings, Putraiaya*, Malaysia.

Mohamed Elshaer and Ahmad Mohamed, Smart Optimal Control of DC-DC Boost Converter for Intelligent PV Systems.

Timothy J. Ross, Fuzzy Logic with Engineering Applications