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A HIGH EFFICIENT FUZZY LOGIC CONTROLLED MAXIMUM POWER POINT TRACKING (FLMPPT) IN SOLAR PV FOR BRUSHLESS DC MOTOR DRIVES

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ABSTRACT

In this paper, the solar panel using fuzzy controlled maximum power point tracking is analysed for a brushless DC motor (BLDC). The BLDC is powered by the solar panel through an integrated inverter circuit to produce an AC signal. The solar panel power obtained is tracked by an artificial intelligent technique using fuzzy logic controller to extract the maximum power from the panel. The maximum power tracking is obtained using the DC to DC converter circuit. The DC to DC converter is controlled to operate at buck and boost mode by controlling the duty cycle. The DC power output is inverted using a three phase inverter circuit to source the BLDC motor. The proposed method improves the power transfer capability by using intelligent controller which overcomes the power losses during the transfer of energy. The proposed system is mathematically modeled using MATLAB. A similar model is experimented and the results are compared and analyzed.

Keywords: brushless DC motor, fuzzy logic controller, DC-DC converter, duty cycle.

INTRODUCTION

The energy demand is the major issue in all developing countries. The energy which is required is produced from conventional and non-conventional resources. The conventional resources like coal, water and nuclear produce very large amount of power and are in practice for many years. The issue of environmental protection is increasing everyday due to the power produced through conventional resources. The use of non-conventional resources like solar, wind and hydro replace the use of conventional methods to solve the environmental issues. Among the non-conventional resources the solar energy is one of the most significant energy resources. Many researches in solar power have proved that it is the efficient way of solving the power demand in the developing countries. However the solar power conversions do not produce 100% power extraction from its resources due to many factors like temperature, irradiation and angle of inclination. These factors are subjected to variations with respect to time period. So, it becomes necessary to extract the maximum available power from the resource without many losses. Many power extraction techniques are designed to obtain the maximum power. It simply uses a DC-DC converter circuit to track the maximum power. The maximum power extraction (MPPT) technique is obtained by controlling the duty cycle of the converter. This control technique should be used such that the converter tracks the maximum power from the panel.

Many controllers are being used for the MPPT technique but, it is proved that an artificial intelligent controller like fuzzy logic controller will produce and effective results in MPPT. In the proposed technique, a brushless DC motor drive is driven which is powered using the solar power. The solar panel uses the fuzzy logic controller for the converter circuit to obtain the maximum power from the panel. The solar power is regulated and then the DC supply is converted to AC supply using a three phase inverter circuit which acts as the source to the BLDCM. The proposed system block diagram is shown in the Figure-1.

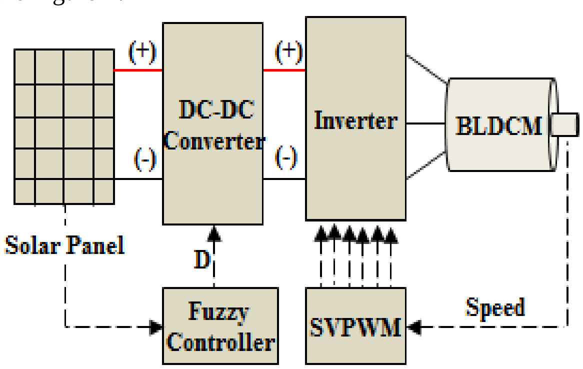

Figure-1. Block diagram of the proposed system.

The solar panel output is connected to a DC to DC converter. The converter gate pulses are controlled using fuzzy logic controller which gets the input from the solar panel. The controller uses a fuzzy program designed to obtain the duty cycle (D) for the gate pulse. The gate pulse operates the converter circuit to track the maximum power. This DC output obtained is constant and is given as an input to the three phase inverter. The three phase inverter circuit is controlled using space vector pulse width modulation (SVPWM) to obtain high efficient output for the brushless DC motor (BLDCM). The inverter pulses are controlled to produce controlled motor speed. The use of BLDCM is efficiently studied through both simulation and hardware implementation.

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MODELING OF PROPOSED SYSTEM

Modeling of solar PV panel

The modeling of solar panel is done by using the solar input equations which describes the electrical characteristics. The Figure-2 shows the equivalent circuit of the solar panel.

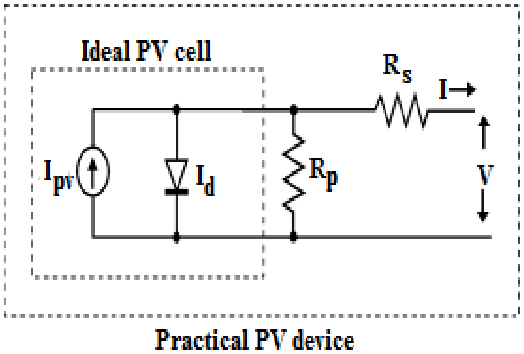

Figure-2. Equivalent circuit of PV panel.

The solar panel equations relating the I-V characteristics is given as,

$$I = I_{pv,cell} - I_d$$

Where,
$I_{pv,cell}$ is the PV cell current generated by the solar cell, I_d is the Shockley diode current which is given as,

$$I_d = I_{0,cell}\left[\exp\left(\frac{qV}{akT}\right) - 1\right]$$

Using the above equations, the solar output equation is given as

$$I = I_{pv,cell} - I_{0,cell}\left[\exp\left(\frac{qV}{akT}\right) - 1\right]$$

$I_{0,cell}$ is the reverse saturation current of the diode, q is the electron charge, k is the Boltzmann constant, T is the temperature in kelvin and a is the diode identity constant.

Using the above equation with theoretical assumptions, the solar PV panel is modeled in MATLAB. The PV panel modeling involves a closed loop control. The input variables are the temperature, irradiation, parallel resistance, series resistance and the reference values are assumed to be constant.

The photovoltaic current I_{pv} and the diode saturation current I_o are mathematically modelled separately and then synchronised to obtain the panel current equation. The number of series (N_s) and the parallel (N_p) cells determines the series and the parallel resistance.

Modeling of MPPT using fuzzy logic controller

The equation of the I-V curve of the PV panel shows that the graph draw between the panel current and output voltage is that the panel current remains constant for any values of the voltage. We also know that the diode I-V characteristic under forward biased conditions is that the diode current increases exponentially above the threshold voltage level. Appling the above practical concept in the solar output current equations, which is the difference of the both, gives an I-V characteristic that has constant maximum current for any change in the voltage from minimum to maximum values.

The I-V characteristics of the solar panel are shown in the Figure-3. It is observed that the maximum current is obtained at maximum voltage applied above which the current falls to zero. Therefore it is necessary to track the maximum power at the point having the maximum values of current and voltage.

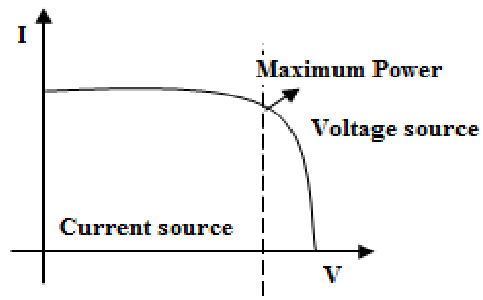

Figure-3. I-V characteristics of solar panel.

The point with maximum power is to be tracked for varying input parameters like temperature and irradiation to obtain the maximum efficient power output with reduces power losses. The fuzzy logic controller is use to gate the converter circuit such that the duty cycle D is controlled. The fuzzy controller follows a closed loop control taking the current and voltage values of the panel and the output respectively. Using the input data a fuzzy rule is created such that the desired output is obtained. The rules for the fuzzy controllers are set using the required output based on the input applied. The controller input variables are change in solar panel power (ΔPpv) and the change in voltage (ΔVpv). The change in values requires a comparative value for the desired output. The reference voltage (ΔVref) is taken for the output reference. These value maximises the output that to be obtained. The direction of variation will be either in positive or the negative direction. The variations in increase and decrease the values depends on the direction of tracking the values. This can be obtained by using the linguistic variables [20] such as BN (big negative), MN (means negative), SN (small negative), Z (zero), SP (small positive), MP (means positive), and BP (big positive)). These linguistic values are used by the fuzzy controller to obtain the desired change in output error. This is compared and the corrections are obtained. The corrections are obtained in sampled times which are used as the pulses for the boost converter.

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Table-1. Fuzzy logic rules for obtaining the maximum power from the solar panel.

ΔVpv/ΔPpv	NB	NS	Z	PS	PB
NB	NB	NB	NB	NS	Z
NS	NS	NS	NS	Z	Z
Z	Z	Z	Z	PS	PS
PS	Z	Z	PS	PS	PS
PB	Z	PS	PB	PB	PB

The main concepts in fuzzy control are fuzzification, rule-base and defuzzification. The loop is formed to obtain the change in converter current reference (ΔI_{ref}). The Figure-4 shows the fuzzy logic control used for obtaining reference panel current values.

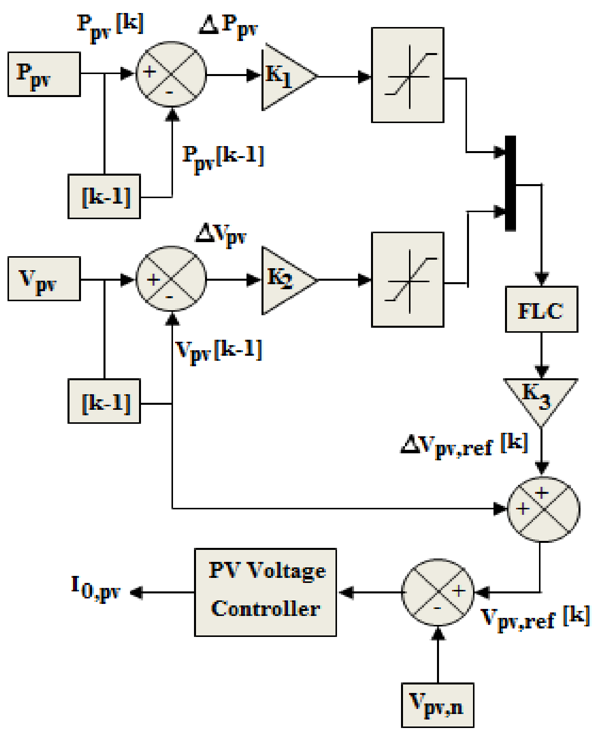


Figure-4. Fuzzy logic control.

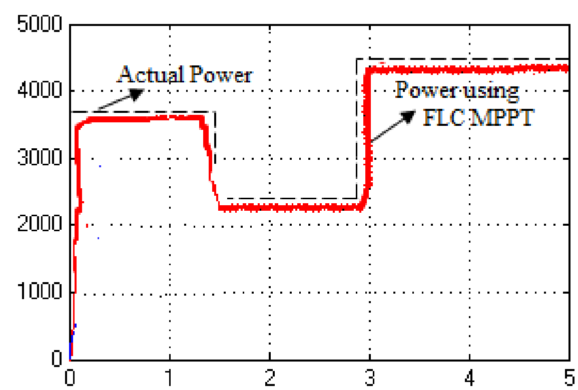
OUTPUT MODEL OF PROPOSED SYSTEM

Simulation model and results

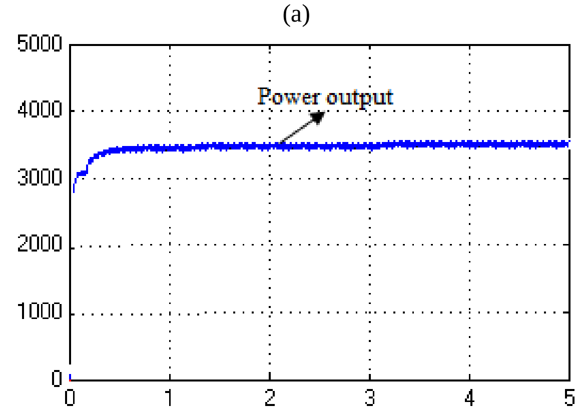
The proposed system is mathematically modelled in Matlab. The solar PV panel is modelled for 3.5kW power. The solar panel is subjected to different temperature and irradiation values are simulated and the results are shown in Figure-5. The theoretical analysis of the fuzzy logic maximum power point tracking (FLMPPT) shows the power plot in dot lines. In Figure-5(a), it is observed that the power tracked along the theoretical analysis using FLMPPT is close to the actual power. The power tracked by the fuzzy logic controller is very much close to the maximum available power with respect to the different temperature levels and the different values of irradiations.

The maximum power tracked by the controller during the operation period varies with respect to the input parameters which is the open loop output of the DC-DC converter. To obtain the fixed and regulated output, a closed loop DC-DC converter based FLMPPT is designed where the output is analyzed against the reference values of voltage and power. The closed loop FLMPPT based DC-DC converter output power is show in the Figure-5(b).

The output is observed that the power obtained is constant for any variation in the input parameters. The FLMPPT adjusts the duty cycle thus making the converter to operate both in buck and boost operation. This is obtained by controlling using the Mamdani fuzzy logic interference. This method is associated with max-min composition. The de-fuzzification method is based on the centroid method which is used to compute the crisp output. The range is set and the rules are imported in the FL controller interface system as a membership coding to obtain the desired output. The error obtained in used to calculate the change in error thus the change in output of fuzzy controller is obtained.



(a)



(b)

Figure-5. Simulation output (a) Power using FLMMPT (b) Output power of the converter.

The converter output voltage is 440V which is the input power to the three phase inverter circuit. The three phase inverter switches are operated using the space

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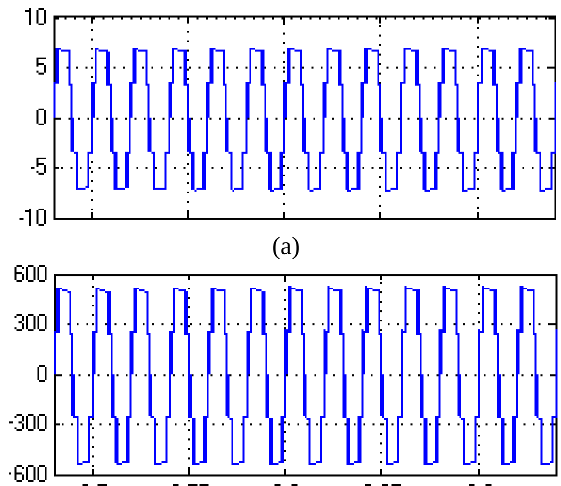
vector pulse width modulation (SVPWM) technique. The three phase inverter RMS output is obtained for 400V, 4.8A. The inverter R phase output current and voltage is shown in the Figure-6.

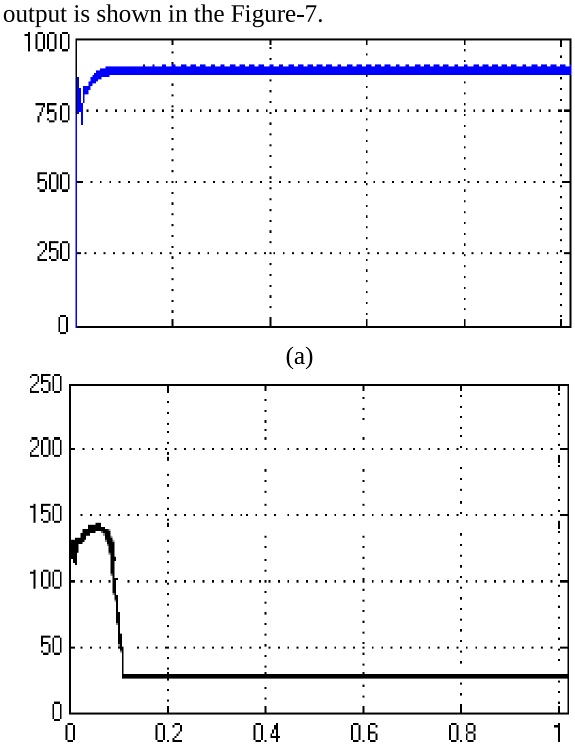


(a)

(b)

Figure-6. Inverter output (a) current in R phase (b) voltage in R phase.

The inverter output is fed to the BLDCM drive system. The BLDCM output speed and the motor torque output is shown in the Figure-7.



(a)

(b)

Figure-7. BLDCM outputs (a) Speed (b) Motor Torque.

Experimental model and the results

A similar model is experimented using a 1kW panel connected to a DC-DC converter and then to an inverter. The inverter output is fed to a BLDCM. The experimental model is shown as in Figure-8.

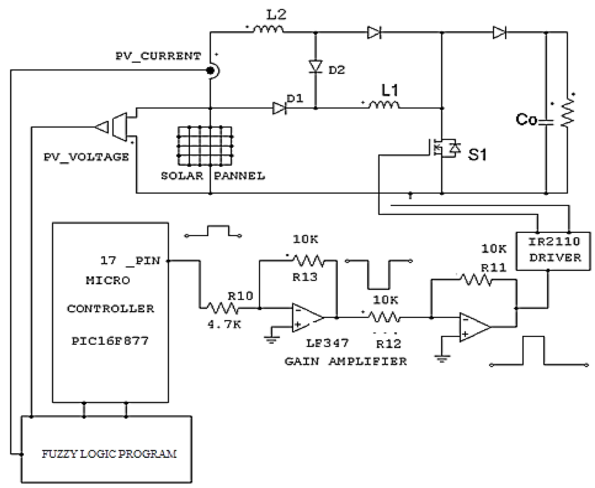


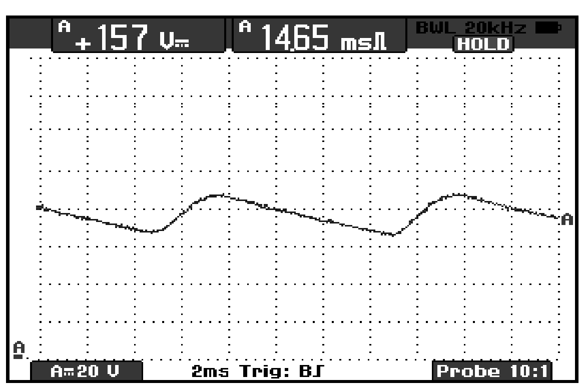
Figure-8. Proposed hardware model.

The PIC16F877 microcontroller is used to produce the switching pulse at 20kHz. The fuzzy logic rules are programmed to obtain the gate pulse signal through the PIC controller to the converter circuit. The table shows the component values used for obtaining the desired output.

Table-2. Component values used in the hardware circuit.

Component	Value
Inductor (L)	2mH
Capacitor (C)	100µF
PWM Switching	20kHz

The DC output voltage of the converter is shown in the Figure-9.



(a)

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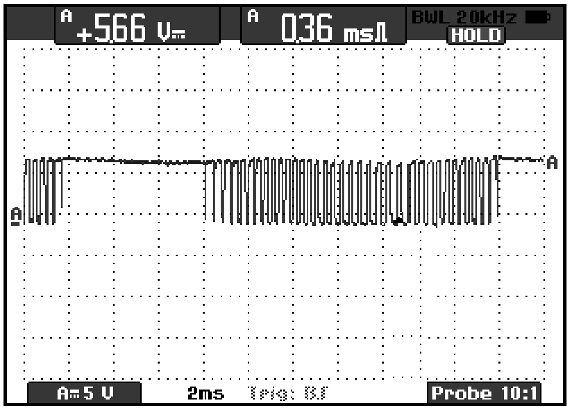
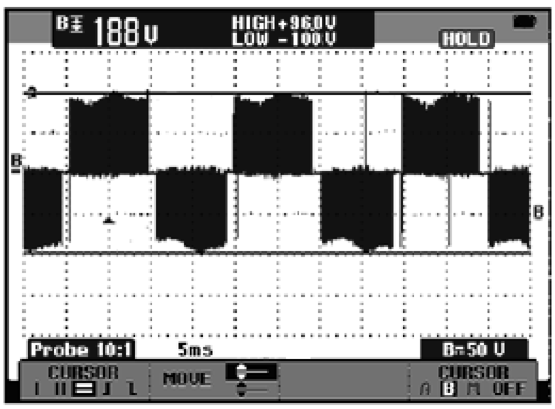


(b)



(c)

Figure-9. Hardware results (a) DC voltage from converter (b) Gate pulse at 20kHz (c) R Phase Inverter output voltage.

RESULTS AND DISCUSSIONS

The simulated mathematical model is analysed by operating the solar panel with and without fuzzy logic controller. The energy tracker for different temperature and irradiations are analysed. The results are tabulated and shown in the Figure-10.

Table-3. Simulated results analysis for different temperature values (Load, R=1kW; t=1hr).

Temp. in ^{o}C	Actual Energy in kilo-joules	Watt-hr. without FLC	Watt-hr. with FLC
15	30	398.54	491.30
20	40	598.32	631.48
25	50	761.43	810.33
30	60	968.43	993.92
35	50	761.43	810.33
45	30	398.54	491.30

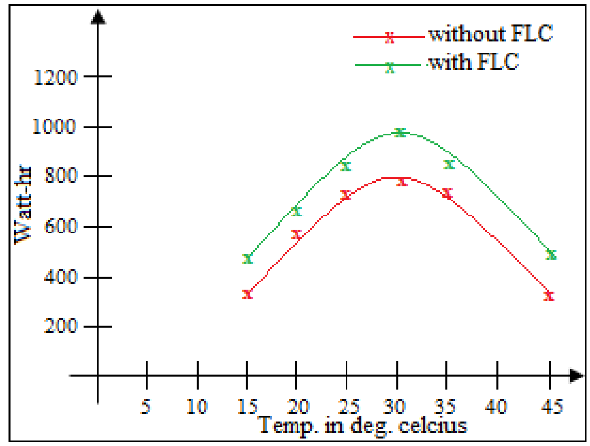


Figure-10. Output power using with FLC and without FLC.

The analysis shows that the solar power tracking using fuzzy logic controller (FLC) produces 2.5% increase in the power output compared to without a FLC. This result also shows the maximum power obtained during the proposed technique is more efficient compared to conventional MPPTs.

CONCLUSIONS

The proposed system using fuzzy logic controlled maximum power point tracking for the brushless DC motor drive is simulated and experimented. The results obtained in the simulation model uses both with and without the fuzzy controller and the analysis is made. The power extraction using the proposed FLC increases 2.5% of total energy that is being extracted. This increases the efficiency of the system accurately. The constant DC supply obtained is powered for the three phase inverter which is controlled using the SVPWM. The BLDCM is driven at a constant speed by the closed loop control of the inverter fed drive system. The proposed FLC used in MPPT increases the power output from the solar panel thus the maximum power is tracked.

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