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Simulation of MPPT using Fuzzy Logic Controller for AC Drive

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Abstract: The need for renewable energy sources is increasing due to increase in world's energy demand. Solar energy is one of the widely used renewable energy source due to efficiency, size, maintainability. In this work dc power from the solar panel is boosted using a boost converter and then it is given to inverter which gives AC Power which runs an induction motor. To get the maximum power available a MPPT controller is used to control the Boost converter. There are different types of MPPT algorithms in which artificial intelligence techniques are popular. Artificial neural networks and fuzzy logic are two different types of artificial intelligence techniques used to design MPPT controller for PV system. Depending on solar radiation and temperature MPPT controller gives optimum duty cycle to the switch of the boost converter. In this work fuzzy logic technique is used to control the MPPT to give optimized duty cycle.

Keywords: MPPT, PV, ANN, FL.

I. INTRODUCTION

The large usage of fossil fuel such as coal, gas and oil results in the green -house effect and environmental pollution. Meanwhile increase in the global energy demand decrease in conventional energy resources leads to the increase in the fossil fuel costs[1]. These are the limitations for the human development. So there is a need for renewable energy sources.

Among several sources of renewable energy sources solar energy is the primary one. On an average earth receives $1.2*10^{17}$W of solar power. It has several advantages like no fuel cost, requires little maintenance, non -polluting etc [2].

Solar power system finds extensive application in remote areas where access to the grid supply is not possible[3]. Solar pump operated with AC drive uses an inverter with ac motor. Induction motor offer better choice in terms of size, ruggedness, efficiency and maintainability. The DC power from solar array is boosted using a boost converter and fed to an inverter which gives ac output. Output of the inverter drives the motor.

PV generation systems generally have two major problems. One is low conversion efficiency and electrical power generated by the solar array changes under varying weather conditions [4]. Therefore photovoltaic power system usually requires maximum power point tracking (MPPT) controller, which is an electronic system which operates the Photovoltaic (PV) modules, such that it allows all the modules to produce maximum power. There are different types of MPPT algorithms like Perturbation and Observation (P&O) Method, incremental conductance methods come under the group of traditional techniques. There are other techniques called as Artificial intelligence (AI) techniques are alternate approach for conventional physical modelling techniques as they do not require the knowledge of internal system parameters, involve less computational effort and offer a compact solution for multivariable problems. They have been used to solve complicated practical problems in various areas. These techniques are becoming more popular in PV systems which exhibits non-linear features. Artificial neural networks (ANNs) and fuzzy logic (FL) are two different types of artificial intelligence techniques, are used to design the MPPT controller for PV system [3]. In this paper Fuzzy Logic technique is used for the design of MPPT controller.

II. PV ARRAY

A photovoltaic cell is a device which converts incoming sunlight into electric current by means of photoelectric effect. Basically PV cell is a p-n junction semiconductor diode. An ideal solar cell is can be modelled as a current source in parallel with a diode. But there is no ideal PV cell[3].

The equivalent circuit of a non-ideal PV cell is as shown in the Fig. 1 which consists of a current source, a diode, a series resistance and shunt resistance [5][6].

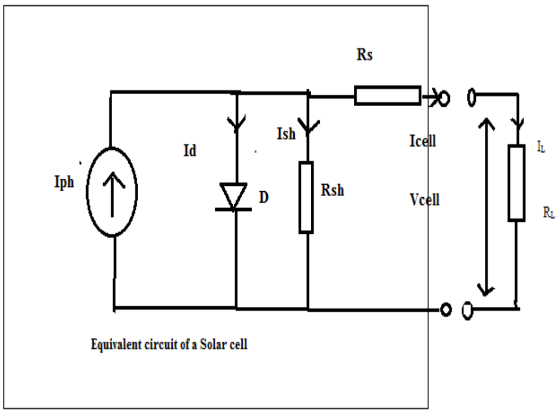

Fig. 1: Equivalent electrical circuit of a PV cell

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The output current of non- ideal PV cell is derived by Kirchhoff's current law and it is given by [5]

$$I_{cell}=I_{ph}-I_d-I_s \quad (1)$$

The overall current that the PV cell can provide is given by the equation

$$I_{cell}=I_r+[\alpha(G/G_r)(T_c-T_{cr})+((G/G_r)-1))I_{sc}] \quad (2)$$

where I_r is the reference value taken from the I–V curve[5], G is active radiation and Gr is reference radiation, T_c and T_{cr} are module temperature and reference temperature. Isc represents the short circuit current of the module and α is the temperature coefficient of short circuit current.

The voltage of the PV cell is given by

$$V_{cell}=-\beta(T_c-T_{cr})-R_s\Delta I+V_r \quad (3)$$

Where $\Delta I=[\alpha (G/G_r)(T_c-T_{cr})+((G/G_r)-1))I_{sc}]$

In the above equation β is temperature coefficient of open circuit voltage, V_r is the reference voltage taken from I-V curve[5], R_s is used to represent the voltage drop at the output of the PV cell.

The output of a single PV cell is very low. So several such PV cells are connected in series and parallel to form the PV module to achieve the required power level.

In this case the output current and voltage are given by the equation (4) and (5) respectively.

$$V_m=N_{sc}V_{cell} \quad (4)$$

$$I_m=N_{pc}I_{cell} \quad (5)$$

Where V_m and I_m is the output voltage and output current respectively. N_{sc} is number of series connected PV Cells, N_{pc} is parallel connected PV cells.
Power output of a PV panel depends on the radiation and temperature at a particular instant which varies with climatic conditions.

A. *MPPT Controller*

The solar cell V-I characteristic is non-linear and varies with radiation and temperature. In general there is a unique point on the V-I or V-P curve called Maximum Power Point at which entire PV system produces its maximum output power. The maximum power point can be found either through calculation models or by few algorithms. Therefore Maximum Power Point Tracking techniques are needed to maintain the PV array's operating point at its MPP[4].

There are different types of MPPT algorithms like Perturbation and Observation method, Incremental Conductance method etc which come under the group of traditional methods. There are some other techniques called as artificial intelligence techniques in which Artificial Neural Networks and fuzzy logic are two different types[3]

In this work fuzzy logic technique is used for the MPPT controller. Fuzzy Toolbox in Matlab is used for simulating the MPPT controller. Solar panel output is used as the source and this output is boosted using a boost converter and then fed to the load after required conversion. The output of PV panel depends mainly on the availability of solar radiation and temperature. MPPT controller is used to operate the system at MPP at that instant. Depending upon the solar radiation and temperature the artificial fuzzy logic controller find the optimum duty cycle to be fed to the switch of the boost converter [3]. Fig.2 gives the configuration of the MPPT controller. Fig.3 represents the flow chart for the controller.

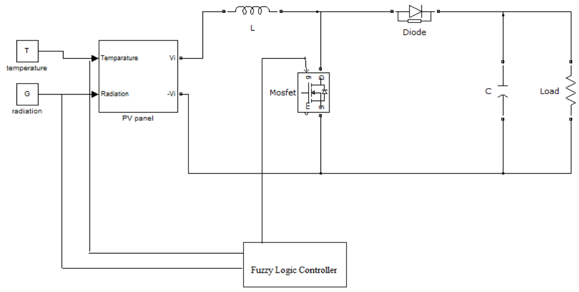

Fig.2: Configuration for MPPT controller

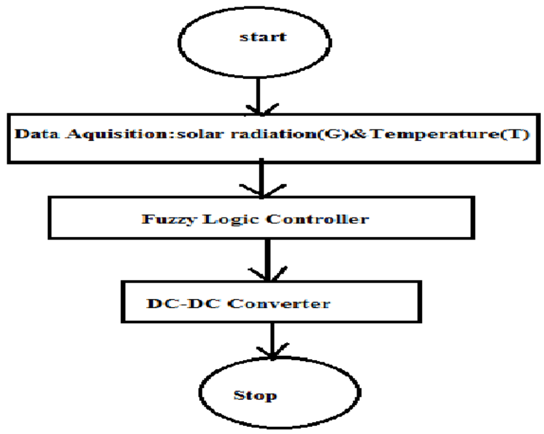

Fig.3: Flow chart for FLC

B. *Fuzzy Logic Controller*

Fuzzy logic controller is relatively simple to design as they do not require the knowledge of the exact model. Compared to other methods fuzzy logic system provides faster results using the expert knowledge and measured database. The algorithm for the MPPT controller is based on three steps: the knowledge base of expert, fuzzification ,inference diagram and defuzzification. Fig.4 shows the generalised fuzzy logic controller[3].

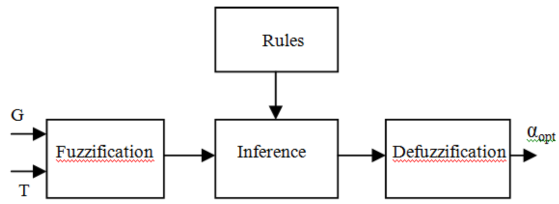

Fig.4: General block diagram of Fuzzy Logic Controller

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Fuzzification : converting crisp facts into fuzzy sets described by linguistic expressions, Inference: The fuzzy IF THEN rule expresses a fuzzy implication relation between the fuzzy sets of the premise and fuzzy sets of the conclusion. Defuzzification: To obtain a crisp output.

Mamdani model in Matlab is used to model the fuzzy logic controller which has two inputs solar radiation and temperature and one output optimum duty cycle .Each input and output has four membership functions small, means ,large and very large .Fig.5,Fig.6 and Fig.7 shows these membership functions[7].

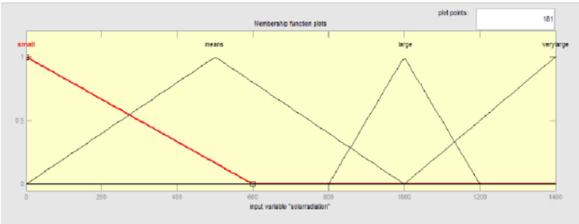

Fig.5: Membership function for solar radiation

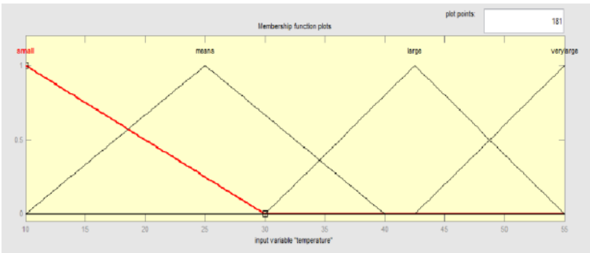

Fig. 6: Membership function for temperature

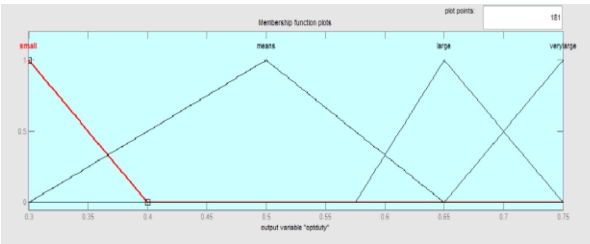

Fig.7: Membership function for optimum duty cycle

Input output relationship between the variables are defined using fuzzy rules as shown in table 1. Based on these rules optimum duty cycle is fed to the boost converter and it delivers maximum power.

TABLE I FUZZY RULES

	Solar radiation	
Temperature	small	means
small	small	small
means	small	means
large	small	means
very large	small	means

III. SYSTEM CONFIGURATION

The proposed system consists of PV panel , boost converter, inverter ,ac load and a MPPT controller to produce maximum power at a particular instant[3]. The block diagram representing this system is given by Fig.8.

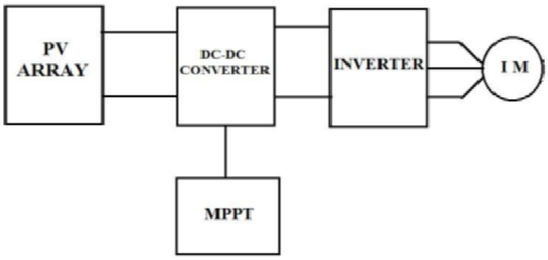

Fig.8:system block diagram

PV panel output power is fed to a boost converter. Optimum duty cycle is given by a MPPT controller to the converter switch. The fuzzy logic MPPT controller depending on the solar radiation and temperature produces optimum duty cycle which makes the system to give maximum power at that particular instant.

Fig.9 shows a boost converter circuit which is used to boost the power output of the PV panel[8][9].

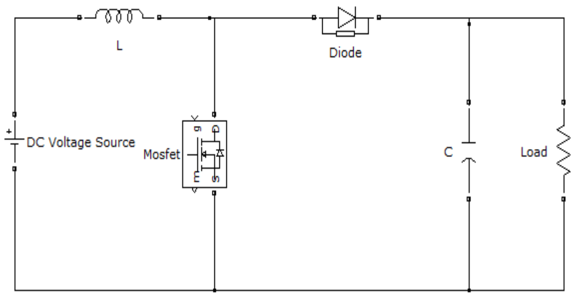

Fig.9: Boost converter circuit diagram

For which L and C can be designed using the equation

$L= V_i*D/(f*\Delta I_l)$ (6)

$C=D/R*f*(\Delta V_o/V_o)$ (7)

IV. SIMULATION BLOCK AND RESULTS

Solar panel is modelled using mathematical equations 1-5.Block diagram of PV simulation model is as shown in theFig.10[5].

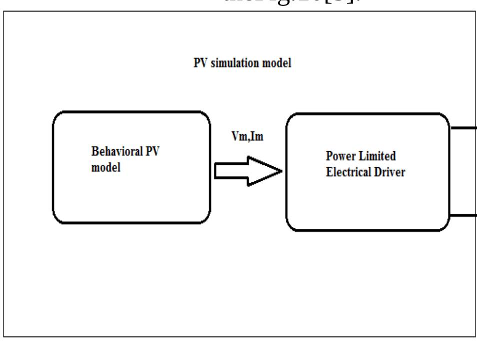

Fig.10: Block diagram of PV simulation model

Simulink model of the behavioural PV model is given by the following figure

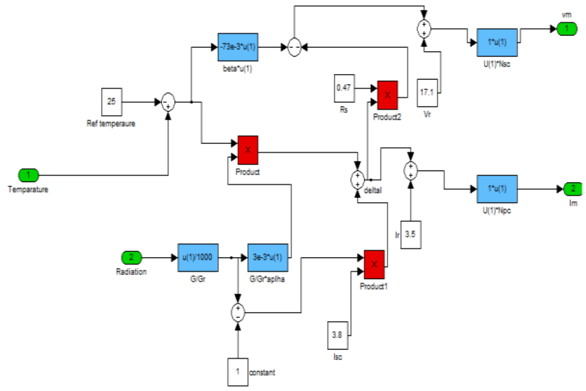

Fig.11: Simulink model of behavioural PV model

Fig.12 shows the Simulink model of the electrical drive.

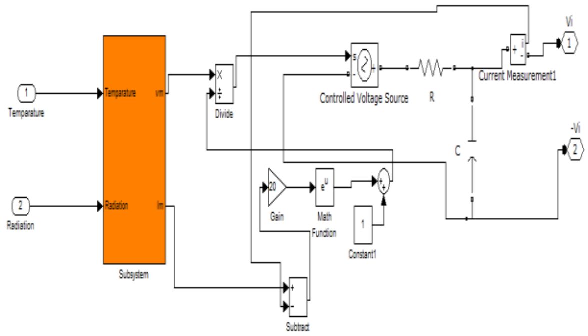

Fig.12: Simulink model of electrical driver

Parameters used for the PV module in simulations is given by table II

TABLE II PARAMETERS USED FOR PV MODULE IN SIMULATION

PV module parameters	Values
Serial Resistance R_s	0.47ohm
Internal Resistor R_i	1 ohm
Internal capacitor C_i	10^{-2}F
Reference voltage V_r	17.1V
Reference current I_r	3.5A
Short circuit current temperature co efficient(α)	$3*10^{-3}$mA/°C
Open circuit voltage temperature coefficient(β)	$-73*10^{-3}$mW//°C
Short circuit current	3.8A

Simulink simulation of a PV module for a DC load is given by the Fig.13

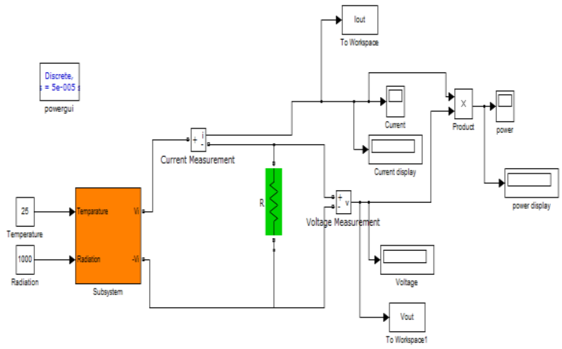

Fig.13: Simulink simulation of a PV module

Here the load resistance R_L was set to 4.2 Ω to work nearby maximum power point .A reference radiation of 1000W/m^2 and module temperature of 25°C are used for the simulation. The internal resistance R_i is set to 1Ω and internal capacitance C_i is set to 10^{-2}F.Then the simulation result of solar panel is voltage current and voltage power characteristics as shown in Fig.14 and Fig.15 respectively.

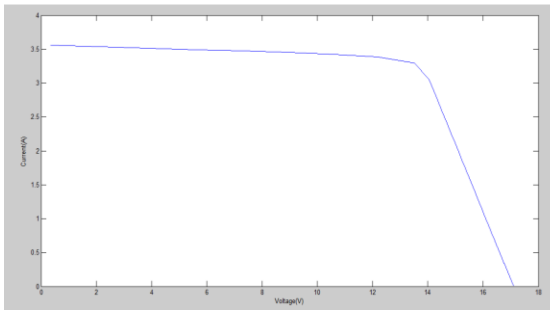

Fig.14 : voltage current characteristics

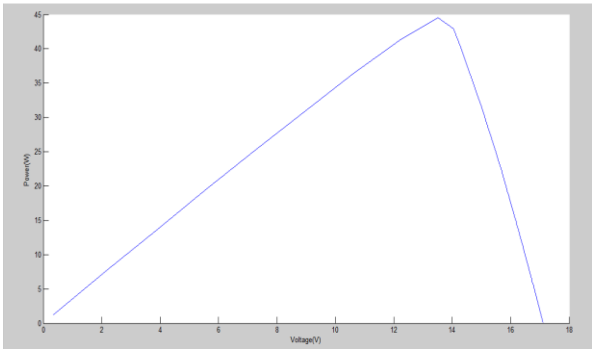

Fig.15 : Voltage Power characteristics

MPPT controller uses two inputs solar radiation and temperature and it produces optimum duty cycle as the output .

Fuzzy logic controller is implemented using Fuzzy toolbox available in matlab. Mamdani inference mechanism is used in fuzzy controller. Figure 5 and figure 6 shows the two input membership functions for solar radiation and temperature. Figure 7 shows the membership function of output variable i.e optimum duty cycle. Each input and

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output variables have four membership functions. Depending on the fuzzy rules controller gives optimum duty cycle. Fig.16 shows the Simulink diagram for the fuzzy controller.

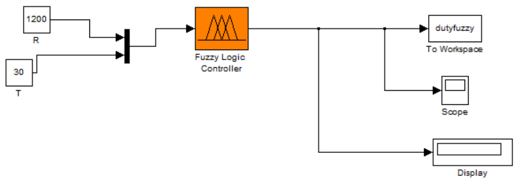

Fig.16: optimum duty cycle from controller

The DC output from the boost converter is fed to the inverter which gives AC output. This is given to the ac drive system .PWM technique is used to generate pules for the gate of the inverter. To realise AC drive, a load of 1.5N-m is connected to induction motor. The final simulation block diagram of the converter drive is as shown in the Fig.17.

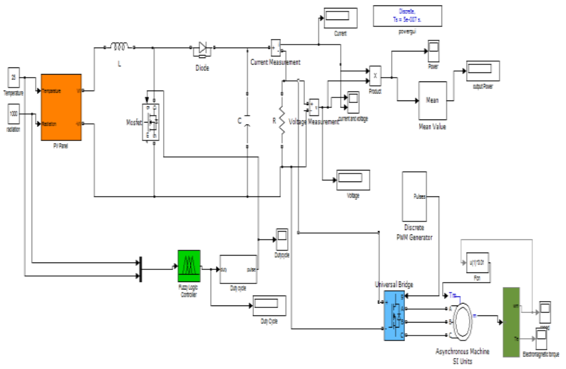

Fig.17: simulation diagram for converter drive

Output of the above final simulation diagram that is speed corresponding to load torque of 1.5N-m is as shown in below Fig.18.

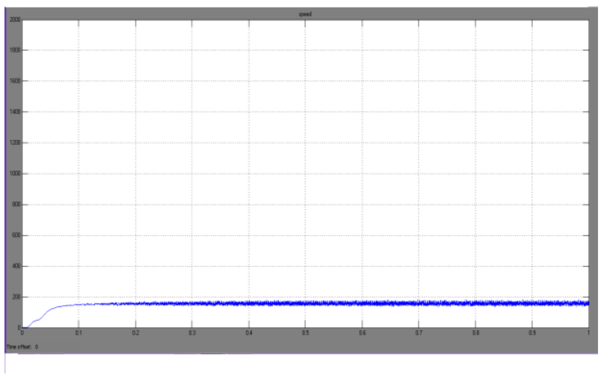

Fig.18 : Waveform for speed

V. CONCLUSION

In this work power output from the boost converter is observed for various radiation and temperature. Maximum power from the boost converter is observed at a duty cycle of 0.48 for radiation of 1000W/m^2 and module temperature of 25°C.The maximum power from the boost converter observed is 1097W and it is obtained at duty cycle of 0.48.Power output of the converter is as shown in Fig.19.

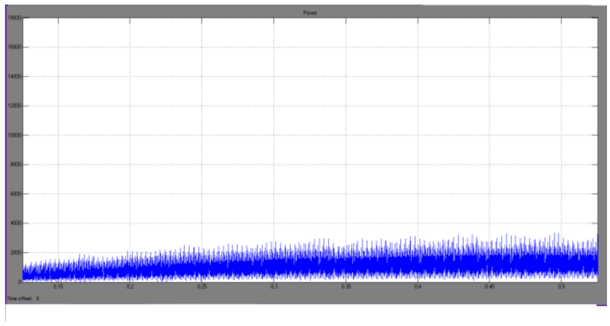

Fig.19 : Power output of converter

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REFERENCES

[1] Athimulam Kalirasu and Subharensu Sekar Dash, "Simulation of closed loop controlled boost converter for solar radiaton ", Serbian Journal of electrical engineering ,vol.7.pp.121-130, May 2010.
[2] Dr. A. Moussi , A, Saadi , A.Betka, and G.M. Asher , "Photovoltaic pumping systems Technologies Trends" , Larthyss Journal ISSN .pp.127-150, June 2003
[3] Anna Mathew and A. Immanuel Selvakumar "MPPT Based Stand Alone Water Pumping System "International Conference on Computer communication& Electrical Technology ICCCET2011,18th and 19th March 2011
[4] Robert o Faranda ,Sonia Leva"Energy Comparision of MPPT techniques for PV systems"WSEAS Transactions on power system ,vol 3,June 2008
[5] Cemal Keles,B.Baykant ,Murat Akcin,Asim Kaygusuz,Abdulkerim Karabiber "A photovoltaic system model for Matlab/Simulink simulations".
[6] "How PV cells work", Aug 25, 2010[online].Available at http://www.fsec.ucf.edu/en/consumersolar_electricity: basics/how_pv_cells_work.htm
[7] 'Fuzzy Logic Toolbox users guide', The Math works Version 7.6.0.324(2008a)
[8] Mohan Ned, Undeland Tore M and Robbins William P,"Power Electronics,converters Applications and design ", John Wiley & sons Inc.,Book 1995
[9] Daneil W Hart, "Power Electronics", Mcgraw Hill education (India) Pvt.Ltd Book 2011