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An MPPT Control of Photovoltaic system using Fuzzy Logic Controller

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ABSTRACT: In a photovoltaic system,the maximum power point varies with insolation and cell temperature . Maximum power point tracking (MPPT) is implemented to identify the maximum power operating point and subsequently system is operated at that particular operating voltage for maximum power gaining.Thisalgorithm is implemented in charge controllers for extracting maximum available power from PV module. Maximum power point tracking in photovoltaic systems using artificial intelligence methods are very popular. Fuzzy systems are very effective than simple conventional MPPT tracking. In the simulation part, a buck-boost converter feeding a permanent magnet dc load is achieved. The accuracy of the overall system depends on the fuzzy rule base and membership functions defined. The performance curves for comparison was obtained using MATLAB/Simulink platform.Simulation results show that fuzzy based tracking has better performance where it can facilitate the solar panel to produce a more stable power.

KEYWORDS: GUI-Graphical User Interface; MPPT-Maximum power point tracker; NN- Neural Network; PV-Photovoltaic; P&O- Perturb and Observe; RCC- Ripple correlation control

I.INTRODUCTION

In spite of new progresses in Technology, the problems caused due to global warming and pollution effects become the main research issue these days. Energy shortage aggravates with industrial development. Increasing energy demand cannot be met with conventional energy sources like fossil fuels since their availability is significantly less. Therefore theuses of renewable systems gain more attention worldwide. Among renewable energy sources, photovoltaic systems are considered as the best option for generating clean energy. Photovoltaic systemgenerates maximum energy at a particular operating point. MPPT Technique is the most commonly used algorithm for tracking this maximum power. Several MPPT techniques which are either voltage or current feedback based or power feedback basedare used commonly. It includes perturb and observe (P&O), Incremental conductance method, Parasitic capacitance, Constant voltage control and Constant current control strategies. The main objective of each algorithm is to tap the maximum energy available in the system. The efficiencies of each method vary significantly.

PV array is an unregulated dc power source which has to be properly conditioned in order to connect it with the grid or any other power source. For extracting the maximum power available for a particular insolation level, a dc-dc converter is placed in between the PV panel and load. By maximum power transfer theorem maximum power may be transferred to the load when load impedance equals source impedance. This is done by varying the duty cycle of dc-dc converter. The performance of PV array system will depend on operating conditions. The output voltage, current and power of PV array vary as functions of solar irradiation level, temperature and load current.

One of the most popular MPPT techniques is Perturb and Observe scheme. In this method, in order to get the maximum possible power output, the duty cycle of DC-DC converter is perturbed in fixed steps. If the step size is large, system will oscillate much and if it is too small response time will be large. Thus there is a problem of convergence and oscillation which can occur during tracking. Another technique that can reduce the drawbacks related to P & O method is improved P&O method. In this method a fixed algorithm is proposed which automatically adjusts the reference step size and hysteresis bandwidth for power comparison. The IP&O method increases the total PV output power by 5% at an unsettled weather condition.

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Another widely used MPPT technique is incremental conductance, or IncCond. The slope of PV curve is zero at maximum power point. IncCond make use of the fact that the power curve slope unravels whether the array current has yet to reach MPP, is at MPP, or has exceeded MPP and must be reduced. Thus if the system reaches maximum power point, then incremental conductance is (ΔI/ΔV)=-I/V.Ripple correlation control harness the imposed ripple current and has the advantage that its response time is quick and analog implementation is less expensive. RCC correlates the time derivative of power with the timederivative of current or voltage to drive the power gradient to zero. Thus it is a virtual implementation of P&O without the need of external perturbation. Another well- known technique is fractional open circuit voltage which makes use of the fact that a PV cell's open circuit voltage will vary under irradiance and temperature conditions with approximate similarity to an array under load. In the fractional open-circuit voltage scheme, the array is disconnected from the converter at regular intervals and the open circuit voltage is measured. But this results in a momentary loss of power.

A number of soft computing techniques exist for maximum power tracking. This includes Neural network, adaptive fuzzy etc. In neural network (NN) technique, a trained neural network outputs the reference voltage for MPP. The reference voltage can be attained using either a fuzzy or a PI controller. This can be done with less computational efforts and the knowledge of internal system parameters may not be required. Neural network has to be periodically trained since the characteristics of a PV array can change with time. Section II provides details about photovoltaic system and MPPT strategy. Proposed fuzzy logic controller is explained in Section III and the verified simulation results are presented in Section IV which is followed by conclusion in Section V.

II.PHOTOVOLTAIC SYSTEM

The power produced by a single PV cell may not be sufficient for general use. Thus PV cells are connected in series so as to increase the voltage. Several such series string of cells may be connected in parallel thus increasing the current. These interconnected cells are then sandwiched between a top layer of glass or clear plastic and a lower layer of plastic and metal. To mount a unit as a module, an outer frame is attached which also increases the mechanical strength. The amount of current produced depends on cell size, conversion efficiency and the intensity of light [1].

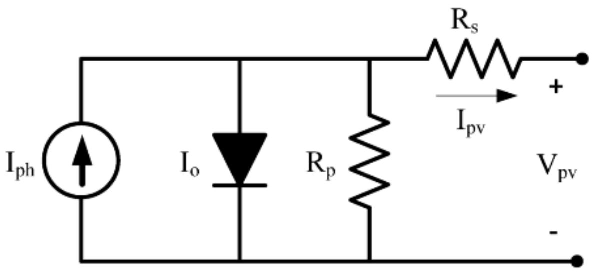

Fig.1 Equivalent circuit of a PV cell

Depending on sunlight intensity and temperature, the output current of PV may be indicated by the relation as in Eq.4. The standard conditions which yields maximum output power called peak power will be under sunlight intensity S=1000W/m^2, air mass 1.5 and cell temperature 25^{0}C. PV cell characteristic is highly nonlinear as in Fig.2, so it is neither a constant voltage source nor a constant current source. PV cell can be modeled as per following equations.

$$I_{ph} = I_{SCr} + K_i(T - 298)\frac{\lambda}{1000} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

$$I_{rs} = \frac{I_{SCr}}{\exp\left(q\frac{V_{oc}}{N_s kAT}\right) - 1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots,,\ldots.(2)$$

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$$I_o = I_{rs}\left[\frac{T}{T_r}\right]^3 exp\left[\frac{qE_{go}}{Bk}\left\{\frac{1}{T_r}-\frac{1}{T}\right\}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (3)$$

$$I_{PV} = N_P * I_{ph} - N_p * I_o\left[exp\left\{\frac{q^*(V_{PV}+I_{PV}R_S)}{N_S AkT}\right\} - 1\right] \ldots\ldots(4)$$

I_{ph}= Light generated current in a PV module
I_{rs} = Module reverse saturation current
λ = PV Module illumination
T = Module operating temperature
T_r = Reference temperature
E_{go} = Band gap for silicon =1.1eV
k = Boltzmann constant = 1.38* 10^{-23} J/K
A = ideality factor =1.6
I_{SCr} = PV Module short circuit current at 25°C and 1000W/m^2 = 2.5A
Ki = Short circuit current temperature coefficient = 0.0017A/°C
I_o = PV module saturation current
I_{PV} = Output current of a PV module
N_p = No. of cells connected in parallel

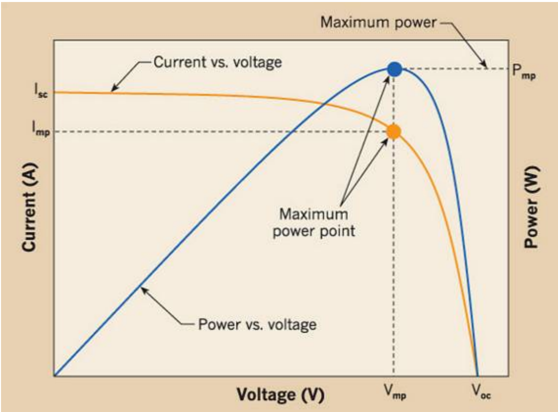

Fig.2 PV module characteristics

III. FUZZY LOGIC CONTROLLER

The maximum power point tracking using a fuzzy logic controller is implemented. A detailed block schematic of MPPT using fuzzy is shown in Fig.3.Fuzzy logic systems have the advantage that it is robust and is relatively simple to design .The exact model of the system is not required in fuzzy systems[2].Fuzzification is a process of transforming crisp values into grades of membership for linguistic terms of fuzzy sets. The membership function is used to link a grade to each linguistic term. Inference means evaluating all rules and finding their truth values. If an input does not precisely correspond to an IF THEN rule, partial matching of the input data is used to interpolate an answer. The final stage is defuzzification. It converts the fuzzy value obtained from fuzzy composition into a crisp value. This process is quite complex since the fuzzy set might not translate directly into a crisp output value. Defuzzification is necessary, since controllers of physical systems demands discrete signals

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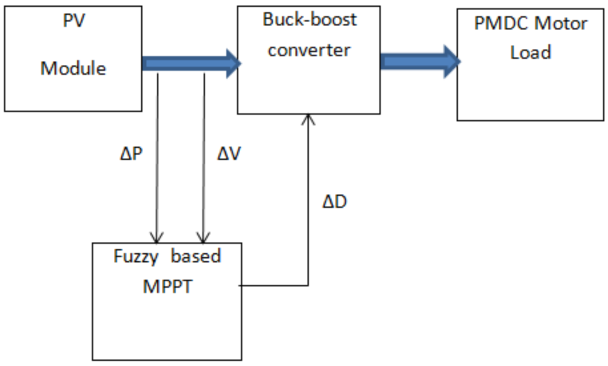

Fig.3 Block Schematic of overall system

The input membership functions for controller are error and change of error whereas the output variable is chosen as change in duty ratio dD. Input membership function values are described as linguistic variables, using five fuzzy subsets: NB(negative big), NS(negative small), ZE(zero),PS(positive small) and PB(positive big).The two input variables may be expressed as follows

E(k) = (P(k)-P(k-1)) / (V(k)- V(k-1))……………(5)

CE(k) = E(k) – E(k-1)………………………………(6)

Where P(k) and V(k) are the power and voltage of PV array. So our aim is to track maximum power point where E(k) is zero. In the fuzzy rule base of the system, each entries of the matrix are fuzzy sets of error (E), change of error (CE) and change of duty ratio (dD) of the boost converter. Defuzzification method for this system is the center of gravity approach which computes the output of this fuzzy logic controller [3]. Duty ratio which is the output of fuzzy logic control is given to the PWM which generates pulse to control MOSFET switch in DC-DC converter. Thus the output of fuzzy logic controller is switching pulses which drive converter circuitry.

MATLAB/SIMULINK can be used for modeling, simulating and analyzing various dynamic systems. It can be utilized for linear and nonlinear systems modeled in continuous time, sampled time or a hybrid of two. For modeling, SIMULINK has a graphical user interface (GUI) based on building concept. The simulation was performed using this software. The algorithm used for MPPT controller is based on fuzzy logic and fuzzy logic toolbox in MATLAB was utilized here. The PV system was modeled, simulated and results are verified. The designed controller with the adequate choice of membership functions can make sure that the MPPT will follow the true maximum power point.

IV.SIMULATION RESULTS

Maximum power point tracking was performed using the conventional P&O method and fuzzy based controller and the comparison was obtained. Voltage and current output from the buck-boost converter in both cases was plotted (as in Fig.4 and Fig.5) and analyzed. The initial transient was found to be less in fuzzy controller than perturb and observe based maximum power point tracking. With less perturbance, a photovoltaic system with fuzzy logic controller was found to settle faster than P&O algorithm.

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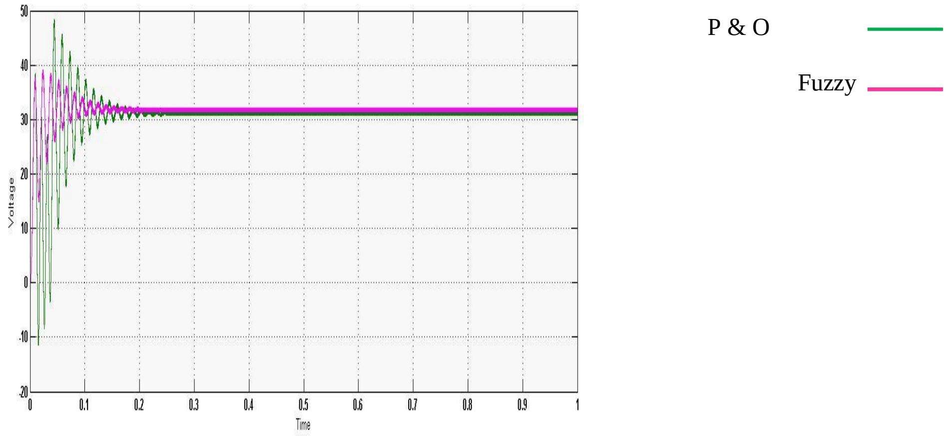

Fig.4 Voltage output from buck-boost converter

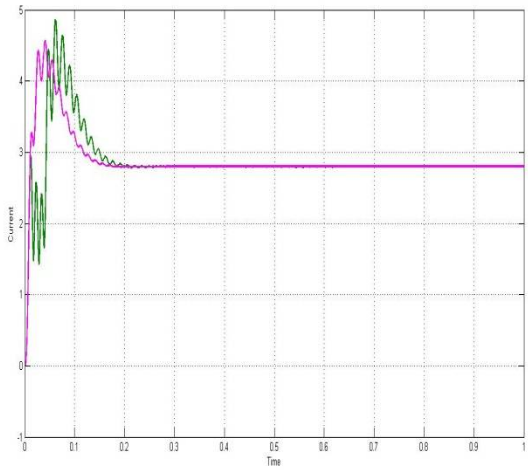

Fig.5 Current output from buck-boost converter

Output pulse from buck-boost converter drives a permanent magnet dc motor. DC motor parameters including speed, armature current and torque were plotted against time as in Fig.6.For this MPPT employed with fuzzy controller was used.

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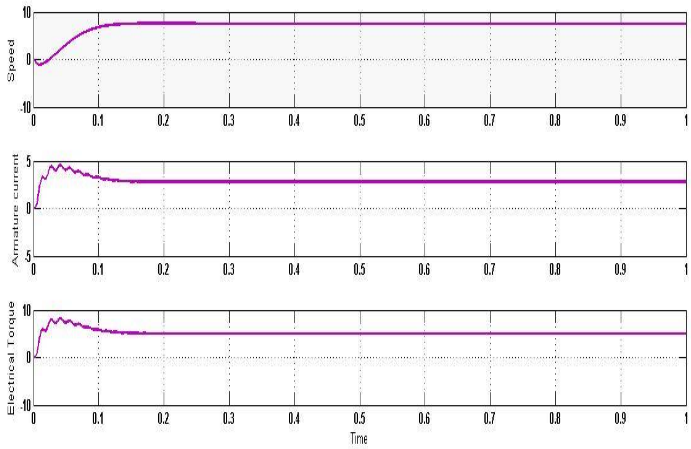

Fig.6 DC Motor parameter curves

.V. CONCLUSION

MPPT controllers are unquestionably the most commonly used control algorithm in photovoltaic system due to their practicality. When MPPT technique involves artificial intelligence strategies, performance was found to improve. With less perturbance, a photovoltaic system with fuzzy logic controller was found to settle faster than P&O algorithm. From the experimental results it is clear that the proposed method with fuzzy inference gives better performance compared to the other MPPT techniques.

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