A Comparison of MPPT Control of Photovoltaic System using Conventional and Artificial Intelligence Techniques

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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. This algorithm 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. Adaptive-Neuro Fuzzy Inference Systems (ANFIS) are found to be very effective than simple conventional MPPT tracking. In the simulation part, a buck-boost converter feeding a permanent magnet dc motor load is achieved. The accuracy of the overall system depends on the fuzzy rule base and membership functions defined. The performance curves for comparison between MPPT tracking, fuzzy and ANFIS controllers were obtained using MATLAB/Simulink platform. Simulation results show that ANFIS based tracking has better performance in terms of response time, settling time and initial perturbance.*

Keywords — *ANFIS- Adaptive-neuro fuzzy inference system, FLC-Fuzzy Logic Controller, MPPT-Maximum power point tracking, PV-Photo Voltaic.*

I. INTRODUCTION

In our modern world, the problem due to global warming and pollution effects has become an important issue for research. Renewable energy sources can be considered as an advanced option for generating clean energy. Among them, photovoltaic (PV) system has received a large attention as it emerges out as one of the most promising renewable energy sources .MPPT or Maximum Power Point Tracking is an algorithm that is included in charge controllers used for extracting maximum power available from PV module. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage). Maximum power varies with solar radiation, ambient temperature and solar cell temperature. Both conditions change during the day and are also different depending on season of the year. The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage. This algorithm is necessary because PV arrays have non-linear voltage-current characteristics. This work aims to compare the different algorithm for MPPT. The technique is based on maximum power transfer theorem ie, maximum power can be transferred when load impedance equals source impedance. Section II provides details about photovoltaic system and MPPT strategy. Proposed fuzzy logic and ANFIS 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

A solar cell is fabricated in a thin wafer of semiconductor. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor creates some electron-hole pairs proportional to the incident irradiation. The equivalent circuit of a PV cell is as shown in Fig.1

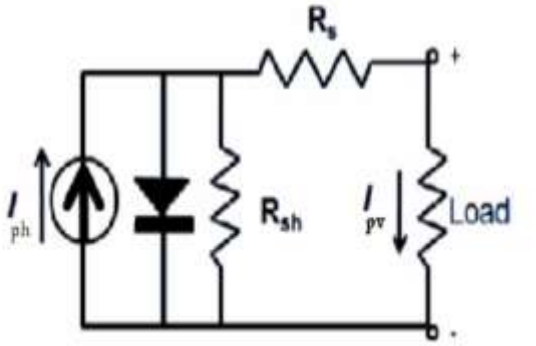

Fig.1. PV cell modelled as diode circuit

The PV cell or module is usually represented by the single exponential model or the double exponential model. The single exponential circuit model is shown in Fig.1.

The overall block schematic of system is as shown in Fig.2. The most popular conventional method for the maximum power tracking in a photovoltaic system is the perturb and observe (P&O) scheme. In this method, the duty cycle of the DC/DC converter is perturbed in fixed steps until the operating point gets the maximum possible power out of the panel. If the power increases due to the perturbation then the perturbation is continued in the same direction. After reaching maximum power point, from the next instant onwards power decreases and hence after that the perturbation reverses .When the stable condition is arrived the algorithm oscillates around the peak power point. In order to maintain the power variation small the perturbation size remains very small. Instead of conventional P&O strategy, artificial intelligent techniques including fuzzy and adaptive-neuro fuzzy can also be used to modify the duty cycle of converter.

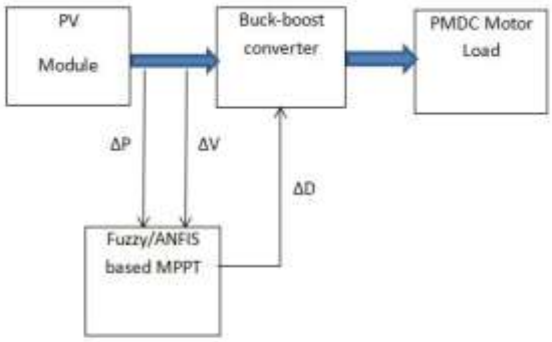

Fig.2. Overall block schematic of photovoltaic system utilizing MPPT via fuzzy/ANFIS controller

III.FUZZY AND ANFIS IMPLEMENTATION

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. Microcontrollers have also helped in the popularization of fuzzy logic control. The fuzzy knowledge-base controller is a part of FLC which is composed of three main parts: fuzzification, inference engine and de-fuzzification. Membership function values are assigned to the linguistic variables. The nine fuzzy subsets utilized here includes NB (negative big), NM (negative medium), NS (negative small),NZ(negative zero), ZE (zero), PZ(positive zero), PS (positive small), PM (positive medium), and PB (positive big)[3].The number of membership functions used depends on the accuracy of the controller, but it usually varies between 5 and 7. The partition of fuzzy subsets and the shape of membership function, can adapt a shape for appropriate systems. The value of inputs are normalized by an input scaling factor. Gaussian membership function was used in the simulation[2].

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. There are two types of fuzzy inference system, ie. Mamdani and Takagi-Sugeno type. Adaptive-neuro fuzzy controller makes use of Sugeno fuzzy system. The composition operation is the method by which a control output is generated[5]. Several composition methods such as Max–Min and Max-Dot have been proposed in the literature. The commonly used method, Max–Min, is used in this here. The output membership function of each rule is given by the Min (minimum) operator and Max (maximum) operator.A defuzzification stage is needed since a plant usually requires a non-fuzzy value of control. Defuzzificaion for this system is the centroid method which is both simple and fast. The output of FLC is used to modify control output. Then, control output is compared with the sawtooth waveform to generate a pulse for controllable switch of the boost converter.

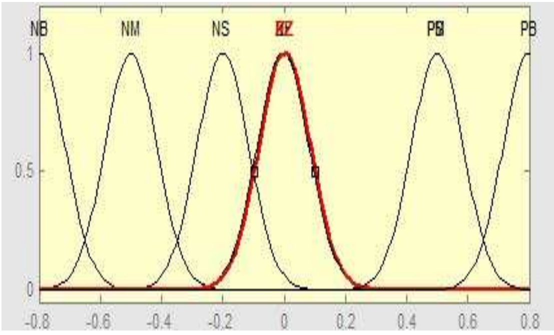

Fig.3 Input membership function, change in power

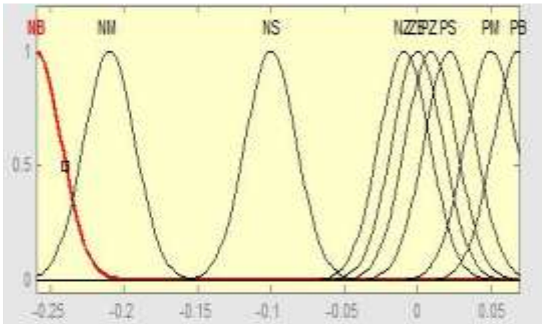

Fig.4 Input membership function, change in voltage

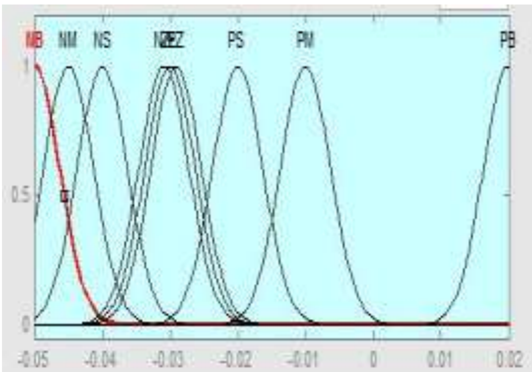

Fig.5 Output membership function, change in duty cycle

Input fuzzy membership functions used in this paper are shown in Fig.3 and Fig.4 and the output membership function is shown in Fig.5.The advantages of these controllers, besides dealing with imprecise inputs, not needing an accurate mathematical model and handling nonlinearity, are fast convergence and minimal oscillations around the MPP [1]. Furthermore, they have been shown to perform well under step changes in the irradiation. Simulation diagram of MPPT utilizing a fuzzy logic controller is shown in Fig.6.

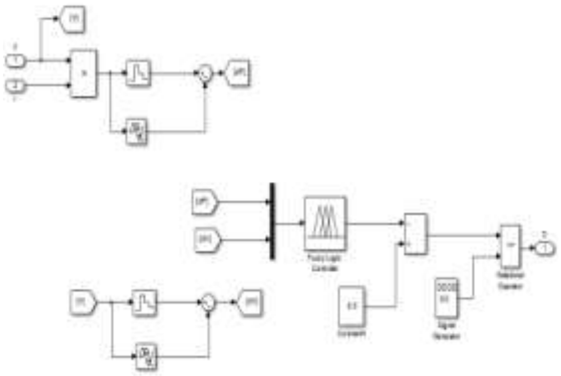

Fig.6 Simulation diagram of MPPT using Fuzzy logic controller

MPPT of PV system was also implemented using ANFIS controller. Neural data was tabulated by obtaining dP and dV values for different PV ratings. The neural data was loaded and tested. For obtaining an anfis based system, grid partitioning method was used. The optimization method used for training the data set is hybrid approach.(Epochs was chosen as 3).The input and output membership functions were chosen as 3. With the generated membership functions, adaptive-neuro fuzzy system yields the duty cycle of buck-boost converter (Gaussian membership function was selected here).Anfis file is saved and loaded into the workspace in the same way as fuzzy (fis file). The only difference was that a set of neural data was used for training purpose[4].

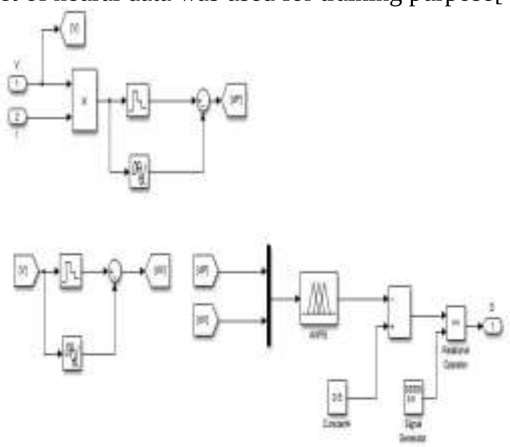

Fig.7. Simulation diagram of MPPT using ANFIS controller

IV. SIMULATION RESULTS

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 two 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. ANFIS training, testing and checking was done using Anfis editor. 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.

Photovoltaic system generates an output power around 250W at STC condition. It implies that rated power is obtained for an of irradiation of 1000W/m^2, cell temperature 25°C and air mass index of 1.5. A step change in irradiation input was given with constant cell temperature. The overall simulation diagram used for comparison of different controllers is shown in Fig.8. For the step change in irradiation, maximum power point tracking was obtained using the conventional P&O method, fuzzy based controller and ANFIS controller. The comparison was obtained for the above three cases. Voltage and current output from the buck-boost converter for the above cases was plotted (as in Fig.9 and Fig.10) and analyzed. The initial transient was found to be less in ANFIS controller than perturb and observe based maximum power point tracking. With less perturbance, a photovoltaic system with ANFIS controller was found to settle faster than P&O algorithm.

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. DC motor chosen has a rated power of 198W. The armature resistance and inductance of the prescribed motor is 1.2ohms and 3.7H. Fig.11 and Fig.12 shows speed and torque comparison plots for the corresponding irradiation with the different controllers. The results shows that artificial intelligence based methods are better than the conventional strategies.

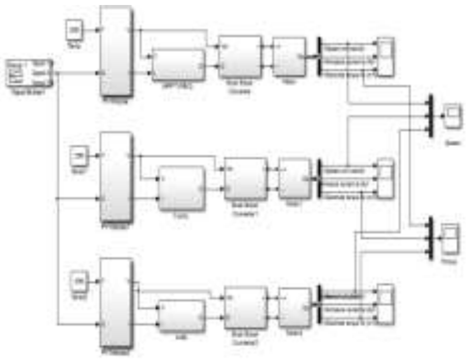

Fig.8. Overall simulation diagram

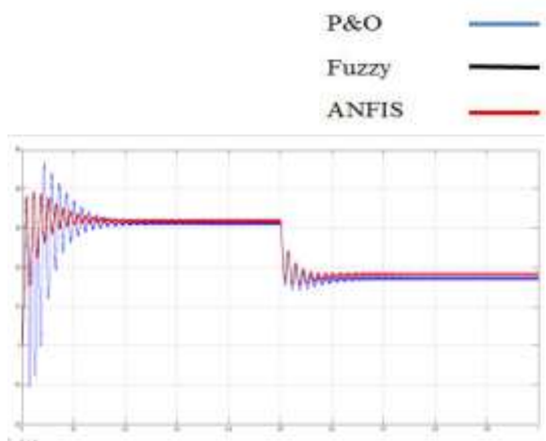

Fig.9 Voltage output from buck-boost converter for varying input irradiation level (S=1000W/m^2 to S=500W/m^2 at t=0.5sec)

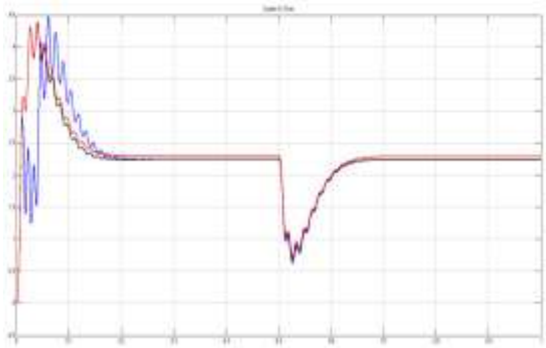

Fig.10 Current output from buck-boost converter for varying input irradiation level (S=1000W/m^2 to S=500W/m^2)

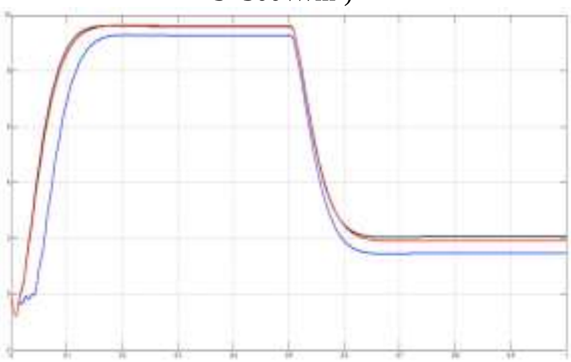

Fig.11 Speed Comparison plot for irradiation level change from S=1000W/m^2 to S=500W/m^2

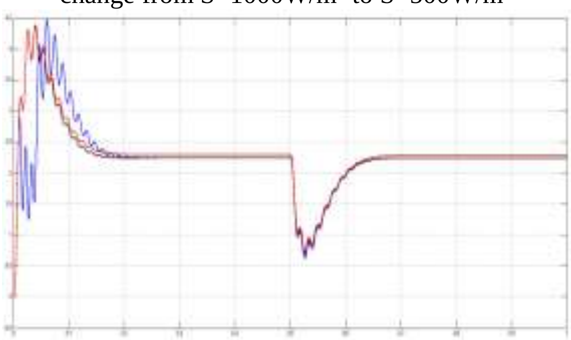

Fig.12 Torque output from load for varying irradiation level

It can be observed that artificial intelligence based strategies are better than P&O in giving a fast response. It can be noted that speed of DC motor is more in fuzzy systems when compared to ANFIS whereas the armature current drawn for the operation of motor is more in ANFIS than fuzzy and P&O strategy, hence the torque developed will be more.

V. CONCLUSION

This thesis work developed an MPPT algorithm in Simulink using classical P&O, fuzzy and ANFIS based controllers. A PMDC motor load was controlled whose input was regulated using a buck-boost converter. With the introduction of fuzzy and ANFIS, the initial tracking time will be less than the time taken for classical P&O strategy. Moreover the settling time was less for ANFIS controller compared to P&O and fuzzy based systems. Another finding was that the initial transient of voltage and current was found to be much less in artificial intelligence strategies than classical approach. Speed of DC motor is more in fuzzy systems when compared to ANFIS whereas the electrical torque developed is more in ANFIS than fuzzy and P&O strategy. Thus the performance criteria including response time, settling time and initial perturbance were analyzed in Simulink for P&O, fuzzy and ANFIS controllers.

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