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An ANFIS based Global Maximum Power Point Tracking Approach for PV Modules under Partial Shading Condition

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Abstract: *In This work proposes an ANFIS-based global maximum power point tracking (GMPPT) technique designed for photovoltaic (PV) systems which experience partial shading conditions (PSC). However, when photovoltaic (PV) array is subject to partial shading conditions (PSC), several local maxima appear on the P-V characteristics curve of the PV array which are due to the use of the bypass diodes to avoid hot spots effect. The appearance of these multiple peaks on the characteristics of PV array makes the tracking more difficult under these conditions and requires the integration of a more efficient power control system which is able to discriminate between local and global maxima to harvest the maximum possible energy and therefore increase the efficiency of overall system. In conventional method, the P&O method is utilized under uniform irradiation conditions, where it tracks the unique MPP. Whereas, when partial shading occurs, the FireWorks Algorithm is used to determine the GMPP, following which the P&O tracker compensating for varying environmental variations. In addition to implementing a global maximum power point tracking strategies, the mismatch losses associated to the shading effect can further be reduced by using alternative configuration such as FireWorks Algorithm. For this purpose, the main aim of this paper is to design an intelligent MPPT controller that allows predicting and extracting the global maximum power point (GMPP) from PV array under partial shading conditions (PSC) whatever is the used configuration or its size. This intelligent MPPT controller is based on adaptive neuro-fuzzy inference system (ANFIS). Furthermore, the ANFIS network uses a hybrid learning algorithm that combines the least-squares estimator and the gradient method. Simulation and experimental results verify the effectiveness of the proposed GMPPT method.*

Keywords: GMPPT, ANFIS, Photovoltaic systems

I. INTRODUCTION

According Photovoltaic (PV) systems have a structure containing solar cells (SCs), connection, protection, and storage components and some additional elements depending on load characteristics. The most important element of these systems, the solar cells, also has distinctive features especially on the initial investment cost and the quality and quantity of other elements. Therefore, in the initial installation stage, it is very important to design for operating of SC under the best conditions and effectively. Switching power converters are used, that is called as maximum power point tracker (MPPT) for the solution of this problem. However, efficient use of a PV panel includes some problems for the following two main reasons. Because of rotation of the world around the sun and itself ongoing, it may not have a fixed position to receive constant vertical solar radiation continuously. Thereby, PV systems may include some circuits to track the world movements depending on the sun consisting of stepper motor or other devices. These mechanisms are called the mechanical tracking systems and increase the amount of produced PV energy.

Due to nonlinear I-V curves of PV cells, output power depends on intersection point of load line with this curve. For solar radiation and cell temperature values taken as examples, there are only one point where maximum power is

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produced. Therefore, operation of the cell at this point is the right option. This process is called as electrical maximum power point tracking or simply MPPT.

II. CONVENTIONAL GMPPT ALGORITHM

In There is a need to execute a global search only when partial shading has occurred. In keeping with this principle, in the conventional GMPPT scheme, the FWA is called only when the onset of partial shading has been detected. Fig.3. 13 shows the flowchart for the conventional GMPPT algorithm. When the controller is started for the first time, the FWA is called as there no initial information about the existing shading pattern (step 1). When the initial GMPP has been determined, the P&O algorithm is employed (steps 2 and 3). On its convergence, the values of the MPP voltage Vmpp and current Impp are stored and monitored continuously (step 4). When there is a change in the insolation, there will be a change in the power level, as well as in the values of Vmpp and Impp. The change in each of these quantities is computed with respect to the most recently stored values (step 5). Based on the trends in Vmpp and Impp, the present state of shading is determined (step 6) according to the scheme shown in Fig.3. 12. In case partial shading has not occurred, the P&O algorithm is allowed to continue its operation around the present MPP. Else, the FWA is called to determine the GMPP (step 1). As soon as the GMPP has been determined, the P&O algorithm is initiated at that point, where it continues to track small changes in insolation and load.

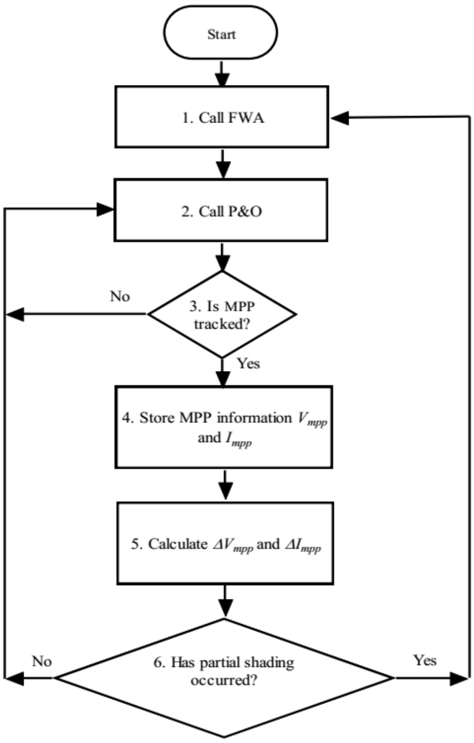

Fig.1. Flowchart for the conventional GMPPT scheme.

III. PROPOSED METHOD

Designing the ANFIS Controller

Fuzzy systems, artificial neural networks and neurofuzzy systems are examples of the artificial intelligence systems. AI systems are systems that make decisions like humans beings by adapting to the situations and coming with adequate decisions automatically for future similar situations . They do that by learning rules from examples. The primary learning mechanism of fuzzy logic (FL) is based on conditional if-then rules, called fuzzy rules, who use fuzzy sets as linguistic variables in antecedent and conclusion parts of decision making. A set of these fuzzy if-then rules can be issued by human experts or can be generated from observed and analyzed data. The main advantage of fuzzy systems is the lightness to interpret knowledge in the rule base. Neural networks get inspiration from biological neuron systems found in brain, and mathematical learning theories. They are determinated by their learning ability with a paralleldistributed structure and can be considered as black box designing. The adaptive neuro-fuzzy inference system (ANFIS), proposed by Jang, is one of the examples of neurofuzzy systems in which a FL system is embedded in the framework of adaptive networks. ANFIS constructs an input-output mapping based on human knowledge (in the form of fuzzy if-then rules) and generated input-output data pairs using a hybrid algorithm who is a part the leastsquares and part back propagation gradient descent method. In this paper, the ANFIS reference model is developed by using the ANFIS editor of Matlab/Simulink software package. Implementation of ANFIS-based MPPT is presented in Figure 4.1.

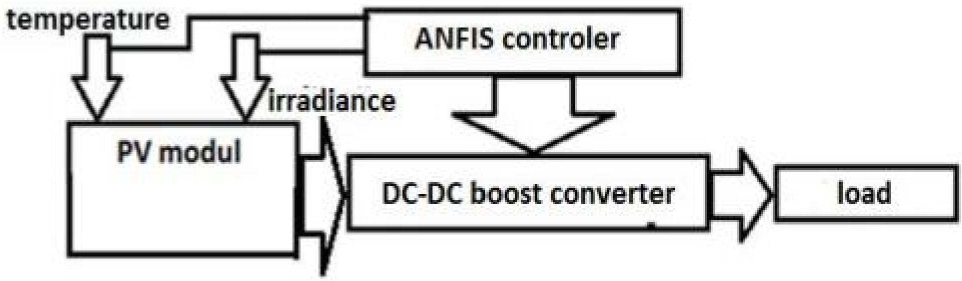

Figure 2. Implementation of ANFIS-based MPPT controller inside the PV system

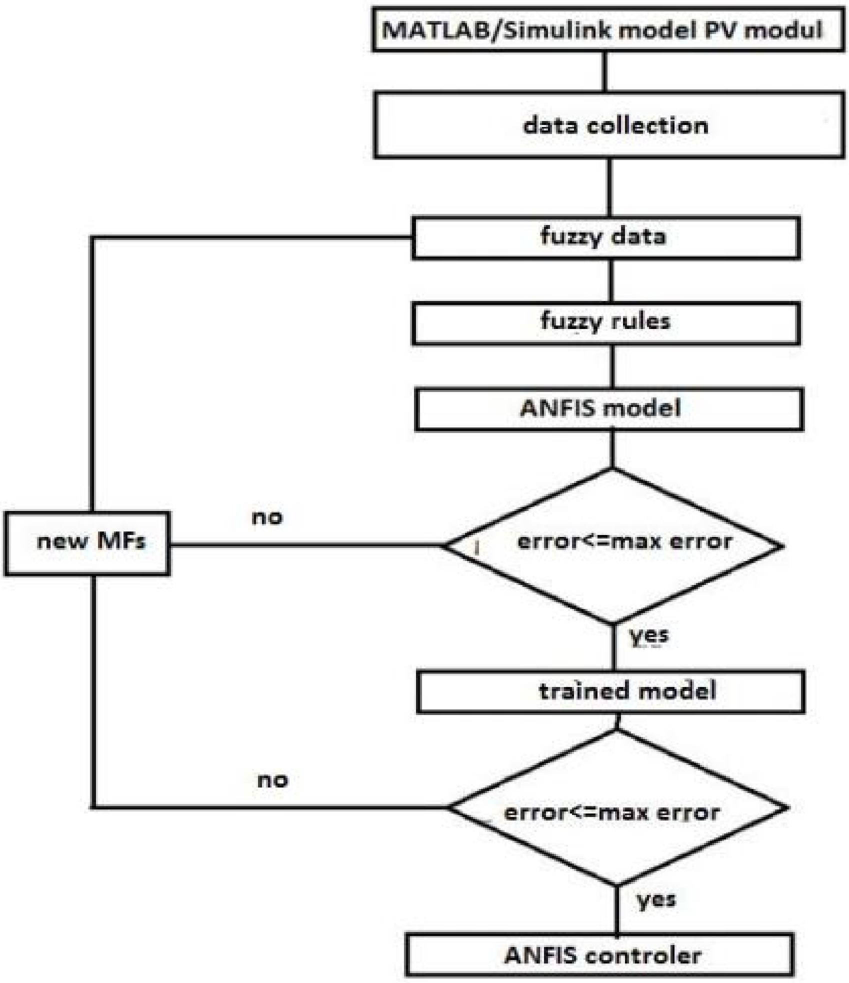

Figure 3. Workflow diagram for the ANFIS controller

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ANFIS is able of coming with the input-output mapping of training data sets when trained with sufficient number of epochs. ANFIS generates the set of fuzzy rules in order to produce the appropriate output for different values of inputs. Parameters of membership functions are adjusted or changed till the error is reduced to a minimum value. Once all the parameters of the membership function are adjusted, the ANFIS model becomes a learning model which is ready to be used in the MPPT control scheme. However, before using the ANFIS learning model for the MPPT control, its results are checked by using the checking data which is different from the training data. If a produced error is more than a desired value, parameters of membership functions are adjusted to bring down the error. The DC-DC boost converter is designed to be placed between a solar PV module and a load in order to transfer the maximum power to load by changing the duty cycle of the DC-DC boost converter. From the Matlab/Simulink model of the PV module is generated data set used for training of ANFIS by varying the operating temperature in steps of 5°C from -10°C to 35°C and level of solar irradiance in a step of 50 W/m2 from 100 W/m2 to 1000 W/m2. For each pair of the input data (solar irradiance and operating temperature), maximum available power of the PV module is recorded in form of table of crisp data. Together, 190 training data sets with 100 epochs used to train the ANFIS reference model and training error is reduced to about 5%. As result, ANFIS constructs a FIS by input/output data sets and membership function parameters of FIS with 50 MFs. MFs are tuned using the hybrid optimization method who is combination of the least-squares type of method and back propagation algorithm. The ANFIS structure developed by the Matlab code is shown in Figure 4

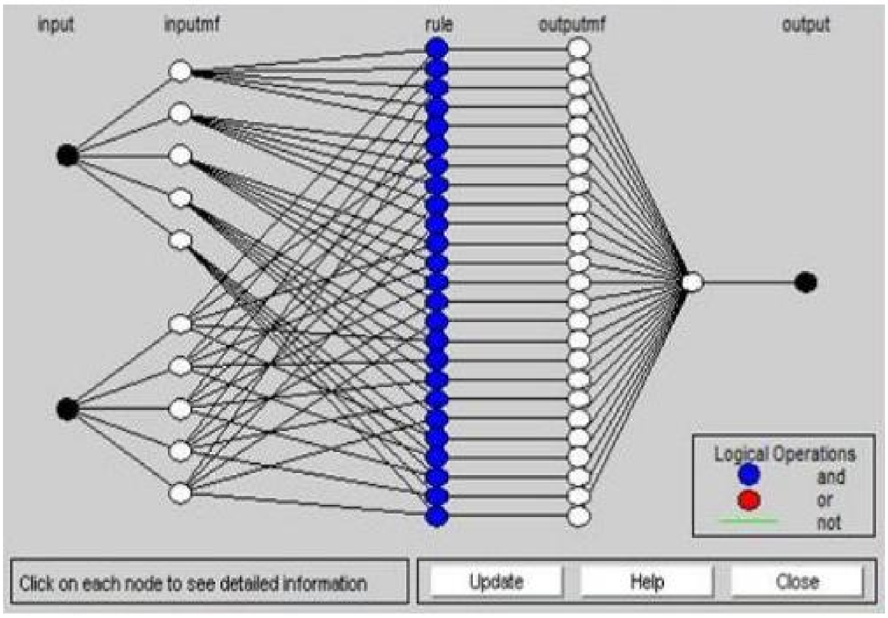

Fig 4 ANFIS-generated levels.

Each input parameter has three membership functions that are generated by the ANFIS method. According to the output mapping of data sets, nine fuzzy rules are derived to produce the maximum output power for each value of the input temperature and irradiance level. The ANFIS generated surface is shown in Figure 4.4, which is a 3D plot between temperature, irradiance and maximum power. The ANFIS surface depicts that the maximum available power of the solar PV module increases with an increase in the irradiance level and moderate temperature that verifies the non-linear behavior of the PV module.

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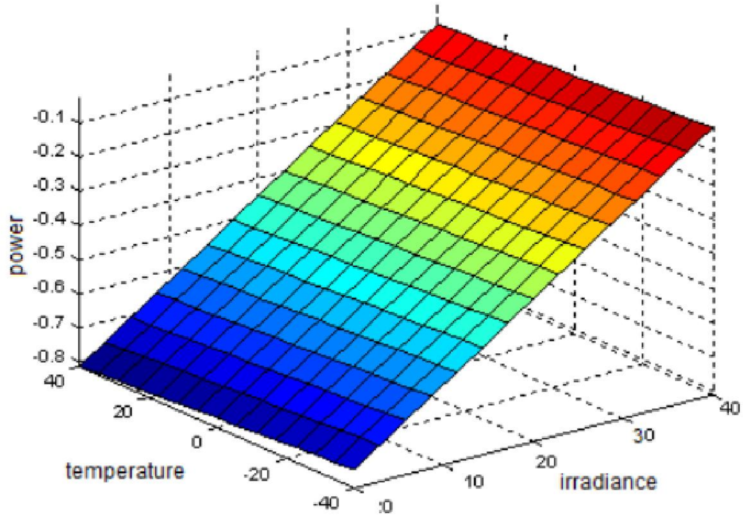

Fig5. Generated surface for 2 inputs and 1 output

ANFIS-based MPPT is designed by using user friendly icons from Simulink library of Matlab/Simulink. Pure resistance from 0 to 100 Ω is connected on the output of the PV module where it contains MPP of modeled solar PV module on 1000 W/m2 irradiance. Duty cycle of the converter is varied with the help of an MOSFET switch. Simulated adjusting signals for DC-DC boost converter are depicted in Figure 4.5. Crisp value of the maximum available output power at a specific irradiance level and temperature without load, is inserted from the ANFIS reference model and it is compared with the actual output power taken from the simulated model of the PV module in form of voltage and current. The divergence between these two powers is a signal who goes into on the DC-DC boost converter which has installed a pulse DC voltage source connected to high frequency P-type MOSFET. The pulse DC voltage source is about 50 kHz and serves as a signal for ON or OFF for MOSFET. From that signal is generated simulation for ON and OFF time according to the irradiance level and working temperature, and by that, the maximum power of the PV module is achieved.

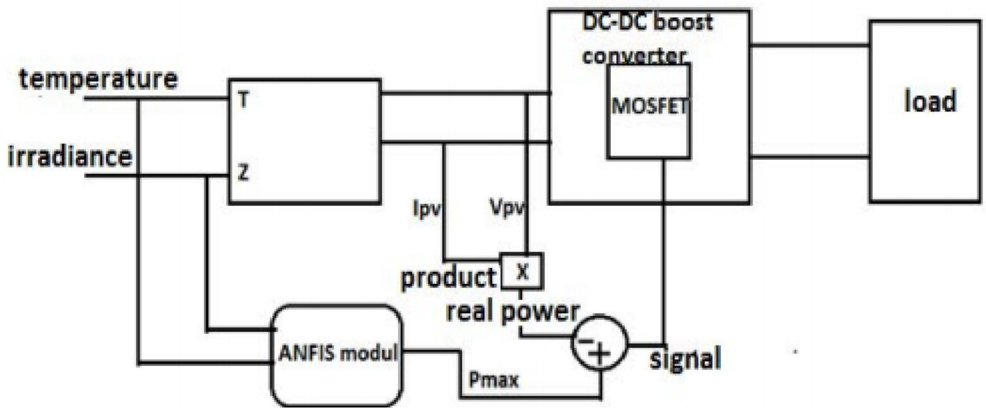

Fig6 ANFIS-based MPPT control scheme

IV. SIMULATION

Simulation Diagram of Proposed Method

In order to validate the performance of the MPPT controller, the system is designed with the source modeling in MATLAB /Simulink and the experimental waveforms are obtained. The performance of the converter is studied under steady state condition. The performances of the converter are validated with the models to their efficiency conditions.

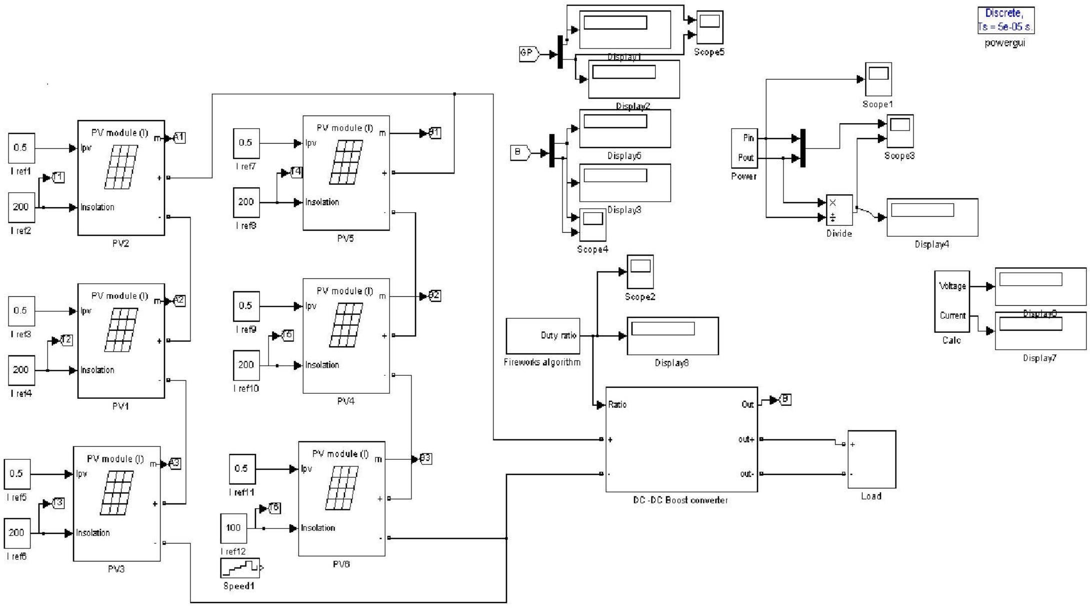

Fig 6 simulation diagram of the MPPT boost type DC-DC converter using fireworks algorithm.

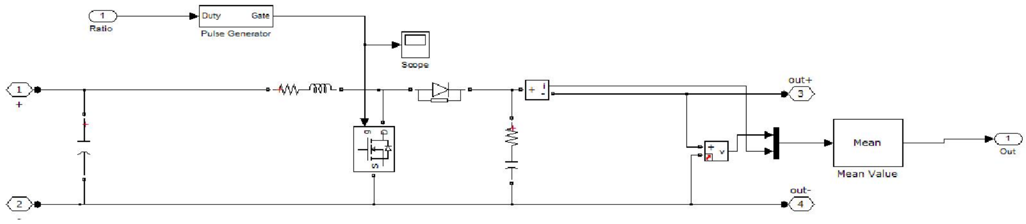

Fig 7 Boost-type dc–dc converter is connected between the PV power generation system and the load.

Simulation Diagram of ANFIS Algorithm

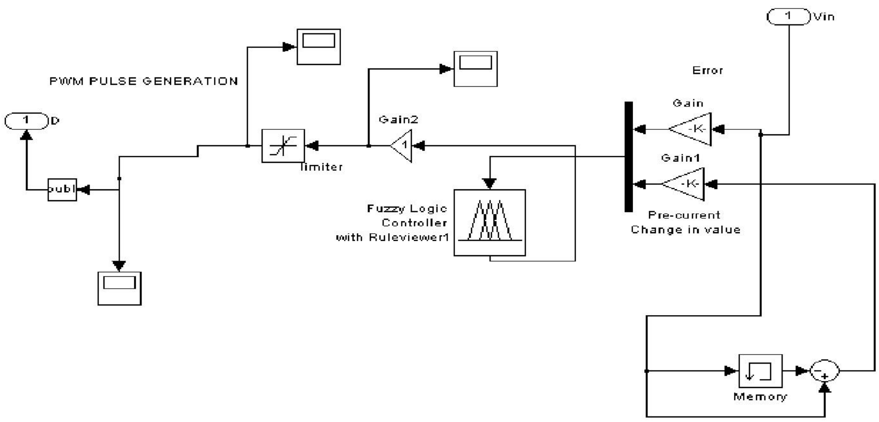

Fig 8simulation diagram for ANFIS algorithm.

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V. SIMULATION RESULTS

Input Power, Output Power & Efficiency Of Converter

Fig. 9 shows the Input ,output power and efficiency of the converter. Y axis denoted as Power and the X axis denoted as Time. The efficiency is around 94% of existing system

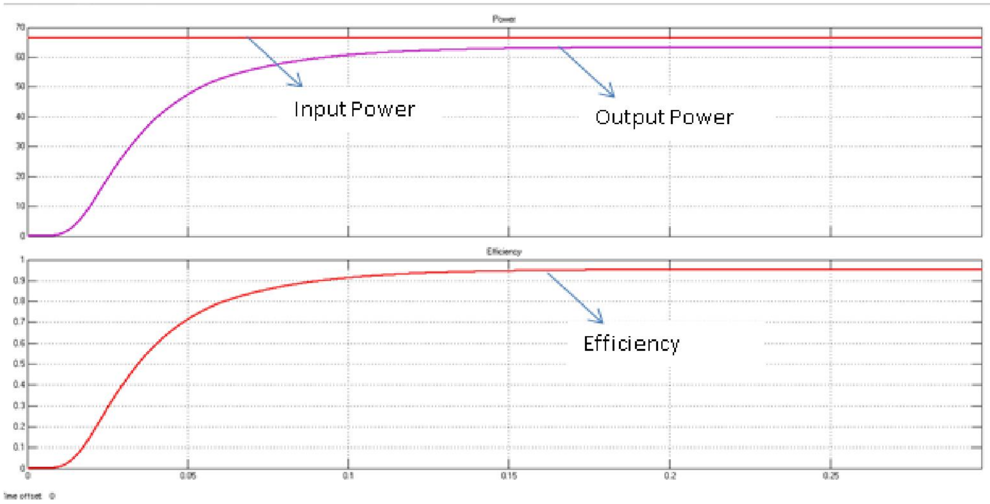

Fig. 9 Input ,output power and efficiency of the converter existing system

Fig. 10 shows the Input ,output power and efficiency of the converter. Y axis denoted as Power and the X axis denoted as Time. The efficiency is around 99% better than the existing method

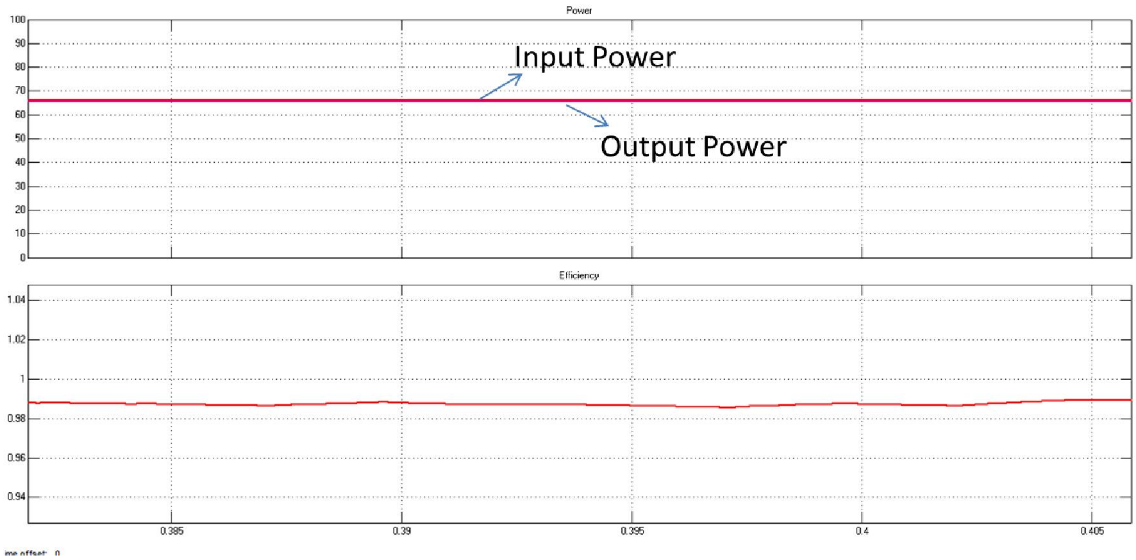

Fig. 10 Input ,output power and efficiency of the converter Proposed system

VI. CONCLUSION

Maximum power generated by the PV has been obtained real time using the MPPT model developed earlier. Then ANFIS was used to control the duty cycle of the dc-dc converter to provide constant output voltage and harnessable maximum output power at the load end. The ANFIS is implemented to tune the scaling factors of the FLC. An optimal performance of the FLC has been observed through simulation for fixed and variable load conditions. Knowing the available power through real-time robust load matching, using the MPPT model, allows for true maximum power tracking. The use of ANFIS to determine the duty cycle, allows for real time maximum power tracking under varying weather conditions. The practical impact of this research is in knowing the true available maximum power and tracking it properly on a real-time basis. This research work allows one to perform real time robust load matching and increase the harnessed power from the PV module

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