Simulation Study of High Speed MPPT Using Fuzzy Logic Method for PV Systems.

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Abstract : The fast-paced migration of solar energy across the world has necessitated the need for robust controller designs and efficient systems. The advanced of semiconductor switches in these devices has reached significant improvement. The emergence of machine learning has helped in the search for efficient control algorithm using neural network. One such application is the use in non-linear peak finding in maximum power point tracking of solar systems. Current systems employ a complex set of sensors, advanced DSP, and FPGA's. Besides from increased cost to develop such systems they are complicated and hard to build. Further commercialization to wider users becomes difficult. Adaptive neuro-fuzzy inference systems circumvent such obstacles and relatively cost effective to implement. The proposed system does not require accurate sensor data and additional circuitry. This thesis discusses in brief about the various maximum power tracking of Photovoltaic arrays. The proposed MATLAB model is developed and simulated. A table of different parameters used in MATLAB/SIMULINK is discussed and tabulated.

***Index Terms* - DC-DC Boost Converter, P&O Algorithm, ANFIS Logic, MPPT.**

I. INTRODUCTION

The global climate change is one of the pressing challenges of our generation. Countries from all over the world are actively involved in reducing their dependence on hydrocarbon for power generation. The Paris climate accord signed by 195 countries to limit the global temperature rise to 2°C. Almost all of our gadgets, houses and factories run on electricity. Governments all around the world have actively started the migration to sustainable source of energy for their electricity requirement.

Generation of electrical power from hydrocarbon are inefficient and harmful to the environment. Continued burning of coal and other petrol chemical generate greenhouse gasses which negatively impact the atmosphere and its composition. In the category of consumer and producer of electricity in the world India ranks third position. The major source for production of energy in the world comes from burning of coal. Approximately three fourth of power comes from burning of coal. The supply of fossil fuel is limited and the reserves are expected to last only for a couple of decades. Further, burning of coal and petrol has created excess carbon in the atmosphere and has led to the negative impact on the weather and climate for human survival in cities across the world. Hence, there is an urgent need for power generation plants to produce our primary energy from renewable source.

The most promising sources of energy naturally is the sun. The sun is expected to last for about 5 billion years so we can be confident that we will not run out of energy anytime soon. Other source of clean energy are wind and geothermal heat. Figure I illustrates the future growth and percentage contribution in the total power generated worldwide.

The extraction of energy from sun presents a host of challenges. Some of the challenges are lack of efficient converter, control systems, unpredictable in the solar irradiance. But some problems that are still persistence in our current network also add to the loss of the system as a whole such as long-distance power transmission challenges, excess power storage in large inefficient battery banks and much more. The chief among the obstacles of solar power is the lack of continuous power output. Furthermore, the lack of technological innovation and less support from the public in general this sector was not given much importance in the past.

However, advancement in power semiconductors, improved efficiency of solar cells and reduction in solar panel cost have driven wider adoption of solar power as the major source of renewable sources of energy. The cost of solar power generation per kW has declined steadily over the past decade. Furthermore, the advancement in battery technology with advanced materials has also seen significant improvement in energy density and capacity.

In 2018 international energy agency reported the global solar PV capacity expansion accounted for an increase of approximately 43 GW. 47% of that was contributed by China. China represents the leading solar market in the world. Distributed solar power generation has reached a capacity of 6 GW in 2018 (Solar Power Europe, 2019a).

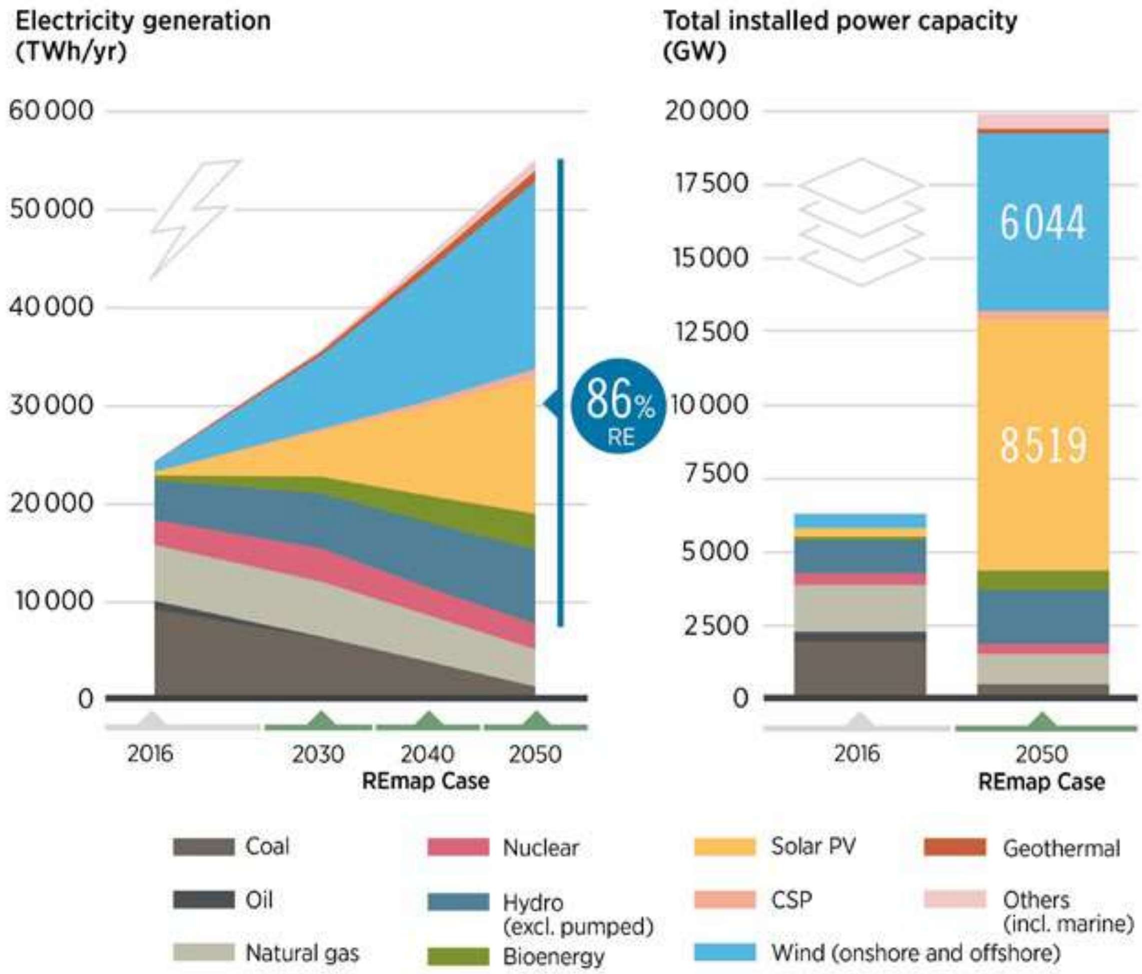

Figure I: Renewable Energy Profile Prediction [1]

In conclusion, it is estimated that solar and wind energy have the potential to transform the global electricity sector. The share of energy from solar PV would drastically improve, estimated to contribute more than one-third of the global electricity demand. By 2050 an optimistic outlook on the future of solar PV generation seems to hint towards a tenfold increase in share of total power generation mix as compared to 2016 levels.

II. BLOCK DIAGRAM

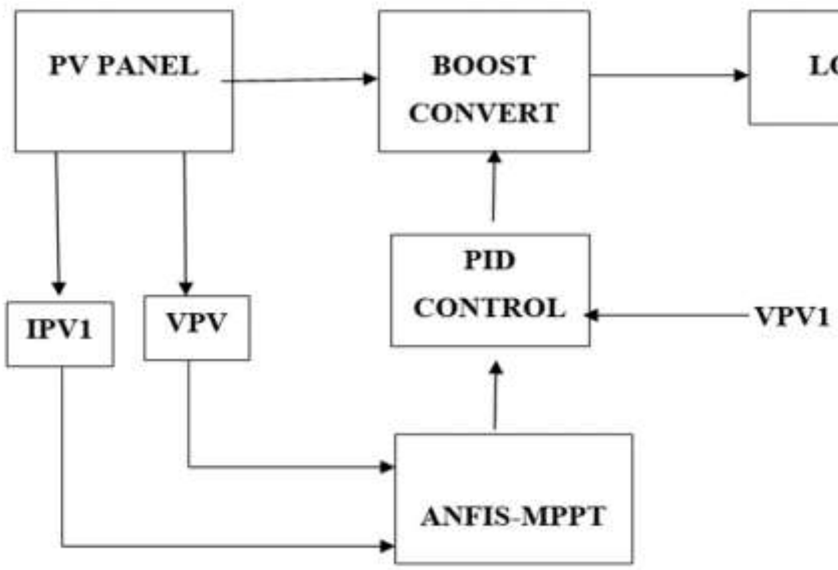

Figure 2: Block Diagram of Proposed System

III. ANFIS ARCHITECTURE OVERVIEW

ANFIS is a hybrid neural network algorithm which combines ANN and fuzzy logic controller. The fuzzy rules and decision-making process is handled by the fuzzy controller. The different steps used in the fuzzy controller was discussed in the previous section. The PSC creates multiple peaks in the power curve of the module. Due partial shading most of the conventional algorithms fail to perform efficiently and get stuck at local maxima. The proposed algorithm is better suited to handle multiple peaks during partial shading condition. The neural network performs parameter selection based on the learned data for both the inputs and output. A single algorithm is used for both the input and output parameter selection.

The ANFIS architecture can be identified into five layers. The first layer takes in the inputs and assigns the membership function. This layer is commonly known as fuzzification. The second layer is the rule layer, it determines the firing strength of the input. In layer three output of the second layer is normalized with respect to the combined firing strength of the input. The fourth layer takes as input the third layer's normalized firing strength and the consequent parameter to compute the de-fuzzified value. The final layer computes the result of the summation of all the previous layer output.

The input variables that are chosen are PV voltage (V_{pv}), PV current (I_{pv}), and the PV cell temperature (T). The output parameter is the chosen as the duty cycle. The duty percentage of the boost converter is the primary variable that controls the power. The membership function for the fuzzy logic is chosen as bell curve.

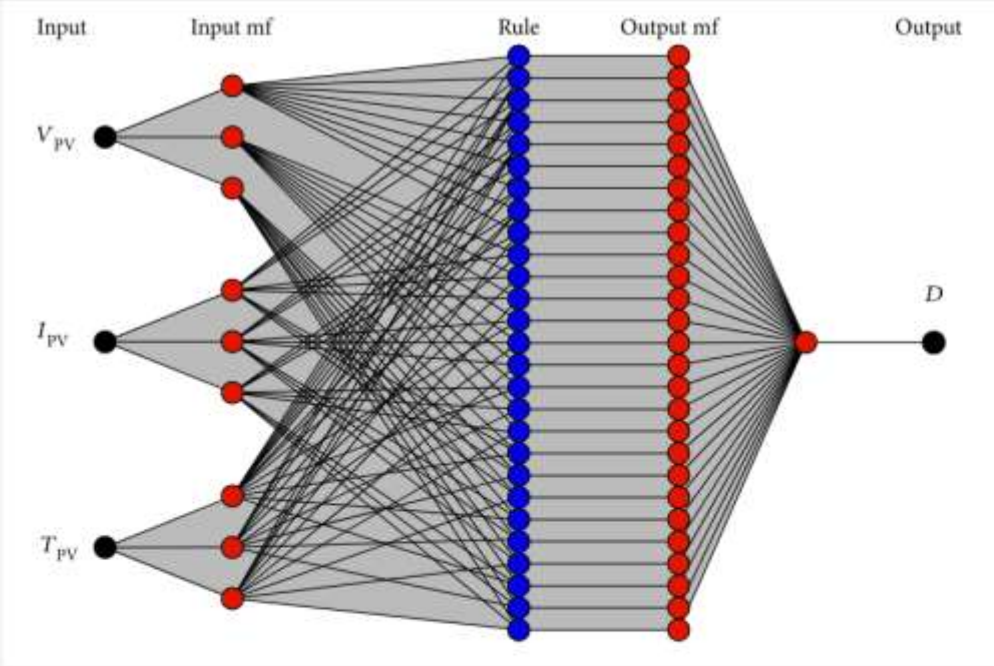

Figure 3: Generalized ANFIS MPPT

The voltage from the PV module varies from 17 V to 21 V. On the other hand, the variation of current is from 3 A to 5 A. Also, the PV cell temperature variation is 298 K and 323 K. The algorithm flow is illustrated in the **Error! Reference source not found.**4. The ANFIS controller generates the membership function based on the inference of the training dataset.

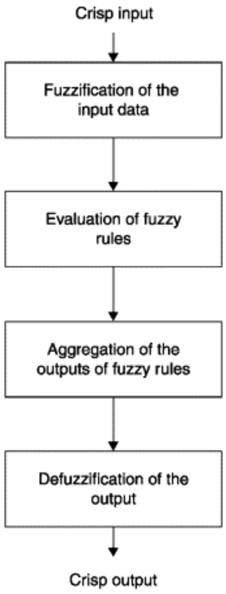

Figure 4: Algorithm Flow

IV. SYSTEM SIMULATION

The solar PV system simulation is carried in MATLAB SIMULINK. The simulation parameter values used are given in Table 1 and Table 2.

Table 1: PV Module Specification

PV Module	
Maximum Power	80.099 W
Open circuit voltage (V_{oc})	21.6 V
Voltage at maximum power point (V_{mp})	17.3 V
Temperature Co-efficient of V_{oc}	-0.36℃
Cell per module	36
Short Circuit Current (I_{sc})	5.16 A
Current at maximum power point (I_{mp})	4.63 A
Temperature Co-efficient of I_{sc}	0.09℃

Table 1 which is tabulated based on the data that was obtained from the datasheet of the manufacturer of the solar panel.

Table 2: Simulation Parameter

PV Simulation Parameter	
Solar module (Array)	120 Watts
Inductor	161 µH
Capacitor	500 µF
MOSFET	IRF840
Diode	15ETH06
Resistive Load	6.5 Ω
Switching Frequency	3 Khz

Table 2 is a tabular list of all the components used in the hardware implementation of the boost converter. The model for the switch is based on IRF840 MOSFET, diode -15ETH06 and the switching frequency of the DC converter is 3Khz. The inductor is a wire wound inductor on a iron core. The load chosen is 6.5 ohms. The capacitor is 500uF is of higher value to remove unwanted ripples at the output.

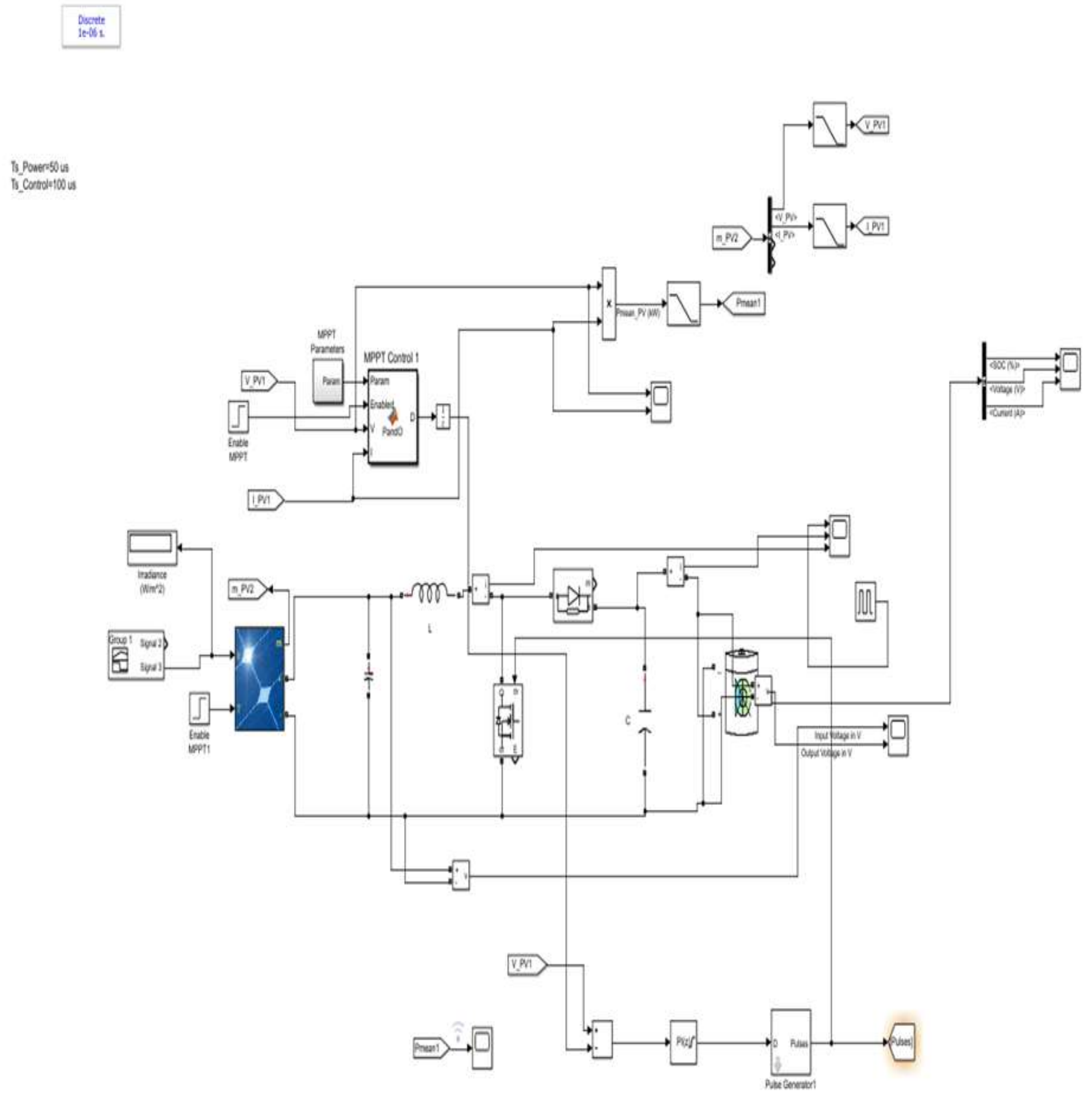

Figure 5: MATALB Model of P&O Algorithm Converter

The Figure 5 shows the model of a boost converter with input from solar PV and the controller based on P&O algorithm. The MATLAB foundation library was used in creating this model. The load at the output of the converter is a battery. The solar insolation and power character can be changed and modelled into the design of the system to mimic real life condition. The P&O algorithm generates the MOSFET PWM pulses to make step changes in tracking the maximum power curve.

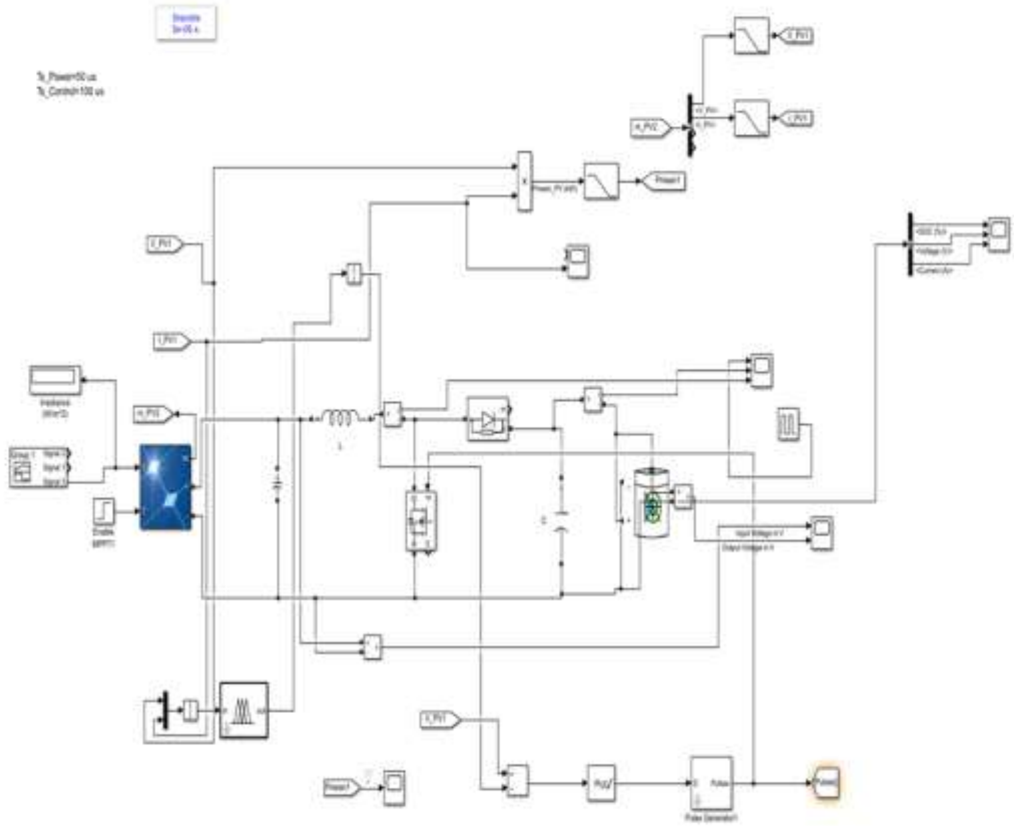

Figure 6: MATLAB Model of ANFIS Based Converter

The Figure 6 is the model of a solar PV system using ANFIS based MPPT controller. It is similar to the one discussed in Figure 5 but with a slight change i.e., a different controller. The controller is based on ANFIS model consequently the control PWM pulses are generated to track the maximum power output.

V. RESULTS AN DISCUSSION

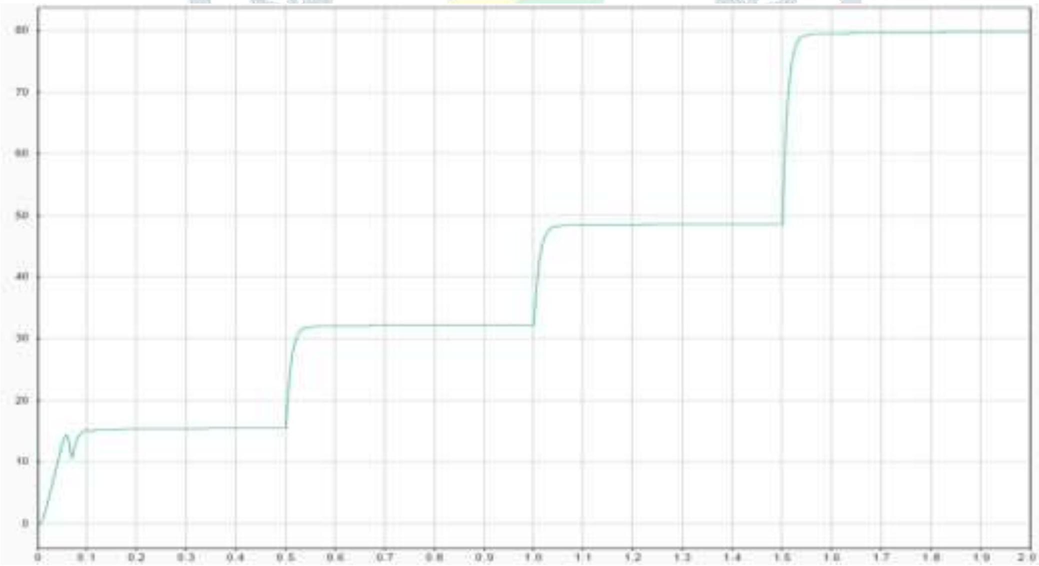

Figure 7: Power Output of P&O Algorithm

On simulating the MATLAB model in Figure 5 we obtain the results that is shown in Figure7. The controller is designed based on the traditional P&O algorithm. The simulation is carried out for a period of 2 seconds. To bring the solution faster and improve the accuracy. The shape of the curve is having multiple peaks due to partial shading condition.

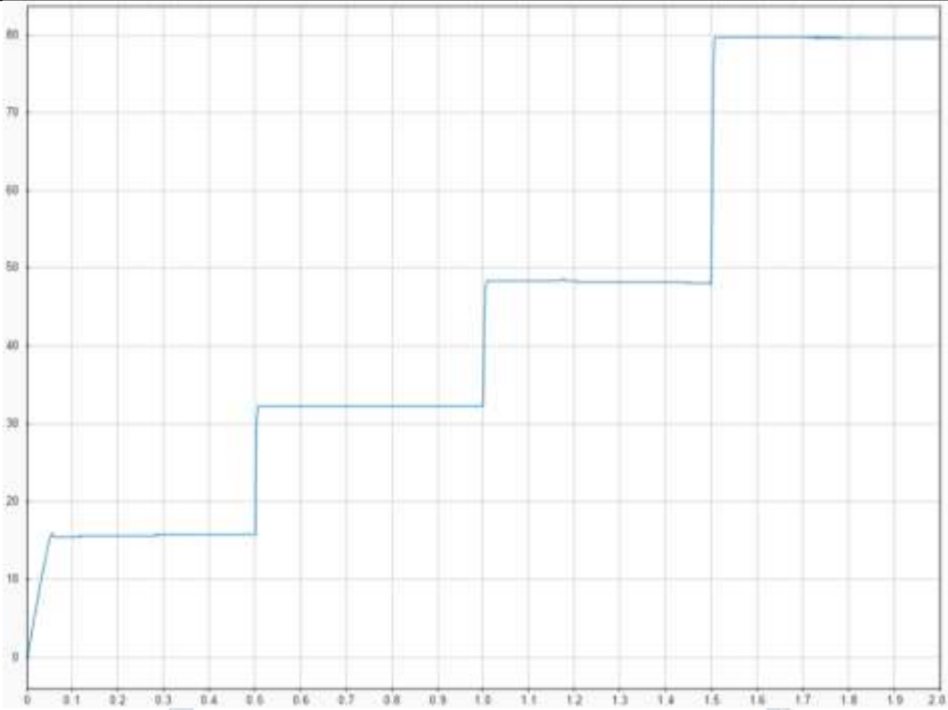

Figure 8: Power Output of ANFIS Algorithm

The Figure 8 highlights the result of the MPPT controller based on ANFIS algorithm. The simulation parameters are retained as the previous model since our objective is observe the effects of partial using ANFIS controller.

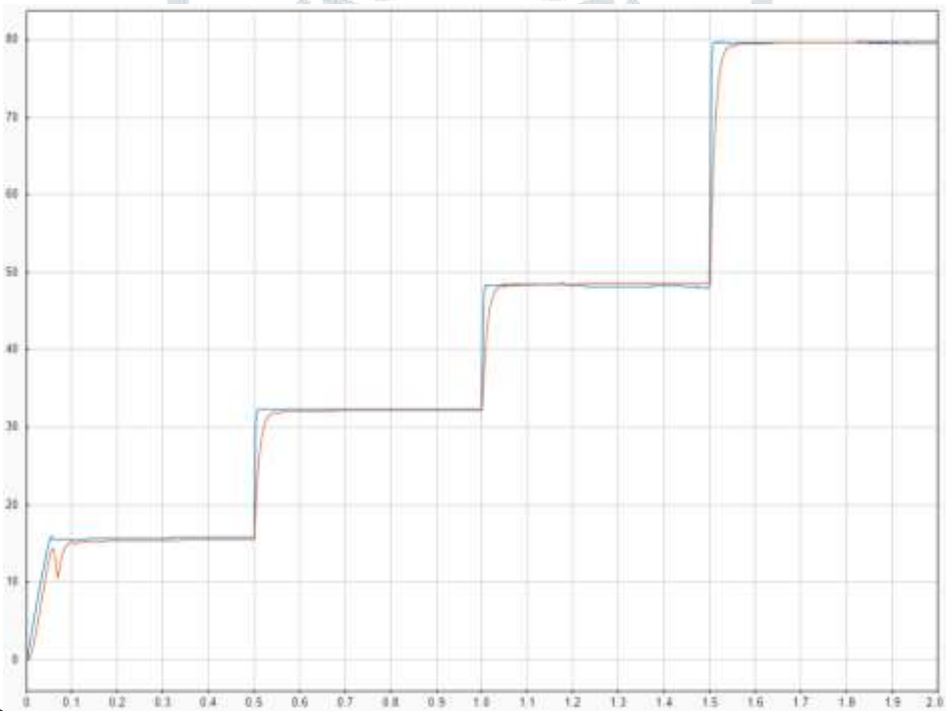

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Figure 9: Side by Side Comparison of both Algorithms

The above two figures are combined into a single graph which is shown in Figure 9. From Figure 9 the curve for MPPT and P&O algorithm shows that are closely matched. The slight variation in the curves could be attributed to slow response time for ANFIS due to the complex computation required.

Because ANFIS is soft computational algorithm it avoids the needs for the use of multiple sensor. The advantage of ANFIS control lies in the reduced number of multiple voltage and current sensor and simple hardware setup. With only a single voltage sensor and current sensor it is able to accurately track and perform efficient conversion.

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