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Implementation of Maximum power control of Solar Panels using Modified Perturb and Observe Algorithm based on Adaptive Neuro Fuzzy Inference System

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ABSTRACT

In this modern era, the need for renewable energy is increasing, and solar panels are one of the main solutions. To maximize the efficiency of energy extraction from solar panels, a method is needed. Based on the characteristics of voltage and current, the output power of these solar panels changes following changes in irradiation and temperature. Changes in the output power value have a maximum point, where each voltage and current value has a different maximum power point at each change in temperature. For this reason, the Maximum Power Point Tracker (MPPT) method is used to solve this problem by adjusting the solar panel voltage at the maximum point using a power converter. In this study, the MPPT control system will be implemented using a boost converter. This study develops a Maximum Power Point Tracking (MPPT) control system based on the Adaptive Neuro-Fuzzy Inference System (ANFIS), which is developed from conventional perturbation and observation algorithms. The ANFIS-based MPPT control system is implemented using an Arduino microcontroller. The experimental results verify that the proposed ANFIS-based MPPT system has successfully controlled the output power of solar panels at the maximum point.

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1. INTRODUCTION

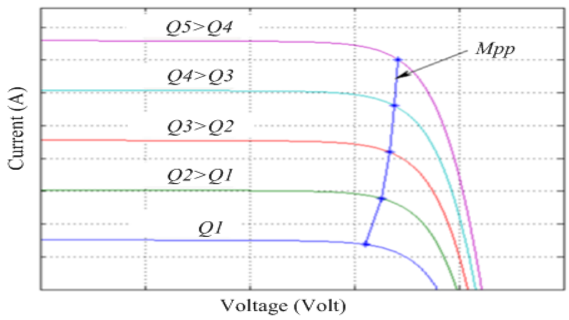
Electrical energy is one of the most important energies and is widely used for various purposes in human life. With the increasing population, the need for electrical energy is increasing . To meet the need for electrical energy, power plants are built using primary energy from various energy sources such as coal, fossil fuels, hydropower, and renewable energy [1]-[5]. The use of renewable energy to generate electricity has recently increased. In addition to abundant electricity sources, renewable energy power plants can also be built in remote areas that are not yet connected to the electricity grid, thus encouraging the electrification of Indonesia. Solar panels are one of the power plants that utilize renewable energy, namely sunlight. Solar panels are composed of solar cells generally made of silicon [6]-[8]. The power of solar panels depends on the amount of light absorbed by the solar cell, so solar panels are more efficient for use in areas whose geographical conditions always receive sunlight [9]-[12]. Indonesia is a country whose geographical location is on the equator, so that all regions of Indonesia do not lack sources of sunlight every year. This is certainly very beneficial for the solar power plants [13]. The performance of solar panels is influenced by several factors, namely solar irradiance and temperature. In addition, the output power of this solar panel is also determined by the amount of current and voltage produced by the solar panel. Based on the characteristics of voltage and current, the output power of this solar panel changes with the irradiance and temperature, and the change in the output power value has a maximum point. For this reason, the Maximum Power Point Tracker (MPPT) method is used to solve this problem.

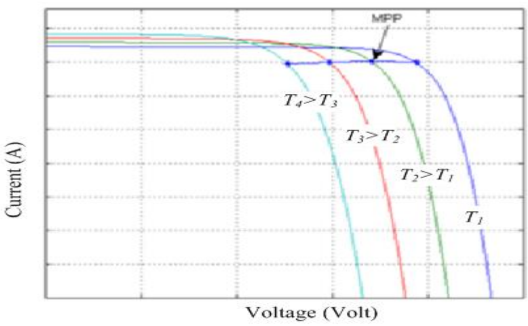
Solar panel voltage control to obtain maximum power can be applied using a dc-dc converter, such as a buck converter, boost or other types of dc-dc converters [14]-[19]. In this study, the MPPT control system will be applied using a boost converter that has a higher output voltage than the input voltage [20]-[24]. Solar panel voltage control with a boost converter at the maximum power point can be done by adjusting the modulation pulse of the semiconductor switch in the converter. This modulation pulse will regulate the on/off of the semiconductor, so that the output voltage of the converter can be controlled as desired. One method of setting the on and off time of the semiconductor in a power converter is to use the Pulse Width Modulation (PWM) method. The on and off time of a semiconductor in the PWM method is determined by the duty cycle, which is the ratio of the switch on time to the switching period [21]. Based on this concept, the output voltage regulation of the converter in the solar panel MPPT control system can be done by adjusting the duty cycle of the switch used in the converter.

In the MPPT control system, the switch converter duty cycle setting is done using the MPPT algorithm. Several MPPT algorithms have been developed by previous researchers, such as the turb and observe algorithm [25]-[28], incremental conductance [29]-[33], artificial inteligent and so on [34]-[45]. These various methods have various advantages and disadvantages, including being quite expensive and difficult to implement. There is also a simple and easy-to-implement method, namely the fractional open voltage method, but this method is less flexible, because it is unable to adjust to environmental conditions. By looking at the advantages and disadvantages of several methods for MPPT control above, this study designed MPPT control using the Addaptive Neuro Fuzzy Inference System (ANFIS) method. MPPT using ANFIS offers very fast dynamics and very accurate responses. The system consists of a boost converter and an ANFIS controller to control the duty cycle of the boost converter modulation pulse, so that the output voltage is expected to match the reference voltage. This ANFIS-based MPPT control system will be implemented on a 4 x 50 WP solar panel using an Arduino Mega 2560 as its control center.

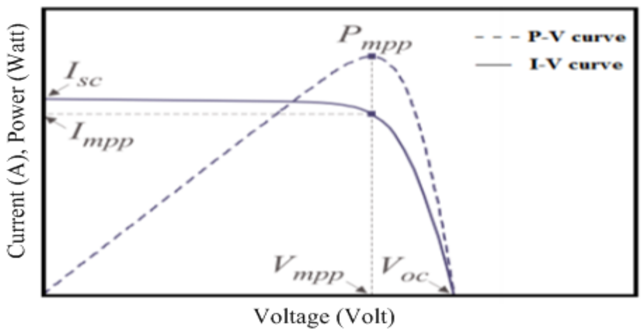
2. METHOD

This research was conducted using an experimental method. Voltage control for MPPT can be done using a DC-DC boost converter. The ANFIS-based output voltage control designed in this study will be applied with Atmega programmed with Matlab Simulink. Maximum power control is based on the power characteristics of the solar panel, which are always changing due to the influence of temperature and temperature. Figure 1 shows the power characteristics of the solar panel.





(a) (b)



(c)

Figure 1. Characteristic curves of solar panels, (a) I-V curve when irradiation varies, (b) I-V curve when temperature varies, (c) P-V curve

Generally, the total power of a radiation source that falls on a unit area is called irradiance. The solar radiation received by the earth is distributed in several wave ranges, starting from 30 mm to 4 microns. Some radiation is reflected in the atmosphere (diffuse radiation) and the rest can reach the earth's surface (direct radiation). These two radiations are used to measure the amount of radiation received by solar cells. Radiation is a source of energy for solar cells so that its output is highly dependent on changes in radiation. Isc is more affected by changes in radiation than Voc. When radiation is high, namely when the number of photons is large, the current produced is also large. And vice versa, so that the current produced is directly proportional to the number of photons. Figure 1(a) shows an example of the characteristics of the I-V curve of a panel when receiving varying solar radiation. Radiation is not the only external parameter that has an important influence on the I-V curve, there is also the influence of temperature. Temperature plays a role in predicting I-V characteristics. Semiconductor components are sensitive to temperature changes, as are solar cells. Solar cells will work optimally at a constant temperature. An increase in temperature will reduce the Voc of the solar cell. Figure 1(b) shows the characteristics of the voltage and current of the solar panel at varying temperatures. The output power of solar panels is the product of current and voltage. Figure 1(c) shows the characteristics of current, voltage and output power of photovoltaic at one point of temperature and solar radiation, which consists of a power versus voltage (*P-V*) curve and a current versus voltage (I-V) curve. Figure 1(c) shows that at a certain temperature and solar radiation value, photovoltaic has a short circuit current (*Isc*), maximum power point current (I_{mpp}), open circuit voltage (V_{oc}), maximum power point voltage (V_{mpp}) and maximum power point (P_{mpp}).

Maximum power can be obtained by controlling the solar panel voltage at the maximum power point using a power converter. In this study, the power converter used is a dc-dc boost converter. Controlling the output voltage of the solar panel with a boost converter can be done by adjusting the converter switch modulation pulse through the duty cycle setting. In the MPPT control system, the duty cycle setting is done through the MPPT algorithm. The MPPT algorithm proposed in this study is ANFIS. Figure 2 shows the maximum power control scheme for solar panels using an ANFIS-based boost converter. The relation between the duty cycle value obtained from the MPPT algorithm and the converter output voltage is written as :

$$V_{out} = DV_{in} \tag{1}$$

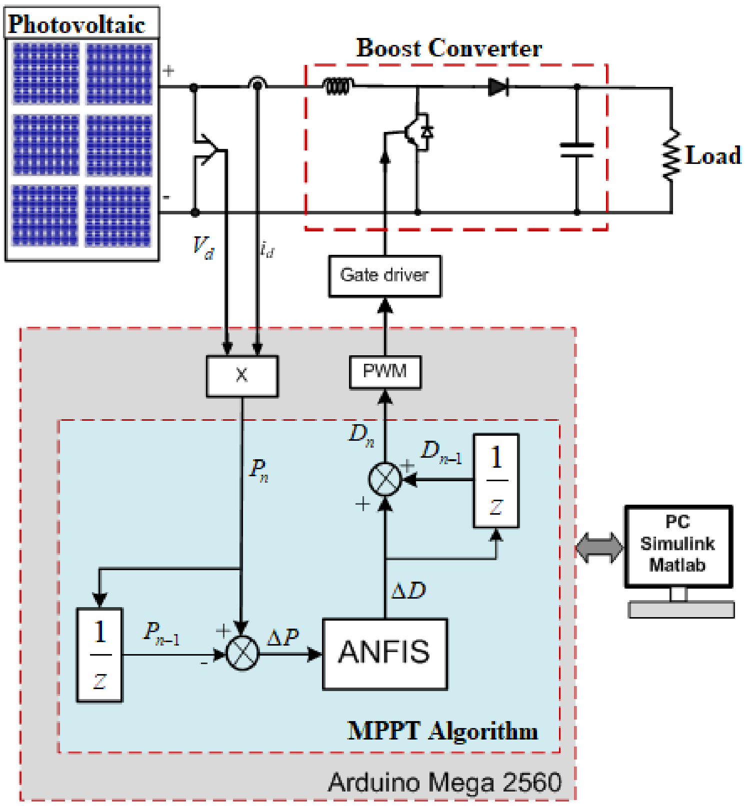


Figure 2. Scheme of proposed MPPT based on ANFIS.

The working description of each component used in the block diagram is a solar panel is a component used to convert solar energy into electrical energy. The power supply is a voltage source that functions to reduce the voltage from AC voltage to DC voltage. The power supply functions to provide electrical power for the Arduino and gate drive. The power supply used in this final project is 12 V. The voltage sensor functions to detect the voltage magnitude from the boost converter. The voltage sensor is used as a voltage divider. The current sensor functions to detect the current magnitude from the boost converter. The current sensor used is ACS712. The Boost Converter functions to increase the output voltage which is greater than the input voltage. The Gate Drive functions as a voltage and current amplifier on the PWM wave connected to the boost converter. PWM (Pulse Width Modulation) is used to control the power on the DC-DC Converter which can generate output signals.

The ANFIS-based MPPT algorithm is developed from the conventional Perturb and Observe (P&O) algorithm. Perturbation and Observation (P&O) Algorithm is one of the optimization techniques used to find the optimum point of a function [25]. This method is based on changing control parameters using steps until the optimum point is reached. The response of the PO algorithm is determined by the step size. The larger the step size, the faster the response reaches the optimum point. In this paper, the P&O algorithm is applied to the MPPT algorithm in a solar power plant using a boost converter. The P&O algorithm is applied to find the duty cycle of the buck converter, operating at the maximum power point. The P&O algorithm works to find the maximum power point based on the power versus voltage characteristic curve, as shown in Figure 3. The steps of the P&O algorithm to reach the maximum point are the value of the change in duty cycle ΔD.

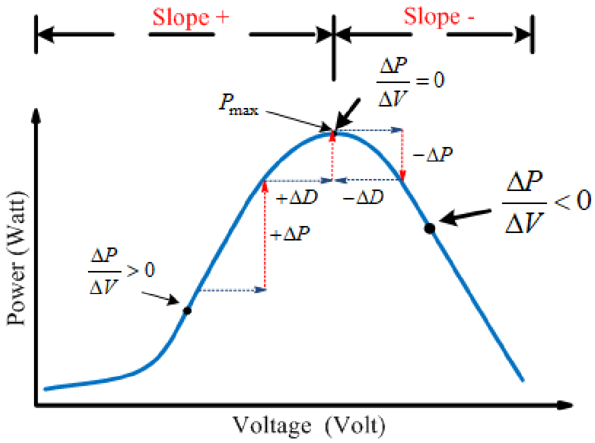


Figure 3. Basic principles of the P&O algorithm

The main objective of the P&O algorithm is for the system to operate at maximum power (P_{max}) when the wind speed changes. Based on Figure 3, the operating point of the generator output power in a solar power plant consists of three slopes, namely the positive slope is located on the left side of P_{max}, the zero slope occurs when the operating point is at Pmax and the negative slope is located on the right side of Pmax. The zero slope is the maximum power point that occurs when the change in power ΔP per change in voltage ΔV is equal to zero. A positive slope occurs when the power change ΔP per voltage change ΔV is greater than zero. A positive slope occurs when the power change ΔP per voltage change ΔV is greater than zero. In this condition, the power change is positive. To reach the maximum point, the buck converter duty cycle is reduced. In other words, the step (ΔD) is positive. A negative slope occurs when the power change ΔP per voltage change ΔV is less than zero. In this condition, the power change is negative, as shown in Figure 3. To reach the maximum point, the duty cycle must be reduced or in other words, the step (ΔD) of the P&O algorithm is negative. Based on this principle, the duty cycle as the output of the P&O algorithm can be formulated as:

$$D_n \begin{cases} = D_{n-1} & jika \quad \dfrac{\Delta P}{\Delta V} = 0 \\ = D_{n-1} + \Delta D & jika \quad \dfrac{\Delta P}{\Delta V} > 0 \\ = D_{n-1} - \Delta D & jika \quad \dfrac{\Delta P}{\Delta V} < 0 \end{cases} \tag{2}$$

$$\begin{aligned} \Delta P &= P_n - P_{n-1} \\ \Delta I &= I_n - I_{n-1} \\ \Delta V &= V_n - V_{n-1} \\ P_n &= V_n\ I_n \end{aligned} \tag{3}$$

Conventional P&O algorithm has a constant step. This will make it difficult to choose the appropriate step value for the MPPT algorithm. To accelerate the response to reach the maximum point, a large step value is needed. But it will have a bad impact with the power ripple increasing at the maximum point. Conversely, to reduce the power ripple, a small step value is needed. To get the solution, a varied step value is needed. Therefore, this paper proposes a varied step value using ANFIS. ANFIS is a combination of fuzzy sugeno with artificial neural networks. Figure 4 shows the structure of ANFIS which consists of five layers, namely fuzzification layer, fuzzy implication layer, weighting normalization layer, fuzzy output value determination layer and defuzzification layer.

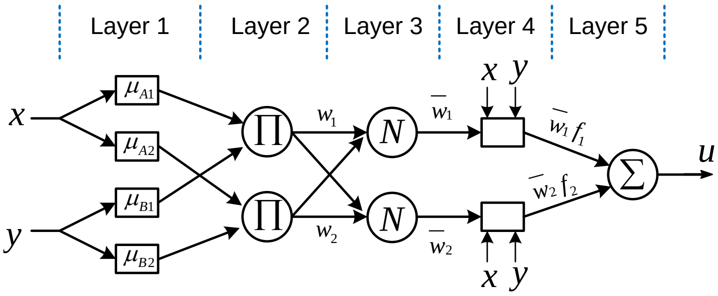


Figure 4. ANFIS structure

3. RESULTS AND DISCUSSION

After the design of the tool is complete, the next step is testing the tool. The solar panel terminal on the roof of the laboratory is connected to a solar panel with a capacity of 4x50 WP. Then it is connected to the boost converter to validate the input current and voltage on the measuring instrument with that displayed on Simulink Matlab. Figure 5 shows the hardware installation for the experiment..

Figure 5. Experimental setup

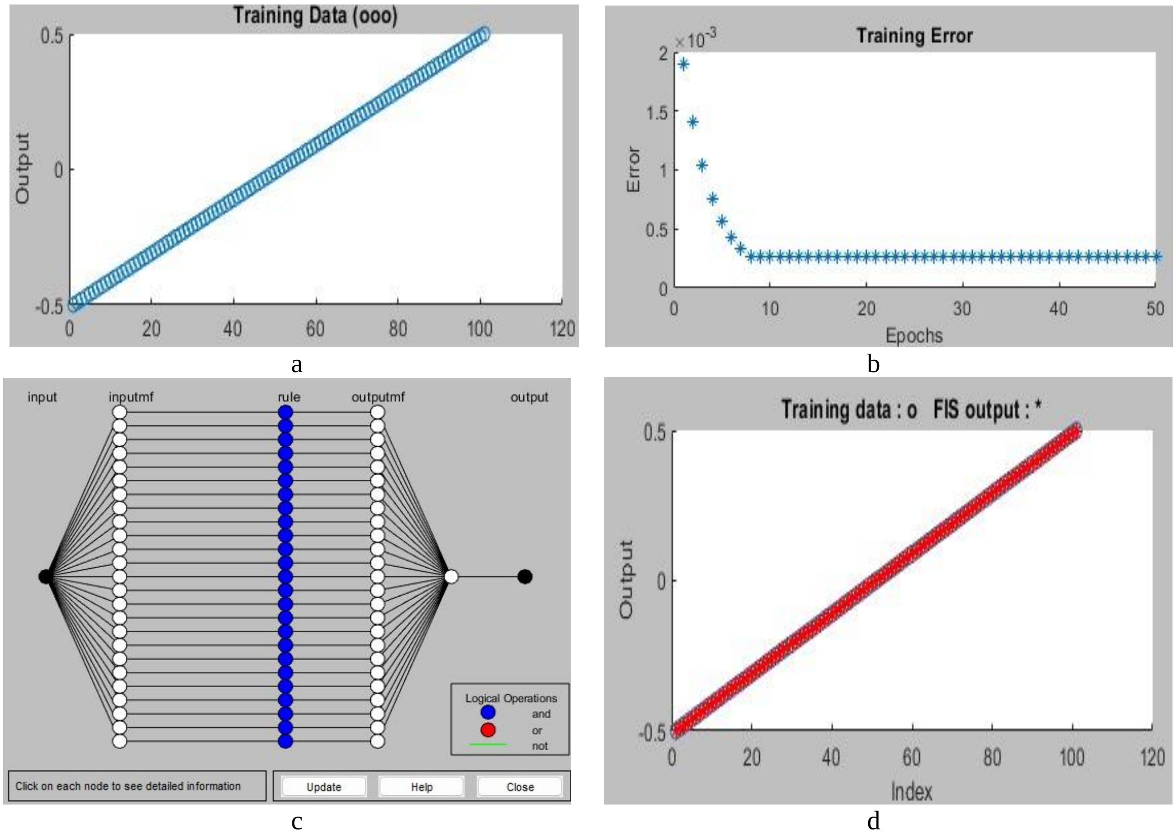


Figure 6. ANFIS training. (a) Training Data, (b) Training Error, (c) Structure of ANFIS Training Data, (d) Output training data

Before testing, training data is first carried out to be inputted into the MPPT ANFIS program. There are several stages in creating an MPPT ANFIS program, first creating training data, then the training data is entered into the ANFIS model. The next step is to enter the ANFIS model into the overall program of the MPPT system. Figure 6 is the result of ANFIS data training from input data and output from training data that will be inputted into the MPPT program. Figure 6(a) shows . Figure 6(b) shows the training data error. Figure 6(c) is the ANFIS structure form of the training data results, then the target training data output is shown in Figure 6(d). The data training process is stopped when a condition has been achieved, namely when the tolerance error value has been achieved. Figure 7 shows the overall program of the ANFIS MPPT control system in Simulink Matlab.

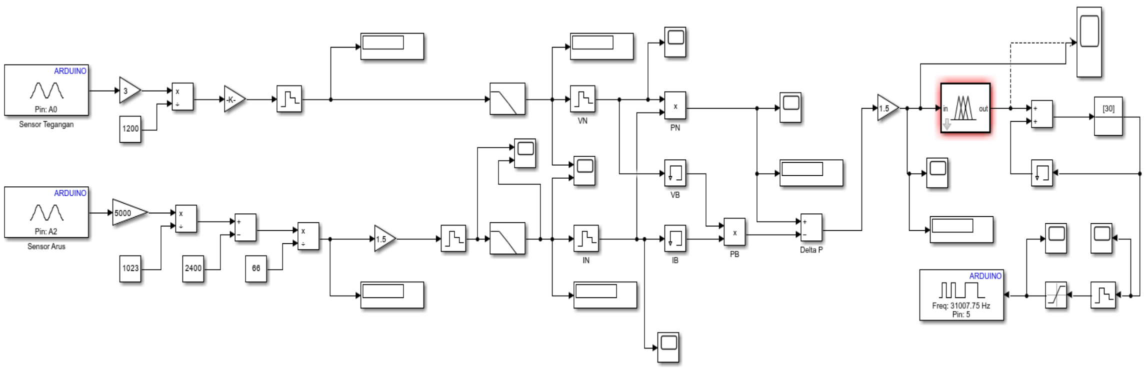


Figure 7. MPPT program in Simulink Matlab

The results of the experiment of the solar panel MPPT control system using the ANFIS algorithm are shown in Figure 8 which shows the voltage and current as well as input power.

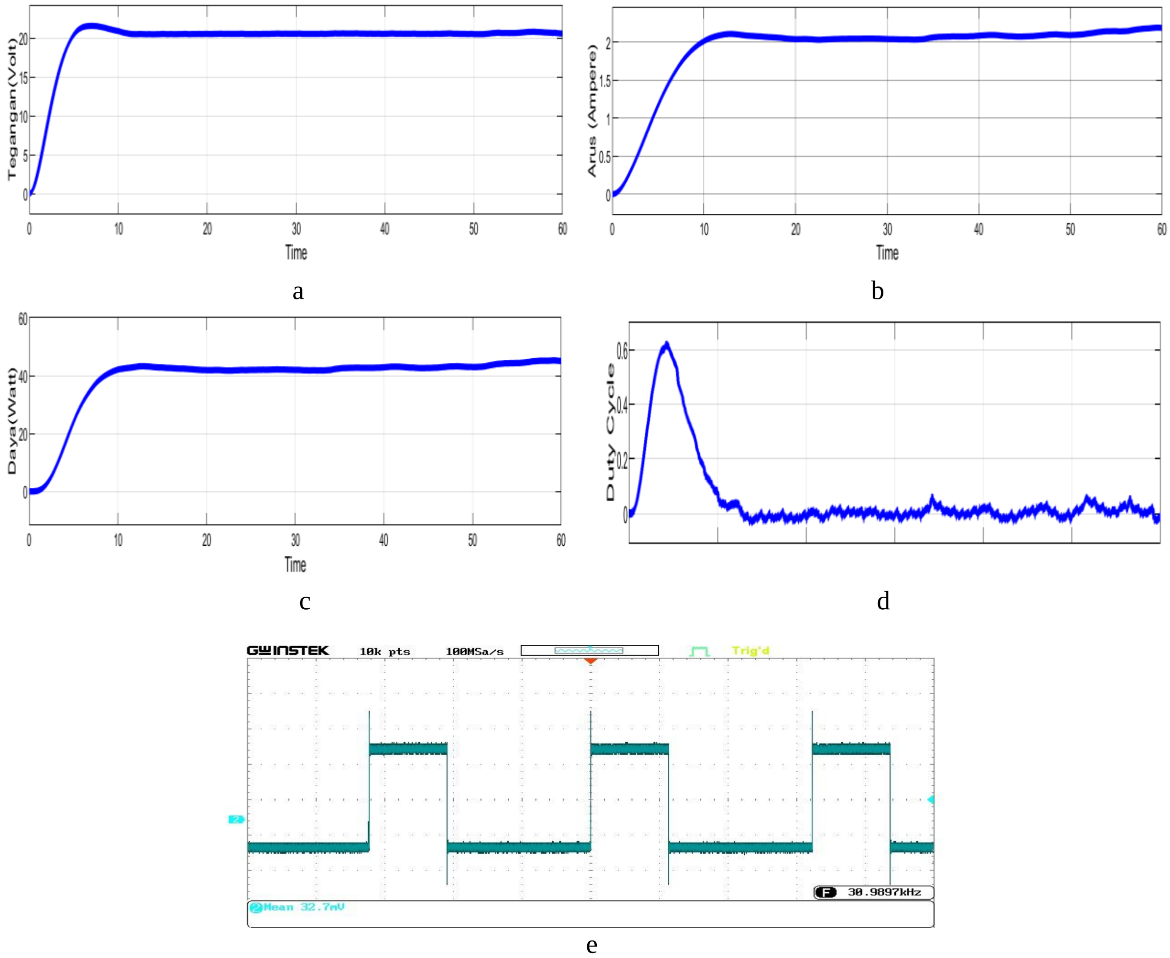


Figure 8. Experimental results (a) Voltage, (b) Current, (c) Power, (d) Duty Cycle, (f) PWM

The experimental results illustrated by Figure 8 provide the conclusion that the proposed maximum power control system for solar panels with the ANFIS algorithm has been able to accelerate the response to reach the maximum point and has also produced smooth power ripples at the maximum point.

4. CONCLUSION

This paper proposes a maximum power control system for solar panels using a dc-dc boost converter based on the ANFIS algorithm. The ANFIS algorithm is developed based on the conventional P&O algorithm which has a constant step value to a variable step value. The proposed MPPT control system is realized on a solar panel using an Arduino Mega 2560 microcontroller. The experimental results show that the ANFIS-based MPPT algorithm has successfully accelerated the response to reach the maximum power point and has also successfully reduced the power ripple at the maximum point. These results provide a conclusion that the proposed MPPT system has worked well according to the objectives..

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