Analysis and Implementation of Fuzzy Control for the MPPT Based PV Systems

Sarab Al-Chlaihawi 1, Ashwaq N. Hassan 2
1Electrical Department of Najaf Technical Institute, Al-Furat Al-Awsat Technical University, 31001 Al-Najaf, Iraq.
2Technical Collage of Management, Al-Furat Al-Awsat Technical University, Iraq.
corresponding author’s e-mail address sarab.haedar@yahoo.com inj.srb@atu.edu.iq ashwaqnama@atu.edu.iq

Abstract. In a photovoltaic system, electronic transducer control is highly essential for sufficient use of solar systems. The present article suggests to modify the Perturb and Observe MPPT (i.e., Maximum Power Point Tracking) with a fog controller to control a DC-DC impulse converter in a photoelectric system under shade and variable cases of the weather. The present study includes a proposal of a different method to the MPPT from a photovoltaic (PV) system for the purpose of obtaining the maximal power from a photovoltaic system. In the traditional approaches, the capability of the tracking includes the power output fluctuations. The modelling and simulation of the PV system with the suggested algorithm has been performed with the use of the MATLAB / SIMLINK software. The model results of the simulation show that the Perturb and Observe (P&O) based fuzzy control algorithm has been considered as a fast transient state, with fewer and smooth fluctuations in the power signal generated.

Key-words: Photovoltaic, Maximum Power Point tracking, Fuzzy, Capacitor, Boost converter

1. Introduction

These guidelines, The PV system is responsible for the generation of the electricity from the sunlight. At a distinctive point on I-V or P-V curve of Photovoltaic system, The Photovoltaic cell performs the generation of a maximal power, which has been referred to as the Maximum Power Point (MPP). As a result of the changes in the temperature and the radiation, the generation of the current from the Photovoltaic modules has been changing as well [1-3]. Voltage current a Photovoltaic module curve exhibits the non-linearity for various conditions of radiation and temperature an optimal load extracting the maximal level of the energy from the Photovoltaic cells. There is a wide range of the methods for the Photovoltaic module MPPT [4]. They represent the approach of the open circuit voltage, short-circuit approach, constant current voltage approach; P&O incremental conductance method.

The approach of the constant voltage represents essay approach, however, in this approach, approximately 80% of available Maximal power under various irradiiances. With the use of the approach of the approach of the constant voltage that has been utilized for finding the maximal power output voltage. Like the approach of the constant voltage, the approach of the Constant Current has been utilized for finding the current of the short circuit to maximal power. Per-turb and Observe approach [5] has been utilized for maximal power through the change of PV current or voltage and estimation of the changes in the power of the Photovoltaic output. The present research proposes a Fuzzy logic-controlled algorithm of maximal point tracking has been suggested on the
basis of the Per-turb and Observe approach. The controller of the fuzzy logic has been fitted to the PV system and MPP under a variety of the conditions of irradiance have been estimated according to fitted model [6-8]. Through the use of the Fuzzy logic Based P&O approach that has the ability of obtaining high speed point of tracking with very low oscillations of the steady state. The suggested PV System, P &O and Fuzzy control have been modelled with the use of the Fuzzy Tool block and MATLAB/Simulink.

The presented paper has been organized as: PV system modelling is a Modelling and Performance properties Section2. Detail Description concerning the photovoltaic System in section3. The suggested fuzzy logic controller and the P&O approach will be presented in section4. The results of the simulation can be seen in section5. And the final section presents the conclusions.

2. Formatting the title, Photovoltaic Cell and Its Characteristic Modelling

An equivalent photovoltaic cell circuit has been illustrated in Fig1. The following expression for the current in photovoltaic cell equivalent circuit can be expressed as:

\[ I = I_{PH} - I_{S}(e^{\frac{V - I_{PH}R_{S}}{NkT}}) - 1 \]  

Vt represents the thermal voltage;IPH represents the light created current; represents the diodes’ saturation current. N represents the factor of quality. The light generated current value is proportionate to the intensity of light (Ir) and

\[ I_{PH} = \frac{I_{PH0}}{Ir} \]  

In the equation above, I, represents the intensity of the light, (Io) represents the light generation current and I_{PH0} represents the standard light intensity. The PV module model is represented by the above photovoltaic cell model [9]. Forget required current and voltage A represents the amount of the photovoltaic cells has been connected in series as well as in parallel. In the equation above, Ir represents the intensity of light, I_{PH0} represents the standard intensity of light, and (Io) represents the current of the light generation. The PV module model is represented by abovementioned photovoltaic cell model. Forget required current and voltage A number of the photovoltaic cells has been connected in series and in parallel. The properties of the efficiency of the separate photovoltaic cell and series and parallelized photovoltaic module connections are identical.

![Figure 1. photovoltaic cell equivalent](image)

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The reverse blocking diode and the by pass with the photovoltaic cell is utilized for the prevention of the consumption of the power throughout the conditions with less irradiation. A set of the connected
photovoltaic modules that are connected in series with the blocking of the diodes and by pass diodes have been connected in a parallel manner to every one of the photovoltaic cells. Fig 2 illustrates I-V and P-V Characteristic curves of the photovoltaic cell in a variety of the conditions. The curve exhibits the P–V system properties in the case of the conditions of the uniform shading, while B & C exhibit properties under the partially shaded conditions with and with no by pass and blocking diodes. It has been observed from I–V properties that have been illustrated in Fig2 that the existence of the by pass diodes allow unshaded modules of the assemblies of every series to carry out their maximal current at a certain temperature and irradiation. However, in the case where there are no bypass diodes, shaded modules will result in limiting the unshaded modules’ current output of photovoltaic string. Which might results in the photovoltaic modules’ thermal destruction, as well as decreasing available output power from photovoltaic array. Blocking diodes result in prevention of reverse current via assemblies of the series, generating lower voltage of the output in comparison with others that are connected in a parallel manner. Such reverse current could be causing excessive generation of heat and photovoltaic modules’ thermal breakdown. The photovoltaic array that has those diodes has introduced several phases in I–V properties and several peaks in P–V properties, under the partly shaded states.

![Figure 2. P–V & I–V characteristics curve of the photovoltaic array: (A) under the even irradiations, (B) Under the partially shaded with no by pass and block diodes, (C) Under the partial shaded with the blocking diodes and by-pass.](image)

3. DESCRIPTION OF THE SYSTEM

Fig 3 exhibits the photovoltaic module diagram, including the PV cell, MPPT controller, DC to DC Boost converter, and load. In the case where sun-light hits photovoltaic Panels, then solar array produces the electrical current and voltage. The produced electric output that is connected to the DC-DC boost converter for stepping up the solar cells’ DC output voltage. Assuming the fact that a solar panel works under a variety of the conditions of irradiation. Converter of DC-DC is controlled using Per-tube and Observed algorithms for the tracking of the optimal MPPT voltage. For the generation of the signals of the PWM to the DC-DC converter a fuzzy controller has been utilized for the quick responses in the transient states, maintaining fewer and smoother ripples of the steady states. In this case, the produced power has been fed to the DC capacitor. DC-link value has been estimated through the use of the formula below:
4. **THE SUGGESTED FUZZY CONTROLLER AND MPPT ALGORITHM**

Every one of the Photovoltaic arrays includes an individual operating point of tracking, in which it produces maximal power. Under a variety of the conditions of shading and irradiations, photovoltaic array properties increase in complexity to the presence of several peaks. One of the most successful and straightforward methods for the MPPT is the P&O, for the controller power. However, this approach is responsible for the generation of the power with a few oscillations and ripples. For the purpose of eliminating that issue, the P & O approach has been carried out with Fuzzy controller that is utilized for the generation of the calculation of the duty cycles for the boost converter of the DC-DC [10-12]. The modified fuzzy base P&O approach diagram has been illustrated below:

![Diagram](image)

**Figure 3.** A diagram of the photovoltaic systems

**Figure 4.** (a) Per-turb and Observe approach (b) modified P&O approach with the fuzzy controllers
Fig 5 illustrates that the fuzzy logic control systems, which consist of the Fuzzification, Decision making, Rule based controls, De-fuzzification. For such system of the FLC, the inputs are considered to be an error in the power differences and the changes in the voltage difference error. In the process of the Fuzzification inputs have been transformed to 7 linguistic variables that have been illustrated in Fig.8 & Fig.9. For the decision making, Mandani approach has been utilized with 49 rules that have been illustrated in fig 8.

![Control Systems of the Fuzzy Logic](image1)

**Figure 5. Control Systems of the Fuzzy Logic**

![Error of the power difference](image2)

**Figure 6. Error of the power difference**

![Error of the voltage difference changes](image3)

**Figure 7. Error of the voltage difference changes**

| Co/e | NB | NM | NS | Z | PS | PM | PB |
|------|----|----|----|---|----|----|----|
| NB   | NB | NB | NB | NM| NM | NS | Z  |
| NM   | NB | NB | NM | NM| NS | Z  | PS |
| NS   | NB | NM | NM | NS| Z  | PS | PM |
| Z    | NM | NM | NS | Z | PS | PM | PM |
| PS   | NM | NS | Z  | PS| PM | PM | PB |
| PM   | NS | Z  | PS | PM| PB | PB | PB |
| PB   | Z  | PS | PM | PM| PB | PB | PB |

**Figure 8. Fuzzy rule**
5. RESULTS AND DISCUSSION OF THE SIMULATION

The present section includes a discussion of simulation details about the photovoltaic system in addition to suggested controller. The solar system was simulated with the use of software of MATLAB/SIMULINK. Fig9 has shown Simulation designs of the solar MPPT controller.

![Solar MPPT Simulink design](image)

**Figure 9.** Solar MPPT Simulink design

Fig10 has shown that the Voltage, Current, power of the Solar panel with the Per-turb and Observe approach and Modified Fuzzy controlled Per-turb and Observe method. Form fig10 it can be seen that modified approach of the P&O has generated smooth and fewer ripple voltage current values.

(a) (b)

**Figure 10.** Voltage, Current, and Power Values at a variety of the irradiation values by (a) Per-turb and Observe approach (b) Modified fuzzy controlled Per-turb and Observe approach
6. CONCLUSIONS

In the present study, the PV system has been explained under a variety of the irradiation and atmospheric condition cases. The suggested tracking of MPP with the modified P&O approach with the fuzzy logic controller has been advanced for the generation of the PWM pulse for the DC-DC boost converters. Suggested system was shown through simulation results in software of MATLAB/Simulink. Form the results it has been concluded that the P&O approach has generated some oscillations in the produced electric energy and modified fuzzy controlled P7-O approach has given smooth outputs from photovoltaic cells.

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