# INTELLIGENT CONTROL OF MPPT FOR PHOTOVOLATIC AND FUEL

[1]Anil Kumar,[2]Dr. Loveleen Kaur

[1]Master of Engineering,[2]Assistant Professor,
[1] Department of Electrical Engineering,
[1]Punjab Engineering College, Chandigarh, India

***Abstract :*** In this paper, a new and effective method is designed that is based on the Neuro-fuzzy or ANFIS system along with the MPPT algorithm. A literature survey is conducted which shows that by using the MPPT algorithms along with the solar PV panels the voltage can be regulated and provide effective results. However, these methods have certain drawbacks which include complexity which degraded their overall performance. In addition to this, the biggest concern for experts was to charge EV when solar irradiance is decreased to zero. For this the proposed model used a fuel cell as an alternative source of energy and is responsible for providing enough power to EV battery in absence of sunlight. This is done efficiently by using the switching module in the suggested method. The efficiency of the proposed ANFIS-MPPT based model is validated and compared with the conventional P&O methods in the MATLAB Simulink software. The simulated outcomes proved that the proposed model is effective in charging the batteries of EVs.

***Index Terms* - MPPT Systems, Intelligence in electrical systems, Power systems, P&O method.**

## I. INTRODUCTION

Over the last few years, the use of renewable power generation techniques has expanded drastically, thus it is critical to develop a mechanism in order to ease the implementation of RERs so that the overall efficiency, safety and dependability of the grid is enhanced. As there is a drastic increase in electricity demand all over the world which makes it crucial to use new sources of power generation which include solar, wind fuel cells etc. [1]. These RERs have been found very effective in order to meet the rising demand of energy while also addressing some major environmental issues. Out of the all the Renewable power generation sources, PV is the most common and effective one because it is cost effective, highly efficient with low maintenance charges [2]. Despite the intermittent nature of sunshine, energy generated by the solar PV panels is free of cost.

In a typical solar power generation system, solar PV panels are installed serially or parallelly in order to generate the maximum power. The power generated by the solar panel directly depends on the intensity of sunlight which means if intensity of sunlight is more, more power is generated and vice versa [3]. Each panel generates a small amount of electricity, but they can be linked together to produce a larger amount of energy in a solar array. Solar panels generate electrical power in the form of DC. Although control devices use direct current to work with the electrical utility grid, which uses alternating current (AC). As a result, before solar energy can be used, it must first be converted from direct current to Alternating current with the help of an inverter. The inverter's AC electrical energy can be used to operate local electronics or sent to the electrical grid to be used elsewhere [4].

Batteries are commonly used in Photovoltaic system to power the photovoltaic array during the day and provide power to electrical loads as required. The function of the Photovoltaic array, MPP and to operate electrical loads as desired are the reasons for using the Photovoltaic system [5]. Another uses of batteries in photovoltaic systems include managing the photovoltaic array at the Maximum Power Point to operate electric power loads at constant power and providing surge current to loads and inverters. In these methods, a battery charge manager is used to protect the battery from overcharging and over discharging. The major drawback of using solar power generation systems is its dependency of atmospheric factors such as solar irradiance and temperature. This leads to in efficiency as the solar panels are unable to extract maximum power [6]. To increase the system efficiency and to extract maximum power from the panels, different MPPT (Maximum Power Point Tracking) techniques are used. Some commonly used techniques are: Fuzzy logic, Perturb and Observe (hill climbing method), Neural Network, Fractional open circuit voltage, Incremental Conductance method, Fractional short circuit current [7].

Among all the method, P&O is considered as the simplest one. In this method, only one sensor is used which is called as the power sensor that is used to monitor the drop-in voltage readings to enhance the performance of the system. it causes the terminal voltage to oscillate around the maximum power point voltage by determining the operating point of the system even when solar irradiance and cell temperature is constant. P&O is one of the mostly used MPPT algorithms because its simplicity and increased performance [8]. On the other hand, fuzzy logic is a type of several logic which interacts with estimated instead of fixed and accurate reasoning. Unlike, the conventional binary sets, the true value of the fuzzy system varies from 0-1 range [9]. However, in case on incremental conductance approach the value of MPP is extracted by monitoring that whether the solar Panel is moving toward the right of MPP or left. In this method, two present power sensors are utilized in order to compute the final value of power and current values [10]. The connection of cells in a neural system is determined by the network structure. The two most frequent architectures of neural networks are supervised learning and unsupervised learning. Basically, the supervised algorithm gets trained by using the labelled training data that helps to predict the final output [11]. By using the techniques mentioned above various researchers have performed several techniques to extract maximum power from the solar PV panels that is mentioned in the next section. This fixed request H-infinity controller is remembered for this method to distinguish the position. The position can be broke down through the further developed particle swarm improvement[12].

## II. LITERATURE SURVEY

To extract maximum power from the solar PV panels[13], experts have proposed several techniques, out of which some are mentioned here: S. Shabaan et al. [14], investigated MPPT for a solar water pump based on adaptive neuro-fuzzy inference system. The efficiency of the scheme with and without maximum power point tracker approval was compared under changing light intensity and heat. Since Photovoltaic cells are non-linear, an adaptive neuro-fuzzy inference system-based controller was responsible for providing rapid response with high efficacy at all heating rates and levels of irradiance. K.Amara et al. [15],verified MPPT approach based on the adaptive neuro-fuzzy interference system could improve not only efficiency but also monitoring accuracy, speed, and system durability in a changing climate. As a result, this improvement has been shown to be beneficial for Photovoltaic scheme-based networks. N. Uddin and M. S. Islam [16], The optimum power for growing solar Photovoltaic effectiveness in shifting weather conditions was illustrated by the authors. It's a hybrid strategy that involves an adaptive neuro-fuzzy interference system-based small-scale solar power transformation method. The authors also optimized the model using MATLAB/Simulink tools. The Maximum power point tracker controller's simulation findings show that it is much more useful and competitive than the traditional scheme. Y. Chu et al. [17], Maximum power point tracker system based on Adaptive neuro-fuzzy inference system for a Photovoltaic framework in an isolated phase was proposed in this paper to attain maximal energy, a DC-DC buck/boost converter was established among the Photovoltaic element and the load. The suggested model was more accurate and also has a better response behavior. The suggested solution is spotted to be a superior option under various load conditions based on the study. S. Padmanaban et al. [18], A control scheme known as ABC with MPPT for a grid integration based solar penal system was introduced in this paper. To verify the inverter control system's working and maximum power point tracker, the control board SPACE was used. In this paper, the ABC algorithm was used to transform the adaptive neuro-fuzzy interference system membership function. S. Sheik Mohammed et al. [19], suggested the controller based on MPPT scheme which is useful in different pv array regulated system. In MATLAB/Simulink, a Photovoltaic power setup with a Photovoltaic array, DC-to-DC boost converter, and Adaptive neuro-fuzzy interference System based Maximum power point tracker controller was planned. H. Afghoul et al. [20],discussed how to improve Photovoltaic power management using a smart control scheme for Maximum power point tracker. The model was created using a DC-DC converter mechanism with a neuro-fuzzy controller. The simulation was used to show the configuration of this controller. The proposed methodology and P&O results were compared to display the function level in terms of power optimization and fast reaction to changes in the process situation. H. Abu-Rub et al. [21], In the standalone method, the paper suggested an AI based solution to provide maximum power and interface from Photovoltaic power-producing systems. To handle injected power and retain strict electric power, frequency state, and current, quasi-Z-source inverter's closed-loop regulation regulates shoot during modulation index and service cycle. An independent load condition was used to assess the suggested methodology. The effectiveness was confirmed using simulation and experimental techniques. Ammar A. Aldair et al. [22], aimed to ensure that Adaptive neuro-fuzzy interference can monitor Maximum power in a Photovoltaic stand-alone system effectively. This is a method to enhance the effectiveness of Photovoltaic cell by balancing the load to the Photovoltaic cell. The model's results showed that the Adaptive neuro-fuzzy interference model controller is very efficient and has a better dynamic response than the constant voltage and gradual conductance techniques. T.Shanthi et al. [23], suggested an AI based method for connecting a Photovoltaic array to a 3-phase alternate current load, transmitting the maximum energy to the system. The suggested framework was simulated using MATLAB/Simulink tools, and the results showed that the suggested maximum power point tracker Controller based on Adaptive neuro-fuzzy Inference system is very basic, cost-effective, and effective.

From the literature survey conducted it is observed that various MPPT algorithms have been utilized in majority of solar systems in order to extract the power effectively from the solar PV panels. As charging is considered as one of the most crucial and significant activities of EVs and has gained attention of various experts which utilized various swarm intelligent algorithms. However, after examining these systems it is observed that no doubt they produce some superior results but still has some limitations which degraded the performance of overall system. These systems were not efficient enough as the size of error is increases. Moreover, in traditional systems continuously changing environment conditions leads to change in the direction errors. In addition to this, another issue in the current model is that it would be impossible to charge batteries if the PV systems will be unable to gain solar energy for whatever reason. It would have a direct influence on performance because charging batteries with a solar PV panel would be challenging. Inspired from these findings, a new an effective model will be developed by incorporating new techniques.

## III. PRESENT WORK

In order to overcome the limitations of traditional model, a novel and effective system is proposed in this paper which basically works in two phases, in the first phase neuro-fuzzy system is implemented and in the second phase, fuel cell is introduced.

### 3.1 Phase 1: Implementing neuro-fuzzy system

Recently, a large number of MPPT algorithms have been utilized by different experts along with the fuzzy and neural networks in order to enhance their performance. However, the proposed model utilized both fuzzy and neural networks as ANFIS, to make the proposed model more efficient. The block diagram of the proposed ANFIS model is consists of solar panels, MPPT controller, EV battery and is shown in figure 1.1.

Figure 1.1 illustrates the block diagram of the proposed ANFIS model in which solar PV panels are installed which converts the solar energy into electrical energy. The MPPT technique is used to extract the maximum power from the solar panels in order to provide sufficient energy to the EV for charging batteries. The power generated by the solar PV panels is controlled and managed by the neuro fuzzy based MPPT algorithm which takes two membership variables i.e. error and change In Error along with their seven membership functions as input. These inputs are then passed to the proposed ANFIS model to generate a final output as Vref along with its 49 membership functions.

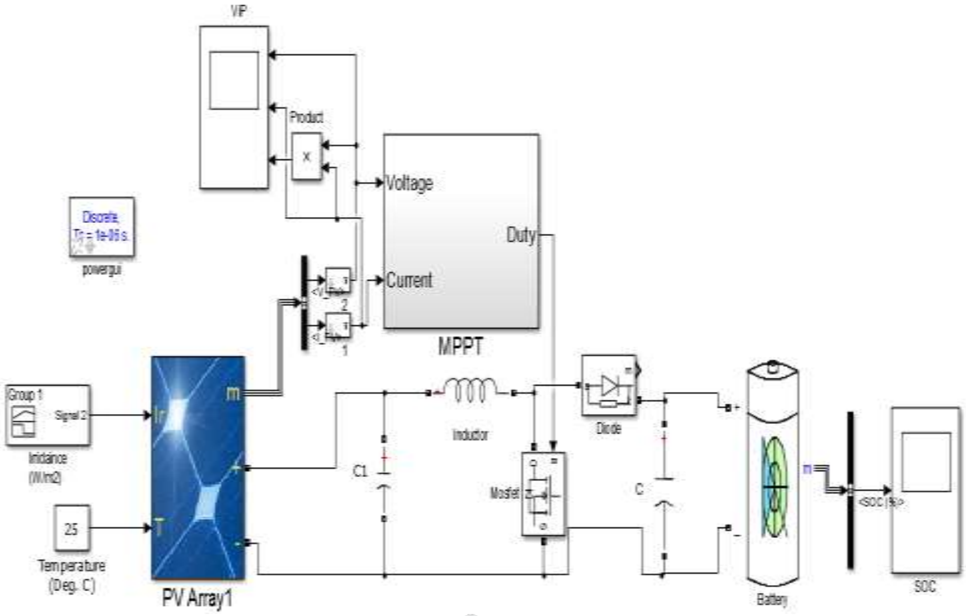


**Figure 1.1**. Proposed ANFIS system

### 3.2 Phase 2: Installing fuel cell

In the second phase of the proposed model a fuel cell is installed in the system in order to provide sufficient energy to the EV battery in absence of sunlight. A switching module is also introduced in the system that decides when to turn on the fuel cell supply and when to turn it off. The goal of employing a switching technique is to keep charging going in any tough situation so as to provide charging services effectively. It would work when PV array does not work, the charging of battery will continue by switching the source of power from PV panel to fuel cell. The configurational block diagram of the proposed fuel cell model is shown in figure 1.2.

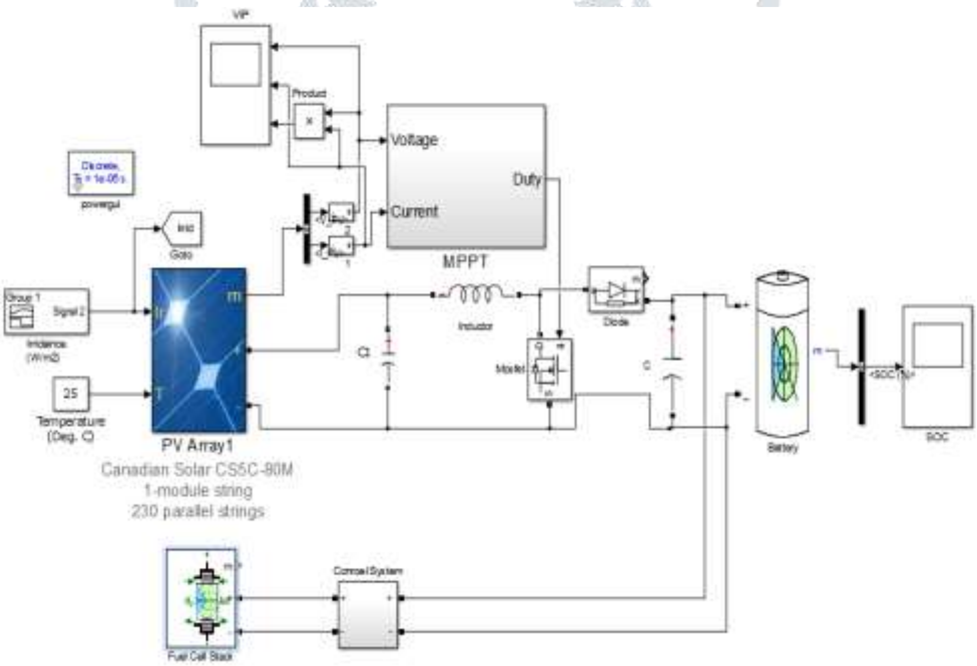


**Figure 1.2** Proposed fuel cell model

Figure 1.2 illustrates the block diagram of the proposed model in which fuel cell is installed. The fuel cell is utilized in order to provide enough energy to battery of EV so that it can get charged even when the solar light is absent. As a result of using the aforementioned methods, an improved model with effective output is anticipated. The following is a full description as to how this model works.

### 3.3 Methodology

The process that is followed by the proposed ANFIS model is given below:

1. The very step that is opted by the proposed NAFIS model is to initialize the network by defining various parameters of solar panels which are mentioned in table 1.

Table 1: Solar panel parameters

| Solar Panel Parameter | Value |
|---|---|
| Input Irridaince (w/m$^2$) | 1000 to 0 |
| Input Tempearture(deg.C) | 25 |
| Parallel strings | 230 |
| Series-connected modules per string | 1 |
| Maximum Power (W) | 80 |
| Open circuit voltage Voc (V) | 21.8 |
| Cells per module (Ncell) | 36 |
| Short-circuit current Isc (A) | 4.97 |
| Voltage at maximum power point Vmp (V) | 17.5 |
| Current at maximum power point Imp (A) | 4.58 |
| Temperature coefficient of Voc (%/deg.C) | -0.37399 |
| Temperature coefficient of Isc (%/deg.C) | 0.088994 |

2. Moreover, different attributes of the EV battery are defined which include voltage, rating capacity, SOC and battery response time. The exact value of these parameters are given in table 2.

Table 2: Different EV battery parameters

| EV Battery Parameter | Value |
|---|---|
| Nominal voltage (V) | 30 |
| Rated capacity (Ah) | 200 |
| Initial state-of-charge (%) | 17.3 |
| Battery response time (s) | 1e-6 |

3. After this the electrical energy is passed through the dc-dc boost converter which is connected to the solar PV panels in order to fetch the Voltage from these panels.
4. Once the voltage is generated, DC-DC converter requires a duty cycle to perform effective operations. For this a MPPT technique is designed which would assist the converter to produce duty cycle.
5. As the model needs a load device in which the converted energy can be stored, therefore the proposed model will utilize EV battery as a load device. The battery will be charged with the help of converted energy from PV panel and the objective of proposed work will finally meet the requirements.
6. Furthermore, a fuel cell is utilized in the proposed model as an alternative energy source that charges the battery of EV efficiently. The switching is done in the proposed model with the help of intelligent controller. The various parameters of the fuel cell are defined in table 3.

Table 3: fuel cell parameters

| Fuel Cell Parameter | Value |
|---|---|
| Nominal stack efficiency (%) | 46 |
| Number of cells | 42 |
| Operating temperature (Celsius) | 55 |
| Nominal Air flow rate (lpm) | 2400 |
| Nominal supply pressure [Fuel (bar), Air (bar)] | [1.5 1] |
| Nominal composition (%) [H2 O2 H2O(Air)] | [99.95 21 1] |
| Maximum Power (kW) | 1.26 |
| Voltage | 24 |

7. Lastly, the efficiency of the proposed model is validated and compared with the conventional models and is explained briefly in the next section.

## IV. RESULTS AND DISCUSSION

The performance of the proposed ANFIS model is evaluated and compared with the standard model in the MATLAB environment. The simulated results are attained in terms of their voltage, current and power generation. The detailed description of the results is given in this section.

### 4.1 Performance Evaluation

The performance of the proposed ANFIS-MPPT approach is firstly evaluated and compared with the conventional P&O approach in terms of their voltage generation ability and is shown in figure 1.3.

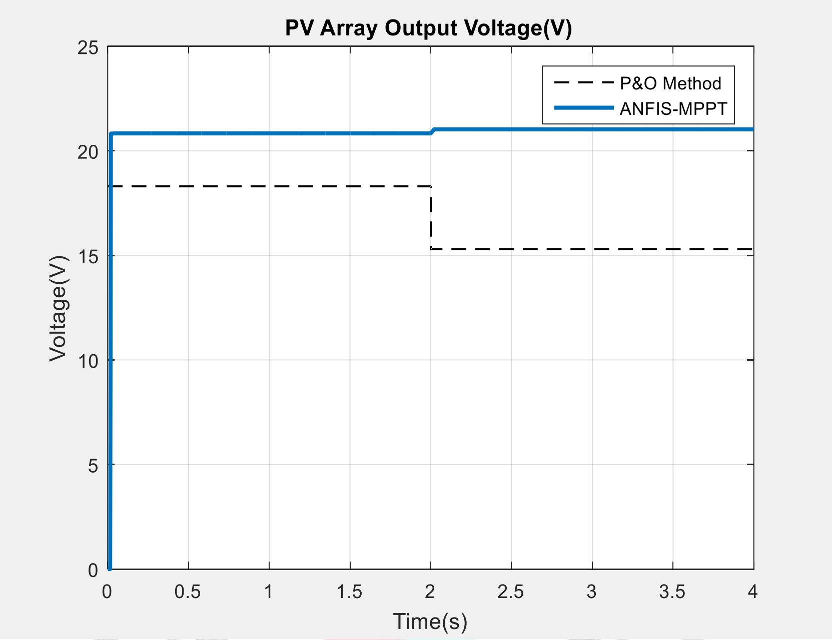


Figure 1.3 Comparison Graph for voltage

Figure 1.3 represents the comparison graph of the proposed ANFIS-MPPT approach and conventional P&O approach in terms of voltage generation ability of solar PV panels. From the obtained graph, it is observed that the maximum voltage reading achieved in the traditional P7O approach is just 17V which is then decreased after 2s and came out to be close to 15V. However, in case of proposed ANFIS-MPPT approach the voltage rises from zero to 21V in no time and then remains constant over the remaining time.

Moreover, the performance of the proposed ANFIS-MPPT model is analyzed and compared with the standard P&O approach in terms of power generation ability and is shown in figure 1.4.

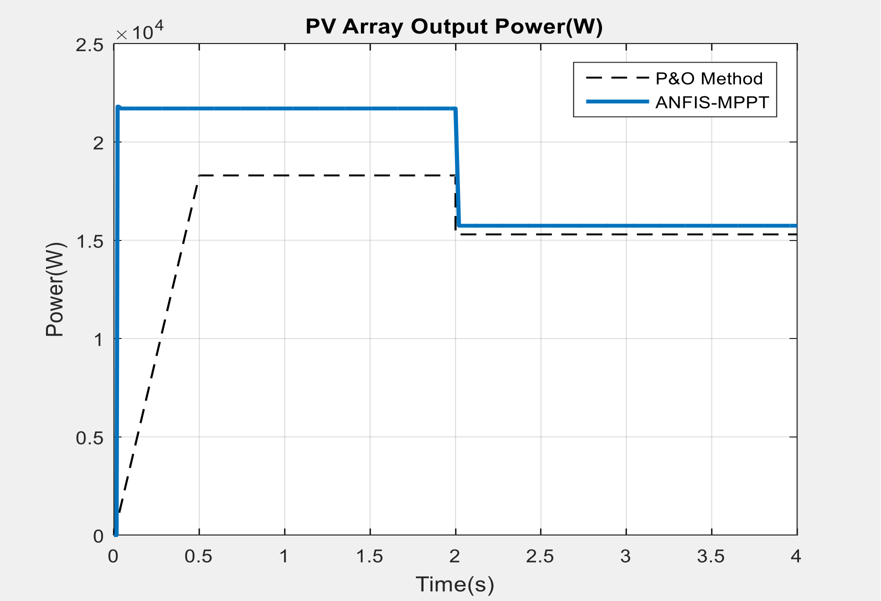


Figure 1.4 Comparison graph for power

Figure 1.4 demonstrates the comparison graph of the proposed ANFIS-MPPT approach and standard P&O approach in terms of their power generation ability. From the obtained graph it is observed that the power generation ability of traditional P&O model is increasing slowly when the irradiance is high and reaches to maximum of 1.7×104W in just 0.6seconds. However, after 2s, the power generation ability decreases in traditional model and reaches to 1.5×104W. On the other hand, in proposed ANFIS-MPPT approach the power reaches from 0W to 2.2×104 W within no time. Although, the power rating decreases after 2s, when irradiance is decreased but it is still able to provide 1.7×104W of power by using the fuel cell energy.

In addition to this, the efficiency of the proposed ANFIS-MPPT method is verified and compared with the conventional P&O model in terms of their battery SOC, when irradiance is high and is shown in figure 1.5.

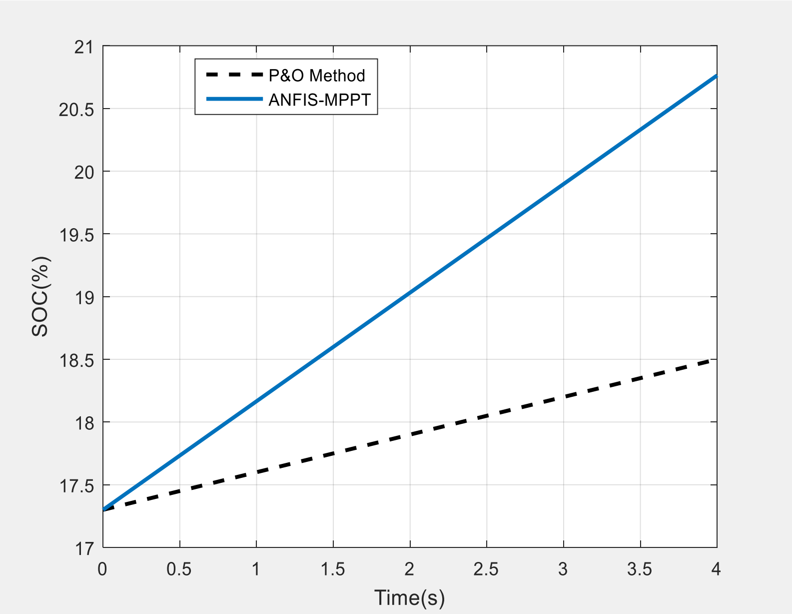


Figure 1.5 Comparison graph in terms of SOC

Figure 5.6 represents the comparison graph of the proposed ANFIS-MPPT model and traditional P&O method in terms of battery SOC percentage. From the graph it is observed that the when the irradiance is high the battery is getting charged more effectively in the proposed ANFIS-MPPT model whose value reaches more then 20.5% after 4s. while as, this is not the case in traditional P&O method which is charging slowly and reaches up to only 18.5% after 4s.

Finally, the SOC of the battery with PV panels and fuel cell is obtained and is shown in figure 1.6.

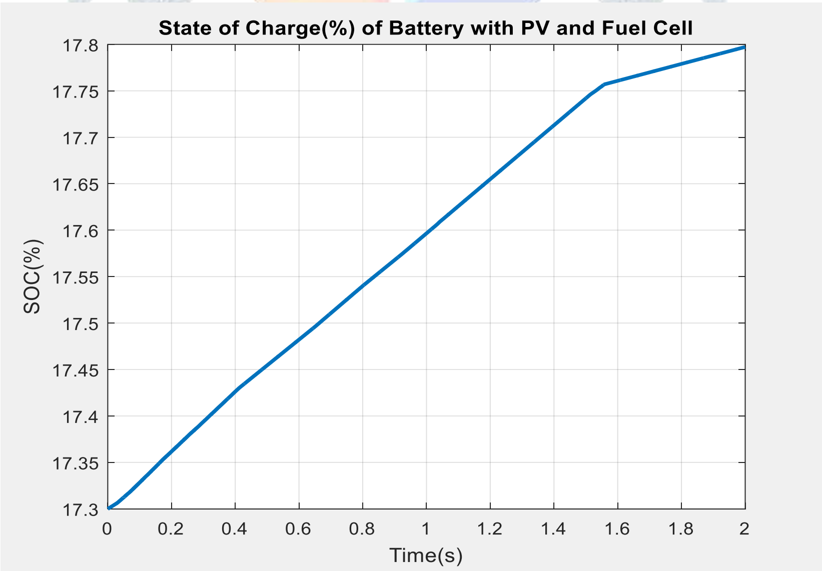


Figure 1.6 SOC of battery with PV and fuel cell

Figure 1.6 represents the SOC battery diagram of the proposed model with PV panels and Fuel cell. From the graph, it is observed that the battery is getting charged effectively when the solar irradiance is high. Although, after 1s, the solar irradiance is decreased but still battery is getting charged because fuel cell is supplying energy at this time. However, the charging ability decreases slightly after 1.5s because fuel cell is getting discharged.

From the graphs it is observed that the proposed ANFIS-MPPT method is more effective and convenient for charging the EV batteries.

## V. Conclusion

This paper proposed a model that is based on neuro-fuzzy system for charging the batteries of EVs efficiently. The efficiency of the proposed ANFIS-MPPT model is validated and compared with traditional P&O methods in the MATLAB Simulink software in terms of voltage, current, power and battery SOC. After analyzing the results closely, it is observed that the traditional P&O system is producing a maximum of 1.7×104W. Whereas, in proposed ANFIS-MPPT model the maximum power generation ability of the system reaches up to 2.3×104W. In addition to this, the battery SOC in traditional P&O method is slow and reaches a maximum of 18.5% only. While as in proposed ANFIS-MPPT model, the battery SOC reaches up to 20.5% and is able to charge the battery of EV effectively even in absence of sunlight. The fuel cell is used as an alternative energy source which supplies energy to the battery of EV when solar irradiance is zero. Hence, the proposed ANFIS-MPPT model outperforms the traditional P&O method in all parameters which proves it more effective and convenient.

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