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# Maximum Power Point Tracking Improvement in Electric Vehicles Using HPSOGSA Algorithm

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**ABSTRACT:** Electric Vehicles (EVs) are gradually becoming the essential part of our daily life. Due to fast depletion of the fossil fuels like petroleum and diesel and also increasing concentration of pollutants in the atmosphere, EV is widely serving as an alternate of these fossil fuels. Many electric vehicles, solar powered cars or hybrid vehicles obtain the input from a solar PV panel. To store the energy, some energy storage device is vital that can store the surplus energy during production, and then transfer this excess energy during deficit. To serve this purpose, battery is considered as a major element for an electrical vehicle. But these batteries can damage due to overcharging by a solar panel. So, to safeguard the battery from any sort of damage because of overcharging, some sort of intelligent or smart battery management system is necessary. In the present research work, a smart battery management system based on fuzzy logic is proposed. This system is supported by the solar PV panels that can provide the faster charging to the electrical vehicles, protecting the battery life from the overcharging, and enhancing the life of battery by utilizing the optimum power from the battery. To achieve this improvement of maximum power point tracking (MPPT) is necessary in solar PV panels. Present research work includes an HPSOGSA algorithm that is a hybrid system of two most proficient (PSO & GSA) algorithms for improving MPPT in solar PV systems. Various parameters such as rise time, settle time, peak time, overshoot, under shoot, irradiance, battery voltage ($V_{bat}$), and state of charge (SOC), are used for comparing the results of two particular controllers (PID & FOPID) for the suggested HPSOGSA system.

***Key Words:*** Electrical Vehicle (EV), Maximum Power Point Tracking (MPPT), Particle Swarm Optimization (PSO), Gravitational Search Algorithm (GSA), Image Enhancement Factor (IEF)

## 1. INTRODUCTION

Electric vehicles are emerging as an alternate way of transportation due to increased level of pollutant gases in the atmosphere as well as changing government policies towards the usage of zero emission vehicles. The vision of using electric vehicles has been increasing from the last few years. A recent advancement in EV sector [1] is the hybridization of the power storage space. The hybrid power storage space arrangement basically consists of more than one energy storage device be used to power the motor. Around the world, different models of fuel cell, ultra capacitor based, solar and battery based vehicles [2] have been emerging due to large improvement in the efficiencies of these vehicles. The knowledge used in the designing of these electric vehicles [3] depends on the different parameters such as fuel consumption efficiency, battery charging, discharging cycles, and driving range of vehicle and also the effect of greenhouse gases to the environment. The success of any of the approaches will dependent on energy storage unit (batteries, ultra capacitors) capabilities that are power, density, life, and cost. Ultra capacitors (UC) [4] utilize number of electrolytes connecting into different modules to meet the required energy, voltage and current ratings. Batteries [5] store charge chemically when compared with the ultra-capacitors which stores the energy electro statically. The cost of ultra-capacitors is higher when compared with the cost of batteries [6]. The ultra-capacitors [7] store energy through the separation of charge at the interface of the electrodes. Finally the ultra-capacitors can uphold thousands of charge and discharge cycles without any effect and also provide quick transfer of energy [8]. Global concerns and growth in electricity demand, especially for rural and remote settlements, has forced governments, scientists, engineers, and researchers to look for alternative solutions in the form of renewable energy sources. High global growth in solar energy technology applications has added more weight in operations and maintenance (O&M) of solar-photovoltaic (SPV) systems. O&M plays a central role in ensuring sustainability and long-term availability throughout the operational lifetime of the elements of SPV systems whilst boosting confidence of ultimate consumers in solar energy [9]. Solar Photovoltaic (SPV) technology advancements are primarily aimed at decarbonizing and enhancing the resiliency of the energy grid. Incorporating SPV is one of the ways to achieve the goal of energy efficiency. Because of the nonlinearity, modeling of SPV is a very difficult process. Identification of variables in a lumped electric circuit model is required for accurate modeling of the SPV system. A new state-of-the-art control technique is presented based on human artifacts dubbed Drone Squadron Optimization for estimating 15 parameters of a three-diode equivalent model solar PV system. The suggested method simulates a nonlinear relationship between the P–V and I–V performance curves, lowering the difference between experimental and calculated data [10]. A maximum power point tracking (MPPT) algorithm is presented in a solar photovoltaic (SPV) system that is simple to implement, requires lesser number of sensors and also offers a decent tracking efficiency as well as speed. P&O algorithm is one of the most popular MPPT algorithms as it needs a simple circuitry and easy implementation, but it suffers against fast-changing environmental conditions mostly in the case of partial shading conditions and requires two sensors, i.e., voltage and current. To overcome this limitation, one sensor-based method is proposed which is based on the modified converter design that eliminates the effect of partial shading conditions as well as the fast-changing environmental condition [11]. One of the most promising forms of renewable energy is solar energy. However, efficient exploitation of this energy form is a topic of great interest, especially in obtaining the maximum amount of power from the solar photovoltaic (PV) system under changing environmental conditions. A feasible maximum power point tracking (MPPT) technique is presented for DC/DC boost converters applied in load-connected stand-alone PV systems to extract the maximum available power. This proposed method is based on the combination of the modified perturb and observe (P&O) and fractional open circuit voltage (FOCV) algorithms. The simulation results show a tracking efficiency with an average value of 99.85%, 99.87%, and 99.96% for tracking the MPP under varying loads, irradiation, and simultaneously varying temperature, load, and irradiation, respectively [12]. Fuzzy based MPPT research works have been published more since some application of fuzzy control has been successful in photovoltaic applications. The advantage of FLC is that it does not require a mathematical model for SPV system for controlling the complex system. Fuzzy logic is a computational technique that can track the MPP of SPV panel as it offers the salient features to deal with the imprecise and nonlinear parameters. FLC is advantageous in the sense that the control algorithm is dependent on linguistics terms only. Mostly the general-purpose microprocessor or microcontrollers can be utilized to implement the FLC, but it often faces difficulties to deal with the systems needing high speed of processing. Technology advancements have provided the designers an option to implement a controller using various devices such as Field Programmable Gate Arrays (FPGAs) and Programmable Logic Devices (PLDs) etc. [13, 14].

In this paper, **Section 1** describes the comprehensive literature review of various papers published by different authors. Whereas, the proposed algorithm is provided in **Section 2**. Results and discussions are described in **Section 3**. Also, conclusions drawn from present research work are provided in **Section 4.**

## 2. PROPOSED DESIGN

A schematic of SPV based smart battery charging system is illustrated by Fig. 1. A SPV panel is utilized as a preferred energy resource for producing the electrical output. Electrical energy generated by these PV panels depends on parameters such as SPV cell temperature as well as irradiance. The charge is stored in a lead-acid battery (18AH, 12V). A DC-DC boost converter is utilized for charging the battery towards an optimal level using a PV panel as an input source of electricity.

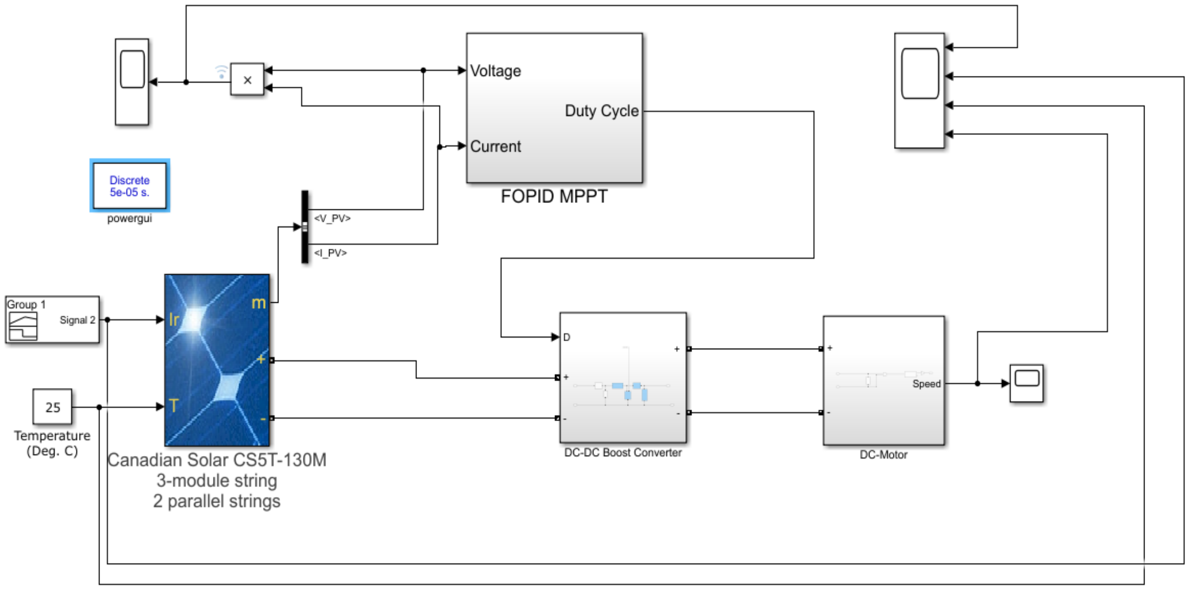


**Figure 1: Schematic of SPV based Smart Battery Charging System**

PV based smart battery charging system is operated in two distinct modes which are bulk and float charging modes. A perturb and observe (P&O) MPPT system is utilized in bulk mode of charging, whereas for float mode of charging, a controller is utilized for maintaining an optimal voltage in a battery. If the power in solar PV panel is more than 5 Watt, the bulk mode is utilized for charging of the battery using MPPT system. But when voltage in the batteries reaches to its optimum voltage level, then the battery is charged using floating mode. Additionally a switch (S1) is utilized for cutting-off the battery power supply from the solar PV panels when charging level is completed for protection from over-charging.

PV based smart charging system requires one current sensor and two voltage sensors. One voltage sensor measures the PV voltage and other measures the battery voltage. The current sensor measures the PV panel current. A MOSFET is used in the driver circuit for providing the required gate pulses to DC-DC synchronous boost converter.

## FUZZY LOGIC CONTROLLER (FLC)

Machine learning approaches are not fully successful in various fault detections in solar PV panels. To overcome this disadvantage, the fuzzy logic systems are designed which proves to be more successful in fault detection.

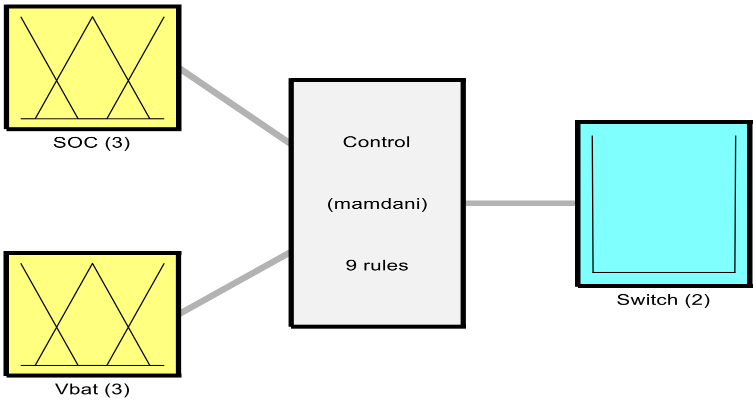


**Figure 2: Fuzzy Inference System for Solar Tracker**

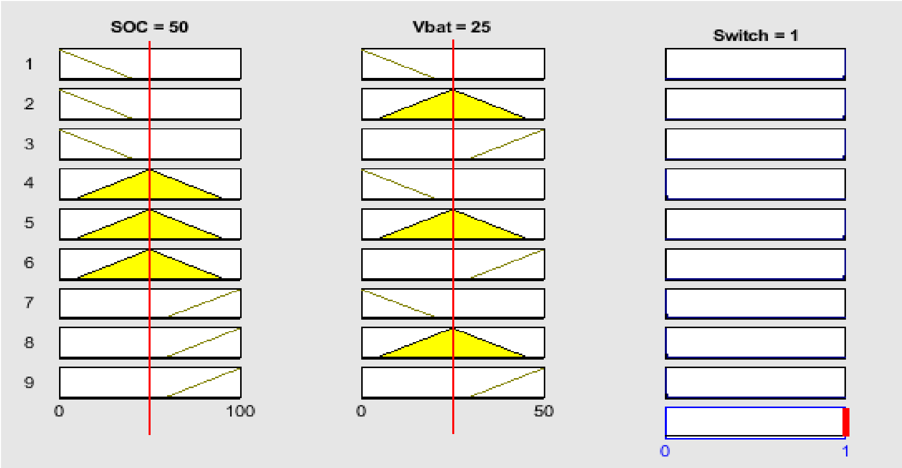


**Figure 3: Rule view of fuzzy inputs versus output in Sun tracking system**

A fuzzy inference model of proposed solar-tracker system is as shown in Figure 2. This system has SOC and Vbat as inputs and the outputs are control switches. Nine fuzzy rules are applied in this system as shown in Fig. 3. FLC are advantageous in circumstances where the controls are too large or too difficult to use mathematically. The management design is based on some consistent rules.

The main functions offered by FLC are:

(1) Fuzzification;
(2) Reasoning decisions;
(3) Fuzzy informational knowledge; and
(4) Removal of spirits.

Fuzzification is a method of changing the values of numbers and symbols to become part of the vision team. Therefore, fuzzy blocks the input data to determine how the status of each command matches the input. The individual workloads in each language group are associated with input changes. This system is applied to the FLC based solar PV panel for defining the current output of a light emitting diode. The fuzzy inference engine provides the input value (see Figure 4).

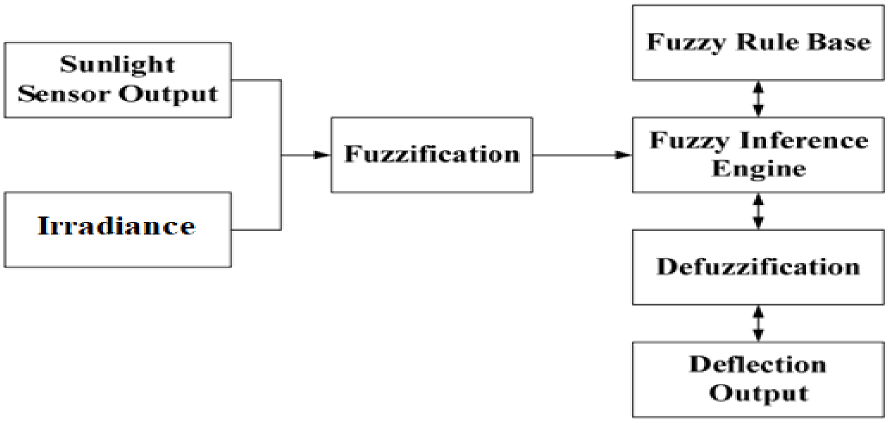


**Figure 4: FLC Framework**

## 3. RESULTS AND DISCUSSIONS

A hybrid model (HPSOGSA) is designed by combining PSO and GSA algorithms using MATLAB. For this model different results are obtained which are discussed as under:

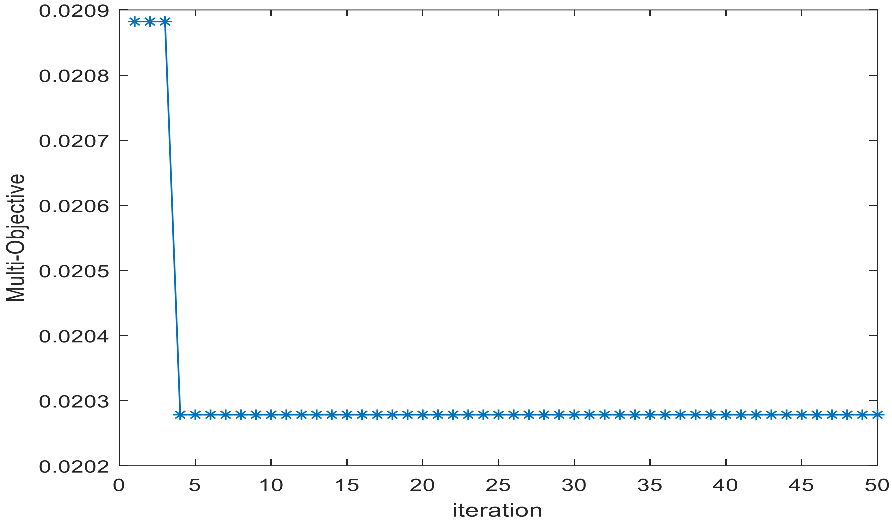


**Figure 5: Multi-objective fitness for different iterations of HPSOGSA algorithm**

Figure 5 provide the variation of multi-objective fitness with respect to iteration values of HPSOGSA algorithm. Different fitness parameters are taken to calculate multi-objective fitness function are as follows:

- Settling time
- Rise time
- Overshoot
- Peak time
- Under shoot

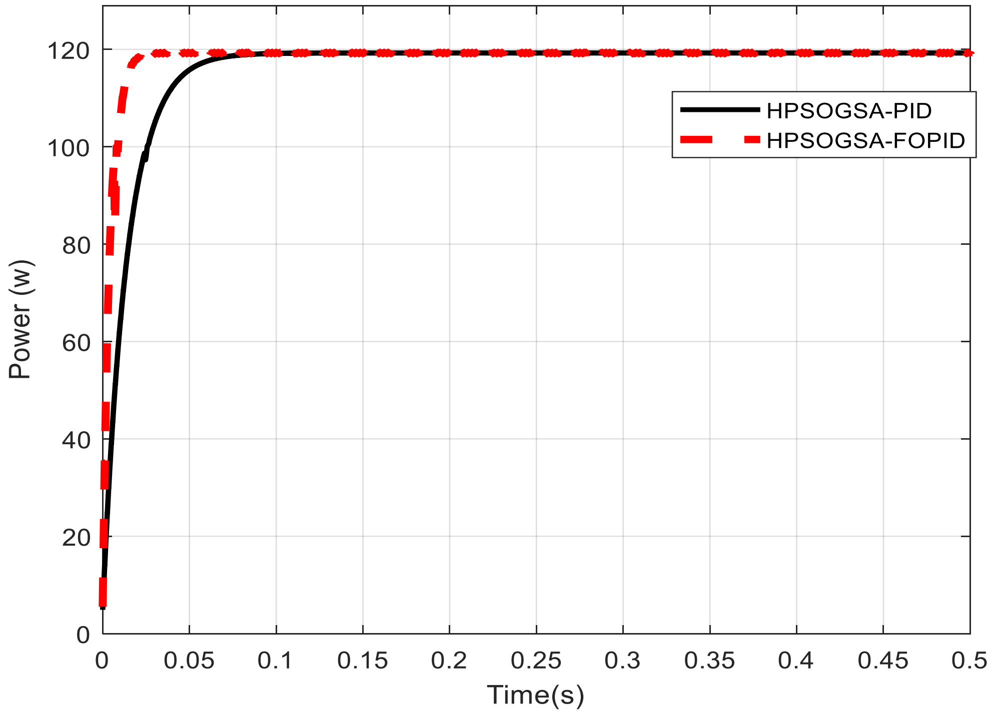


**Figure 6: Comparison of penal power versus time for HPSOGSA algorithm using PID & FOPID controllers**

Parameters of two controllers such as PID and FOPID are tuned for hybrid PSO and GSA algorithms. To obtain the results of these two hybrid algorithms, minimum value of fitness function achieved by HPSOGSA optimized using PID and FOPID controllers are compared. Fig. 6 compares the penal power versus time for HPSOGSA algorithms for PID and FOPID controllers. As indicated by red dotted line in the graph HPSOGSA-FOPID provides much faster response as compared to HPSOGSA-PID model.

The performance of these two controllers is analyzed for varying environment conditions. It is advantageous for a controller to quickly take the controlling actions for compensating the changing temperature and irradiance. The irradiance profile used for obtaining the panel power responses of MPPT methods is shown in Fig. 7.

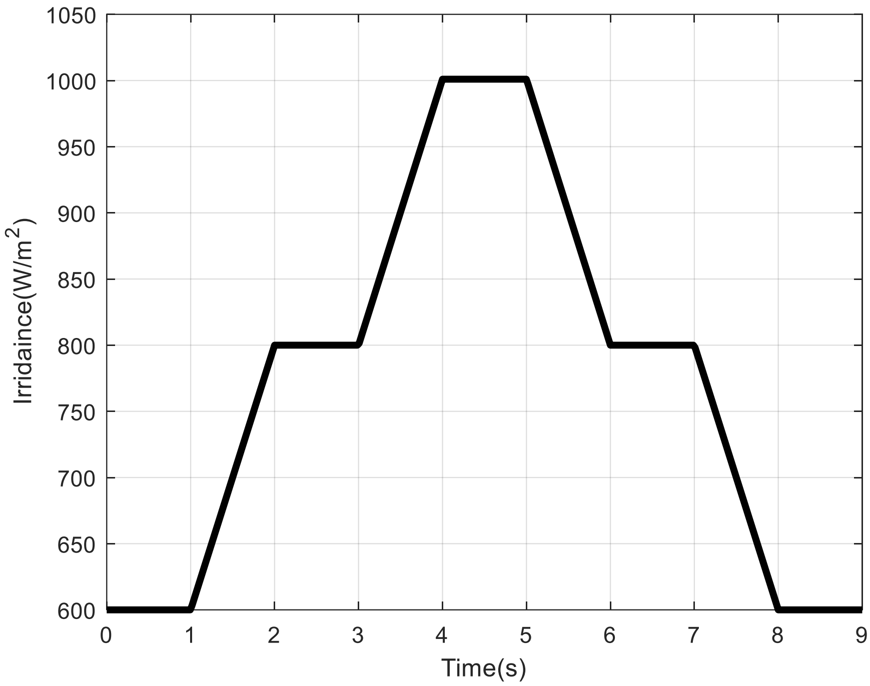


**Figure 7: Input irradiance at varying time for PV panel**

Similarly temperature profile used for obtaining the penal power responses of MPPT method is obtained in Fig. 8.

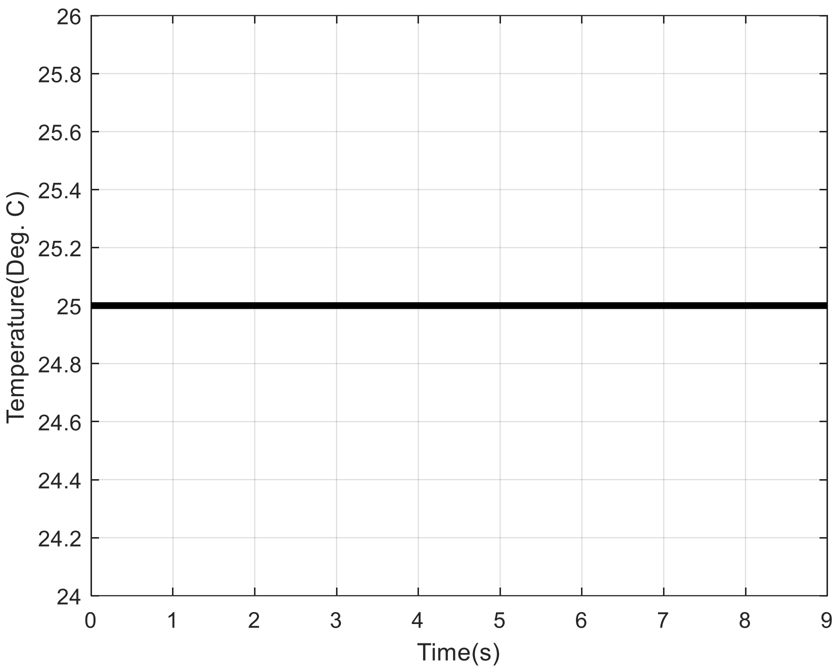


**Figure 8: Input temperature at varying time for PV panel**

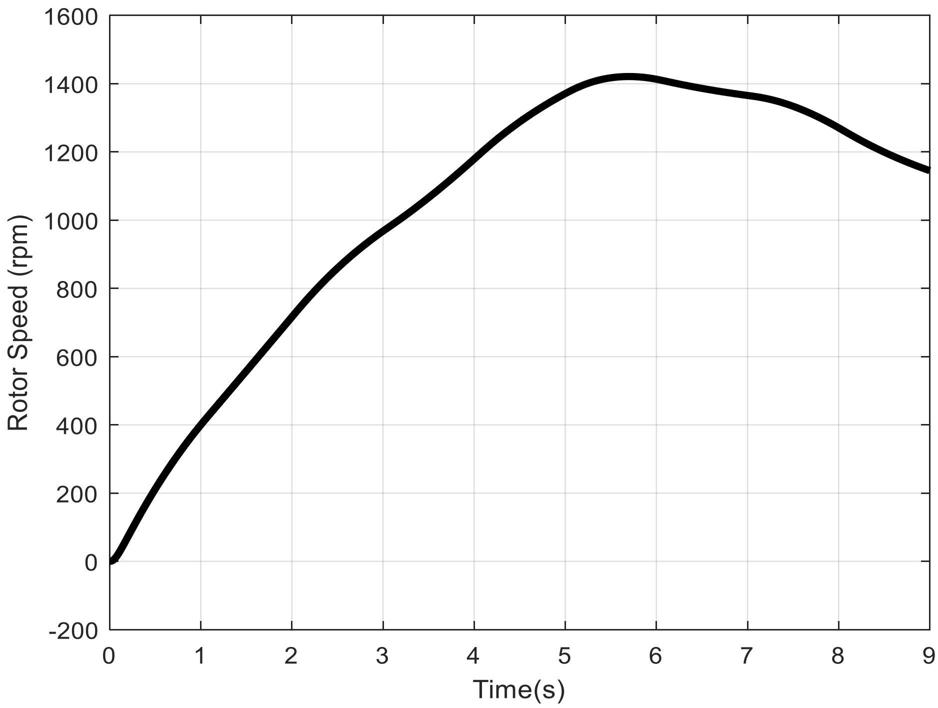


**Figure 9: Rotor speed of DC motor for HPSOGSA algorithm**

Figure 9 indicates the rotor speed variation with respect to time for proposed HPSOGSA algorithm. Maximum rotor speed is 1436 rpm and for HPSOGSA-FOPID controller.

**Table 1: Comparison of fitness parameters for HPSOGSA-PID and HPSOGSA-FOPID algorithms**

| Parameter | HPSOSA_PID | HPSOSA_FOPID |
|---|---|---|
| Settling Time | 0.0561 | 0.0177 |
| Rise Time | 0.0317 | 0.0104 |
| Overshoot | 0 | 0 |
| Peak Time | 0.111 | 0.1104 |
| Under Shoot | 0.021116 | 0.022699 |

A comparison of various fitness parameters like settling time, rise time, overshoot, peak time and undershoot etc. for two models (HPSOGSA-PID and HPSOGSA-FOPID) is provided in table 1. A graphical response is also provided in figure 10. As indicated that much rapid response is provided by HPSOGSA-FOPID model as compared to HPSOGSA-PID model.

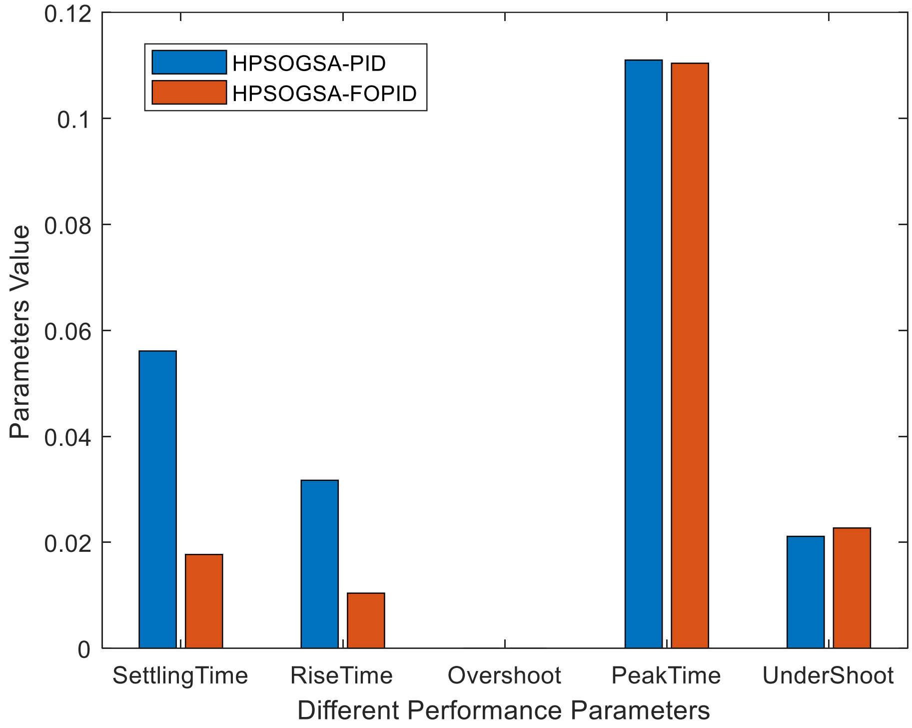


**Figure 10: Comparison of fitness parameters for HPSOGSA-PID and HPSOGSA-FOPID models.**

## 4. CONCLUSIONS

The research has focused on the utilization of solar PV system for fast and efficient (Level III) charging of an electrical vehicle. Furthermore, Fuzzy logic is utilized in designing a smart battery charging system to efficiently protect the electrical vehicle from damage of overcharging. In the proposed system not only the faster charging of an electrical vehicle is achieved but also a protection of overcharging of electrical vehicle is provided using an intelligent controller based on fuzzy logic technique. Two efficient (PSO & GSA) algorithms were hybridized for improving the MPPT for the photovoltaic (PV) systems. The hybridized PSO & GSA algorithm denoted as (HPSOGSA) is used to compare the results of PID and FOPID controllers. Different fitness parameters including settling time, rise time, overshoot, peak time, and under shoot etc. are utilized to calculate multi-objective fitness function and this fitness function is used to compare the results of two selected controllers (PID & FOPID) for the proposed HPSOGSA system.

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