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RESEARCH ARTICLE

# GAO Optimized Sliding Mode Based Reconfigurable Step Size Pb&O MPPT Controller With Grid Integrated EV Charging Station

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**ABSTRACT** The deployment of renewable energy sources has become more frequent in power system networks over the last few years. The prevalence of global warming and some catastrophic climate changes is rising, along with the demand for intricate transport systems, as a result of rapid growth in civilization and modernization in culture. To fight this environmental issue associated with vehicle transmission, almost every nation is promoting electric vehicles (EV). In this article, a novel method for developing a sliding mode maximum power point tracking (MPPT) controller for photovoltaic (PV) systems operating in rapidly varying atmospheric circumstances is put forward. Further, the standard Perturb and observe (Pb&O) algorithm's variable step is driven by the best sliding mode controller (SLMC) gains, which are determined using the Genetic Algorithm (GAO). Additionally, a PI controller, a grid employing current controlling topology, and an effective charging station constructed with GAO-optimized Sliding Mode-based reconfigurable step size Pb&O as an MPPT controller are executed and tested in MATLAB/Simulink for optimal control of power in the EV charging station. The main contribution of this study is to enhance the created controller's tracking performance to reach the maximum power point (MPP) with negligible oscillation, low overshoot, minimum ripple, and excellent speed in conditions of air turbulence that change quickly, as well as ensure continuity in supply to the EV. Furthermore, the developed system as a whole shows good efficacy compared with other existing systems reviewed in the literature. Finally, this proposed strategy ensures continuity of power supply to the charging station even in uncertain weather conditions, as grid integration also plays a vital role in the overall demand.

**INDEX TERMS** Electric vehicle (EV), genetic algorithm, MPPT, sliding mode controller (SLMC).

## NOMENCLATURE

| | |
|---|---|
| GAO | Genetic algorithm. |
| Pb&O | Perturb and observation. |
| MPPT | Maximum power point tracking. |
| CUSA | Cuckoo search algorithm. |
| FSSO | Flying squirrel search optimization. |
| EV | Electric vehicle. |
| EPV | Electric-powered vehicle. |
| GMPPT | Global maximum power point tracking. |
| HEV | Hybrid electric vehicle. |
| PEV | Plug-in electric vehicle. |
| HECPE | Hybrid electric cars with petrol engines. |
| PSO | Particle-swarm optimization. |
| ACO | Ant colony optimization. |
| GWO | Grey wolf optimization. |
| ABC | Artificial bee colony. |

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| | |
|---|---|
| SSO | Slap Swarm optimization. |
| SLMC | Sliding mode controller. |
| V2G | Vehicle to grid. |
| MG | Microgrid. |
| ITAE | Integral time-weighted absolute error. |
| $C_{IN}$ | Input capacitance. |
| $C_{OUT}$ | Output capacitance. |
| BSLMC | Back-stepping sliding mode controller. |
| GAO-SLMC | Genetic algorithm optimized sliding mode controller. |

## I. INTRODUCTION

Difficulties of the energy crisis and global warming are being faced by academics, researchers, and stakeholders worldwide. These issues have sparked a recent trend toward using alternative sources of energy, like solar, tidal, and wind energy. Non-renewable resources, which are quickly running out, are used to meet the majority of our needs for electricity [1], [2]. Because of this, using non-conventional energy has been associated with a decrease in both environmental pollution and the generation of power using fossil fuels. There is a need to explore suitable alternatives because of the growing population. In this context, photovoltaic (PV) systems make it possible to generate power that is both energy-efficient and environmentally friendly by turning sunshine into electricity [3]. PV energy is still regarded as expensive, so it has been a major focus of considerable research to find ways to make PV systems less expensive. To address the aforementioned issues, power electronics can be used to maximize PV output power [4]. Maximum power point tracking for PV systems is crucial to ensuring the extraction of the most available energy in any ambient situation [5]. These solar units need to be operated on an equal basis in single- or two-diode form due to their low power output for maximum power point (MPP) production to be achieved. Perovskite solar cells (PSCs), a type of PV device, are one example, and their photovoltaic modules can only be used in specific environmental situations (such as when there is moving fog, shade, bird faces, etc.). A thorough, critical, and in-depth analysis of the popular and recently created global maximum power point tracking (GMPPT) algorithms for photovoltaic (PV) systems is provided in the proposed study [8]. The four main classes of algorithms are (1) optimization algorithms; (2) hybrid techniques of two separate optimization algorithms; (3) hybrid techniques of optimization algorithm with the conventional algorithms; and (4) other GMPPT algorithms. This makes comparisons between the algorithms easier.

Fossil fuels were the main fuel source in the previous century, but their detrimental impact on the environment necessitated the development of alternate transportation options. Electric vehicle (EV) is one of the potential substitutes, which has resulted in their development. Hybrid electric vehicle (HEV), plug-in electric vehicle (PEV), and hybrid electric cars with petrol engines (HECPE) are the three types of electric vehicles [7].

With an increase in the number of electric vehicles on the road, charging the vehicles will become more difficult if grid electricity is used [8]. The functioning and control of the grid would inevitably degrade when it was used by a large number of electrically powered vehicles. Consequently, a trustworthy network is required for charging electric vehicles that are fueled by renewable energy sources [9].

An in-depth analysis of the various MPPT techniques is conducted since the solar-powered EV charging station described here is empowered by a PV system that is managed by an MPPT controller. In [10], the authors hope to introduce a new principal scheme-based review of the MPPT methods that have been categorized (conventional, novel, and hybrid) based on how their input variables (solar irradiance, PV array temperature, and PV array terminal voltage and current) are deployed. The MPPT methods are organized into six distinct schemes. Prior MPPT research is taken from the literature and examined for every scheme. Next, a comparison and discussion are held regarding the key advantages and drawbacks of the six MPPT schemes that have been given. There have been reports of many MPPT techniques in the literature [11]. The maximum power point (MPP) can be produced by modifying the parameters of the DC/DC chopper, which is typically employed in PV systems [12]. Metaheuristic MPPT approaches have lately gained popularity due to their accuracy and system independence [13], [14], [15]. Many academics have suggested MPPT algorithms that focus on particle-swarm optimization (PSO) [16], [17], including the Cuckoo Search [18], Grey Wolf Optimization (GWO) [19], Ant Colony Optimization (ACO) [20], Artificial Bee Colony (ABC) [21], Slap Swarm optimization (SSO) [22], [23], Grass Hopper Optimization [24], Teaching-Learning based optimization [25], Flying Squirrel Search optimization (FSSO) [26]. Methods based on intelligence have excellent control and optimization capabilities. Researchers in the present period have found that bio- inspired based optimization strategies to track GMPP have good efficiency, accuracy, and minimal settling time. In a boost-converter system, a sliding mode controller is used to manage the inverter output current and maximize PV power [27]. With the energy being wasted in a resistor and no inverter control required, a boost converter for an MPPT uses an SLMC controller [28]. An experimental sliding mode control (SLMC) application for MPPT of solar systems with an open-source card (Arduino) has been proposed [29]. The proposed method is based on two main steps. The first characteristic curves of PV panels based on tracer variable load have been traced to validate the MPPT results. Second, to simplify or reduce the hard party and to give more flexibility in the control technique, a program of MPPT control has been loaded in the open-source card. In [30], a backstepping SLMC (BSLMC) technique is presented that uses Lyapunov criteria to guarantee system stability. In this article, smooth behavior is ensured by using a modified SLMC for MPPT and a fuzzy inference system in place of the saturation function. The particle swarm optimization (PSO) method is used to optimize the parameters of the suggested fuzzy BLSLMC (FBSLMC). Since MPP depends on both temperature and solar radiation, the suggested controller is put to the test using a variety of case studies. Additionally, the controller performance is evaluated in partial shade circumstances. Grid synchronization with PV via a sliding-mode controller is suggested in [31]. The goal of this research is to provide innovative, dependable, and efficient first-order sliding mode control algorithms for solar energy conversion. THD and first-order buck-boost converter problems are being resolved with a sliding mode control for nonlinear loads. The suggested method in [32] makes use of an adaptive terminal sliding mode controller (NN-ATSLMC) and a neural network to make sure the PV system performs at its best even in the face of uncertainty. To drive the system to its maximum power point (MPP), a DC/DC boost converter is used in conjunction with the NN-ATSLMC controller. By minimizing the chattering effect without sacrificing robustness under a range of shocks and load circumstances, this technique guarantees that the error will converge in a finite amount of time. The approach used by the authors in [33] is that SLMC creates a sliding surface that establishes the operational point. A control law must be applied to the DC/DC converter gate in to reach this surface in a finite amount of time [34]. By adjusting the converter's duty cycle, the PV peak power can be obtained smoothly under various circumstances. Through a multilayer inverter, the PV was connected to the grid. However, the main drawback of the suggested approach is that it appears complicated.

To balance solar energy and stored energy in PEV using Vehicle to Grid (V2G) technology, the authors of [35] used three coordinated techniques. During times of low demand, the PEV's batteries are charged, and during times of peak load, they feed the grid and the house with the stored energy. EV charging infrastructure power components utilized in [36] include a single voltage source converter along with a solar photovoltaic (PV) array, a storage battery, the grid, and a diesel generator. An effective design for a lightweight plug-in electric vehicle (PEV) with a small, affordable charging system is designed in [37]. An integrated power system method is also used to develop commercial EV charging infrastructure [38], [39]. The interoperability analysis of a resonating contactless charging system for electric cars (EV) was the main concern in [40]. To accomplish both energy and waste control [41], an MG structure is used, which combines biologically renewable sustainable energy sources like wastewater, agricultural, and domestic wastes with renewable energy sources like solar and wind.

The literature study raises important questions and points of contention that should be addressed and investigated in this article. There seem to be a lot of benefits and stability in theoretical works that investigate optimization applications for renewable energy sources. As opposed to well-known conventional techniques, there are a few things to keep in mind when working with the interface of many modules. Soft computing-based MPPT methodologies already introduced in the literature are one of the most effective approaches

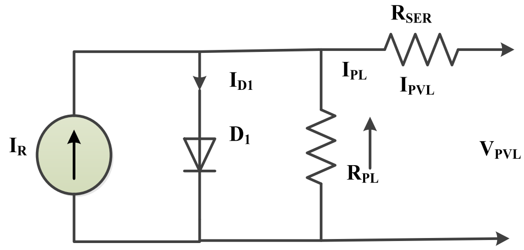



**FIGURE 1.** PV cell's analogous circuit diagram.

to addressing nonlinear problems. Regretfully, compared to traditional approaches, these MPPT algorithms are more complicated and more expensive to implement [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26].

Summarizing the above discussion, it can be said that an efficient MPPT controller is essential for a solar-powered EV charging station that can track GMPP in minimum settling time with negligible oscillation, low overshoot, and minimum ripple. Also, grid integration and stand-by battery (SBB) play a vital role as continuity of power supply for vehicles is also needed. The goals of this study (i.e., optimal modeling for each EV fleet) are in line with the identified research gap.

Therefore, primarily, this study suggests a new sliding mode-based reconfigurable Pb&O MPPT controller for PV systems that is optimized using a genetic algorithm (GAO). The suggested MPPT algorithm is created by the first-order sliding mode controller (SLMC). Genetic Algorithm (GAO) is used to create and implement a control equation that causes the system variables to remain on a chosen surface, also known as a sliding surface. In the second part, this article proposes a charging technique for EV in a grid-connected state that shows its efficiency under partial shading conditions or at night when power from a photovoltaic panel is uncertain or almost zero, respectively.

Among the study's preliminary objectives are the development of a strategy that aids in the construction of a reliable EV charging station and the understanding of rendition, taking into account two goals.

- To develop an MPPT technique that can efficiently track GMPP with minimum settling time and lowest overshoot. In this article, a novel MPPT controller is developed. The proposed GAO tuned sliding mode based reconfigurable step size Pb&O controller is much more beneficial in minimum settling time, better accuracy etc. The suggested algorithm incorporates in MPPT scheme to maximize system output.
- To model and build a grid-associated PV-based electrically powered conveyance charging structure that is reliable and gives continuous charging facilities even in unwanted situations (i.e., partial shading conditions when generations from PV panels are getting low, grid failure environment etc.).

The article's layout appears to demonstrate: segment II offers a clear view of the intended PV system. Section III discusses the limitations of DC-DC constraints. This section

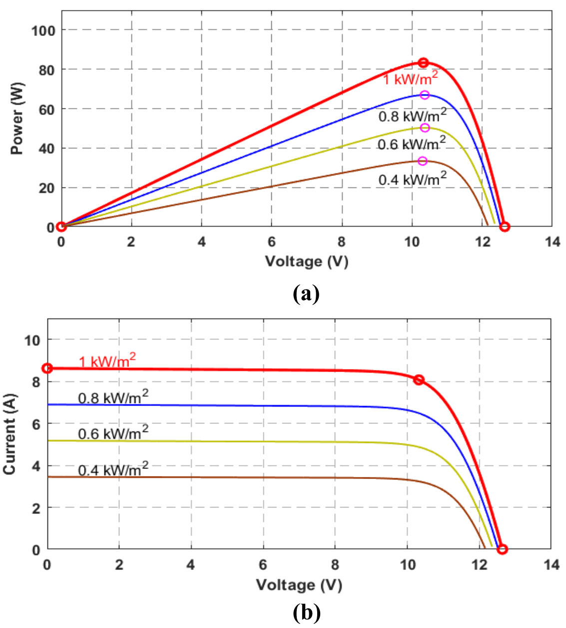



**FIGURE 2.** Solar cell's feature for (a) power vs. voltage and (b) current vs. voltage.

**TABLE 1.** Parameters of proposed boost converter.

| Sl No. | Parameter | Value |
|---|---|---|
| 1 | Inductance (L) | 0.1164 H |
| 2 | Input Capacitance ($C_{IN}$) | 4.8250 µF |
| 3 | Output Capacitance ($C_{OUT}$) | 4.0704 µF |
| 4 | Switching Frequency | 10KHz |

goes into detail on the boost converter and the consequences of partial shading; Section IV deals with battery system representation, while Section V provides a suggested MPPT control scheme and methodology; Section VI briefly elaborates on the simulation outcome of the proposed methodology, whether a conclusion is drawn in Section VII.

## II. PV SYSTEM STRUCTURE REPRESENTATION

PV cells use photovoltaic processes to transform the solar energy gathered into electrical energy. It should be noted that there are numerous PV system configurations available [42]. Fig.1 depicts the schematic layout of a solar photovoltaic cell. The PV cell's output current could be employed for:

$$I_{PVL} = I_R - I_{D1} - I_{PL} \tag{1}$$

where $I_{PVL}$, $V_{PVL}$ are output current and voltage from photo voltaic cell discretely. $I_{PL}$, $I_{D1}$, $I_R$ are parallel resistance ($R_{PL}$), diode and photovoltaic current respectively. Series resistance noted as $R_{SER}$.

$$I_{D1} = I_{RSC} + e^{q\frac{V_{PVL}+I_{PVL*}R_{SER}}{nKT}-1} \tag{2}$$

$I_{RSC}$ is reverse saturation current. q, T, n, K signifies electron charge, atmospheric temperature, diode factor Boltzmann Constant and separately.

Current generated in PV cell expressed as:

$$I_R = \frac{W}{W_0}(I_{SCN} + \lambda(T - T_0)) \tag{3}$$

Short circuit current is designated by $I_{SCN}$, $T_0$ and $W_0$ are temperature and reference irradiance separately. λ and W were noted as atmospheric temperature and irradiance co-efficient.

$$I_{PVL} = I_R - I_{RSC}[e^{q\frac{V_{PVL}+I_{PVL*}R_{SER}}{nKT}} - 1] - \frac{V_{PVL} + I_{PVL} * R_{SER}}{R_{PL}} \tag{4}$$

Figure 2 depicts the PV cells' P-V and I-V features. Corresponding equation is formulated in eqn (5).

$$\frac{dP}{dV_{PVL}} = \left\{ \begin{array}{c} 0 \; at \; MPP \\ > 0, \; at \; left \; hand \; portion \; of \; MPP \\ < 0, \; at \; right \; hand \; portion \; of \; MPP \end{array} \right\} \tag{5}$$

The aforesaid equation is the fundamental concept for MPPT adaptive controller.

## III. DC-DC CONVERTER

### A. DC-DC BOOST CONVERTER

A DC-DC converter connects the solar array and load, allowing the solar array to follow the MPP under specific irradiance and environmental conditions. Using MPPT techniques, the duty ratio of the converter switch is continuously changed to maintain the solar array's continuous operation at the MPP. The specs of the DC-DC converters employed in this case are listed in Table 1. This displays the changes that have been made in the current investigation's DC-DC converter.

### B. THE BIDIRECTIONAL CONVERTER

Due to the benefits described below, this article suggests using a bidirectional DC-DC boost converter to control the storage and transmission of electricity between a PV system and a battery bank [43], [44], [45].

With the fewest external components, it offers the most economical solution.

(ii) It employs the fewest number of components necessary to achieve voltage step-up and step-down.

(iii) When in use, it has a lower duty cycle.

(iv) It functions effectively with input and output voltages spanning a wide range.

(v) Compared to most converters, it is more affordable.

Extra solar power is captured, stored, and used to power a stand-by battery that is used to power electric vehicles charging after sunset. A bidirectional boost DC-DC converter manages the stand-by Battery's (SBB) charging and discharging. It is made of a 240V, 40Ah SBB for the charging station. A minimum 20% SOC discharge rate for stand-by Battery (SBB) is estimated.

### C. GRID IMPLEMENTATION WITH INVERTER MODULE

For the additional power demands of the charging station, the 230V, 50Hz AC grid is examined. In MATLAB/Simulink, a

230V AC grid is connected via an inverter to a 500V DC bus. A current control topology based on the EV's battery power is employed to produce pulses for inverter switches using the PV array energy output. Here, for the EV's battery, 2000 W power is taken into consideration and it is compared with the generated power from the PV module. Based on this, a reference current is generated in an unbalanced d-q frame. A current PI controller in an unbalanced d-q frame is also implemented for inverter control.

## IV. BATTERY STRUCTURE REPRESENTATION

The charging station is designed to use a 240V, 48Ah battery. With a PI controller and a DC-DC boost converter, a 500V DC bus is used to charge the battery of an electrically driven vehicle. For simulation reasons, the incoming EV's battery is anticipated to have a minimum SOC of 9%. The lowest voltage (Vlo), enduring percentage state of charge (SOCre), and amp-hour rating (Ahr) of the battery can all be used to calculate the required energy (Eev) to charge the EV battery.

$$E_{ev} = \frac{V_{no} * SOC_{re} * Ah_r}{100} \quad (6)$$

The model assumes that the internal resistance of the battery can be maintained constant throughout the charge and discharge cycles.

## V. FRAMEWORK OF METHODOLOGY

### A. MPPT CONTROLLER IN GAO-SLIDING MODE

This section discusses a novel technique for synthesizing SLMC using GAO. The SLMC gains driving the control law and the sliding surface are tuned in order to operate a conventional Pb&O MPPT algorithm's changeable step size. The suggested method has novel knowledge for designing this type of controller that solves the design challenge that calls for understanding the bounds of uncertainties, which can be challenging. Frequently, this bound is overestimated, leading to excessive gain and the well-known chattering phenomenon. As is the case with all methods used to lessen the chattering phenomenon, the suggested approach does not necessitate an understanding of the uncertainty bound.

### B. DESCRIPTION OF SLIDING MODE CONTROLLER

The sliding mode control is a kind of nonlinear control that is particularly well suited for the regulation of systems with variable structures [46]. The sliding mode control strategy's fundamental tenets are built on output feedback and a high-frequency switching control action that, under ideal circumstances, is unlimited. In essence, the system trajectories can be guided by this high-speed control law to a region of the state space that is frequently connected to a sliding surface or manifold. The following are the key benefits of a system having sliding mode control characteristics:

- Intolerance of unmodeled dynamics and outside disruptions.
- Controller framework that is simple and flexible.

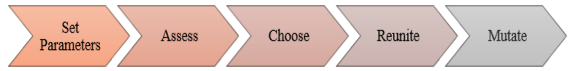



**FIGURE 3. Successive steps of GAO algorithm.**

- Ability to introduce an action mistake into the sliding surfaces and remove steady-state errors from the sliding Mode Controller design process.
- Order reduction, disturbance rejection, decoupling design techniques, sensitivity to parameter fluctuations, and ease of implementation using common power converters.

Because of these characteristics, sliding mode control is well suited for use in nonlinear systems, which explains its widespread industrial use in applications like electrical drivers, automotive, etc.

#### 1) SLIDING MODE CONTROLLER ARCHITECTURE

Two different parts make up the sliding mode controller; between them, while the second entails choosing a control rule that will make the switching surface appealing to the system state, the first involves designing a sliding surface that conforms with design standards.

Taking into account the nonlinear time-dependent switching system, whose equations are as follows [39]:

$$\dot{x} = f(x, t) + g(x, t)u \quad (7)$$

$$y = h(x, t) \quad (8)$$

where, in an n-dimensional space $R^n$, x is the state-variable vector.

F and g are smooth vector fields in the same space, and u is the discontinuous control action.

The goal of the control is to limit the output error variable $e_y = y - y_{ref}$ to a transient duration that is acceptable.

#### 2) FIRST PART

The first step entails defining a specific system state scalar function.

According to tracking error "e" and a number of its derivatives (e (1), e (2), …, e(k)), says $\sigma$(x):

$$\sigma = f(e, e, \ldots\ldots\ldots, e^{(k)} \quad (9)$$

A linear amalgamation of the type described below is the most frequent option for the sliding manifold:

$$\sigma = e^{(k)} + \Sigma_{i=0}^{k=1} c_i e^{(i)} \quad (10)$$

where $c_i$ constants.

The sliding surface in the error space is defined by the equation $\sigma = 0$. Here are some examples of typical sliding surface forms:

$$\sigma = (\frac{d}{dt} + P)^{k} \text{ e}; \quad (11)$$

P is a scalar.

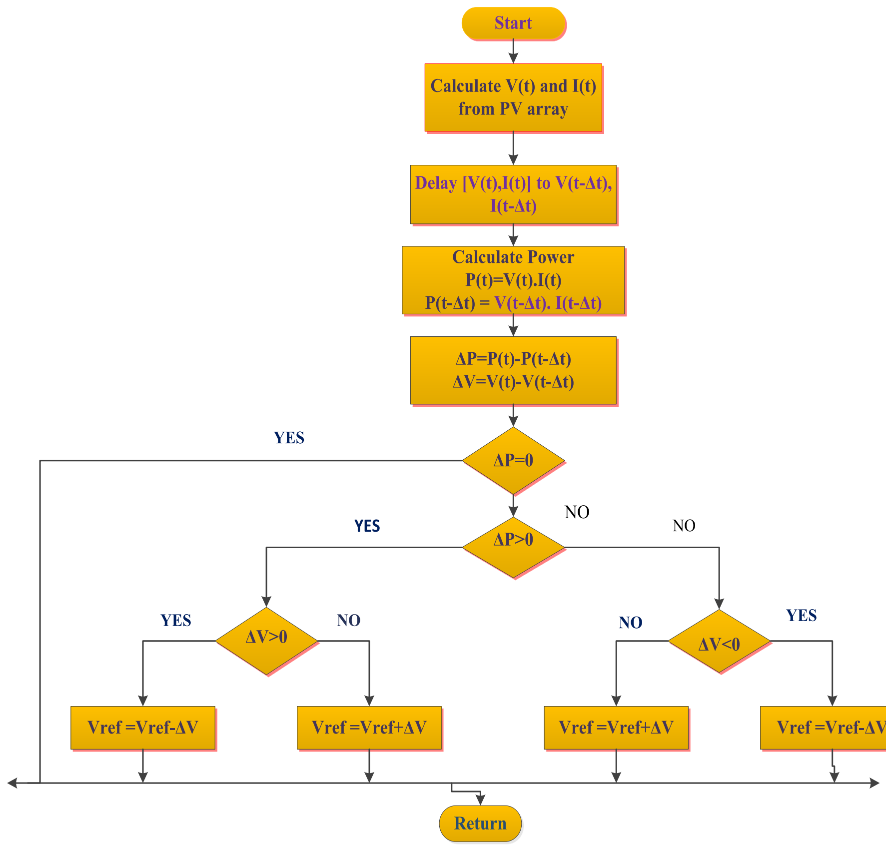



**FIGURE 4.** Pb&O method flow chart.

#### 3) SECOND PART

Design of the control law

Finding a control law to direct system trajectories onto the sliding surface is the goal of the second stage.

The sliding mode control strategy is the foundation for various strategies:

- Control of the first-order standard sliding mode;
- Use a high-order sliding mode for control.

Our focus here is conventional first-order sliding mode control as stated by

$$u = -U * sgn(\sigma) \quad (12)$$

U is a positive constant that is sufficiently large. The control variable u will very rapidly switch between the values +U∗u and U∗u in a steady state.

### C. NOMINATED GAO-SLMC CHANGEABLE STEP SIZE PB &O MPPT APPLICATION

A powerful meta-heuristic approach in search of a superior solution depending on biological behavior is called genetic algorithm (GAO). Holland, in 1975, first discovered this algorithm through survival of the fittest [47]. Detail process has been represented in Fig.3.Perturb and Observations (Pb&O) is well suited for both grid connections and stand-alone systems and can achieve higher efficiency. This approach is suitable for uniform and constant temperatures and gives higher efficiency. Under partial shading conditions, when temperature and irradiance are constantly fluctuating, system output also oscillates around MPP, which is undesirable. Fig. 4 and Fig 5 show the flowchart for the charge controller's Pb&O algorithm and Genetic Algorithm (GAO).

Due to its inherent capability and supremacy, GAO approach has been widely used in non-conventional energy fields. Despite of its different advantages, like good convergence speed and less oscillation around the maximum power point, GAO suffers from some disadvantages. This algorithm is not useful for very long and complex problems. At first, the parent population is shown in equation (13) as:

$$X^1 = [\text{parent}^a.\text{parent}^b \ldots\ldots\ldots.\text{parent}^n] \quad (13)$$

The population size is n, and the objective function is defined as the PV system's output power. The fitness value of each solution is determined using an objective function. GAO must be revised in the MPPT application due to abrupt fluctuations in solar irradiation, air temperature, and load variance.

In this study, we apply the GAO technique to determine the appropriate SLMC parameters, defining the sliding surface and the control law using a fitness function based on the variable step size MPPT performances.

Authors describe a sliding surface in this study as a function of changing currents and voltages:

$$x = K_a.dI + K_b.dV + K_c.perturbation \quad (14)$$

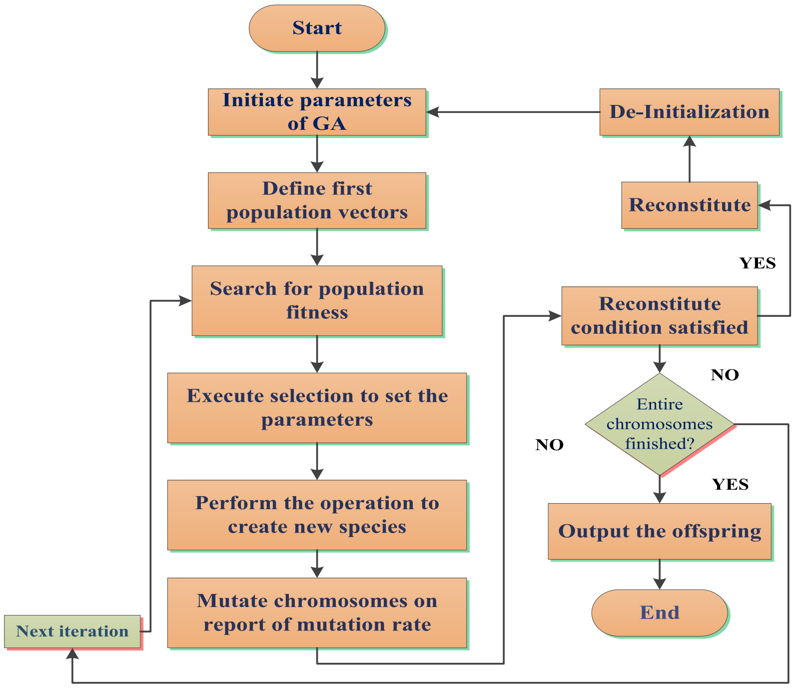



**FIGURE 5.** Flow chart of GAO algorithm.

**TABLE 2.** Specification of PV model used in simulation.

| Specification | Values |
|---|---|
| Open circuit voltage; $V_{OC}$ | 37.30 Volts |
| Short crcuit current; $I_{SCN}$ | 8.66 A |
| Coefficient of temperature at $V_{OC}$ | 0.36901(V/ $^0$C) |
| Coefficient of temperature at $I_{SC}$ | 0.086998(A/$^0$C) |
| Cell foe each module ($N_{Cell}$) | 60 |
| Maximum Power | 250.205W |
| Series connected module per string | 8 |
| Series connected module per string | 1 |

**TABLE 3.** Parameter of lithium-ion battery.

| Specification | Values |
|---|---|
| Nominal voltage | 240 Volts |
| Rated Capacity | 48Ah |
| Initial State of Charge | 9% |
| Battery response time | 0.0001 |
| Cut off Voltage | 180 Volts |

We select a first-order SLMC defined by as SLMC type.

$$\sigma = \frac{dX}{dt} + K_d.x \tag{15}$$

The control law specified is used by the SLMC to drive the PWM ratio D.

$$D = K_e.sgn(\sigma) \tag{16}$$

Using the GAO algorithm, five SLMC gains (Ka, Kb, Kc, Kd, and Ke) are optimized in this article.

We employ the integral time-weighted absolute error (ITAE) metric proposed as an objective function. A typical performance metric used in the design of sliding mode-based controllers is the integral of time-weighted absolute error (ITAE) minimization. It is advantageous to be able to find controller settings for certain loads and/or set point alterations. This criterion may also be easily applied to various processes that are simulated by various process models because it is based on error calculation. Another benefit is that particular load and/or set point alterations can be acquired when searching for controller parameters. The Integral Time Absolute Error (ITAE) method penalizes larger errors over a longer period while emphasizing on minimize the error during the initial transient reaction. Applications that demand a quick response and settling time should use this criterion. The mathematical formula for the ITAE performance index is:

$$ITAE = \int_0^\infty t\,|e(t)|\,dt \tag{17}$$

### D. FUNCTIONING MODE OF CHARGING STATION

The charging station works through three conditional operating modes which are stated as follows:

- PV arrays independently supply the EV battery. In this mode, the GAO-SLMC changeable step size Pb&O controlled technique is working to collect the utmost outcome possible from the PV array while keeping the PV panels' temperature constant (25$^0$C) and irradiance fixed.
- The EV battery is separately supplied by a PV array. While maintaining the PV panels' temperature constant

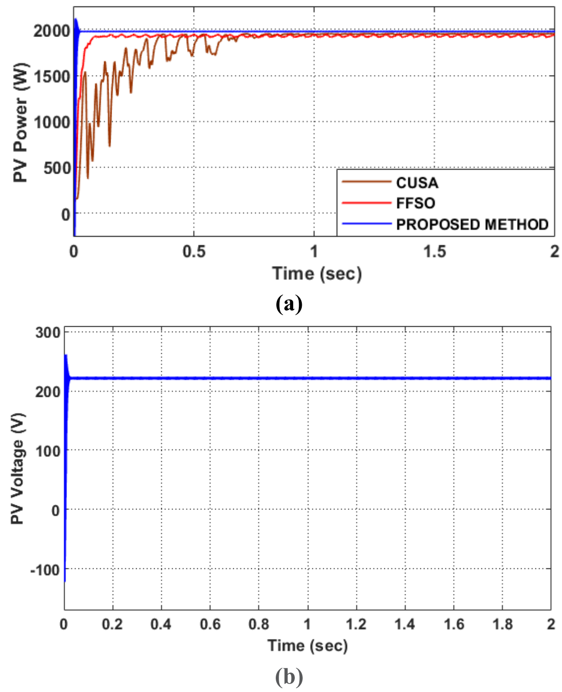



**FIGURE 6.** (a) PV power (b) voltage and under static irradiance condition.

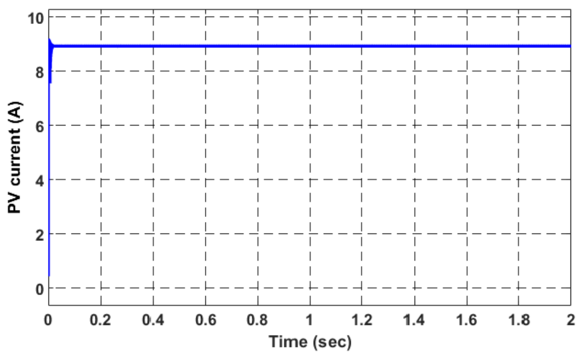



**FIGURE 7.** PV current under static irradiance condition.

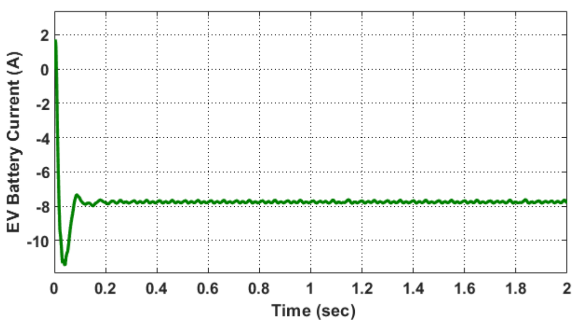



**FIGURE 8.** EV battery current.

(25$^0$C) and irradiance variable in this mode, the approach is trying to collect the maximum output from the PV array.

- The EV battery is charged through the AC grid at night when the PV array has no irradiance. The AC grid's power flow is controlled by a current control topology that is both functional and suitable.

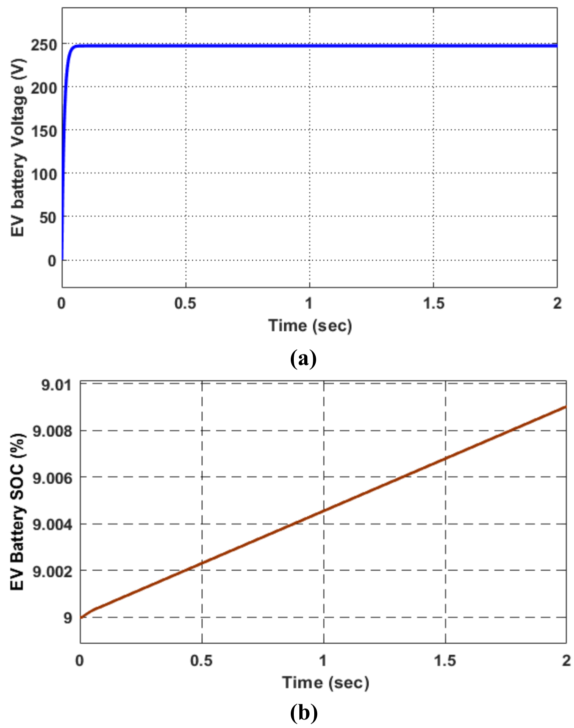



**FIGURE 9.** (a) EV battery voltage (b) % SOC of EV battery.

## VI. SIMULATION OUTCOME AND RESULT ANALYSIS

This section displays and presents the simulation findings. In the MATLAB/SIMULINK 2018 edition, a 2-kW single-phase inverter system connected to the grid is put into effect. To provide 2 kW of output, eight series-connected 1Soltech 1STH-250-WH 250 W panels are utilized. The module specs mentioned above are listed in Table 2. Two alternative modes, including standard test conditions and partial shading conditions, were simulated. Battery specifications are given in Table 3.

A minimal population size is used to implement the GAO-SLMC method. This requirement is critical in practice since it enables the controller to be optimized as early as feasible. The beginning populations in this study are set at 20, while the maximum number of generations G is set at 50.

### A. CASE 1: PERFORMANCE UNDER STANDARD TEST CONDITIONS

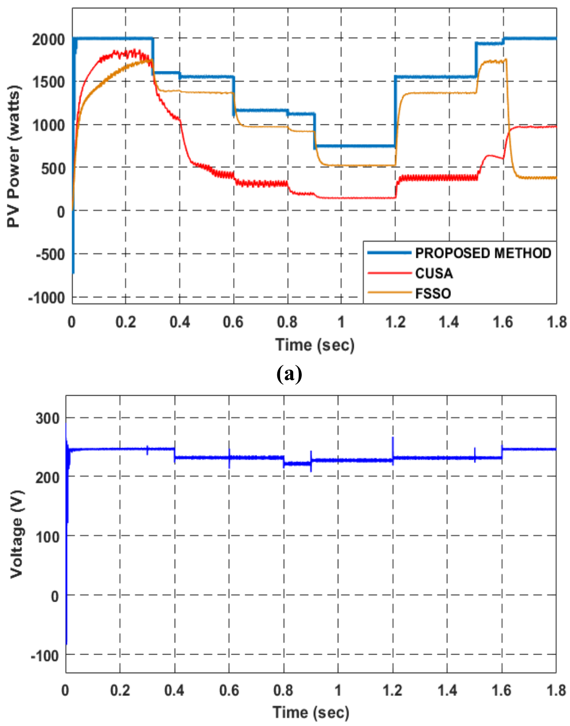
Solar photovoltaic panel performance was tested under standard test conditions while receiving constant irradiance of 1000 W/m2 as an input parameter. Under diverse climatic conditions, the newly designed approach proved to be superior in every situation. A corresponding comparison is also shown in Table 4. Output PV power and voltage graphs have been shown in Fig.6. PV current in this condition is shown in Fig.7. According to the comparison analysis with the existing Cuckoo Search Algorithm (CUSA) and Flying Squirrel Search Optimization (FSSO), the created method successfully detects GMPP more quickly and efficiently than other specified conventional MPPT methodologies. For purposes

**TABLE 4.** Result analysis under uniform irradiance.

| Irradiation | Algorithms | Power at GMPP | Power Received | Settling Time | Efficiency |
|---|---|---|---|---|---|
| 1000 (W/m$^2$) | Proposed Method | 2kW | 1.994 kW | 0.008 sec | 99.70% |
| 1000 (W/m$^2$) | CUSA | 2kW | 1.964 kW | 0.82 sec | 98.20% |
| 1000 (W/m$^2$) | FFSO | 2kW | 1.938 kW | 1.28 sec | 96.90 % |

**TABLE 5.** Utmost sliding-mode controller gain.

| Gain | Values |
|---|---|
| $K_a$ | 0.01378 |
| $K_b$ | -0.01133 |
| $K_c$ | 0.00126 |
| $K_d$ | -0.00275 |
| $K_e$ | 0.00553 |




(b)

**FIGURE 10.** (a) PV power and (b) voltage outcome under varying irradiance condition.

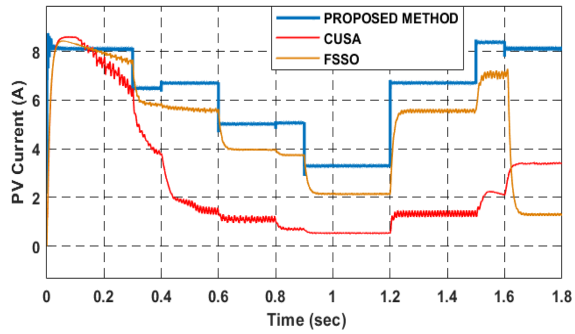



**FIGURE 11.** PV current under varying irradiance condition.

of simulation, 9% SOC of EV is initially taken into account. According to Fig. 8, the EV battery current is negative, which indicates that the battery is charging. Fig. 9. shows the EV battery voltage and % of SOC at standard temperature and irradiance conditions.

### *B. CASE 2: PERFORMANCE UNDER PARTIAL SHADING CONDITIONS*

In the present case, temperature is kept almost constant while irradiance is varied in a partial shading condition. The GAO-SLMC-based MPPT algorithm's interpretation has been contrasted with that of alternative methods regarding tracking efficiency and speed for all scenarios of solar irradiation. A stair generator was utilized to create PSCS-like circumstances with 0.3-second irradiance changes. The authors of the case study use a time range of 0 to 1.5 seconds, which indicates that the irradiance changes at intervals of 0.3, 0.6, 0.9, 1.2, 1.5, and 1.8 seconds. Corresponding irradiances are changing from 1000 w/m$^2$ to 800-600-400-800 w/m$^2$ respectively, with every 0.3 sec, as discussed previously, and after that again, it goes to 1000 w/m$^2$at the instant 1.8 sec. PV power is reached at 2000 W, whether the voltage is kept constant at 250 V. Results from the simulation show that the hybrid technique outperforms alternative methods about vigorous behavior, convergence speed, adherence to the ideal set point, and extremely low oscillations in comparison to the MPP. Simulation results demonstrate the method's superior performance. This approach results in the least power loss because there are the fewest oscillations near the MPP point. Comparison of the proposed method with other pre-existing algorithms, as mentioned earlier in case 1, is shown in Fig. 10. A minimum oscillation with the most stable output PV power can be observed compared with CUSA and FSSO algorithms in Fig. 10. Other approaches to the MPP have a mediocre success rate. With different solar irradiance values taken into account, power output and voltage of the photovoltaic panel are shown in Fig. 10. PV current and EV battery current are also seen in Figs. 11 and 12 respectively, and EV battery voltage and SOC are shown in Fig. 13. Whereas Table 5 shows the ultimate sliding-mode based MPPT controller gain values. For purposes of simulation, 9% SOC of EV is initially taken into account. According to Fig. 12, the EV battery current is negative, which indicates that the battery is charging here also.

### *C. CASE 3: PERFORMANCE AT NIGHT UNDER CERTAIN CONDITIONS*

The grid's power flow is managed by a current control topology that depends on the power of the EV battery. When

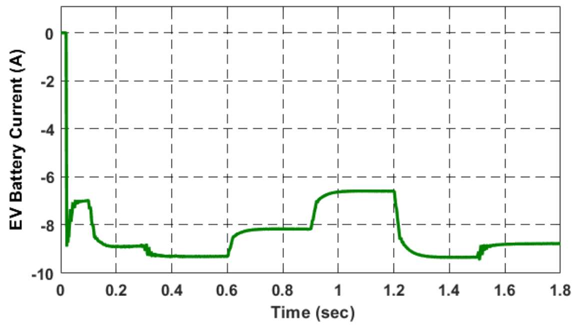



**FIGURE 12.** EV current under PSCS condition.

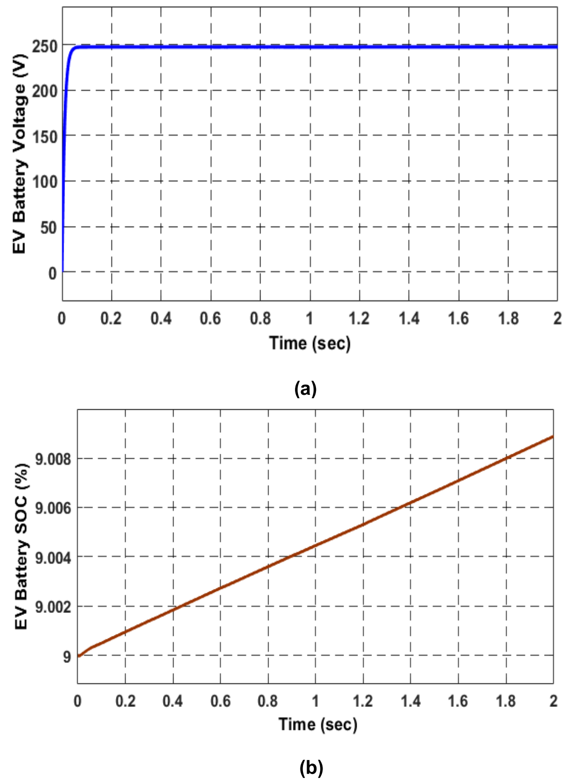



**FIGURE 13.** (a) EV battery voltage (b) % of SOC of EV battery.

the EV battery power is 2000 W, at that time, no power will be taken from the grid. Suppose at some instant, power generated by the PV module is 1000 W, that means an additional 1000 W will be taken from the grid. This method gives reliability at night when PV power is zero, or in cloudy weather or better to say uncertain atmospheric conditions when irradiance is not constant. The AC grid and the DC bus are connected by the inverter. The grid voltage and current via the inverter while the grid is supplying power to the DC bus are shown in Fig. 14. Fig 15. illustrates the charging of an EV battery from a DC bus and the DC Bus voltage which is maintained at 500 V. We are taking the SOC of the EV battery as 50% in this case

Fig. 16 shows PV power and EV battery power correspondingly. From Fig 16, it can be noticed that EV battery power

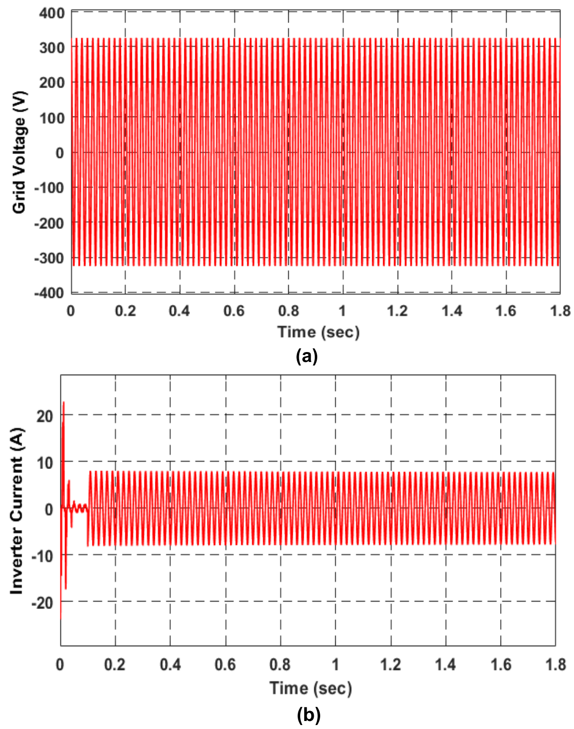



**FIGURE 14.** (a) Grid voltage (b) Inverter current.

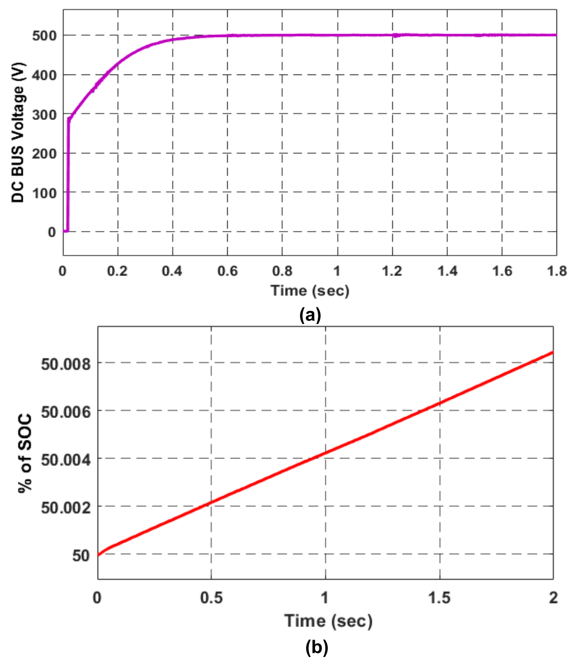



**FIGURE 15.** (a) DC Bus voltage and (b) % of SOC of EV battery.

is constantly maintained at 2000 W but due to partial shading conditions, PV power is fluctuating. So, the remaining power is supplied from the grid so that the EV battery will get a constant power of 2000W which is desirable for customers at various charging stations whether at night, when PV power is almost zero, then the whole 2000W power will be supplied

**TABLE 6. Comprehensive performance analysis of proposed method with other conventional mppt methods.**

| Method | Implementation | Max Overshoot | Performance | Tracking Speed | Accuracy | Steady State Error |
|---|---|---|---|---|---|---|
| Proposed controller | Moderate | Negligible | Excellent | Excellent | Excellent | Less |
| FSSO | Complex | Low | Average | Average | Average | Average |
| CUSA | Easy | High | Good | Average | Moderate | Less |

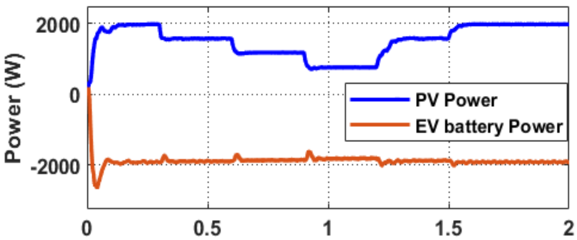



**FIGURE 16. PV power and Battery power at condition.**

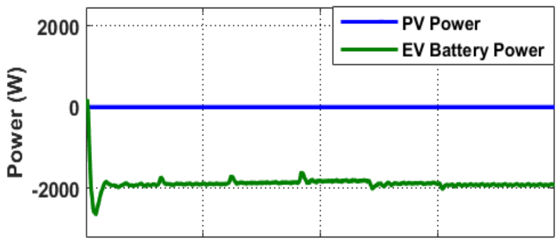



**FIGURE 17. PV power and battery power at night.**

by the grid which is well shown in Fig. 17.A detail analysis between proposed MPPT controller with other existing methods is shown in Table 6.

## VII. CONCLUSION

The increased number of electrically powered motor conveyances on the pavement has made EV charging a significant concern. PV-based EV charging station support from the grid is beneficial to modern vehicles in terms of continuous power supply. This work presents and investigates a novel method for constructing a combined GAO-SLMC reconfigurable step-size Pb&O controller for photovoltaic systems in rapidly varying weather conditions to extract the utmost power from PV panels. GAO-tuned sliding mode-based control platforms are time-varying or nonlinear systems due to their flexibility in responding to unanticipated changes in inputs or system dynamics. The GAO algorithm is used to find the best design for the SLMC that powers the proposed MPPT algorithm's variable step size. Additionally, this kind of controller often requires less setup time, computing time, and system knowledge. A model of a solar array has been made using fundamental equations so that researchers can evaluate the effects of varying cell temperature and irradiation levels. The capacity of a new model to simulate the GMPP has been examined in this research.

One crucial aspect that this research has highlighted is the importance of maintaining a consistent DC bus voltage at the charging terminus. This voltage stability is pivotal in ensuring the reliability and efficiency of the charging process. Through rigorous analysis conducted in MATLAB/Simulink, we have scrutinized and confirmed the station's performance across three distinct operational modes, further cementing its robustness and practicality. Maintaining a consistent DC bus voltage will provide the necessary power. The voltage present in the bus is consistent at the charging terminus. With additional research on the suggested design for extra electrical vehicles, this can be accomplished by setting up an EV charging station with a power rating and capacity of great significance at the workplace or in the charging outlets.

There is significant room for future work and the expansion of this research. First and foremost, scaling up the proposed design to accommodate a larger number of electric vehicles and higher charging demands is an imperative next step. This could involve the deployment of EV charging stations with substantially greater power ratings and capacities, potentially at workplaces or within widespread charging networks. Additionally, incorporating cutting-edge technologies such as energy storage innovations and more advanced control algorithms can further optimize the efficiency and sustainability of EV charging infrastructure. Furthermore, exploring integrating renewable energy sources beyond solar panels, such as wind or hydropower, could diversify the energy mix and enhance the system's resilience. Overall, this research lays a solid foundation for the evolution of EV charging stations, contributing to a sustainable and environmentally responsible future in transportation.

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