IJITCE

ISSN 2347- 3657

International Journal of Information Technology & Computer Engineering

Email : ijitce.editor@gmail.com or editor@ijitce.com

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 13, Issue 2, 2025

Optimized Sliding Mode P&O MPPT Control for Grid-Connected EV Charging Using Genetic Algorithms

[1]B. Mallikarjuna, [2] Ganji Sravani, [3]Kotekanti Aliya,[4] Kondreddygari Bhanya, [5]Chippala Aparna,

[1] Assistant Professor, Department of EEE, Ananthalakshmi Institute of Technology and Sciences, Itikalapalli, Near Sk University, Ananthapur.
[2,3,4,5] Student,Department of EEE, Ananthalakshmi Institute of Technology and Sciences, Itikalapalli, Near Sk University, Ananthapur.

ABSTRACT

Power system networks have seen an increase in the use of renewable energy sources in recent years. Due to the fast expansion of civilization and cultural modernization, both the need for complex transportation networks and the frequency of severe climatic change are on the rise. Electric vehicles (EVs) are being promoted by almost every country as a solution to the transmission-related environmental problem. Here is a new way to build an MPPT (maximum power point tracking) controller for photovoltaic (PV) systems that work in environments where the weather is always changing. The optimal sliding mode controller (SLMC) gains, as calculated by the Genetic approach (GAO), are the driving force behind the variable step of the conventional Perturb and observe (Pb&O) approach. As an added bonus, MATLAB/Simulink is used to execute and test a PI controller, a grid that uses a current-controlling topology, and an efficient charging station that uses a GAO-optimized Sliding Mode-based reconfigurable step size Pb&O as an MPPT controller to keep the power at the station under optimal control. This study primarily aims to improve the tracking performance of the controller so that it can reach the maximum power point (MPP) with minimal ripple, low overshoot, and oscillation, and to achieve excellent speed in rapidly changing air turbulence conditions while maintaining a constant supply to the electric vehicle (EV). In addition, when compared to other systems that have been studied in the literature, the created system overall demonstrates excellent effectiveness. Lastly, by including grid integration into the total demand, this suggested solution guarantees a consistent power supply to the charging station, regardless of weather conditions.

Terms included in the index: SLMC, electric vehicle (EV), genetic algorithm, maximum power point tracking (MPPT).

INTRODUCTION

Academics, researchers, and stakeholders all around the globe are grappling with the challenges posed by the energy crisis and climate change. Because of these problems, renewable energy sources such as solar, tidal, and wind power have recently become more popular. The bulk of our power comes from non-renewable sources, which are rapidly depleting our supply [1, 2]. Therefore, there is less need to generate electricity from fossil fuels and less pollution when non-conventional energy sources are used.The expanding human population necessitates the investigation of viable substitutes. Here, photovoltaic (PV) systems convert sunlight into electricity, allowing for the generation of power that is both efficient and kind to the environment [3]. There has been a lot of study into finding methods to make PV systems less costly as PV energy is still considered pricey. Maximizing PV output power via the use of power electronics may solve the concerns outlined earlier [4]. In order to maximize energy extraction in every environmental condition, maximum power point tracking for PV systems is essential [5]. Because these solar units have a low power output, operating them in single- or two-diode configuration is necessary to achieve maximum power point (MPP) generation. An example of a photovoltaic device is perovskite solar cells (PSCs), which include photovoltaic modules that are only usable in certain environmental conditions (e.g., in the presence of moving fog, shadow, bird faces, etc.). The proposed research [8] offers a comprehensive evaluation of the widely used and newly developed global maximum power point tracking (GMPPT) algorithms for photovoltaic (PV) systems. Optimization algorithms, hybrid methods of two optimization algorithms, hybrid techniques of optimization algorithms with conventional algorithms, and additional GMPPT algorithms make up the four basic types of algorithms. This facilitates comparisons among the algorithms. The primary source of energy in the past was fossil fuels, but the damage they caused to the environment forced the creation of other forms of transportation. The development of electric vehicles (EVs) is a direct outcome of the need for viable alternatives. The three main categories of electric vehicles are HEVs, PEVs, and HECPEs, which stand for hybrid electric automobiles powered by gasoline engines [7]. As the number of EVs on the road continues to rise, using grid energy to charge them will become more problematic [8]. A huge number of EVs using the grid would eventually cause problems with its control and functionality. For this reason, renewable energy-powered electric cars require a reliable charging infrastructure [9]. Because the PV system used to power the solar-powered electric vehicle charging station in this article is controlled by an MPPT controller, we take a close look at the different MPPT methods. Based on the way their input variables (solar irradiance, PV array temperature, and PV array terminal voltage and current) are implemented, the authors of [10] want to provide a new primary scheme-based evaluation of the MPPT techniques that have been classified as conventional, innovative, and hybrid. Six separate schemes are used to structure the MPPT approaches. Every scheme is evaluated in light of previous MPPT research that has been published in the literature. After that, we'll go over the six MPPT systems, compare them, and talk about their main pros and cons. Numerous MPPT methods have been documented in published works [11]. An MPP may be generated by adjusting the settings of the DC/DC chopper, a device often used in PV systems [12]. More and more people are turning to metaheuristic MPPT methods because of how accurate and independent they are from specific systems [13], [14], [15].

The Cuckoo Search, Grey Wolf Optimization, Ant Colony Optimization, Artificial Bee Colony, Slap Swarm optimization, Grass Hopper optimization, Teaching-Learning based optimization, Flying Squirrel Search optimization, and Slap Swarm optimization are just a few of the particle-swarm optimization (PSO) MPPT algorithms proposed by various academics [16], [17]. Intelligent methods are very good at controlling and optimizing things. Modern research has shown that optimization tactics derived from biological inspiration are very effective in monitoring GMPP, with few drawbacks such as a lengthy settling period and poor efficiency. Sliding mode controllers are used in boost-converter systems to optimize PV power by controlling the inverter's output current [27]. Since there is no need for inverter control and energy is being squandered in a resistor, an SLMC controller is used by a boost converter for an MPPT [28]. An experimental application for maximum power point tracking (MPPT) of solar systems using an open-source card (Arduino) has been suggested [29]. Two primary procedures form the basis of the suggested approach. In order to verify the accuracy of the MPPT calculations, the first characteristic curves of PV panels using tracer variable load have been traced. Secondly, an MPPT control software has been installed onto the open-source card to simplify or decrease the hard party and to provide greater control approach versatility. In order to ensure that the system remains stable, the authors of [30] provide a backstepping SLMC (BSLMC) method that makes use of Lyapunov criteria. In this article, a fuzzy inference system is used to guarantee smooth behavior instead of the saturation function, and a modified SLMC is used for MPPT. For optimal performance, the PSO approach is used to optimize the of the proposed fuzzy BLSLMC (FBSLMC) parameters.

Several case studies are used to evaluate the proposed controller, as MPP is temperature and sun radiation dependent. Furthermore, in partially shaded conditions, the controller's performance is assessed. In [31], the authors propose using a sliding-mode controller to synchronize PV with the grid. An efficient, novel, and trustworthy first-order sliding mode control method for solar energy conversion is the target of this study. Sliding mode control for nonlinear loads is used to alleviate difficulties with first-order buck-boost converters and total harmonic distortion (THD). To guarantee optimal PV system performance regardless of uncertainty, the approach proposed in [32] employs a neural network in conjunction with an adaptive terminal sliding mode controller (NN-ATSLMC). Working in tandem with the NN-ATSLMC controller, a DC/DC boost converter is used to propel the system to its maximum power point (MPP). This method ensures that the error will converge in a limited period by reducing the chattering effect while maintaining resilience under various shock and load conditions. According to the authors' method in [33], the operational point is determined by SLMC's creation of a sliding surface. In order for the DC/DC converter gate to achieve this surface within a defined period, a control rule must be implemented [34]. Under different conditions, the PV peak power may be smoothly achieved by modifying the duty cycle of the converter. The PV was linked to the grid using a multilayer inverter. But the proposed method seems to be rather complex, which is its biggest flaw. The authors of [35] used three coordinated strategies to achieve a balance between solar energy and stored energy in PEVs utilizing Vehicle to Grid (V2G) technology. The PEV's batteries are charged while demand is low, and then used to power the home and the grid when demand is high.

The power components of an electric vehicle charging infrastructure, as described in [36], include a diesel generator, a storage battery, a grid connection, a single voltage source converter, and a solar photovoltaic (PV) array. Lightweight plug-in electric vehicle (PEV) designs with compact and reasonably priced charging infrastructure are shown in [37]. For commercial EV charging infrastructure development, an integrated power system technique is also used [38], [39]. In [40], the primary focus was on the interoperability study of a contactless charging system for

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 13, Issue 2, 2025

electric vehicles (EVs) that resonates. An MG structure is used to achieve both energy and waste management [41]. his structure integrates renewable energy sources such as solar and wind power with biologically renewable and sustainable energy sources such as wastewater, agricultural, and household waste. There are several valid concerns and issues brought up by the literature review that need answering and exploring in this piece. Theoretical studies that look at optimization applications for renewable energy sources seem to provide a lot of stability and advantages. When dealing with the interface of several modules, there are a handful of points to bear in mind that differ from well-known traditional procedures. One of the most successful ways is the use of soft computing for MPPT, which has been previously discussed in the literature.

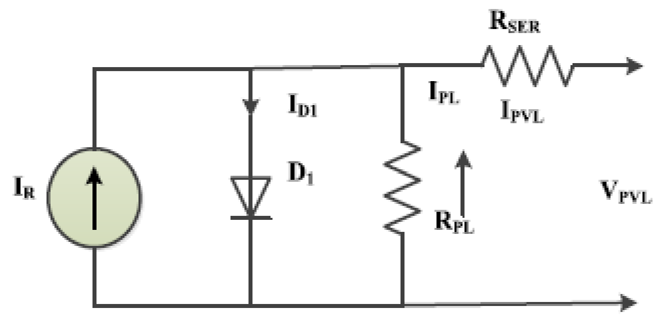
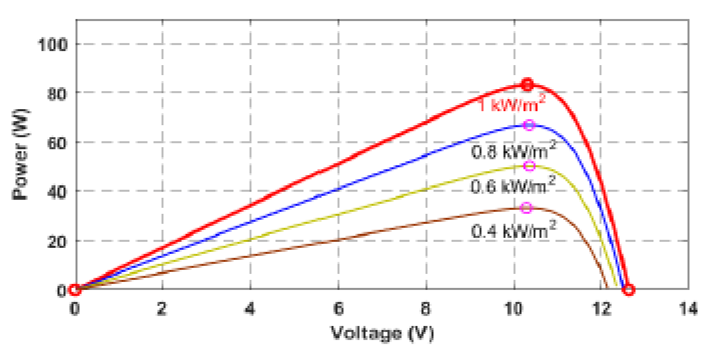


FIGURE 1. **PV cell's analogous circuit diagram.**

problem solving in the nonlinear domain. Unfortunately, these MPPT algorithms are more difficult and costly to execute than conventional methods [16, [17], [18], [19], [20], [21], [22], [23], [24], [25], [26]. After reviewing the topic, it is clear that a solar-powered EV charging station must include an effective MPPT controller in order to monitor GMPP with minimal ripple, overshoot, and oscillation in the settling time. Since a reliable source of power for cars is essential, grid interconnection and stand-by batteries (SBBs) are also crucial. This study aims to fill a knowledge gap by developing the most effective models for all electric vehicle fleets. Consequently, the main aim of this research is to propose a novel genetic algorithm (GAO) optimized sliding mode-based reconfigurable Pb&O MPPT controller for PV systems. A first-order sliding mode controller (SLMC) generates the proposed MPPT algorithm. In order to keep the system variables on a selected surface—also called a sliding surface—a Genetic Algorithm (GAO) is used to construct and execute a control equation. Part two of this article presents a grid-connected electric vehicle charging method that demonstrates its efficacy in two scenarios: first, when there is partial shadowing; and second, when the amount of power generated by a solar panel is unknown or almost nonexistent during the night. Among the study's initial aims are the following: • To create an MPPT method that can effectively follow GMPP with little settling time and no overshoot; and • To learn about rendition so that we can build dependable EV charging stations. This article presents the development of a new MPPT controller. Reduced settling time, improved accuracy, and other advantages are all thanks to the suggested GAO-tuned sliding mode-based reconfigurable step size Pb&O controller. To get the most out of the system, the proposed algorithm uses the MPPT technique. • To design and construct a grid-connected, electrically powered transportation charging system that is dependable and provides continuous charging facilities even in unwelcome situations (such as partial shading when PV panel generation is low or a grid failure environment). Segment II provides a clear perspective of the anticipated PV system, according to the article's arrangement. Section III delves into the DC-DC restrictions' limits. The following paragraphs

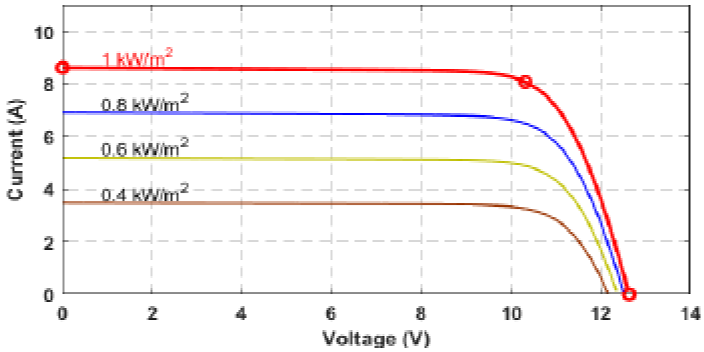


(a)

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 13, Issue 2, 2025



(b)

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

discusses in depth the boost converter and its effects on partial shading; Part IV discusses the representation of the battery system, and Section V offers a proposed technique and scheme for maximum power point tracking (MPPT); Before drawing any conclusions in Section VII, Section VI provides a concise explanation of the results of the simulations conducted using the suggested technique.

II. Representation of the PV System Structure

Solar photovoltaic cells convert light into electricity via a series of photovoltaic reactions. Keep in mind that there are a plethora of PV system layouts to choose from [42]. The basic structure of a solar cell for generating electricity is shown in Fig. 1. Possible uses for the current that the PV cell produces include:

$$I_{PVL} = I_R - I_{D1} - I_{PL} \qquad (1)$$

, where IPVL and VPVL are the individual voltage and current outputs of the photovoltaic cell. ID1, IR, and IPL stand for photovoltaic current, diode, and parallel resistance, respectively. Noted as RSER is the series resistance.

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

Saturation in reverse is represented by IRSC. Electron charge, ambient temperature, diode factor Boltzmann constant, and q, T, n, and K are all shown individually. A PV cell's output current is defined as:

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

Here, ISCN stands for short circuit current, T0 for temperature, and W0 for reference irradiance. The atmospheric temperature and irradiance coefficient were recorded as λ and W, respectively.

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

The P-V and I-V characteristics of the PV cells are shown in Figure 2. Equation (5) is the corresponding one.

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

An MPPT adaptive controller is based on the previously mentioned equation. Part III: The DC-DC Shield Section A: DC-DC Booster With the help of a DC-DC converter, which links the array to the load, the solar panels can track the MPP in response to controlled lighting and other environmental factors. In order to keep the solar array running continually at the maximum power point tracking (MPPT), the duty ratio of the converter switch is continuously modified using MPPT procedures. Table 1 details the specifications of the DC-DC converters used in this example. The modifications made to the DC-DC converter in this study are shown here. D. THE BIDUCTORIAL TRANSFORMER In order to regulate the transfer and storage of power between a photovoltaic system and a battery bank, this article recommends a bidirectional DC-DC boost converter [43], [44], [45]. This is because of the advantages detailed below. It provides the most cost-effective solution with the fewest external components. (ii) It uses the minimum amount of components required to realize voltage step-up and step-down. (iii) Its duty cycle is reduced while it is in use. (iv) It works well with a broad variety of input and output voltages. (v) It's cheaper than the majority of converters. Electric cars may continue to charge even after the sun goes down by tapping into a standby battery that stores any excess solar energy. The charging and draining of the stand-by battery (SBB) is controlled by a bidirectional boost DC-DC converter. The charging station's component is a 240V, 40Ah SBB. Standby batteries (SBBs) are expected to have a minimum SOC drain rate of 20%. C. Using an Inverter Module for Grid Implementation The analysis of the 230V, 50Hz AC grid is conducted to address the increased power requirements of the charging station. Using MATLAB/Simulink, An inverter links a 500V DC bus to the 230V AC grid. Utilizing the energy output from the PV array, a control scheme that is based on the EV's battery power is used to generate pulses for the inverter switches. In this case, we compare the power output from the PV module to the 2000 W power that the EV's battery can handle. In an imbalanced d-q frame, a reference current is formed based on this. For inverter control, a current PI controller is also used in an imbalanced d-q frame. Part IV: Representing the Battery Structure One 240V, 48Ah battery may be used with the charging station. An electric vehicle's battery may be charged from a 500V DC bus using a PI controller and a DC-DC boost converter. The arriving EV's battery is expected to have a minimum state of charge (SOC) of 9% for simulation purposes. Charging an electric vehicle's battery requires a certain amount of energy, which may be determined by looking at its lowest voltage (Vlo), lasting percentage state of charge (SOCre), and amp-hour rating (Ahr).

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

In order for the model to work, the battery's internal resistance must remain constant throughout charging and discharging.

I. METHODS OVERVIEW

A. Gate-Sliding Mode MPPT Controller Here we will go over a new way to synthesize SLMC utilizing GAO. In order to regulate the step size of a traditional Pb&O MPPT algorithm, the SLMC gains that drive the control law and the sliding surface are tweaked. Understanding the limits of uncertainty is a common design difficulty, but the proposed technique includes new information for creating this kind of controller that overcomes this obstacle. Overestimating this limit is a common cause of the well-known chattering phenomenon and undue gain. The proposed strategy, like all others that aim to reduce chattering, does not need knowledge of the uncertainty

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 13, Issue 2, 2025

limit.

The sliding mode controller is described in Section B. As a nonlinear control method, sliding mode control excels in regulating systems with dynamic structures [46]. A high-frequency switching control action that, in an ideal world, is limitless and output feedback form the basis of the sliding mode control method. A area of the state space that is often coupled to a sliding surface or manifold may be effectively steered by this high-speed control equation as the system travels. The main advantages of a system with sliding mode control features are as follows: Simple and adaptable controller architecture; intolerance of unmodeled dynamics and external disturbances.

FIGURE 3. Successive steps of GAO algorithm.

• The capacity to incorporate an error in the sliding surfaces and eliminate steady-state errors from the design process of the sliding mode controller. • The ability to reduce orders, reject disturbances, employ decoupling design techniques, be sensitive to changes in parameters, and be easily implemented using common power converters. Sliding mode control has many industrial uses in areas like as electrical drives, automobiles, and more due to its suitability for nonlinear systems. SLIDING MODE CONTROLLER DESIGN There are two components to a sliding mode controller; the second part is to choose a control rule that will make the switching surface attractive to the system state; and the first part is to create a sliding surface that meets design criteria. With the following equations [39] representing the nonlinear time-dependent switching system's impact:

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

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

where x is the vector representing the state variable in an n-dimensional space Rn. All three variables—u, the discontinuous control action, F, and g—are smooth vector fields in the same space. In order to achieve an appropriate transient length, the control aims to restrict the output error variable ey = y − yref. 2) Section One Establishing a unique scalar function representing the system's state is the first stage. Based on tracking error "e" and many of its derivatives (e (1), e (2),..., e(k)), the following is stated by σ(x):

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

The sliding manifold is most often used with a linear amalgamation of the following type:

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

with ci being constants. Equation σ = 0 defines the sliding surface in the error space. Standard types of sliding surfaces include the following:

ISSN 2347–3657

Volume 13, Issue 2, 2025

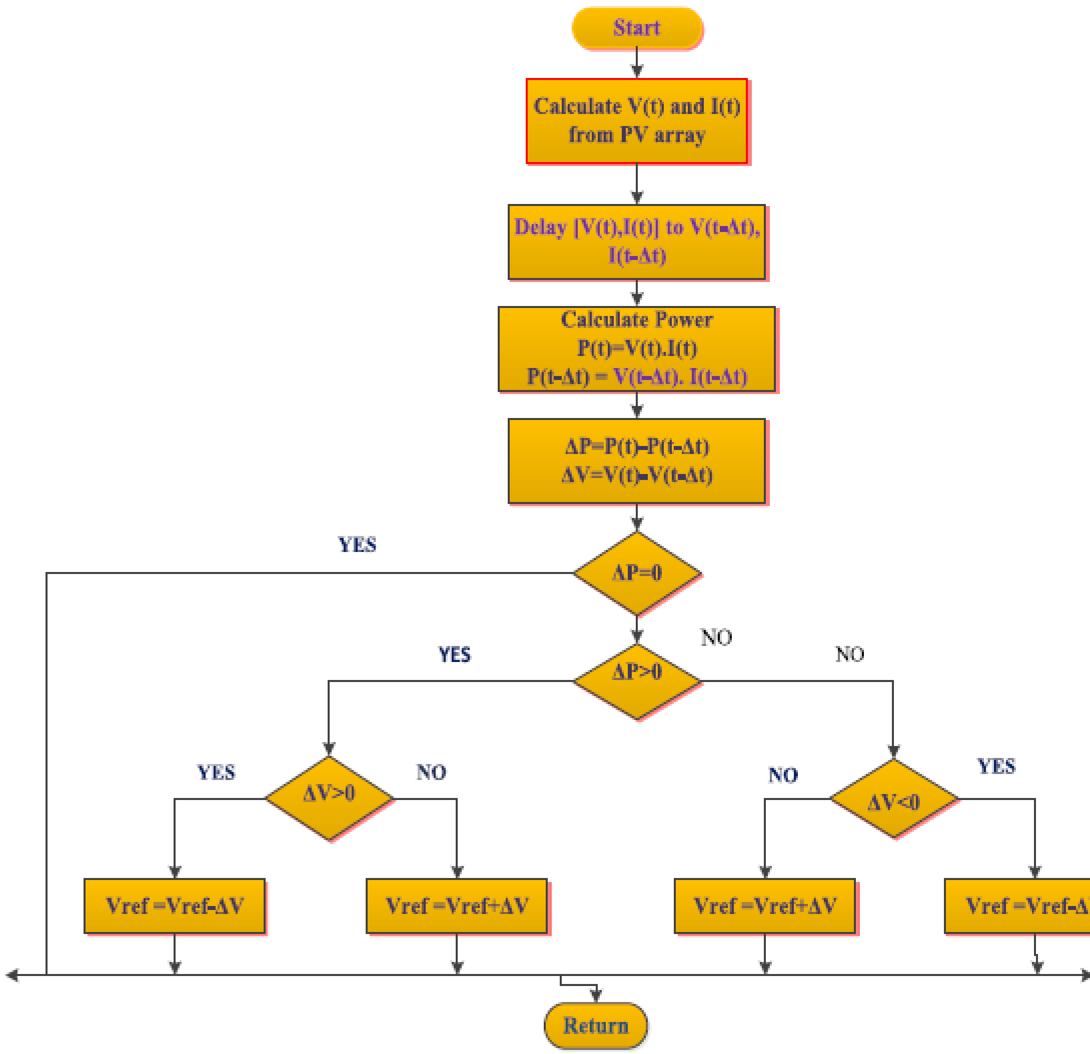


FIGURE 4. Pb&O method flow chart.

2) The Following Section Control law design In the second phase, you'll look for a control rule that will guide the system's trajectories onto the sliding surface. Multiple techniques build upon the sliding mode control strategy: • Regulation of the first-order standard sliding mode; • Regulation by use of a high-order sliding mode. According to, we will be concentrating on the standard first-order sliding mode control.

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

U is a big enough positive constant to be meaningful. In a steady state, the value of the control variable u will quickly fluctuate between +U∏u and U√u. C. Application of Nominated GAO-SLMC with Changeable Step Size PB and O MPPT Genetic algorithms are a sophisticated meta-heuristic technique that rely on biological activity to find a better solution. Using the theory of natural selection, Holland first found this method in 1975 [47]. Fig.3 shows the detailed procedure. With its ability to achieve increased efficiency, Perturb and Observations (Pb&O) works well with both grid connections and stand-alone systems. This method produces better results when the temperature is consistent and uniform. It is undesirable that system output fluctuates about MPP during partial shade circumstances, when irradiance and temperature are continually varying. The charge controller's Pb&O algorithm and Genetic Algorithm (GAO) flowcharts are shown in Figure 4 and Figure 5, respectively. The GAO method has found extensive use in non-conventional energy domains as a result of its inherent superiority and capabilities. While GAO does have certain benefits, such as a fast convergence time and reduced oscillation around the

International Journal of Information Technology & Computer Engineering
ISSN 2347–3657
Volume 13, Issue 2, 2025

maximum power point, it also has several drawbacks. For lengthy and complicated issues, this approach is useless. Equation (13) initially displays the parent population as:

$$X^{1} = [\mathrm{parent}^{a}.\mathrm{parent}^{b}\,.........\,.\mathrm{parent}^{n}] \qquad (13)$$

We define the goal function as the output power of the PV system, and the population size is n. Using an objective function, we may find out how fit each solution is. Since solar irradiance, air temperature, and load variation might experience sudden changes, GAO needs to be updated for use in MPPT applications. This work uses a fitness function based on the variable step size MPPT performances to identify the suitable SLMC parameters using the GAO approach. The sliding surface and control law are developed using this function.In this paper, the authors explain how a sliding surface responds to variations in voltage and current:

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

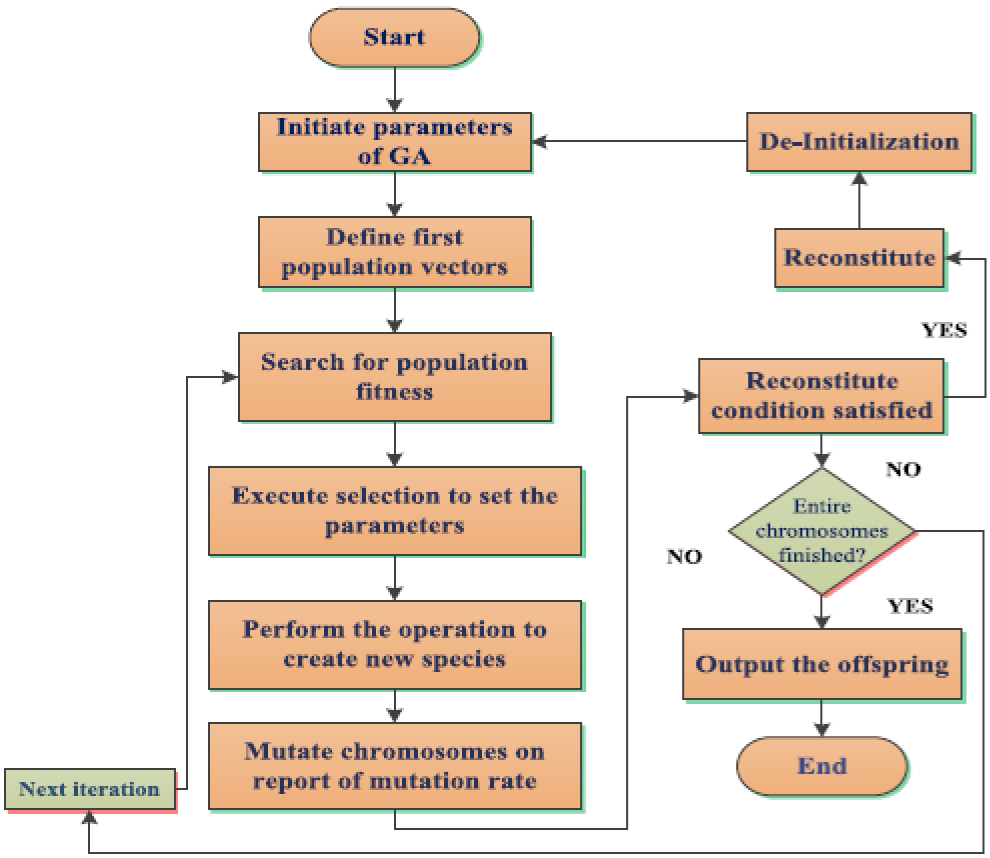


FIGURE 5. Flow chart of GAO algorithm.

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 13, Issue 2, 2025

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

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

$$\sigma = \frac{dX}{dt} + K_d.x \qquad (15)$$

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

$$D = K_e.sgn(\sigma) \qquad (16)$$

Five SLMC gains—Ka, Kb, Kc, Kd, and Ke—are optimized in this article using the GAO method. The suggested goal function, integral time-weighted absolute error (ITAE) metric, is used by us. Sliding mode-based controllers often employ the integral of time-weighted absolute error (ITAE) reduction as a performance parameter during design. Knowing how to adjust the controller for certain loads and/or set points is a huge help. This criteria may be used to different processes that are simulated by different process models. It is based on error calculation. One other perk is that you can get specific load and/or set point adjustments.

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

when looking for settings for the controller. The goal of the Integral Time Absolute mistake (ITAE) technique is to reduce the mistake during the first transient response while penalizing greater errors over a longer time. You should apply this criteria in applications that need a rapid reaction and settling time. The ITAE performance index may be expressed mathematically as follows:

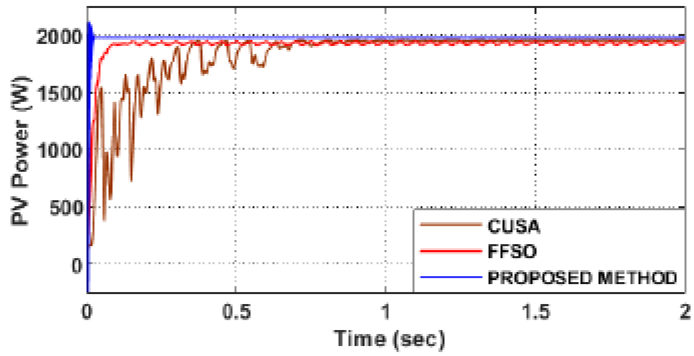
$$ITAE = \int_0^\infty t\,|e(t)|\,dt \qquad (17)$$

Part D: Charging Station Operation Mode Here are the three mentioned conditional operation modes in which the charging station operates: Solar panels charge the electric vehicle's battery on their own. Here, the GAO-SLMC variable step size Pb&O regulated method is doing its best to extract as much power as possible from the PV array at a constant temperature of 250C and a constant amount of sunlight. An independent photovoltaic array powers the electric vehicle's battery. While keeping the PV panels' temperature constant

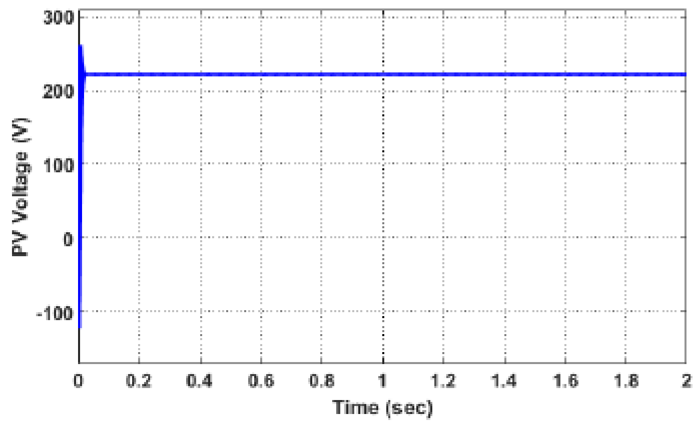
International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 13, Issue 2, 2025



(a)



(b)

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

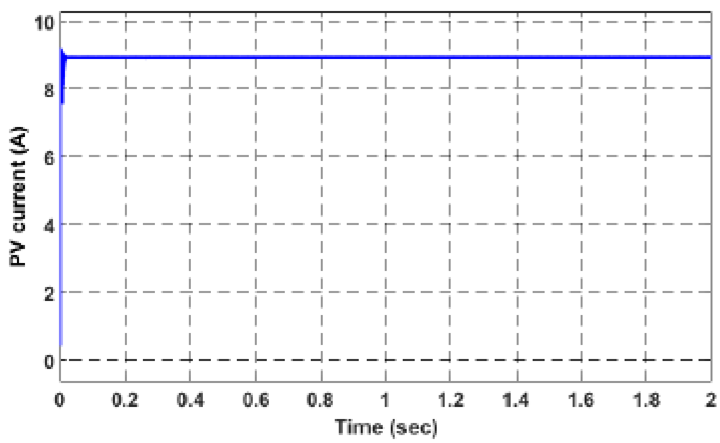


FIGURE 7. PV current under static irradiance condition.

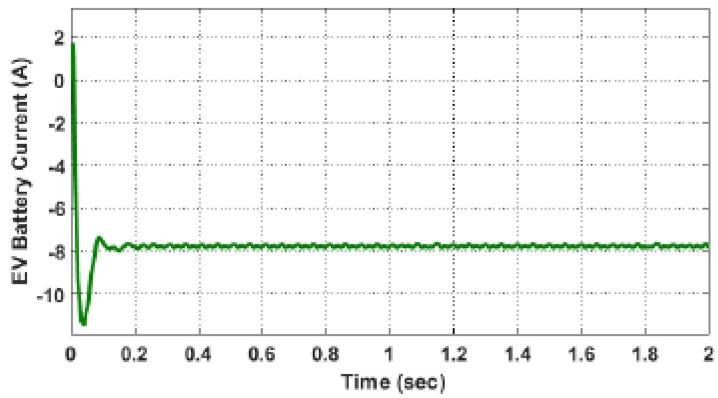


FIGURE 8. EV battery current.

(250C) and a variable for infrared light When operating in this mode, the goal is to maximize the output of the photovoltaic array. In the dark, when the PV array isn't receiving any sunlight, the electric vehicle's battery gets charged by the power grid. An appropriate and practical current control architecture regulates the flow of electricity on the AC grid.

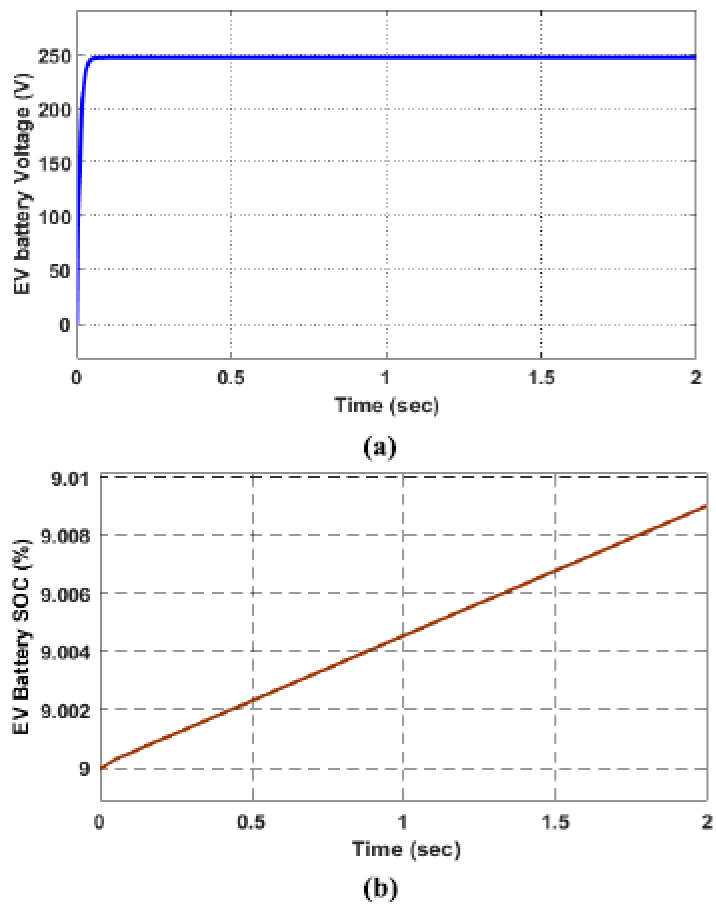


FIGURE 9. (a) EV battery voltage (b) % SOC of EV battery.

VI. SIMULATION OUTCOME AND RESULT ANALYSIS

In this part, the results of the simulation are shown and discussed. A grid-connected 2-kW single-phase inverter system is implemented in the 2018 version of MATLAB/SIMULINK. In order to generate 2 kW of power, eight 1Soltech 1STH-250-WH 250W panels are linked in series. Table 2 lists the module specifications that were stated

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 13, Issue 2, 2025

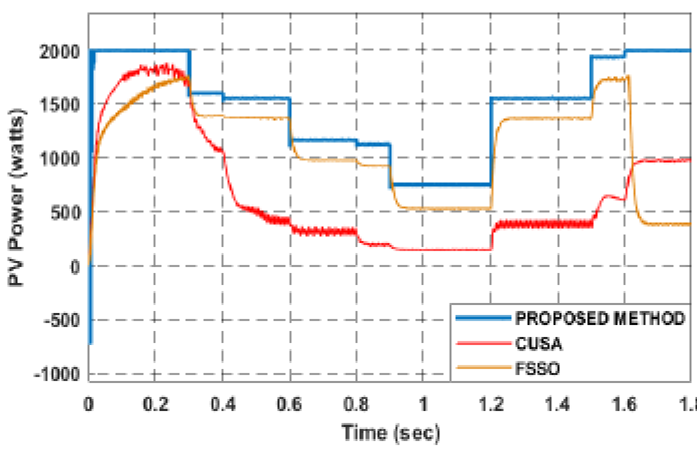
before. The two modes that were simulated were the usual test circumstances and the partial shading conditions. Table 3 provides the specs of the battery. In order to use the GAOSLMC approach, a small population is required. Because it allows the controller to be tuned as early as possible, this need is crucial in practice. Twenty is the starting population size and fifty is the maximum number of generations G in this research. A. Example 1: How Well It Functions Under Regular Test Conditions Under typical testing circumstances, solar photovoltaic panels were subjected to a continuous irradiation of 1000 W/m2. The newly developed method outperformed the old one in every single test, regardless of the weather. Additionally, Table 4 displays a comparison that is comparable. Figure 6 displays the graphs of the output PV power and voltage. Figure 7 shows the PV current under these conditions. The developed technique outperforms the other traditional MPPT approaches in terms of speed and efficiency when compared to the current Cuckoo Search Algorithm (CUSA) and Flying Squirrel Search Optimization (FSSO). In regard to

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 %

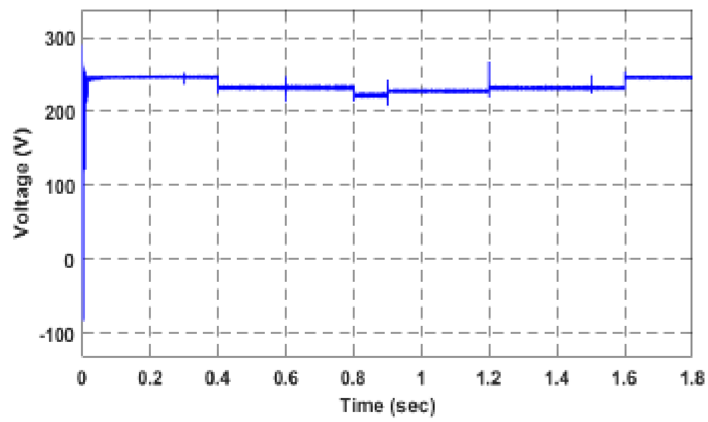
TABLE 5. Utmost sliding-mode controller gain.

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



(a)

International Journal of Information Technology & Computer Engineering
ISSN 2347–3657
Volume 13, Issue 2, 2025



(b)

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

of the simulated EV is first considered to be 9% SOC. A negative electric vehicle battery current, as seen in Fig. 8, indicates that the battery is charging. At typical temperature and light levels, the EV battery voltage and percentage of state-of-charge are shown in Figure 9. Case 2: Performance in the Presence of Partial Shading Here, in a partial shade scenario, we have a near-constant temperature and varying irradiance. We compared the interpretation of the GAO-SLMC-based MPPT algorithm to that of other approaches for all possible circumstances of solar irradiation, looking at tracking efficiency and speed. We used a stair generator to make PSCS-like

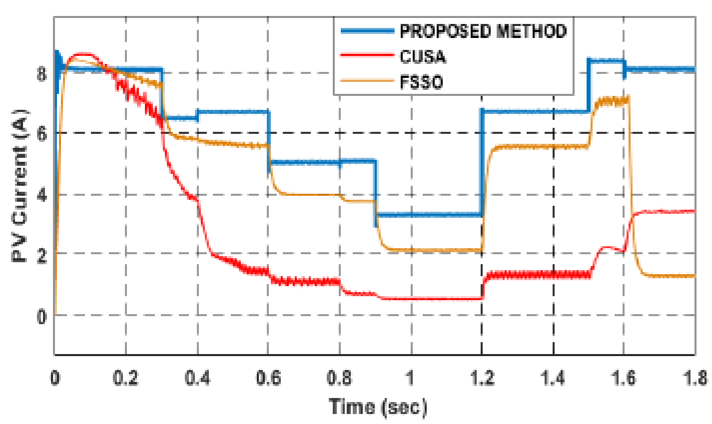


FIGURE 11. PV current under varying irradiance condition.

conditions where variations in illumination occur every three hundredths of a second. The case study's authors state that the irradiance varies at intervals of 0.3, 0.6, 0.9, 1.2, 1.5, and 1.8 seconds, based on a time range of 0 to 1.5 seconds. As mentioned earlier, the corresponding irradiances are varying from 1000 w/m2 to 800-600-400-800 w/m2 every 0.3 seconds, and then back to 1000 w/m2 at the exact second 1.8 seconds. Even with a steady voltage of 250 V, PV power reaches 2000 W. In terms of robust behavior, convergence speed, adherence to the ideal set point, and very low oscillations, the simulation results reveal that the hybrid methodology surpasses competing techniques, especially when compared to the MPP. The method's higher performance is shown by the simulation results. Due to the low number of oscillations close to the MPP point, this method minimizes power loss. Figure 10 shows a comparison of the suggested technique with other current algorithms, as was discussed before in instance 1. Figure 10 shows that when compared to the CUSA and FSSO algorithms, this one produces the most steady output PV power with the least amount of oscillation. There are other methods to the MPP that only provide average results. Figure 10 shows the photovoltaic panel's power output and voltage with various sun irradiance values considered. Along with PV current and EV battery current, Figs. 11 and 12 display these variables, while Fig. 13 shows EV battery voltage and state of charge. Alternatively, the final settings for the gain of the MPPT controller based on sliding mode are shown in Table 5. When starting the simulation, a state of charge of 9% of the EV is considered. The fact that the EV battery current is negative in Fig. 12 suggests that charging is also taking place here.

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 13, Issue 2, 2025

Case 3: Nighttime Performance Under Specific Conditions A control scheme that is based on the EV battery's power manages the flow of electricity to the grid. At the time

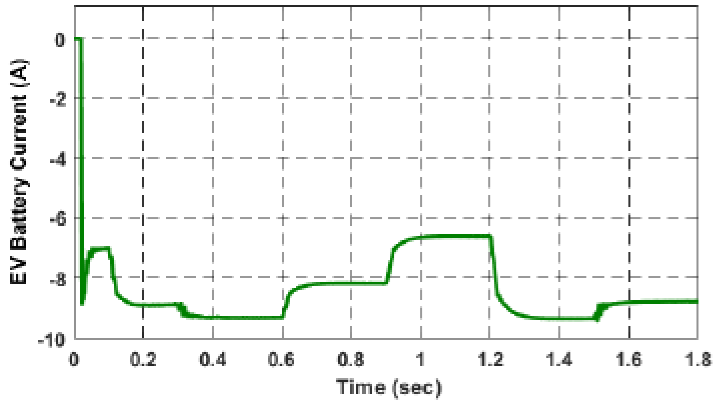
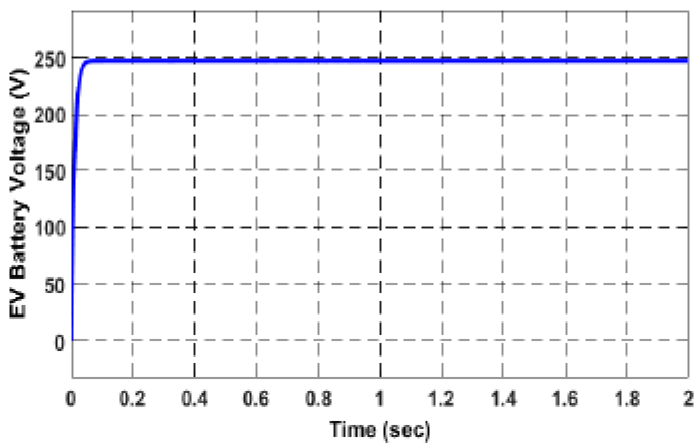
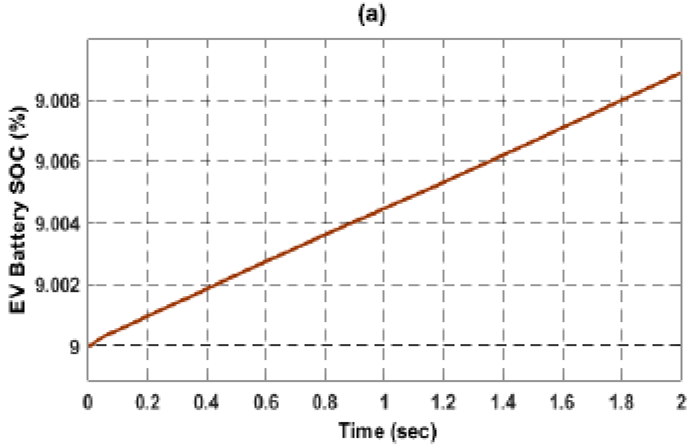


FIGURE 12. EV current under PSCS condition.



(a)

(a)



(b)

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

When the EV battery power reaches 2000 W, the grid will not be used. Assuming the PV module generates 1000 W of electricity at a given moment, the grid will draw an extra 1000 W. When PV power is nil at night, when clouds

International Journal of Information Technology & Computer Engineering
ISSN 2347–3657
Volume 13, Issue 2, 2025

are present, or when irradiance is not continuous due to unpredictable atmospheric circumstances, this approach provides dependability. Inverters link the alternating current (AC) grid to the direct current (DC) bus. Figure 14 shows the grid voltage and current flowing through the inverter when electricity is supplied to the DC bus from the grid. Figure 15 shows the DC bus voltage, which is kept at 500 V, and how an electric vehicle's battery is charged using this voltage. Here, we're assuming that the EV battery's state of charge is 50%. Figure 16 displays the power from the PV panels and the power from the EV battery, respectively. Figure 16 shows that the power output of EV batteries

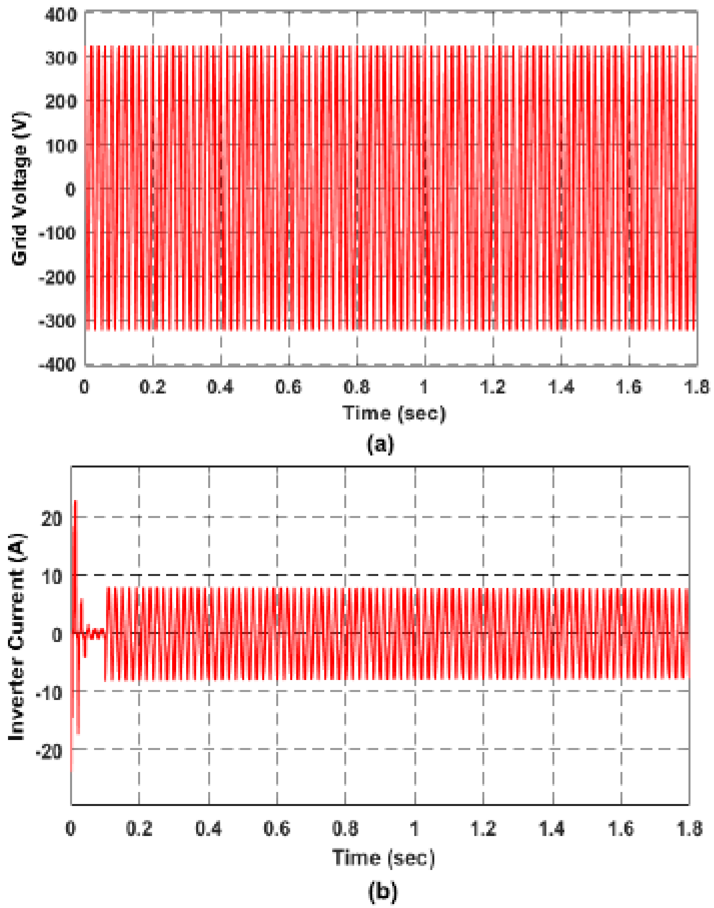


FIGURE 14. (a) Grid voltage (b) Inverter current.

International Journal of
Information Technology & Computer Engineering

ISSN 2347–3657

Volume 13, Issue 2, 2025

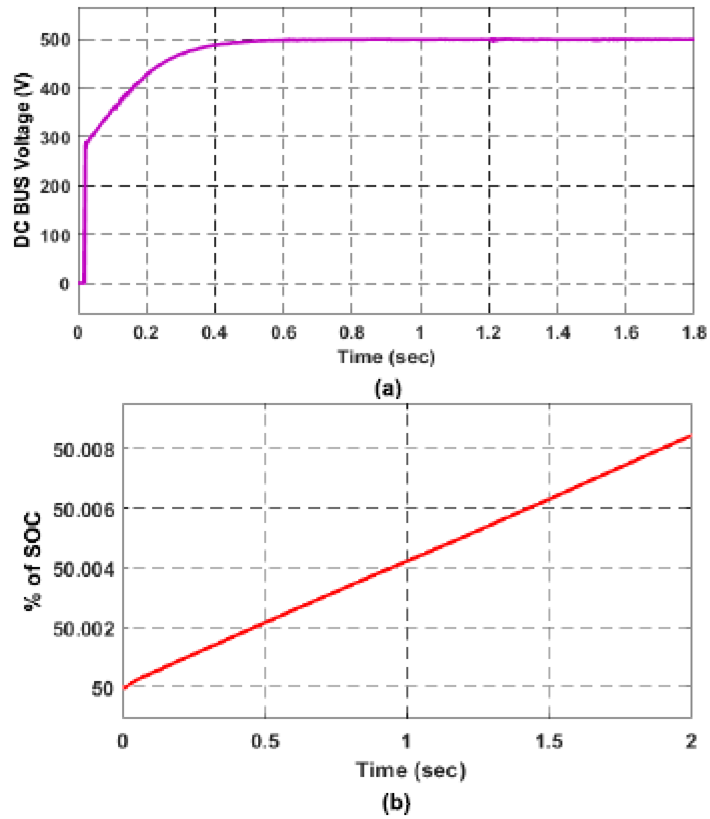


FIGURE 15. (a) DC Bus voltage and (b) % of SOC of EV battery.

PV output varies owing to partial shade situations, but is consistently maintained at 2000W. Thus, the remaining power is drawn from the grid, ensuring that the electric vehicle battery receives a consistent 2000W, a level that is very desired for customers using different charging stations. if the whole 2000W of electricity will be delivered throughout the night, when PV power is almost nonexistent

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

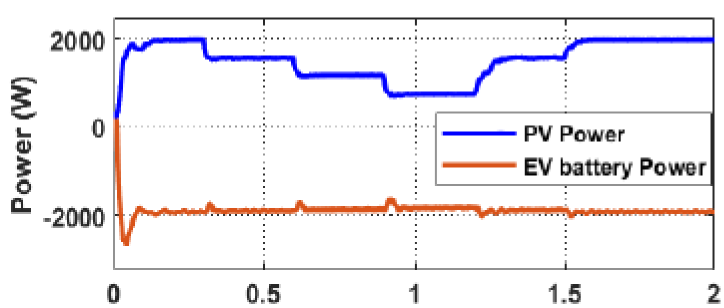


FIGURE 16. PV power and Battery power at condition.

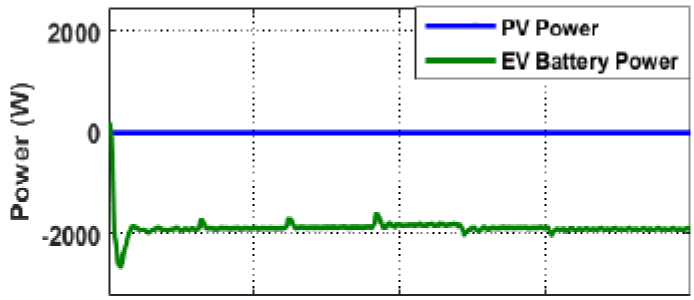


FIGURE 17. PV power and battery power at night.

according to the grid, as clearly seen in Figure 17. Table 6 shows a detailed comparison of the proposed MPPT controller to various approaches that are already in use.

VII. CONCLUSION

A major issue has arisen about the charging of electric vehicles due to the rise in the number of these vehicles on the road. Modern cars benefit from a constant power source, which is why PV-based EV charging stations that get grid assistance are advantageous. under order to get the maximum power out of solar systems under drastically changing weather circumstances, this study introduces and explores a new way of building a combined GAO-SLMC reconfigurable step-size Pb&O controller. Because of its adaptability to sudden shifts in inputs or dynamics, control platforms based on GAO-tuned sliding modes are time-varying or nonlinear systems. The suggested MPPT algorithm's variable step size is determined using the GAO algorithm's optimal design for the SLMC. Furthermore, less computation time, system expertise, and setup time is often required for this kind of controller. Researchers have used basic mathematics to build a model of a solar array, which will allow them to test out different combinations of cell temperature and radiation. This study has investigated the ability of a novel model to mimic the GMPP. The significance of keeping the DC bus voltage constant at the charging endpoint is one important component that our study has brought to light. For the charging process to be dependable and efficient, voltage stability is crucial. Further establishing the station's resilience and practicality, we have examined and validated its performance across three separate operating modes via rigorous analysis performed in MATLAB/Simulink. The required power may be supplied by keeping the DC bus voltage constant. There is no variation in the voltage at the charging endpoint. This may be achieved by installing an EV charging station with a power rating and capacity of high relevance at the workplace or in the charging outlets, as part of further study on the recommended design for more electric cars. Much further effort and development of this research is required. The most important thing to do next is to make the planned design bigger so it can handle more electric cars and more charging needs. One possible solution is to install much larger and more powerful electric vehicle charging stations, either in specific locations like offices or as part of a larger network. Further optimization of the efficiency and sustainability of EV charging infrastructure may be achieved by adding cutting-edge technology, such as advancements in energy storage and more powerful control algorithms. It would be wise to diversify the energy mix and make the system more resilient by looking at incorporating renewable energy sources other than solar panels, such wind or hydropower. In conclusion, our study contributes to a more sustainable and ecologically conscious transportation future by providing a firm groundwork for the development of electric vehicle charging stations.

REFERENCES

[1] J. Hashimoto, T. S. Ustun, M. Suzuki, S. Sugahara, M. Hasegawa, and K. Otani, ‘‘Advanced grid integration test platform for increased distributedrenewable energy penetration in smart grids,’’ *IEEE Access*, vol. 9,pp. 34040–34053, 2021.

[2] H. M. K. Al-Masri, A. A. Al-Sharqi, S. K. Magableh, A. Q. Al-Shetwi, M. G. M. Abdolrasol, and T. S. Ustun, ‘‘Optimal allocation of a hybrid photovoltaic biogas energy system using multi-objective feasibility enhanced particle swarm algorithm,’’ *Sustainability*, vol. 14, no. 2, p. 685,
Jan. 2022.

[3] R. Shirmohammadi, B. Ghorbani, M. Hamedi, M.-H. Hamedi, and L. M. Romeo, ‘‘Optimization of mixed refrigerant systems in low temperature applications by means of group method of data handling (GMDH),’’ *J. Natural Gas Sci. Eng.*, vol. 26, pp. 303–312, Sep. 2015.
[4] F. Zaouche, D. Rekioua, J.-P. Gaubert, and Z. Mokrani, ‘‘Supervision and control strategy for photovoltaic generators with battery storage,’’ *Int. J. Hydrogen Energy*, vol. 42, no. 30, pp. 19536–19555, Jul. 2017.
[5] A. O. Baba, G. Liu, and X. Chen, ‘‘Classification and evaluation review of maximum power point tracking methods,’’ *Sustain. Futures*, vol. 2, May 2020, Art. no. 100020.
[6] A. Nadeem and A. Hussain, ‘‘A comprehensive review of global maximum power point tracking algorithms for photovoltaic systems,’’ *Energy Syst.*, vol. 14, no. 2, pp. 293–334, May 2023, doi: 10.1007/s12667-021-00476-2.
[7] S. M. S. Hussain, M. A. Aftab, I. Ali, and T. S. Ustun, ‘‘IEC 61850 based energy management system using plug-in electric vehicles and distributed generators during emergencies,’’ *Int. J. Electr. Power Energy Syst.*, vol. 119, Jul. 2020, Art. no. 105873.
[8] M. A. H. Rafi and J. Bauman, ‘‘A comprehensive review of DC fastcharging stations with energy storage: Architectures, power converters, and analysis,’’ *IEEE Trans. Transport. Electrific.*, vol. 7, no. 2, pp. 345–368, Jun. 2021.
[9] T. S. Ustun and S. M. S. Hussain, ‘‘Implementation of IEC 61850 based integrated EV charging management in smart grids,’’ in *Proc. IEEE Vehicle Power Propuls. Conf. (VPPC)*, Hanoi, Vietnam, Oct. 2019, pp. 1–5.
[10] S. H. Hanzaei, S. A. Gorji, and M. Ektesabi, ‘‘A scheme-based review of MPPT techniques with respect to input variables including solar irradiance and PV arrays' temperature,’’ *IEEE Access*, vol. 8, pp. 182229–182239, 2020, doi: 10.1109/ACCESS.2020.3028580.
[11] A. H. Chander, K. D. Rao, B. P. Teja, L. K. Sahu, S. Dawn, F. Alsaif, S. Alsulamy, and T. S. Ustun, ‘‘A transformerless photovoltaic inverter with dedicated MPPT for grid application,’’ *IEEE Access*, vol. 11, pp. 61358–61367, 2023.
[12] K. A. Mahafzah, M. A. Obeidat, A. Q. Al-Shetwi, and T. S. Ustun, ‘‘Anovel synchronized multiple output DC–DC converter based on hybrid flyback- Cuk topologies,’’ *Batteries*, vol. 8, no. 8, p. 93, Aug. 2022.
[13] X. Zhang, B. Yang, T. Yu, and L. Jiang, ‘‘Dynamic surrogate model based optimization for MPPT of centralized thermoelectric generation systems under heterogeneous temperature difference,’’ *IEEE Trans. Energy Convers.*, vol. 35, no. 2, pp. 966–976, Jun. 2020.
[14] N. Khanam, B. H. Khan, and T. Imtiaz, ‘‘Maximum power extraction of solar PV system using meta-heuristic MPPT techniques: A comparative study,’’ in *Proc. Int. Conf. Electr., Electron. Comput. Eng. (UPCON)*, Aligarh, India, Nov. 2019, pp. 1–6.
[15] L. T. Omine, M. A. G. de Brito, J. O. P. Pinto, and R. C. García, ‘‘Hybrid MPPT algorithms for photovoltaic systems,’’ in *Proc. IEEE 4th Southern Power Electron. Conf. (SPEC)*, Singapore, Dec. 2018, pp. 1–8.
[16] A.-W. Ibrahim, M. B. Shafik, M. Ding, M. A. Sarhan, Z. Fang, A. G. Alareqi, T. Almoqri, and A. M. Al-Rassas, ‘‘PV maximum powerpoint tracking using modified particle swarm optimization under partial shading conditions,’’ *Chin. J. Electr. Eng.*, vol. 6, no. 4, pp. 106–121,
Dec. 2020.
[17] J. S. Koh, R. H. G. Tan,W. H. Lim, and N. M. L. Tan, ‘‘A modified particle swarm optimization for efficient maximum power point tracking under partial shading condition,’’ *IEEE Trans. Sustain. Energy*, vol. 14, no. 3, pp. 1822–1834, Jul. 2023, doi: 10.1109/TSTE.2023.3250710.
[18] D. A. Nugraha, K. L. Lian, and S. Suwarno, ‘‘A novel MPPT method based on cuckoo search algorithm and golden section search algorithm for partially shaded PV system,’’ *Can. J. Electr. Comput. Eng.*, vol. 42, no. 3, pp. 173–182, Jul. 2019.
[19] K. Guo, L. Cui, M. Mao, L. Zhou, and Q. Zhang, ‘‘An improved gray wolf optimizer MPPT algorithm for PV system with BFBIC converter under partial shading,’’ *IEEE Access*, vol. 8, pp. 103476–103490, 2020, doi: 10.1109/ACCESS.2020.2999311.
[20] Y. Dhieb, M. Yaich, M. Bouzguenda, and M. Ghariani, ‘‘MPPT optimization using ant colony algorithm: Solar PV applications,’’ in *Proc. IEEE 21st Int. Ccnference Sci. Techn. Autom. Control Comput. Eng. (STA)*, Sousse, Tunisia, Dec. 2022, pp. 503–507, doi: 10.1109/STA56120.2022.10019072.