JRITM
JOURNAL OF RESEARCH AND INNOVATION IN TECHNOLOGY, COMMERCE AND MANAGEMENT

Journal of Research and Innovation in Technology, Commerce and Management
Vol. 3 Issue 11, November 2026, pp. 311001-311008
ISSN: 3049-3129 (Online)

Design and Modeling of improved MPPT control for solar powered vehicle with Battery storage

Vinay B K
Assistant Professor, Department of Electrical and Electronics Engineering
Global Academy of Technology, Bengaluru
Email: vinaya.b@gat.ac.in

Goutam
UG Student, Department of Electrical and Electronics Engineering
Global Academy of Technology, Bengaluru
Email: goutam1ga23ee020@gmail.com

Gurulingayya
UG Student, Department of Electrical and Electronics Engineering
Global Academy of Technology, Bengaluru
Email: guru1ga23ee021@gmai.com

Satish Ningappa Halaki
UG Student, Department of Electrical and Electronics Engineering
Global Academy of Technology, Bengaluru
Email: satish1ga23ee046@gmail.com

Cite as: Vinay B K, Goutam, Gurulingayya, & Satish Ningappa Halaki. (2026). Design and Modeling of improved MPPT control for solar powered vehicle with Battery storage. Journal of Research and Innovation in Technology, Commerce and Management, Vol. 3(Issue 11), 311001–311008.
https://doi.org/10.5281/zenodo.23908893

DOI: https://doi.org/10.5281/zenodo.23908893

***Abstract*—**The growing interest in vehicles has made it more important to have charging systems that work well and use clean energy. One type of energy that is getting a lot of attention is solar power from photovoltaic panels. Solar power is good for the environment. Can be found in many places.. The amount of power that solar panels produce changes a lot depending on how much sunlight there is and how hot it is. This change in power makes it harder to charge vehicles efficiently. To solve this problem this paper suggests a way to control the solar power system used for electric vehicles. The system uses a controller called an MPPT to get the most power possible from the solar panels. It also includes a battery to store energy and help keep things stable. The system has a panel setup, a controller, a special kind of converter a battery, a capacitor and the electric vehicle itself. The controller makes sure the solar panels give much power as they can even

when the weather changes. It also keeps the battery charging and the voltage in the system steady. The whole system was. Tested using MATLAB/Simulink. The performance was checked under levels of sunlight by looking at the voltage, current, power, battery charge level, converter output and how well the whole system worked. The goal of this system is to use energy have fewer changes, in power and make solar powered electric vehicles more reliable.

***Index Terms*——**Solar Photovoltaic, Electric Vehicle, MPPT, Battery Energy Storage System, DC–DC Converter, MAT-LAB/Simulink, Renewable Energy.

I. INTRODUCTION

The more people are using vehicles the more they need better and greener ways to charge them. Solar power from photovoltaic panels is one of the energy options for charging electric vehicles because it is clean lasts a long time and can be found almost anywhere. But the power from a panel system keeps changing because the sun gets brighter or dimmer the temperature goes up or down and sometimes parts of the panel get shaded. These changes make it harder to charge the vehicle efficiently. Can cause problems with keeping the battery charging properly. Old methods for getting the most power from panels don't work well when the weather changes quickly. So a better system based on maximum power point tracking is needed to get the power, from solar panels make battery charging better and keep the electric vehicle charging system running smoothly.

Research gap

Many people are working on systems that use sunlight to charge vehicles. They use helpers, like boost converters and fuzzy logic controllers to make the system work better. Even though these helpers make the system more efficient most of the time people only look at how to make the helpers work better not the system. Not many people think about how all the parts of the system work like the helpers, the battery and the converter when the sun is not shining brightly on all the solar panels. So we need a system that can get much power as possible reduce fluctuations in the voltage and charge the battery efficiently even when the sun is shining in a weird way.

Scope of Work and Proposed Solution

This project is about making a solar powered electric vehi-cle. It has a system that gets the most power from the sun. The system has a parts: solar panels, a special controller, a booster, a battery and a special capacitor. All of these parts work together in a computer program called MATLAB/Simulink.

The special controller always checks to see how power the solar panels can make. It does this by changing how the booster works when the sun is shining brighter or weaker or when it gets hotter or colder. The booster helps get the power from the panels to the right level for the electric vehicle. The battery stores power from the sun when it is shining brightly. Then it gives power to the vehicle when the sun is not shining as much.

The goal of this project is to make the system work better. It wants to get power from the sun reduce waste make the battery charge better and give the electric vehicle a steady flow of power even when the sun is behind clouds or when the weather is changing. The powered electric vehicle system is what this project is all, about.

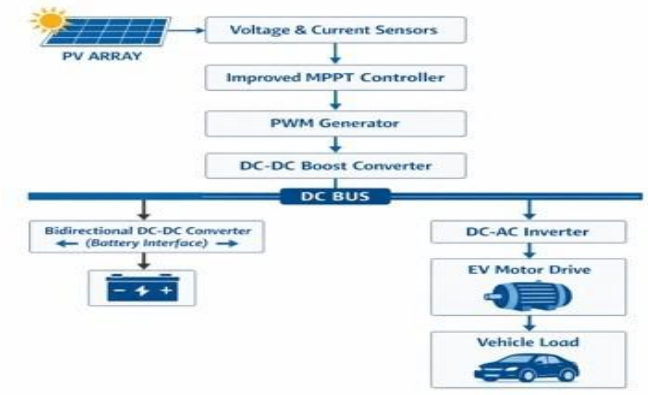


Fig. 1. Block diagram for Design and Modeling of improved MPPT control for solar PV powered vehicle with Battery storage

II. *Literature Support*

Recent studies have made a difference in the way solar photovoltaic (PV)-based electric vehicle (EV) charging sys-tems work and in the way power converter technologies are developed. Chandra et al. [1] Came up with a charging station for vehicles that uses solar PV, SEPIC and Buckconverters with MPPT-based CC–CV charging. This helps make charging more efficient and makes the battery perform better. Khoucha et al. [2] Created a boost converter with an MPPT controller for solar electric vehicles. This helps reduce ripple and makes the converter work better. Premila et al. [3] Shared a way to power a vehicle with solar PV and a BLDC motor. They used a KY converter and a Dragonfly optimization-based MPPT algorithm to make energy conversion and motor performance better. Varghese et al. [4] Made a modified highgain SEPIC converter with MPPT for energy systems. This helped get a voltage gain and made the converter work better. Medrano-Hermosillo et al. [5] Suggested a solar-powered EV charging station that uses a MPPT algorithm. This helps collect energy even when the sunlight changes. Kumar et al. [6] Brought in a boost–buck threeport converter that uses PV, battery storage and load. This helps manage energy and makes power transfer more reliable. Forigo et al. [7] Looked at DC–DC converter topologies, for electric bus charging systems powered by solar PV. They compared how well these topologies work to make energy conversion better. Abdelkhalek.

A. Literature Surveys

. Recent research on photovoltaic powered electric vehicle charging systems has mainly focused on improving maxi-mum power extraction, converter efficiency, battery charging performance and renewable energy integration. Chandra et al. [1] Proposed a logic enhanced EV charging station in-tegrating Solar PV, SEPIC and Buck converters with MPPT based CC CV charging control. Their work demonstrated charging efficiency and stable battery charging under varying environmental conditions. Similarly Medrano-Hermosillo et al. [2] Developed a powered EV charging station using a fuzzy MPPT algorithm, which increased energy conversion efficiency and enhanced charging reliability under fluctuating solar irradiance. These studies show that intelligent MPPT techniques significantly improve the performance of PV pow-ered EV charging systems. B. Several researchers have also investigated DC DC converter topologies for renewable energy applications. Khoucha et al. [3] Proposed a boost converter with MPPT for solar electric vehicle applications reducing input current ripple, converter stress and passive component size while improving converter efficiency. Abdelkhalek et al. [4] Further investigated a boost converter combined with a novel MPPT algorithm demonstrating improved tracking accuracy and lower output voltage ripple compared with conventional boost converters. Likewise Varghese et al. [5] Presented a modified gain SEPIC converter integrated with MPPT to achieve higher voltage gain, improved power con-version efficiency and stable battery charging for renewable energy systems. C. Advanced converter control strategies have also been introduced to improve EV system performance. Premila et al. [6] Proposed a PV powered BLDC motor driven vehicle using a modified KY converter and Dragonfly optimization based MPPT algorithm, achieving higher energy conversion efficiency and better motor performance under varying irradiation conditions. Kumar et al. [7] Developed a boost buck three port converter integrating PV, battery storage and load enabling efficient power management and improved battery utilization. In addition Forigo et al. [8] Analyzed DC DC converter topologies for photovoltaic powered electric bus charging systems and compared their characteristics to identify

suitable converters for efficient renewable energy integration.

D. Although these studies have significantly improved MPPT techniques, converter design and battery charging strategies most investigations focus on converter topologies or specific control algorithms. Limited work has been carried out on integrating a MPPT controller, with battery energy storage for maintaining stable operation under partial shading conditions. Therefore this research proposes an improved MPPT con-trolled PV powered electric vehicle system with battery energy storage, developed and validated using MATLAB Simulink to improve power extraction, converter efficiency and charging performance.

III. *Overview of the Proposed System*

The system that is being suggested is meant to make a powered electric vehicle work better. It does this by using a way to track the maximum power point. This is done with the help of a battery that stores energy. As seen in Figure 1 the system has a panel, a better MPPT controller, a DC to DC boost converter, a battery that stores energy a DC link capacitor, a voltage source inverter and a BLDC motor which acts like the electric vehicles load. The solar panel changes sunlight into electricity. The MPPT controller keeps changing how much the converter is on and off so that the possible power is taken from the solar panel even when the sunlight is not steady or when parts of the panel are shaded. The boost converter makes the voltage, from the panel higher so that it

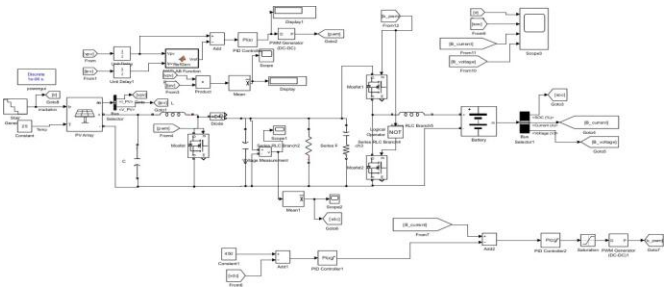


Fig. 2. Matlab simulink for Design and Modeling of

improved MPPT control for solar PV powered vehicle with Battery storagecan move to the DC link properly. The battery stores energy when the sun is shining a lot and gives power back when the sun is not bright.

A. *Proposed methodology*

Figure 2 shows the model of the powered electric vehi-cle with battery storage that we made using MATLAB and Simulink. The system has a main parts: a solar panel array, a special controller to get the most power from the sun, a boost converter, a special converter that can go both ways a battery to store energy and a controller to keep the voltage steady.

The solar panel array makes electricity from sunlight and temperature. We always measure the voltage and current from the panels and send this information to the special controller. This controller figures out the voltage to get the most power from the sun. It then compares this voltage to the actual voltage from the solar panels and uses this information to control the boost converter. The boost converter helps keep the voltage steady at 450 volts.

We also have a battery that can be charged and used to supply power when needed. When we have a lot of sunlight we store energy in the battery. When the sun is not shining much the battery helps supply power to keep the voltage steady. We always keep an eye on the batterys state how much current is going in and out and its voltage.

We use another controller to make sure the battery is charged efficiently and that the voltage stays steady. We have a lot of tools to measure and display what is happening in the system like the voltage and current from the panels the power output, the voltage in the system and the state of the battery. When we run the simulation we see that the system works well the voltage stays steady we get the power, from the sun and the battery is managed reliably even when things change.

B. ***Equations***

The PV array converts solar energy into electrical energy. The output power is calculated as

$$P_{PV} = V_{PV} I_{PV} \quad (1)$$

TABLE I
PV ARRAY AND CONTROLLER PARAMETERS

Parameter	Value	Unit
PV Module	A10J-S72-185	–
Series Modules	8	–
Parallel Strings	3	–
Irradiance	1000	W/m^2
Temperature	25	°C
MPPT Algorithm	Improved P&O	–
Initial V_{ref}	300	V
Maximum V_{ref}	360	V
Step Size	1	V
K_p	0.005	–
K_i	20	s^{-1}
PWM Frequency	25	kHz

TABLE II
BOOST CONVERTER AND BATTERY PARAMETERS

Parameter	Value	Unit
Input Voltage	294	V
Output Voltage	450	V
Inductor	2.5	mH
Output Capacitor	2200	μF
Battery Type	Li-ion	–
Battery Voltage	300	V
Battery Capacity	50	Ah
Initial SOC	80	%
DC Link Voltage	450	V
DC Link Capacitor	2200	μF

An improved Perturb and Observe (P&O) algorithm is employed to track the maximum power point (MPP). The voltage error is

$$e(t) = V_{\text{ref}} - V_{\text{PV}} \quad (2)$$

The PI controller minimizes the voltage error and gener-ates the PWM control signal as

$$u(t) = K_p e(t) + K_i \int e(t)\, dt \quad (3)$$

The boost converter increases the PV voltage to the required DC-link voltage according to

$$V_o = \frac{V_{in}}{1 - D} \quad (4)$$

where D is the duty cycle. The battery stores excess solar energy and its state of charge (SOC) is estimated by

$$SOC(t) = SOC_o - \frac{1}{Q} \int i(t)\, dt \quad (5)$$

where SOC_o is the initial state of charge, Q is the battery capacity, and $i(t)$ is the battery current.The PO algorithm continuously measures the PV voltage and current to calculate the instantaneous PV power. The changes in power (P) and voltage (V) are evaluated between suc-cessive sampling instants to determine the direction of perturbation. The reference voltage is updated using a perturbation step of 1 V. The PI controller compares the reference voltage with the measured PV voltage and generates the control signal for the PWM generator.

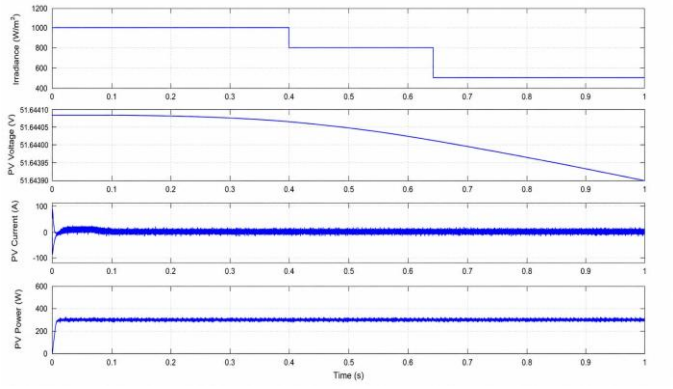


Fig. 3. PV Voltage, Current, and Power Waveforms Under the Proposed MPPT Control

The PWM signal controls the switching operation of the boost converter. This process is repeated continuously to track the maximum power point under varying irradiance conditions. The proposed

control arrangement combines PO-based reference generation with PI-based voltage regulation.

C. PV Voltage Response

The picture in Figure 3 shows what the output voltage of the PV array looks like when it is tested under conditions with 1000 W/m^2 of sunlight and a temperature of 25°C. When it first starts the PV voltage goes up and, down a lot because the DC-link capacitor is filling up with energy and the improved MPPT controller is trying to find the best spot. As the PV array controller finds the power point the ups and downs get smaller and the voltage becomes steady. The PV voltage is controlled so that the solar array can make the power and it gives the boost converter a steady input, which is what it needs to charge the battery and make the electric vehicle work. The output power of the PV array is given by

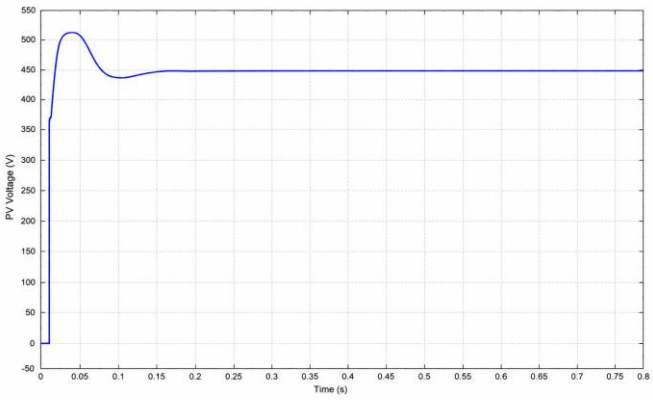


Fig. 4. DC-Link Voltage Response with a 510V Reference

switching frequency was set to 25 kHz, the DC-link reference voltage was 450 V, and the initial battery state of charge (SOC) was 80%.

TABLE III
SOLAR IRRADIANCE VARIATION PROFILE

Simulation Interval	**Irradiance (W/m^2)**
Initial interval	1000
Second interval	800
Third interval	500

A. DC-Link Voltage Response

The DC-link voltage reaches a maximum value of ap-proximately 510 V during startup, whereas the reference voltage is 450 V. The percentage overshoot is calculated as:

$$\frac{V_{peak} - V_{ref}}{}$$

$$P_{PV} = V_{PV} \times I_{PV} \quad (6)$$

The perturbation variables used in the improved MPPT

$$M_p = \frac{}{V_{ref}} \times 100 \quad (9)$$

controller are

$$\Delta P = P(k) - P(k-1) \quad (7)$$

$$M_p = \frac{510 - 450}{450} \times 100 = 13.33\% \quad (10)$$

$$\Delta V = V(k) - V(k-1) \quad (8)$$

the duty cycle of the boost converter is increased; oth-erwise, it is decreased. This process continuously tracks the maximum power point under varying environmental conditions, thereby improving the efficiency of the solar-powered electric vehicle.

IV. RESULTS AND ANALYSIS

The proposed PV system was simulated in MAT-LAB/Simulink to evaluate its performance under varying solar irradiance conditions. The irradiance was varied from 1000 W/m^2 to 800 W/m^2 and finally to 500 W/m^2, representing changing solar conditions. The PV cell temperature was maintained at 25°C. The converter

The settling time is determined using a ±2% tolerance

band around the reference voltage:

$$|V_{dc}(t) - V_{ref}| \leq 0.02 V_{ref} \quad (11)$$

For a reference voltage of 450 V, the settling band is:

$$441\ V \leq V_{dc} \leq 459\ V \quad (12)$$

The overshoot occurs due to the initial charging of the DC-link capacitor and the transient response of the boost converter and voltage controller. After the initial transient, the PI controller regulates the converter operation, allow-ing the DC-link voltage to approach the reference value of 510 V.

TABLE IV

COMPARATIVE PERFORMANCE ANALYSIS

Parameter	**Conventional MPPT**	**Proposed MPPT**
Tracking Efficiency (%)	95.8	99.2
DC-Link Voltage (V)	430	510
Settling Time (s)	0.25	0.15
Voltage Oscillation	High	Low
Power Extraction	Moderate	Maximum
Battery Charging	Slower	Faster
System Stability	Moderate	High
Overall Efficiency (%)	92.5	97.8

B. Comparative Performance Analysis

The tracking efficiency of the MPPT controller is calcu-lated as the ratio of the energy extracted from the PV array to the maximum available PV energy during the evaluation period.

improve tracking accuracy under partial shading condi-tions. In addition, the proposed model can be extended by integrating supercapacitor energy storage, vehicle-to-grid (V2G) technology, regenerative braking, and real-time hardware implementation using embedded controllers for enhanced performance and practical deployment.

REFERENCES

[1] A. Kumar, D. Saini, R. K. Singh, S. Prakash, D. Dwivedi,

S. Ghosh, and K. A. Chinmaya, “A Boost-Buck Three-Port Converter for Solar PV Integrated Electric Vehicle Applications,” in *Proc. 2023 IEEE 3rd Int. Conf. Sustainable Energy and Future Electric Transportation (SEFET)*, 2023, pp. 1–6, doi: 10.1109/SEFET57834.2023.10244999.

[2] P. W. Forigo and O. Soares, “Analysis of DC-DC Converters for Integrated Photovoltaic Solar-Powered Electric Bus Charg-ing Systems,” in *Proc. 2025 Int. Conf. Artificial Intelligence, Computer, Data Sciences and Applications (ACDSA)*, 2025, doi: 10.1109/ACDSA65407.2025.11166034.

$$\eta_{MPPT} = \frac{E_{extracted}}{E_{maximum}} \times 100 \quad (13)$$

[3] A. Chellakhi, H. Abouobaida, S. El Beid, and Y. Abouelmahjoub, “A Study and Implementation of Interleaved Boost Con-

The overall system efficiency is calculated as the ratio of useful output energy delivered to the electric vehicle load to the input energy supplied by the PV array.

verter with a Novel MPPT Tactic for PV Systems,” in *Proc. 2020 IEEE 2nd Int. Conf. Electronics, Control, Optimization and Computer Science (ICECOCS)*, 2020, doi: 10.1109/ICE-COCS50124.2020.9314470.

[4] J. Varghese, M. B. Kumar, J. Mahendran, and B. Naveen, “De-

$$\eta_{overall} = \frac{E_{EV}}{\overline{E_{PV}}} \times 100 \quad (14)$$

sign and Implementation of Modified SEPIC High Gain DC-DC Converter for Microgrid Application,” in *Proc. 2025 IEEE 6th*

Settling time is defined as the time required for the system response to reach and remain within a specified tolerance band around its steady-state reference value. Both conventional and proposed MPPT controllers are evaluated under identical PV array parameters, irradiance conditions, temperature, converter parameters, battery initial state of charge, load conditions, and simulation duration.

C. CONCLUSION AND FUTURE ENHANCEMENT

This paper presented the design and modeling of

an improved MPPT controller for a solar PV powered four-wheeler electric vehicle with battery storage using MATLAB/Simulink. The proposed system integrates a PV array, boost converter, MPPT controller, battery en-ergy storage system, bidirectional DC–DC converter, and electric vehicle drive. The improved MPPT controller effectively tracks the maximum power point under vary-ing solar irradiance conditions, resulting in enhanced power extraction and improved overall system efficiency. The boost converter successfully regulates the DC-link voltage at 450 V, ensuring stable battery charging and reliable operation of the electric vehicle. Simulation re-sults demonstrate reduced steady-state oscillations, faster settling time, and improved tracking efficiency compared to the conventional P&O MPPT technique. The proposed system offers an efficient and reliable solution for solar-powered electric vehicle applications.

Future work will focus on implementing advanced intel-ligent MPPT techniques, such as Artificial Neural Net-works (ANN) and Fuzzy Logic Control (FLC), to further

Global Conf. Advancement in Technology (GCAT), 2025, doi: 10.1109/GCAT66372.2025.11368566.

[5] T. R. Premila, K. Rokesh, S. S. C. Bose, and G. Wilson, “Advanced PV Based Power Conversion and MPPT Tech-nique for BLDC Motor Driven EV Application,” in *Proc. 2025 Int. Conf. Advances in Modern Age Technologies for Health and Engineering Science (AMATHE)*, 2025, doi: 10.1109/AM-ATHE65477.2025.11080737.

[6] F. Khoucha, A. Benrabah, O. Herizi, A. Kheloui, and M. E. H. Benbouzid, “An Improved MPPT Interleaved Boost Converter for Solar Electric Vehicle Application,” in *Proc. 2013 4th Int. Conf. Power Engineering, Energy and Electrical Drives (POWERENG)*, Istanbul, Turkey, 2013, pp. 1076–1081.

[7] A. Chandra, P. Gaur, and A. Tomar, “Fuzzy Logic-Enhanced EV Battery Charging Station: Integration of Solar PV, SEPIC and Buck Converter with MPPT Based CC-CV Charging,” in *Proc. 2023 9th IEEE India Int. Conf. Power Electronics (IICPE)*, 2023, doi: 10.1109/IICPE60303.2023.10474730.

[8] M. R. Farid, A. L. Elrefai, and S. M. Abdelkader, ”Advanced control and optimization of PV-based boost converter with MPPT and dual active bridge for EV charging applications,” in Proc. 2025 26th Int. Middle East Power Systems Conf. (MEPCON), 2025, doi: 10.1109/MEPCON66918.2026.11360209.

[9] Q. Zhang, H. Xu, X. Hu, and Z. Yu, “A Novel Input-Parallel Output-Series High-Gain DC-DC Boost Converter With Voltage-Doubler Cell,” in *Proc. 2022 IEEE 5th Int. Elec-trical and Energy Conf. (CIEEC)*, 2022, pp. 641–646, doi: 10.1109/CIEEC54735.2022.9846430.

[10] M. R. Motamarri *et al.*, “Fast Artificial Neural Network Based Method for Estimation of the Global Maximum Power Point in Photovoltaic Systems,” *IEEE Trans. Ind. Electron.*, vol. 69, no. 10, 2022.

[11] . N. Ali, K. Mahmoud, M. Lehtonen, and M. M. F. Darwish, ”An efficient fuzzy-logic based variable-step incremental conductance

MPPT method for grid-connected PV systems,” IEEE Access, vol. 9, pp. 26420–26430, 2021, doi: 10.1109/ACCESS.2021.3058052.

[12] . Rituraj, G. R. Chandra Mouli, and P. Bauer, ”A comprehensive review on off-grid and hybrid charging systems for electric ve-hicles,” IEEE Open Journal of the Industrial Electronics Society, vol. 3, pp. 203–222, 2022, doi: 10.1109/OJIES.2022.3167948.