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Revolutionizing Solar Energy Conversion: A Neural MPPT-Controlled Photovoltaic Regulator

Ibrahima Gueye, Abdoulaye Kebe, Oumar Dia, Moustapha Diop

Abstract: ***This article presents the design of an innovative photovoltaic solar regulator equipped with a neural MPPT (Maximum Power Point Tracking) control and an advanced battery charge and discharge management algorithm. The main objective of this research is to significantly improve the efficiency of solar energy conversion into electrical energy by optimizing the maximum power point and effectively regulating battery charging and discharging. The neural MPPT control represents a major advancement in the field of solar energy. Unlike conventional algorithms, this approach enables the regulator to adapt to environmental variations, such as fluctuations in sunlight. As a result, the regulator can constantly adjust the maximum power point, ensuring a high efficiency of the solar system. The battery charge and discharge management algorithm is a crucial element in the regulator's design. Effective battery management is essential to maintain a balance between solar energy supply and electrical equipment consumption. Through this algorithm, the battery is kept within optimal charge ranges, thereby avoiding overcharging or excessive discharging, which contributes to prolonging its lifespan. To evaluate the performance of the proposed photovoltaic solar regulator, detailed simulations were conducted using the Matlab/Simulink software. The obtained results confirmed a significant improvement in solar energy conversion efficiency. The combination of the neural MPPT control and the battery management algorithm allows the system to operate optimally, even under changing environmental conditions. The practical applications of this research are diverse. This enhanced solar regulator could be deployed in remote regions without access to the traditional power grid. It also provides an effective solution for rural or isolated areas where solar energy can be a viable energy source, but intelligent management is required to ensure stable electrical supply. In conclusion, this study presents a significant advancement in the field of photovoltaic solar energy, combining a novel neural MPPT control with an advanced battery management algorithm. The simulation results clearly demonstrate a substantial improvement in solar energy conversion efficiency and more efficient battery management. This regulator opens up new possibilities for the utilization of solar energy in various demanding environments, offering a promising solution for powering remote or off-grid areas.***

Keywords: ***Photovoltaic Solar Regulator, MPPT, Neural Control, Battery Charging, Energy Efficiency, Energy Optimization.***

I. INTRODUCTION

Photovoltaic solar energy is a steadily growing renewable energy source worldwide, accounting for over half of the installed renewable energy production capacity in 2020. Technological advancements in this field have led to significant improvements in the efficiency and reliability of photovoltaic systems [1]. However, optimizing the maximum power point (MPPT) remains a key challenge to maximize the efficiency of photovoltaic systems. This technology aims to maximize the production of electrical energy from photovoltaic solar panels. MPPT is a process that adjusts the voltage and current output of the solar panel to maximize the power generated. Several techniques have been proposed in the literature to address this issue, such as perturb-and-observe algorithms, incremental conductance, hill climbing, and methods based on neural networks [2]. Neural control algorithms have emerged as a promising alternative for solving the MPPT problem in photovoltaic systems, thanks to their ability to adapt to varying operating conditions [3,4].

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***Correspondence Author(s)**

Dr. Ibrahima Gueye*, ENSETP, Université Cheikh Anta DIOP, Dakar, Sénégal. Email: Ibrahima64.gueye@ucad.edu.sn, igueye5@gmail.com, ORCID ID: 0000-0001-9921-2617

Dr. Abdoulaye Kebe, ENSETP, Université Cheikh Anta DIOP, Dakar, Sénégal. Email: abdoulaye.kebe@ucad.edu.sn, ORCID: 0000-0001-6043-2575

Dr. Oumar Dia, ENSETP, Université Cheikh Anta DIOP, Dakar, Sénégal. Email: oumar12.dia@ucad.edu.sn, ORCID ID: 0000-0002-3282-4632

Dr. Mosstapha Diop, ENSETP, Université Cheikh Anta DIOP, Dakar, Sénégal. Email: moustapha17.diop@ucad.edu.sn, ORCID ID: 0000-0001-9907-5595

These algorithms rely on artificial neural networks capable of learning and adapting to input data to optimize the MPPT process. Neural control algorithms are particularly useful for photovoltaic systems installed in changing environments, such as mobile systems or rural settings where weather conditions can vary considerably. In addition to MPPT optimization, another important challenge in photovoltaic systems is battery charge and discharge management. The battery is a key component of these systems as it allows storing the energy produced by the solar panels for later use. Optimal battery management is essential to ensure sustainable use of solar energy. Several battery charge and discharge management algorithms have been proposed in the literature, such as threshold algorithms, charge and discharge control algorithms, and charge prediction algorithms [5]. In this article, we present the design of a photovoltaic solar regulator using a neural MPPT control and a battery charge and discharge management algorithm. The objective of our study is to propose an efficient and reliable system to optimize the production of electrical energy from photovoltaic solar panels while ensuring optimal battery management to guarantee its lifespan.

II. LITERATURE REVIEW

Traditional Maximum Power Point Tracking (MPPT) control techniques, such as Perturb and Observe (P&O) and Incremental Conductance (IC), have been widely used in photovoltaic solar regulators to optimize energy efficiency. However, these techniques have certain limitations. P&O is a simple technique, but its performance is limited by solar irradiance perturbations and fluctuations. Under low irradiance conditions, the P&O technique can cause voltage and current oscillations that can reduce energy efficiency.

IC is a more advanced technique than P&O, but it can also have limitations. Indeed, it can cause voltage and current oscillations due to its sensitivity to variations in temperature and load. To overcome these limitations, more advanced MPPT control approaches have been proposed. Among these, neural MPPT control has garnered increasing interest in the scientific community. According to research conducted by renowned researchers in the field of renewable energies, it has been demonstrated that neural MPPT (Maximum Power Point Tracking) control can significantly improve the energy efficiency of photovoltaic solar regulators, even under low irradiation conditions. The results have shown that this approach led to an energy efficiency improvement of nearly 98%, even in low irradiation conditions [6]. Another neural MPPT control approach based on deep neural networks has also been proposed by another team of researchers to optimize the energy efficiency of photovoltaic solar regulators. The results have shown that this approach achieved a maximum energy efficiency of 99.5%, even in low irradiation conditions [7]. In summary, neural MPPT control can offer a promising alternative to traditional MPPT control techniques in optimizing the energy efficiency of photovoltaic solar regulators. The P&O regulator has been widely used in photovoltaic systems due to its simplicity and ease of implementation. However, it has significant limitations such as sensitivity to weather changes, slow response time, and a tendency to oscillate around the maximum power point (MPP) [8][9]. To overcome these limitations, several other MPPT methods have been proposed in the literature. For example, the Modified Perturb and Observe (MPO) method was proposed to improve the performance of the P&O method in terms of response time and accuracy [10]. Moreover, other methods such as the Incremental Conductance (IC) method and the Fractional Open-Circuit Voltage (FOCV) method have also been proposed to enhance MPPT performance in terms of response time, accuracy, and robustness to weather changes [11][12]. However, despite these improvements, these methods also have limitations. For instance, the IC method requires derivative calculations, which can introduce errors under low solar irradiance conditions [13]. Additionally, the FOCV method requires measurements of open- circuit voltage and voltage at open circuit, which can be challenging to obtain in PV systems [14]. Faced with these limitations, the use of neural control has proven to be a promising alternative to enhance MPPT performance. This method allows adaptation to weather changes, reduces system response time, and avoids oscillations around the MPP [15][16]. In summary, while many MPPT methods have been proposed to enhance the performance of photovoltaic solar regulators, each has specific limitations. Therefore, the use of neural control can be considered a promising alternative to improve MPPT performance.

III. STUDY AND DESIGN OF THE PHOTOVOLTAIC SOLAR REGULATOR WITH MPPT CONTROL

This chapter is focused on the in-depth study and design of the photovoltaic solar regulator equipped with Maximum Power Point Tracking (MPPT) control. The primary goal of this phase is to develop an efficient system that optimizes solar energy production by precisely tracking the maximum power point of the solar panels. Additionally, it includes a detailed description of the method employed for managing battery charge and discharge. The section will present a thorough analysis of the crucial components of the solar regulator, along with the methodologies utilized to implement the MPPT control. Furthermore, the chapter will place significant emphasis on design considerations, algorithm selection, and the simulations conducted to assess the performance of the solar regulator.

A. Components of the Proposed Regulator

The proposed study system is depicted in the schematic below (Figure 1) and is composed of the following elements:

- Photovoltaic Solar Panels
- Buck Converter with Neural MPPT Control and PI Regulation: This component extracts the maximum power supplied by the solar panels. It continuously adjusts their input voltage to maintain the panels at their maximum power point, thereby ensuring optimal and safe battery charging. The neural MPPT control is responsible for this function.
- Battery: The battery stores excess solar energy, provides continuous electrical supply, and stabilizes the system.
- Power Switches (MOSFET Transistors): These two power switches manage the flow of energy between the battery and the load.

Their main role is to regulate the voltage and current from the solar panels to ensure optimal and secure battery charging. They adjust the input voltage of the solar panels continuously to keep them at their maximum power point, thus achieving the highest possible efficiency from the available solar energy. This function is carried out by the neural MPPT control. Additionally, with the help of switches K1 and K2, the regulator continuously monitors the battery's state of charge. It limits the incoming power or completely stops charging to prevent overcharging when the battery is full or reaches a predefined charge level. Similarly, it protects the battery from excessive discharge by cutting off the load when the battery voltage reaches a critical low level.

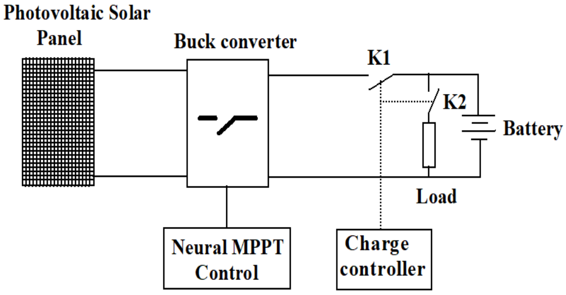

Fig. 1. Schematic of the Proposed Photovoltaic Solar Regulator.

B. Buck Converter Analysis

The modeling of the buck converter involves analyzing the different operating sequences that emerge based on the state of the switch. The duty cycle α determines the duration of these sequences, allowing control over the output voltage level of the converter. Specifically, we will explore two distinct operating sequences, which occur when the switch is in two different states.

These sequences play a crucial role in transforming the input DC current into regulated and adapted DC output current tailored to the specific needs of the load. Through an in-depth analytical approach, we will describe the mathematical equations and models that depict the behavior of these operating sequences. The obtained model will serve as the learning input for the neural network to be subsequently used for the neural MPPT control

- **Presentation of the Study System**

The search for the maximum power point is achieved by adjusting the duty cycle of the buck converter. The use of a buck converter is justified by the fact that the voltage provided by the solar panel is higher than the nominal voltage of the battery, which is 12 V.

Figure 2 illustrates the connection between the solar panel and the battery via the buck converter.

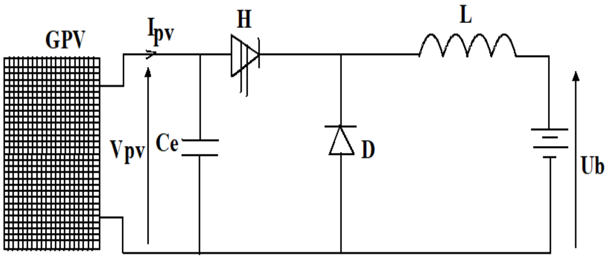

Fig. 2. Components of the Study System

- **Modeling**

The purpose of analyzing static converters through mathematical modeling is to present this model in a continuous canonical form. These systems, known as "switched systems," switch between a set of continuous states, making the development of control laws challenging. The obtained model allows us to derive the transfer function. The time evolution is based on the equations of the storage elements (L, C) and can be represented by a linear state-space representation, with the duty cycle α as a parameter. [17]

$$\begin{cases} \frac{dV_{pv}}{dt} = \frac{V_{pv}}{R_{pv}C_e} - i_L \\ \frac{di_L}{dt} = \frac{V_{pv} - U_b}{L} \end{cases} \quad (1)$$

Switch H open.

$$\begin{cases} \frac{dV_{pv}}{dt} = \frac{V_{pv}}{R_{pv}C_e} \\ \frac{di_L}{dt} = \frac{-U_b}{L} \end{cases} \quad (2)$$

The average model of the converter is obtained by considering both operating sequences

$$\begin{cases} \frac{dV_{pv}}{dt} = \frac{V_{pv}}{R_{pv}C_e} - \frac{\alpha i_L}{C_e} \\ \frac{di_L}{dt} = \frac{\alpha V_{pv} - U_b}{L} \end{cases} \quad (3)$$

In small-signal modeling, in dynamic regime, any variable x is represented as:

$$x = X + \tilde{x} \quad (4)$$

With X: average value; $\tilde{x}$: small variation.
Thus, we obtain:

$$v_{pv} = V_{pv} + \tilde{v}_{pv} \quad (5)$$

$$i_L = I_L + \tilde{i}_L \quad (6)$$

$$\alpha = \alpha_0 + \tilde{\alpha} \quad (7)$$

With this change of variable, we obtain the following equations:

$$\begin{cases} \frac{d\tilde{v}_{pv}}{dt} = \frac{\tilde{v}_{pv}}{R_{pv}C_e} - \frac{\alpha_0 i_L + \tilde{\alpha} i_L}{C_e} \\ \frac{di_L}{dt} = \frac{\alpha_0 \tilde{v}_{pv} + \tilde{\alpha} V_{pv}}{L} \end{cases} \quad (8)$$

The Laplace transformation allows us to obtain the transfer function of the b converter, which is necessary for implementing the control loop.

$$G(s) = \frac{\tilde{v}_{pv}}{\tilde{\alpha}} = \frac{LI_L s + U_b}{-LC_e s^2 + \frac{L}{R_{pv}} s - \alpha_0^2} \quad (9)$$

Specifications

The controller synthesis must aim to best meet the following requirements:

- Phase margin mφ ≥ 45° and gain margin mg ≥ 10dB.
- Accuracy: The measurement should reach the setpoint with 98% precision.
- speed: Maximum response time of 5 ms.

Determination of the Controller Parameters

Tracking the Maximum Power Point (MPPT) in the system requires correction to optimize the voltage delivered by the solar panel. A controller is used to adjust the duty cycle of the buck converter based on variations in the panel voltage. The control loop measures the panel voltage, compares it to an optimal reference voltage, and generates a correction command to adjust the duty cycle. This maintains the panel voltage close to the optimal voltage, thus maximizing solar energy production. The controller parameters are calculated based on the system's characteristics to ensure effective tracking of the maximum power point

The expression of the controller is given by the equation:

$$C(S) = K_p + \frac{K_i}{S} \quad (10)$$

Several methods can be used to determine the coefficients kp and ki. In the context of this work, a numerical method with Matlab was employed. The results obtained are recorded in Table 1.

Table 1: PI Controller Parameters

Parameters	Kp	Ki
Found values	0.064	91,25

C. Presentation of the Neural MPPT Method

In this study, we explore the use of neural networks in developing a neural controller using Matlab/Simulink software. This neural controller will be subsequently implemented in the studied system.

The developed neural controller will utilize data collected from the P&O MPPT controller associated with the PI controller for its training. However, several steps must be taken before this training:

Step 1: Creation of the database
Step 2: Selection of the neural network structure
Step 3: Training of the neural network (including testing and validation phases)
Step 4: Development and implementation of the neural controller

The database is built based on a regulator using the P&O (Perturb and Observe) Maximum Power Point Tracking (MPPT) control and a PI (Proportional Integral) controller. We conducted a simulation using Matlab/Simulink while randomly varying the solar irradiance. This simulation allowed us to obtain the input power and output power profiles ([figure 3](#)). It can be observed that the output of our system closely follows the input despite the variations in solar irradiance. The efficiency achieved with this P&O MPPT regulator is 95.47%.

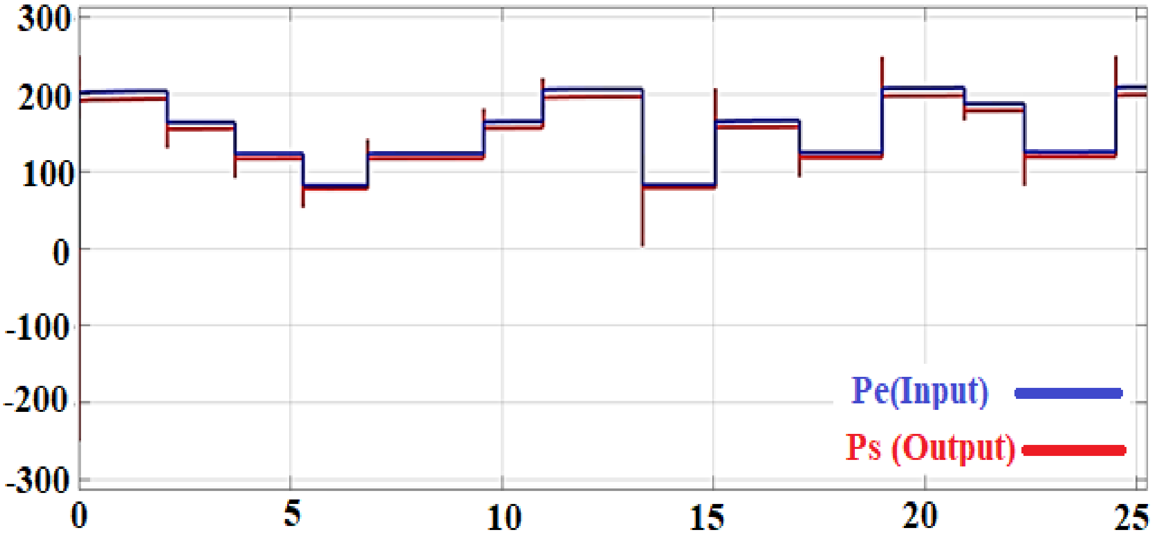

Fig. 3. Input Power and Output Power

Once the data is collected by the regulator, we use it to build the database in the "WORKSPACE" environment of Simulink using the "DATABASE" element (see [Figure 3](#)).

This database will then be provided to the neural network for training.

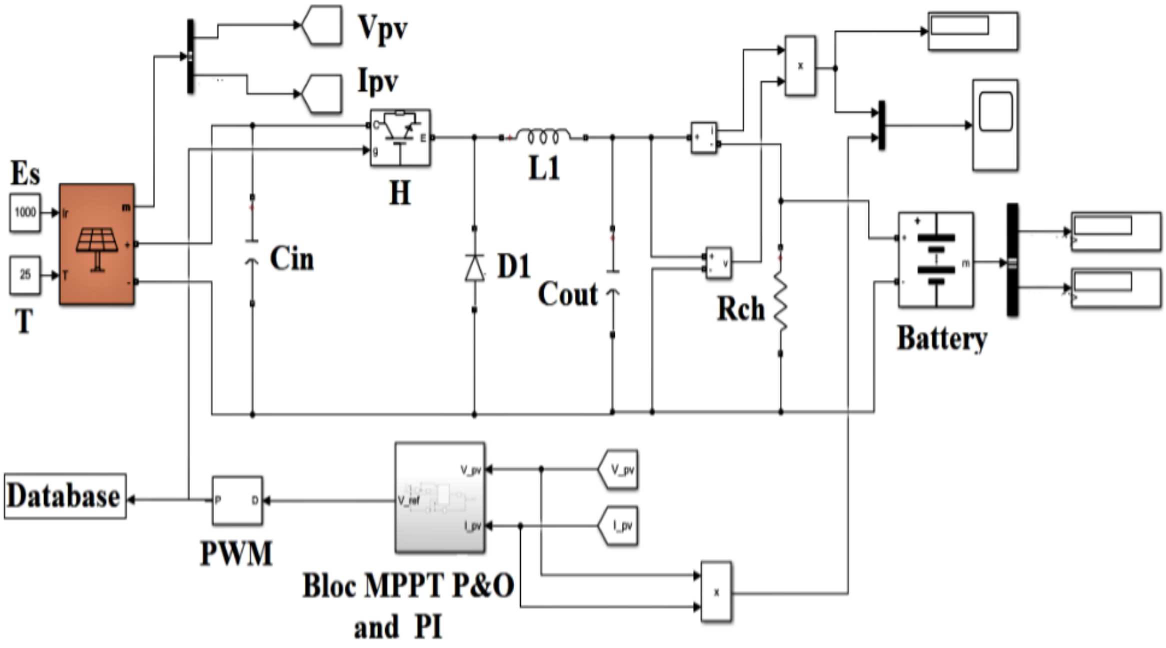

Fig. 4. Simulink Diagram of the Study System

The "DATABASE" has collected 2x2 million data points, meaning two million input data points and two million output data points. The next step is to construct the database, which constitutes the input of our neural network, called "input." These data correspond to the data collected at the input of the P&O MPPT controller. Also, the data that constitutes the output of the neural network, called "outputs." We will use these data with Simulink for training and finally generate a neural controller that we can implement in the system for simulations. [Figure 4](#) represents the generated neural controller in Simulink.

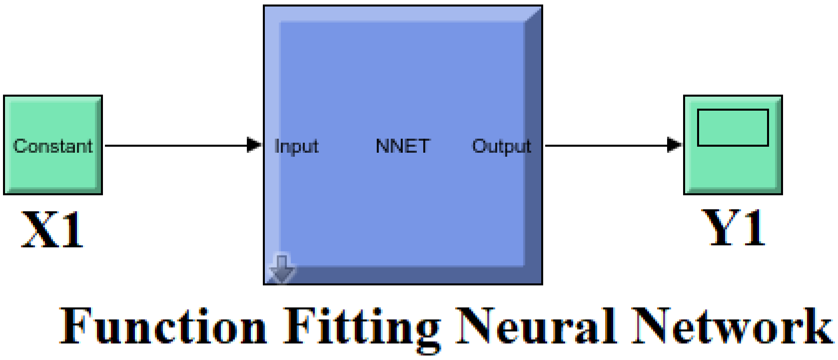

Fig. 5. Neural Controller Generated in Simulink.

The developed neural controller is implemented in the study system (see Figure 6).

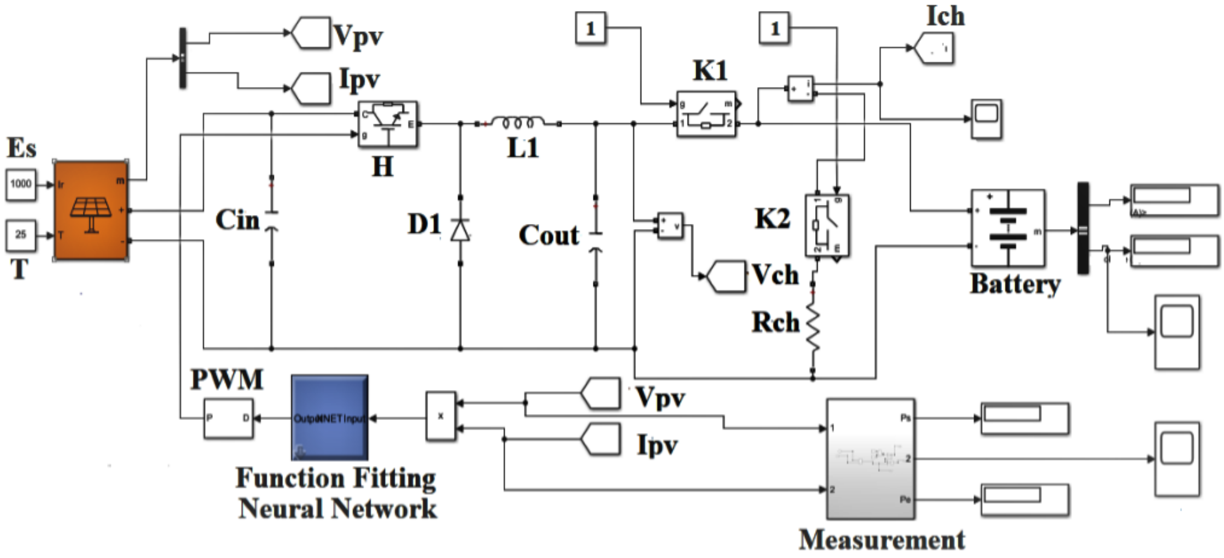

Fig. 6. Complete Schematics of the Regulator in Simulink.

Es: Irradiation
T: Temperature
Vpv: Photovoltaic panel output voltage
Ipv: Photovoltaic solar panel output current
H: Buck converter switch (Power bipolar transistor)
Cin : Buck converter input capacitance (Buck converter input capacitor)
Cout : Buck converter output capacitance (Buck converter output capacitor)
L1: Chopper inductor
D1: Diode
K1: Energy flow management switch to load and battery (MOSFET transistor)
K2: Energy flow management switch to load (MOSFET transistor)
Rch: Resistive load

IV. PRESENTATION OF THE BATTERY CHARGING AND DISCHARGING ALGORITHM

The algorithm described below manages the charging and discharging of a battery using switches K1 and K2. The switching process of the switches is controlled by this algorithm. Here are the initial conditions:

- The battery is empty, and its voltage Ub is below 12.5 V.
- The load is disconnected (K2 is open), but the solar panel (PV) is connected.
- There is no sunlight.

When there is sunlight (good irradiation), K1 remains closed, and the load stays disconnected, but the battery starts charging, increasing its terminal voltage (Ub). Here are the steps that follow based on the battery voltage Ub:

- If Ub reaches 12.5 V, we connect the load by closing K2.
- If Ub reaches 14 V, we disconnect the solar panel by opening K1, while keeping the load connected.

When the battery powers the load, its voltage gradually decreases. Here are the next steps based on the battery voltage Ub:

If Ub drops to 13.6 V, we reconnect the solar panel by closing K1, allowing the battery to continue charging.

If Ub reaches 14 V again, we disconnect the solar panel again by opening K1.

In this situation, where the voltage Ub is between 14 V and 13.6 V, the battery's charging and discharging are managed by keeping K2 always closed.

However, if the battery discharges and there is not enough sunlight, the voltage Ub may drop below 13.6 V. In this case:

- If Ub reaches 11.5 V during the discharge, we must disconnect the load by opening K1 to prevent battery damage
- If sunlight returns to normal, the battery will resume its charging automatically.

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This process effectively manages the battery charging and discharging based on voltage and sunlight variations while avoiding the risks of overcharging or excessive discharge that could damage the battery. For a battery with a nominal voltage of 12 V, the upper threshold (opening of K1) is set to 14 V, while the lower threshold (closing of K1) is set to 13.6 V. This means that when the battery voltage reaches 14 V, switch K1 opens to prevent any overcharging. Similarly, when the voltage drops to 13.6 V, switch K1 closes to ensure sufficient charging of the battery.

The figure 7 presents the battery charging and discharging algorithm

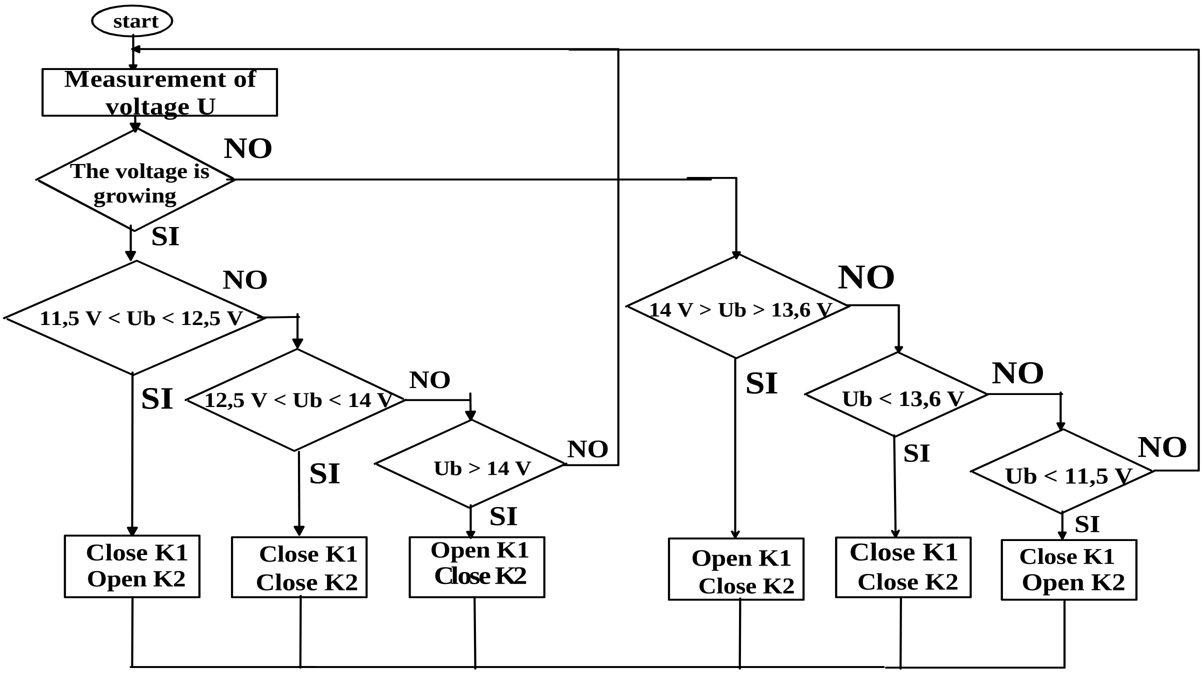

Fig. 7. Battery Charge/Discharge Management Algorithm.

V. DESCRIPTION OF SIMULATION RESULTS USING MATLAB/SIMULINK

This chapter presents the simulation results obtained using MATLAB/SIMULINK to evaluate the performance of the complete solar system. It includes the MPPT regulator with neural control and the battery charge and discharge management algorithm. The objective is to analyze the overall efficiency of the system in tracking the maximum power point (MPPT) while optimizing the utilization of stored energy in the battery. The results will demonstrate the synergy between these components for a high-performance, autonomous, and sustainable solar system. Figure 8 presents the characteristics of the output and input powers of the MPPT regulator with neural control as a function of varying sunlight intensity. The system was subjected to varying sunlight conditions to assess its robustness and effectiveness in tracking the maximum available power. The overall system efficiency was measured at 99.65%, demonstrating the excellent behavior of this MPPT regulator under real-world operating conditions. The curves plotted in this figure illustrate the remarkable performance of the MPPT regulator with neural control in response to sunlight fluctuations. There is a close correlation between the output power and the input power, indicating efficient regulation of the maximum power point. The output power curve faithfully follows the variations in the input power, confirming the system's ability to extract the maximum available power from the solar panel. The exceptional efficiency of 99.65% is a key indicator of the energy efficiency of this MPPT regulator. Such efficiency is of crucial importance for solar applications as it maximizes the utilization of available solar energy while minimizing losses.

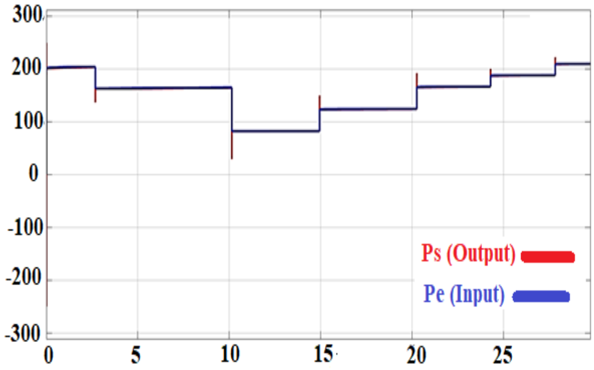

Fig. 8. Evolution of panel power and optimal power

The figure 9 illustrates the evolution of the battery voltage under conditions of good sunlight exposure. At the beginning of the simulation, the voltage increases rapidly as the solar panels generate energy and recharge the battery. We observe a steady rise in voltage, eventually reaching the maximum value of 14 V, indicating that the battery is fully charged. However, one of the most interesting aspects of this curve lies in the observation after disconnecting the solar panels when the battery is at its maximum charge. This demonstrates the efficiency of the battery charge and discharge management algorithm, which prevents overcharging by cutting off the connection with the solar panels once the battery is fully charged. This curve highlights the system's ability to maintain a stable battery voltage and prevent potential damage due to overcharging. This ensures increased battery durability and ensures efficient utilization of captured solar energy.

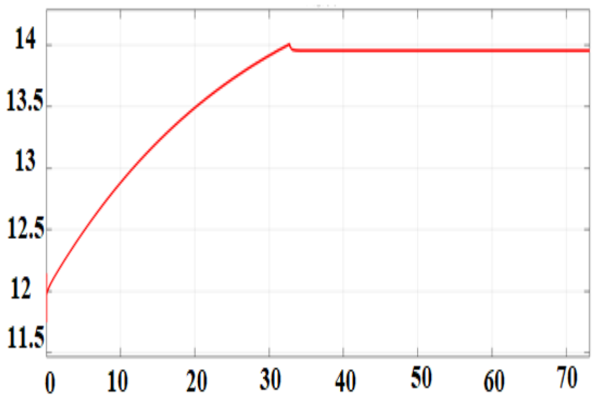

Fig. 9. Evolution of Battery Voltage with Disconnected Load

The curve (figure 10) represents the current intensity's evolution in the load connected to both the battery and the solar panels. Initially, the solar panels supply power to the load, and the battery is being recharged. Once the battery reaches its full charge, the solar panels are disconnected, and the load is solely powered by the battery. As a result, the current intensity decreases and stabilizes at a lower level. This efficient energy management is ensured by the battery charge and discharge management algorithm. These results confirm the effectiveness of the complete solar system in achieving optimal utilization of solar energy and intelligent battery management.

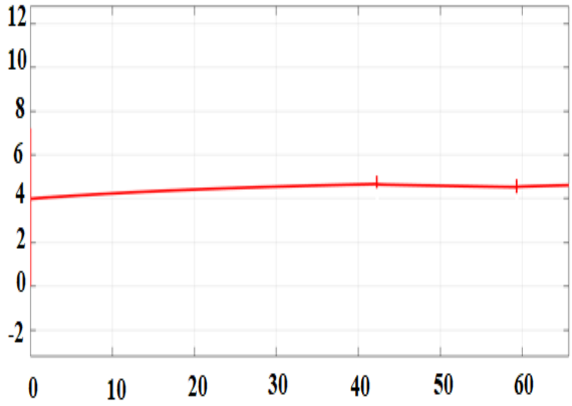

Fig 10. Evolution of current intensity in the load

The figure 11 present the evolution of battery voltage with good sunlight exposure, highlighting several distinct voltage zones, each corresponding to a specific configuration of the solar system. In zone OA, the solar panels are connected to the battery, and the battery charge is increasing. If the voltage reaches 12.5 V, the load is connected to utilize the stored energy. As soon as the voltage reaches 14 V, the solar panels are disconnected to prevent any overcharging of the battery.

Moving to zone AB, the solar panels are disconnected, and the battery directly powers the load, leading to a gradual decrease in voltage. When the voltage drops to 13.6 V, the solar panels are reconnected to resume charging the battery.

In zone BC, the battery is recharged again until it reaches 14 V, at which point the solar panels are disconnected again to avoid overcharging. The zones CD and DE repeat the same process as AB and BC, alternating the battery's charging and discharging while managing the solar panels. Zone EF represents a situation where the solar panels are disconnected, and there is no significant sunlight. The battery continues to power the load, but when its voltage drops to 11.5 V, the load is disconnected to preserve its durability.

Entering zone FG, the solar panels are connected, but there is no sunlight, so the battery cannot discharge into the load as it is disconnected. Finally, zone GH shows the return of good sunlight exposure. The battery charging is resumed, and when its voltage reaches 12.5 V, the load is connected again. When the voltage reaches 14 V, the solar panels are disconnected to avoid overcharging. This curve clearly demonstrates the intelligent and efficient management of the solar system under different sunlight conditions. The alternating between charging and discharging modes, along with protection against overcharging and excessive discharging, ensures optimal utilization of solar energy while preserving the battery and load's lifespan. These results confirm the reliability and overall efficiency of the complete solar system, making it practical and applicable in real-world scenarios.

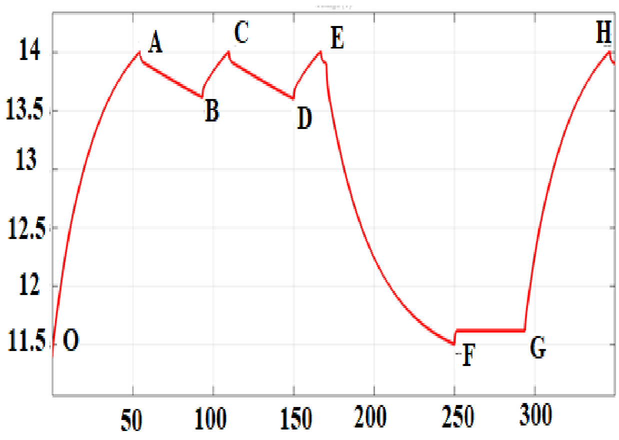

Fig. 11. Evolution of battery voltage

VI. CONCLUSION

In this article, we have explored the optimization of the Maximum Power Point Tracking (MPPT) in photovoltaic solar systems using an innovative approach based on neural control. This promising technology has been demonstrated as an effective solution to maximize the electrical energy production from photovoltaic solar panels, dynamically adjusting the output voltage and current to reach the maximum power point. The results obtained through simulation in MATLAB/SIMULINK have confirmed the superior performance of the neural MPPT control compared to traditional techniques. In addition to optimizing the MPPT, we also addressed the challenge of managing battery charging and discharging, a crucial element in photovoltaic systems. Thanks to the battery charge and discharge management algorithm, we have successfully ensured optimal use of stored energy while preserving the battery's lifespan. This intelligent approach guarantees a sustainable and efficient utilization of solar energy, making the system more reliable and self-sufficient, even in changing environments. By combining neural MPPT control with the battery management algorithm, our photovoltaic solar regulator provides a comprehensive solution to optimize the overall system performance.

This approach is particularly relevant for photovoltaic systems installed in environments where weather conditions can vary significantly, such as mobile systems or rural setups. Our study has demonstrated that using neural MPPT control in conjunction with a battery charge and discharge management algorithm is an effective and reliable approach to maximize solar energy utilization and ensure optimal battery management. This solution offers new perspectives for optimizing photovoltaic systems as part of the transition towards sustainable and environmentally-friendly renewable energy sources. Future research could focus on the practical implementation of this system in real-world applications, as well as continuous optimization of the neural control and battery management algorithm for even better performance.

DECLARATION

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Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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AUTHORS PROFILE

Dr. Ibrahima Gueye I have nineteen (19) years of experience in Technical Education and Vocational Training. I hold a Ph.D. in Automation, Production, Signal and Image, and Cognitive Engineering from the University of Bordeaux. Additionally, I have a Master's degree in Renewable Energies and Electrical Systems, as well as two pedagogical certificates. I have taught in technical and vocational training at the National Center for Professional Qualification (CNQP) in Dakar. CNQP is a public institution with commercial and industrial objectives, responsible for providing initial training to young individuals who have not received vocational education, as well as professional development for those already in the workforce. Moreover, CNQP offers training services upon request from companies. To fulfill this mission, CNQP adopts a pedagogical approach that involves a continuous liaison with businesses to define their training and development needs. For more than a decade, I have been actively involved in this training system, starting as a trainer and later becoming the Director of Initial Training. Currently, I am an associate professor at the Higher National School of Technical and Vocational Education. In this institution, I actively contribute to the training of teachers destined for technical and vocational education. In the Department of Industrial Techniques at ENSETP, I am responsible for the electrical engineering program as well as a recently established Mechatronics program at the undergraduate level. For both programs, under the department's supervision, I handle the complete management of teaching and learning activities, including scheduling, organizing training, and coordinating all pedagogical activities. In addition to my pedagogical activities, I am also actively engaged in research. I am affiliated with the Energy, Water, Environment, and Industrial Processes Laboratory (L3EPI) at the Polytechnic Superior School of Dakar, where I collaborate with a team of researchers on the design of electronic systems involved in the energy chain of photovoltaic solar systems (inverters, charge controllers, etc.). Our aim is to optimize the transfer of electrical energy produced and promote the local manufacturing of electronic systems.

Dr. Abdoulaye Kebe is a teacher-researcher at UCAD in Dakar. He holds a doctorate in physics from the University of Paris Sud in 2013. He holds a Certificate of Aptitude in Technical Vocational Secondary Education (CAESTP). His research is mainly oriented towards renewable energies. He is the author of several publications in the field of energy conversion In addition, he obtained a master's degree in Analysis, Design and Research in the Field of Engineering Technologies in Education (ACREDITE) at the University of Cergy Pontoise in 2016. He teaches electrical engineering and is also involved in the professionalization of student teachers by taking charge of modules related to specialty didactics. He is currently Director of ENSETP

Dr. Oumar Dia has been a Teaching-Researcher since October 2022 in the Department of Industrial Sciences and Technologies (STI) at the Higher National School of Technical and Vocational Education of Cheikh Anta Diop University in Dakar (ENSETP/UCAD). He teaches automation, industrial computing, classical and renewable energy production, electricity, and electrical networks. He holds a Doctorate degree from Iba Der THIAM University of Thiès in Science and Technology, specializing in Photovoltaic Solar Energy. In 2012, he obtained a Certificate of Aptitude for Technical Vocational Secondary Education Teaching from ENSETP/UCAD. He served for nine years at the Electrotechnics Department of the National Center for Professional Qualification as a teacher, where he was the head of the Computer and Industrial Automation (I.I.A.) section and the head of the continuing education department. His research is mainly focused on renewable energies, power converters, signal processing, and intelligent systems. He has published in several international journals.
Nothing is to be believed anymore; everything is to be known!

Dr. Moustapha Diop was born in Senegal, in 1987. He received the Master's and Ph.D. degrees in Electrical systems and renewable energies from ESP, UCAD, in 2014 and 2018, respectively. He is currently an Assistant Professor at the STI Department, ENSETP, UCAD, and a permanent researcher at the 3EPI Laboratory of ESP. His current research is basically focused on power converter, control systems, and renewable energies. Dr. Diop has published some papers.