Energy and Power Engineering, 2022, 14, 509-522
https://www.scirp.org/journal/epe
ISSN Online: 1947-3818
ISSN Print: 1949-243X

Solar Controller with Automatic Search Technology for the Maximum Power Point with Autonomy Display

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How to cite this paper: Sall, M., Sow, O., Gueye, S., Diop, G., Habiboullah, L., Wade, M. and Sissoko, G. (2022) Solar Controller with Automatic Search Technology for the Maximum Power Point with Autonomy Display. *Energy and Power Engineering*, **14**, 509-522.
https://doi.org/10.4236/epe.2022.149027

Received: August 21, 2022
Accepted: September 27, 2022
Published: September 30, 2022

Abstract

In our work, we have been interested in conducting technological research on the use of photovoltaic energy for lighting. In fact, we have produced a stand-alone photovoltaic system with automatic search for the maximum power point, consisting of a photovoltaic module, a solar regulator, a storage battery and a digital control by microcontroller. The solar field is connected to the input of the regulator and the battery to its output. When the battery voltage is lower than the regulation voltage, the controller operates the photovoltaic generator at maximum power Pmpp and transfers this power to the output. In addition to the protection function, this regulator ensures tracking of the maximum power point (MPPT) and allows the photovoltaic generator to deliver its power whatever the variation of climatic conditions (sunshine and temperature). The main role of the solar regulator is the continuous monitoring of the state of charge of the battery to ensure its protection against overcharging and excessive discharging, the coupling and decoupling of the user as well as its maintenance. The principle of operation is based on controlling a DC-DC converter by a rectangular "PWM" signal generated by a PIC16F874 microcontroller which also controls the entire system. The results of simulation after realization were presented to illustrate the operation of the regulator by curves.

Keywords

Index Terms-Battery, Charge/Discharge, Regulator, PIC16FC874

1. Introduction

Using a renewable energy source, the photovoltaic generator [1] is a central component of the system. Other renewable sources such as hydraulic or wind turbines as well as thermal engine generators (e.g. diesel generators or cogeneration plants) can provide additional power.

The Solar Regulator-Charger is an advanced battery charger with automatic maximum power point search (MPPT) for off-grid photovoltaic (PV) systems. The regulator incorporates an intelligent search algorithm that optimizes energy recovery by photovoltaic (PV) panels while providing charge regulation to prevent battery over-discharge.

The battery charging process [2] has been optimized to extend battery life and improve system performance. It is also equipped with a battery temperature sensor [3].

The objective of this work is the realization of a solar regulator based on PIC16F874 microcontroller [3] with automatic search technology of the maximum power point with autonomy display intended for the control of the state of charge of the batteries.

Accumulators to protect them.

1.1. Photovoltaic Effect

The photovoltaic effect corresponds to the appearance of a potential difference between the two sides of a semiconductor junction under the action of light radiation [4].

This photovoltaic conversion (**Figure 1**) is carried out using photovoltaic cells generally made of crystalline silicon [4].

1.2. Design of a Photovoltaic System

Solar energy is an inexhaustible and clean source of energy because it does not cause emissions of gases harmful to the environment. It propagates in space in

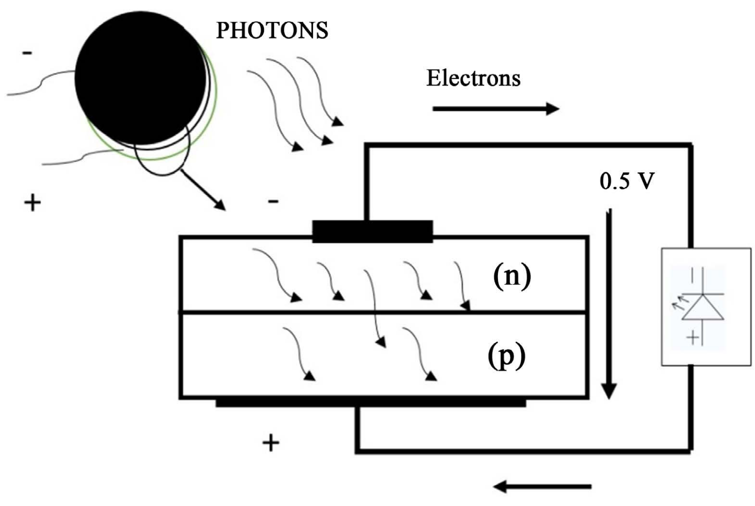


Figure 1. Operating principle of a photovoltaic cell.

the form of photons and which is available everywhere and constantly [4] [5] [6].

A photovoltaic system comprises the various elements indicated by **Figure 2**, where each element must be determined according to technical and economic constraints.

1.2.1. Photovoltaic Module

Optimal use of the photovoltaic module requires adapting the electrical quantities to the needs of the application and also to environmental conditions: the temperature and intensity of solar radiation [6].

1.2.2. Photovoltaic Module

Optimal use of the photovoltaic module (**Figure 3**) requires adapting the electrical

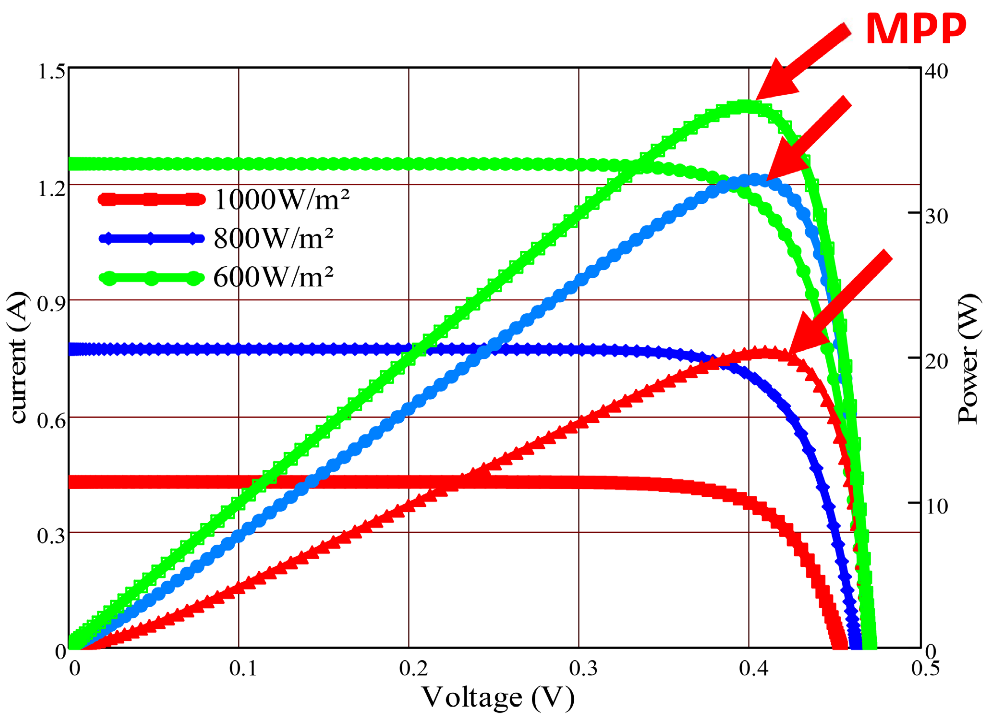


Figure 2. Network with current-voltage characteristic of a solar cell.

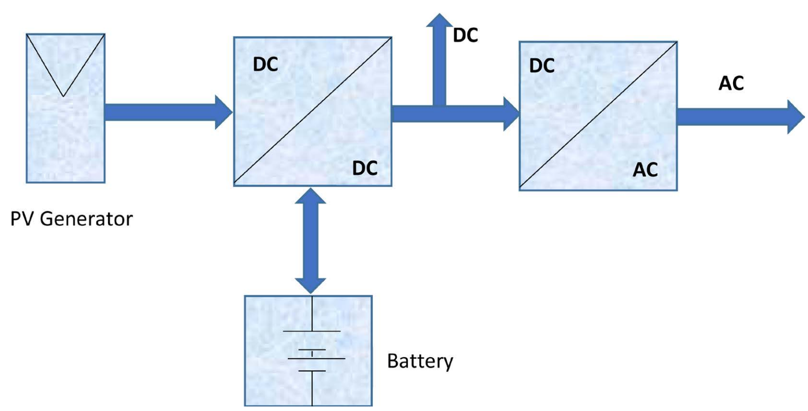


Figure 3. Block diagram of a photovoltaic system with storage battery.

quantities to the needs of the application and also to environmental conditions: the temperature and intensity of solar radiation

2. Presentation and Implementation

Presentation of the P.O-type MPPT method

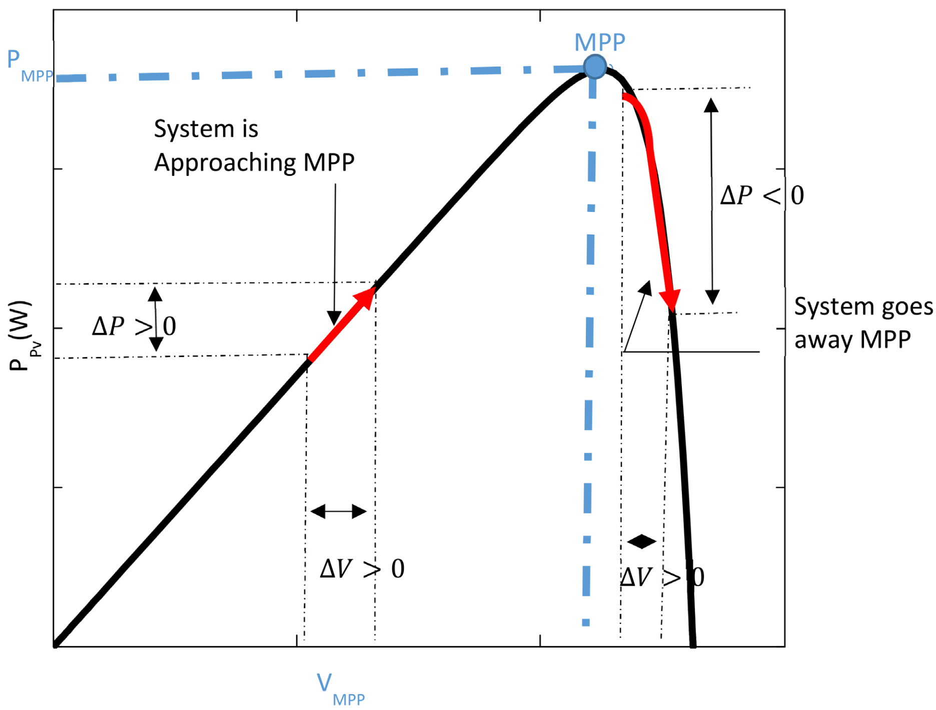
A photovoltaic generator is a generator whose characteristic I = f(U) is strongly nonlinear. In consequently, for the same amount of sunshine, the power delivered will be different depending on the load. A controller MPPT is used to control the static converter, re-linking the load (a battery for example) and the panel photovoltaic, so as to permanently supply the maximum power at load.

The Disturbance and Observation (P & O) method is the fastest maximum power search method used. It is an iterative method allowing to obtain the maximum power point (MPP)

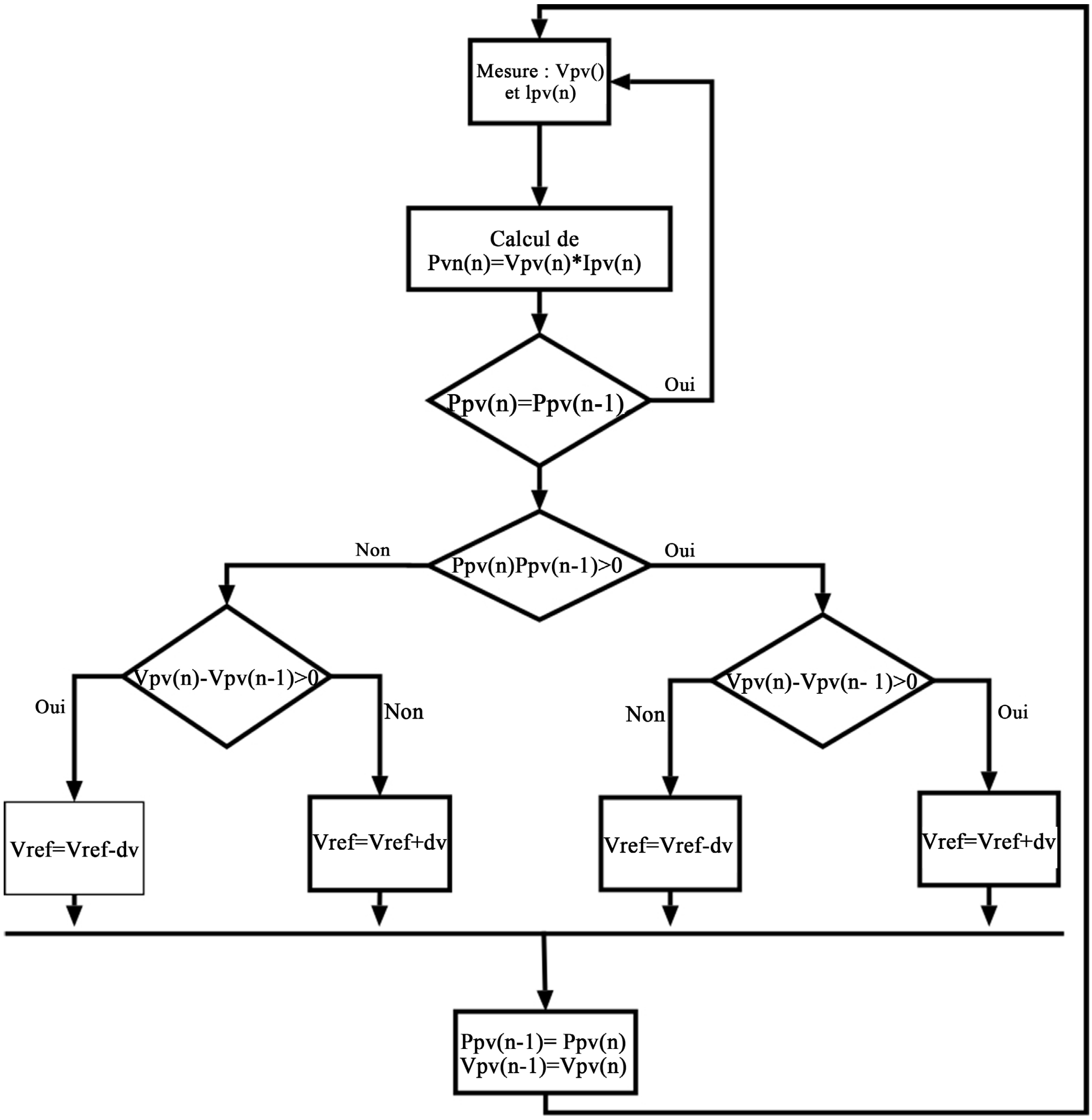
The principle of the Disturbance and Observation method can disturb the voltage V PV of the generator by a low amplitude around its initial value and to analyze the behavior of the power variation P PV which results.

If a positive increment of the voltage V PV generates an increase in the power P PV, this means that the operating point is at left of the PPM (see **Figure 4(a)**). If, on the contrary, the power decreases, this implies that the system has exceeded the PPM. A similar reasoning can be made when as the voltage decreases.

Based on these various analyzes of the consequences a voltage variation on the P PV characteristic (V PV) it is then easy to locate the operating point-ment with respect to the PPM, and to make the latter converge deny towards maximum power through an order of appropriate command.



(a)



(b)

Figure 4. (a) Picture. Maximum power point tracking; (b) Picture. Power point tracking algorithm maximum.

In summary, if following a disturbance voltage, the PV power increases, the direction disturbance is maintained. Otherwise, she is reversed to resume the convergence towards the new PPM calf. The algorithm presented in Figure 4(b) illustrates the PO méthode.

The synoptic diagram (Figure 5) explains the operating principle of the device.

The power block ensures the transfer and conversion of power between the two sides, source and load. It is mainly made up of:

1) An energy source made up of a single type module whose electrical characteristics "current-voltage" and "power-voltage" have been simulated thanks to its parameters introduced in a program developed in Matlab.

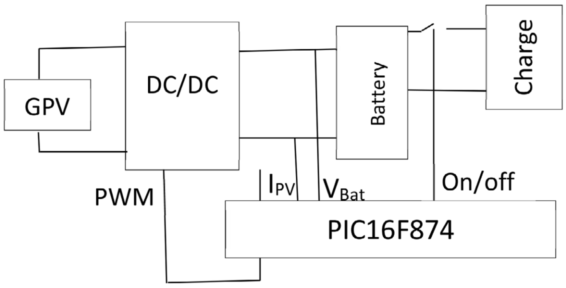


Figure 5. Synoptic diagram of the model produced.

2) A DC-DC converter type adjustable buck Converter Module 8 - 35 V to 1.5 - 24 V [7].

3) A "Deep-Cycle" [8] [9] lead acid solar storage battery with a nominal voltage of 12 V and a capacity of 100 Ah.

The control unit allows the battery voltage to be controlled and the charging current to be varied. It is mainly constituted by the integrated circuit which is the PIC16F874 driven by a quartz oscillator of frequency 20 MHz.

• The batV voltage is measured through the RA1 pin configured as A/D input, a voltage divider made up of resistors R15, R16 and R25 was used.

V + + + =

The measured value will then be converted into a digital nV value through an internally integrated analog/digital converter. The battery voltage check is visualized by a series of five LEDs, the color of which is chosen to facilitate the interpretation of operation.

Led1: "yellow"; When it is on, it indicates the correct configuration of our peak. It does not turn off until the Led5 turns off.

Led2: "orange"; when it is on, it indicates that the battery voltage is higher than LDVV and the charging process is in the first "bulk charging mode Charge".

3. Construction Diagrams

The work was carried out on the software Eagles [10]. The prototype produced by the photoengraving method using a UV insulator [11]

4. Realization of the Experimental

SYSTEM The production of our solar regulator was carried out in the laboratory, from Vocational and Technical Training Center Senegal/Japan and at the Laboratory of the University Institute of Technology of Thiès.

This regulator consists of a DC-DC converter and a control unit based on a PIC16F874, as shown in **Figure 6** and **Figure 7**.

This regulator has a block of control elements based on a microcontroller of the Microchips 16F874 family Connection to the battery a temperature probe.

To avoid charging the battery at too high a temperature and to adjust the charging voltage accordingly.

Battery life display: After switching on, the display indicates the battery voltage

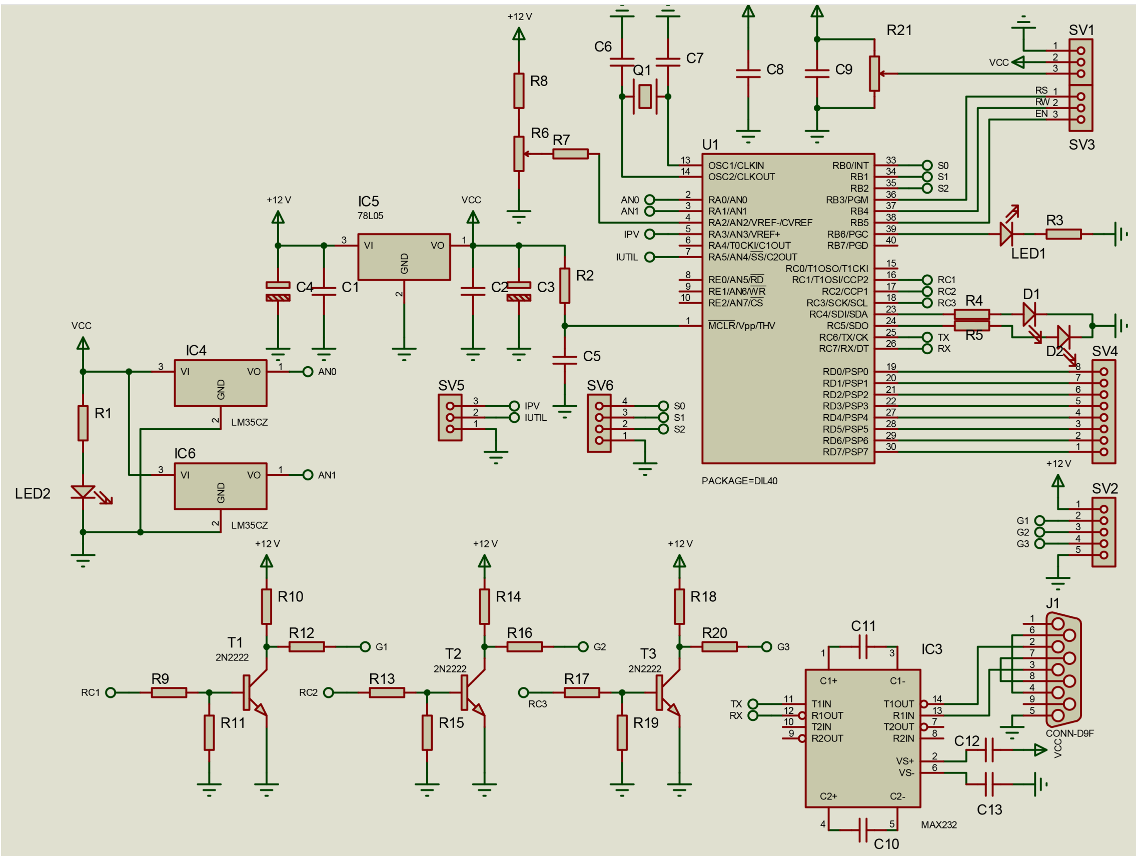


Figure 6. Wiring diagrams.

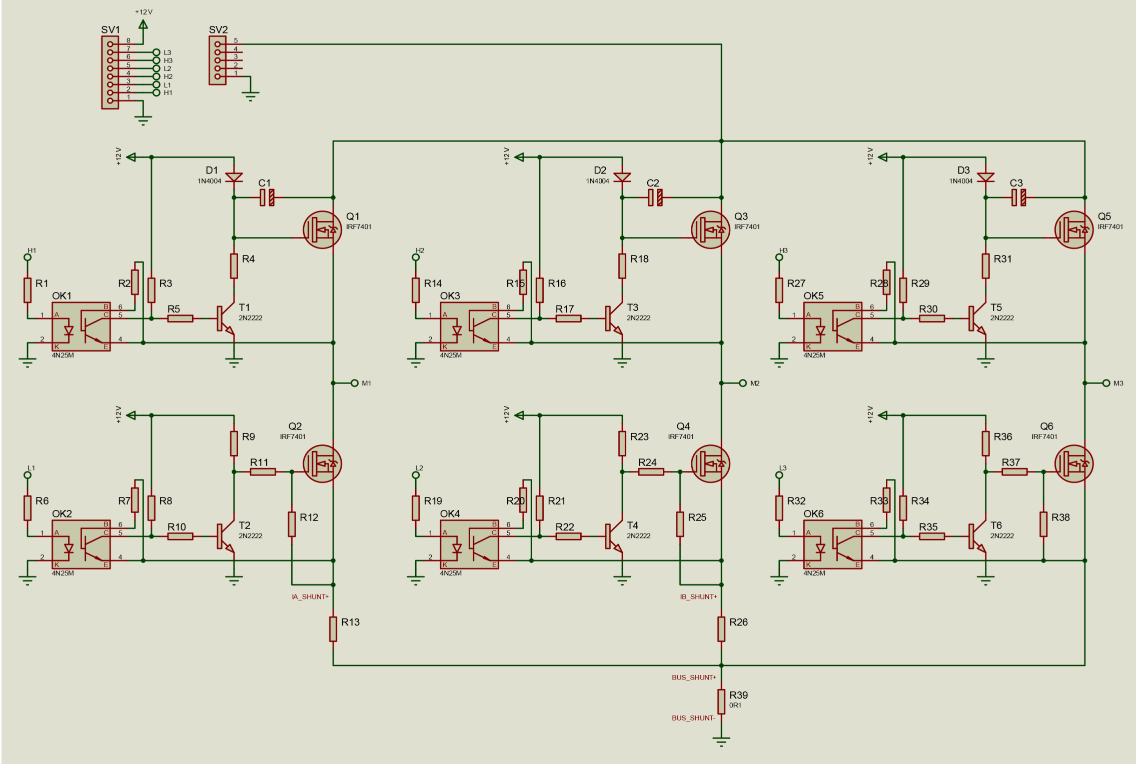


Figure 7. Wiring diagrams.

by lighting up the indicator if the battery is connected.

The red fault light flashes as soon as a fault is signaled by the charger.

The autonomy calculation takes into account the aging of the battery and the instantaneous consumption.

Autonomy is considered:

- As zero voltage if the battery voltage is less than or equal to 11.7 Volts 00:00 display;
- As maximum if the battery voltage is greater than 13 Volts full display;
- If the battery is charging Charge display.

5. Presentation of the Organization Chart

The load algorithm to be implemented is shown schematically by the flowchart below.

The program is written in assembly language using an MPLAB IDE 'development tool from Microchip. [12] [13] [14]

6. Experimental Results and Discussions

Simulation under Proteus

- The program is written in assembly language and it has been successfully simulated in MPLAB.

The model produced in PROTEUS is as follows

- The oscilloscope allows you to view the state of the various PORTC bits to which transistors have been associated here represented by LEDs for a first test.
- We obtain the following flowchart:

Thus we obtain the following signals:

Conclusion: The device carried out as well as the simulated program made it possible to successfully validate the first test.

The operation of the realized regulator is managed by the hex code injected into the flash memory of the PIC16F877. This code is obtained after compiling the program source in the MPLAB IDE.

7. Analysis of the Results

The operation of the regulator is achieved. It is managed by the MPlab IDE program [8] [9]. It is injected into the 16 flash 'memory of the PIC16F874 via a writter [5] [6] Full Drawings in **Figure 8** we have the image of the realization in **Figure 9** we have the operating flowchart of the system in **Figures 9-12**, we have the results of the curves on the oscilloscope. In **Table 1** we have the table which describes the ports and the connected equipment and in **Figure 13** we have the regulator which works with lamps [14] [15] [16] [17].

8. Conclusion

In order to test and verify our work, tests have been carried out, we have exposed

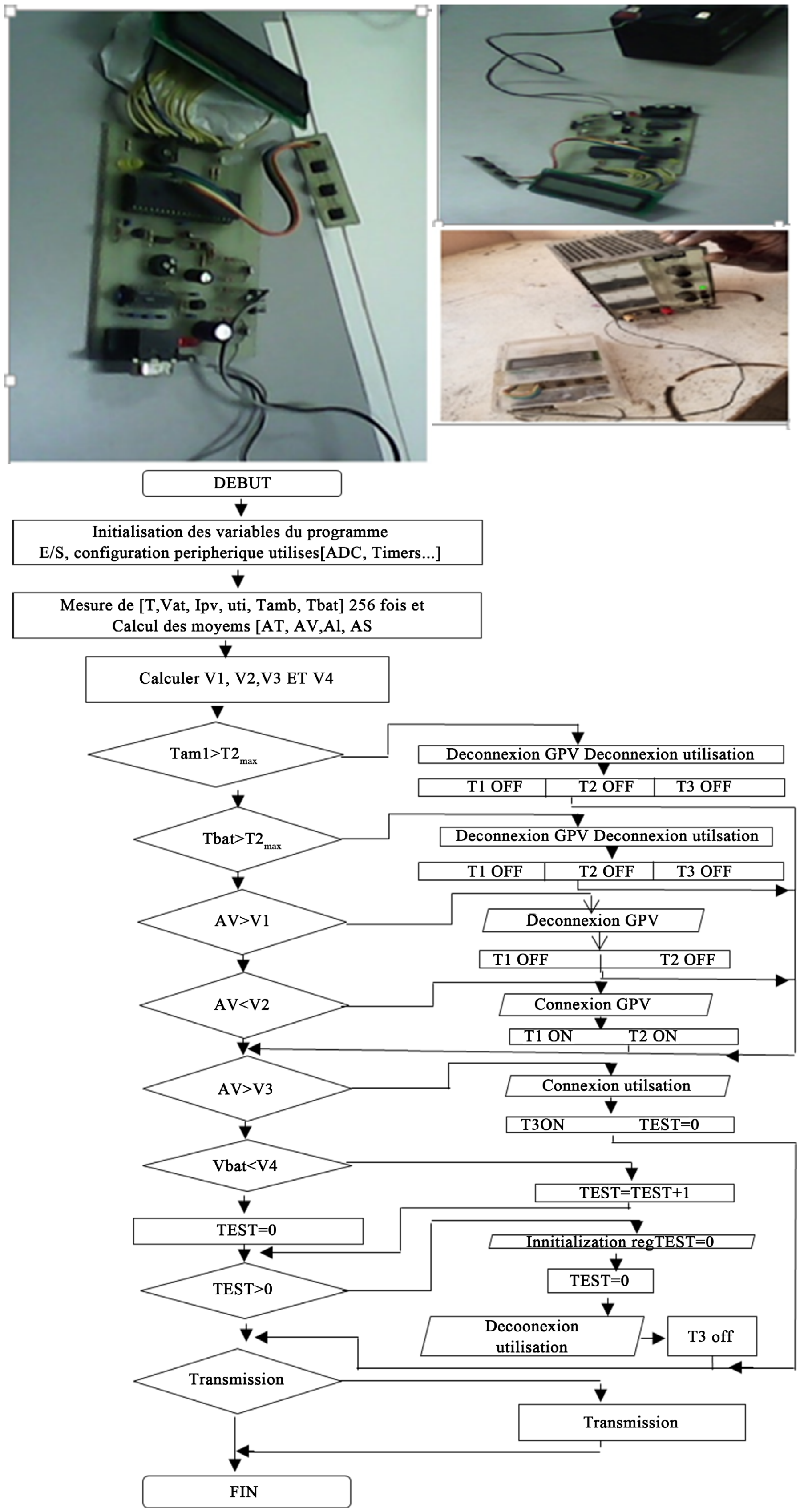


Figure 8. Practical realization of the device on the printed plate.

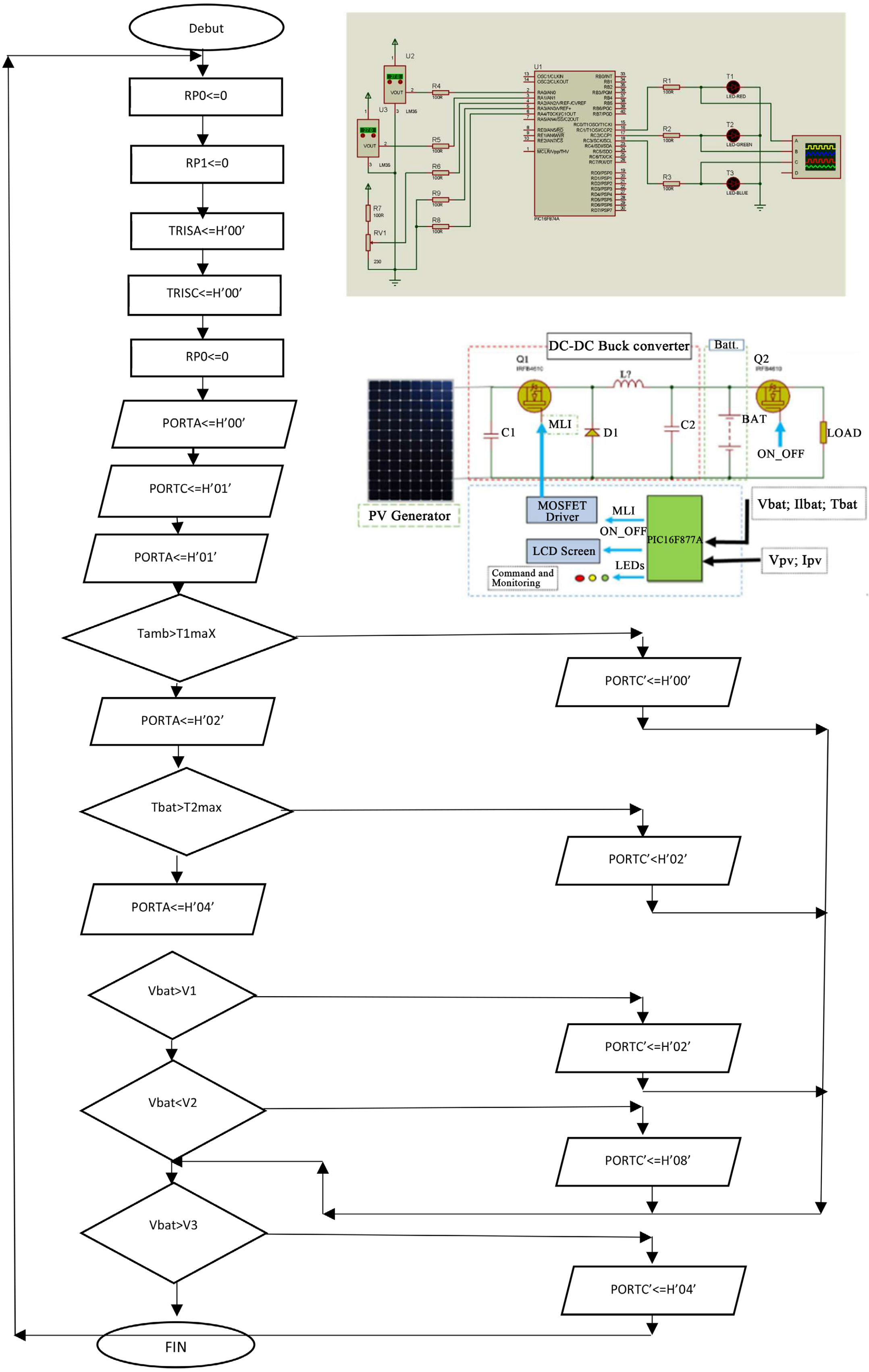


Figure 9. Simulation on proteus.

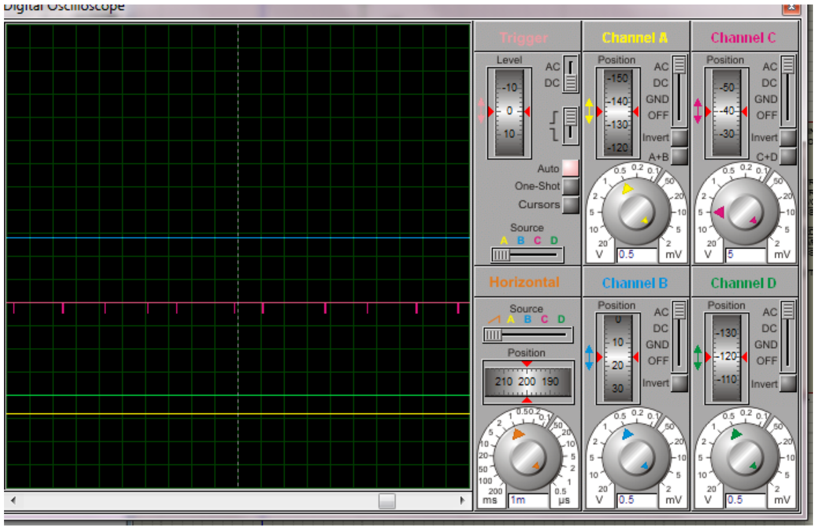


Figure 10. For T1on.

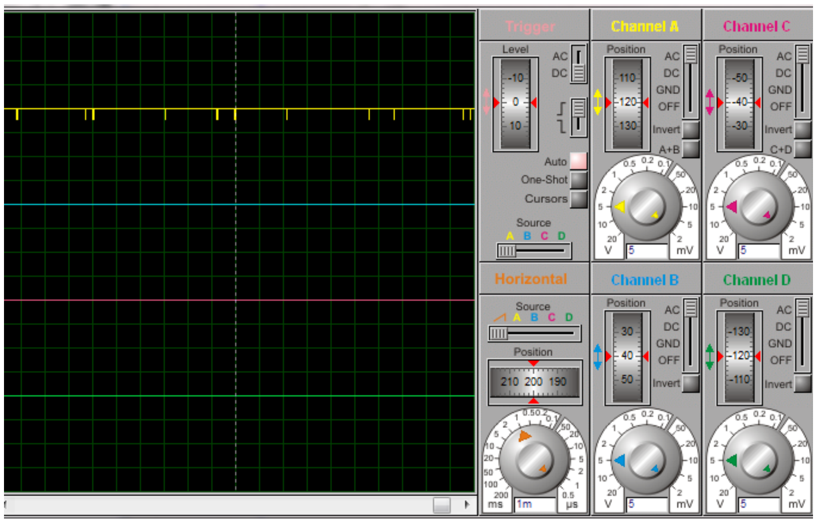


Figure 11. For T2on.

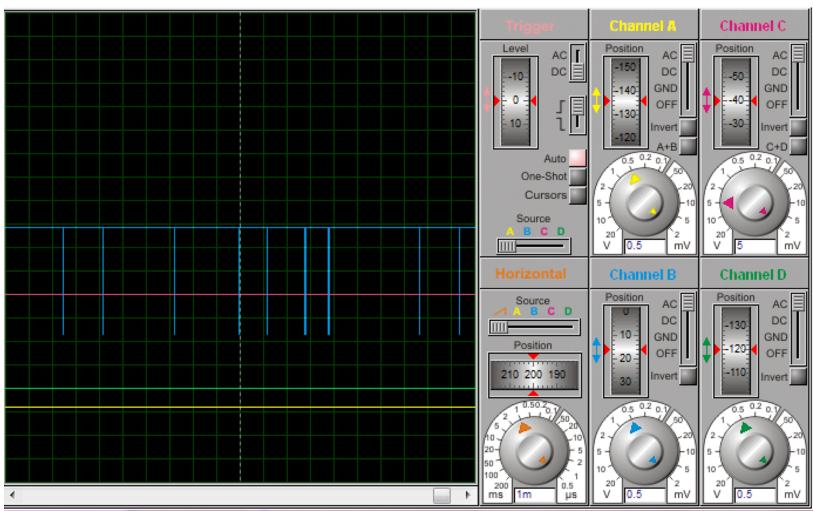


Figure 12. For T3on.

Table 1. From the following.

Valeurs mis au niveau du PORTC H'	T?	Description
02	T1	Déconnexion panneaux et utilisation
04	T2	Connexion utilisation
08	T3	Connexion panneaux

Figure 13. Complete intelligent system operation—Battery charge.

the oscillograms of the various PWM control signals generated by the PIC16F874 which can control the opening and closing of a typical DC-DC converter, "buck" to check the state of charge of an accumulator battery.

The development of control of programmable circuit systems has occupied the field of modern technology, which has prompted us to choose pic microcontrollers which are more reliable, less bulky and can be flashed easily in order to ensure several tasks in the system.

Afterwards, we approached the control part, where we determined the constituent elements of the DC-DC converter in order to adapt the current supplied by the photovoltaic panel to the battery. First we based on the steps follow to configure the PIC16F877 so that it can generate the PWM signals necessary to drive the opening and closing of the "Mosfet" power element of a typical DC-DC converter "Buck".

We can conclude that the results obtained are satisfactory, taking into account the limitations of the material and the means at our disposal.

In this work, we developed a charge/discharge regulator for 12 V and 24 V lead-acid batteries. This controller, designed around the PIC16F877A microcontroller, is based on a three-stage charging algorithm in which a first constant current charging phase is followed by two phases at constant voltage. The proposed algorithm also incorporates protection against deep discharges and temperature drifts. In addition to the protective functions, the proposed controller incorporates a control and monitoring component.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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