

Development And Realization of a Power Strip Equipped With charge/discharge Regulator And Digital MPPT Command In Photovoltaic System using GSM Technology

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ABSTRACT- *The paper presents the results related to the design, the realization and the experimentation of an autonomous PV system equipped with a solar regulator, digital MPPT command and power strip. The solar regulator controls the state of charge of batteries, and at the same time the energy supplied by photovoltaic panels is optimized to the maximum using a DC/DC converter of Boost-type , a digital MPPT command and a power strip. The results obtained during days with weather perturbations, showed the robustness of the PV system (stability, optimal functioning of PV panels),and good control of charge of batteries under the maximum of energy supplied by the PV panels, The programmable power strip, DC/DC converter and digital MPPT command constructed with the relays and controlled by the microcontroller allows to control and optimize the whole system through wireless transmission and determinate the state of charge of battery and provide protection against the overcharge and the deep discharge.*

Keywords- *Digital MPPT (maximum power point tracking); Regulator, PV(photovoltaic) system; , Efficiency; optimization of photovoltaic energy*

I. INTRODUCTION

Photovoltaic energy is one of the promising energy sources, sustainable and clean. Currently, much of work is done on PV system, which exploits this energy for different applications. In the autonomous PV applications, the main problem is the storage of energy in lead-acid batteries , which have a low energy density and low life cycle . Because of their cost-efficiency ratio , they are considered as the preferred choice for autonomous PV applications. The batteries overcast with several types of degradations and that because of their ageing , they represent the weakest element of a system statement. The control and the optimization of the lifespan of the battery pass by an optimization of strategies management of charge and discharge by regulators .that existed on the market are usually serial or shunt and only ensure a direct connection between the PV panels and batteries. They are characterized by a control parameters of the charge and the end of discharge fixed by the manufacturer , not adapted to the standard whole of batteries used, and secondly a charge rate that is not precise in PV applications, and not exploiting the maximum power point of the PV panels. These results in insufficient battery charge (well below 60%), overcharge or deep discharge , which degrades the batteries, and the loss of electrical power supplied by PV panels . Moreover, using different techniques and algorithms for charging and discharging batteries: constant current (CC), constant voltage (CV), ON / OFF.... These techniques often present difficulties of completely charging batteries and protected from causes of ageing . In this context, in order to protect and control with precision the charge of the various batteries and to exploit the maximum power supplied by the PV panels, we propose the design, the implementation and the experimentation of a digital solar controller equipped with MPPT (maximum power point tracking)command and power strip. The main objective of our work is to achieve the MPPT ensuring maximum charge determination with precision protection of battery and optimizing operation of the system through wireless transmission. These electronic modules are controlled by the micro-controller and follow a GSM(global system for mobile communications) technology for consummation of energy conservation and management in the system.

Abbreviation

C	Nominal capacity of battery (Ah)
DoD	Depth of discharge (%)
I_{BAT}	Current of charge battery (A)
$I_{CH(MAX)}$	Maximum current of charge the battery (A)
I_{OCT}	Current of over charge terminate
I_{PV}	Panel photovoltaic current (A)
Le	Irradiance (W/m ²)
MPP	Maximum Power Point
MPPT	Maximum Power Point Tracking
n	Number of cells in battery of 2V nominal volt
PIC	Programmable Interface Controller
Ppv	Power provided by PV panel (W)
PV	Photovoltaic module
PWM	Pulse-width modulation
S	Surface of PV module (m ²)
SoC	state of charge (%)
STC	Standard test conditions
V_D	Voltage limit of discharge (V)
V_{BAT}	Voltage of battery (V)
V_{CO}	Open circuit voltage (V)
V_{FLT}	Floating voltage (V)
V_{PV}	Panel photovoltaic voltage (V)
V_R	regulation voltage (V)
α	Duty cycle (%)
η_{conv}	Converter efficiency (%)
η_{panel}	PV Panel efficiency (%)
η_{sysPV}	System PV efficiency (%)
GSM	Global system for mobile communication

II. BLOCK DIAGRAM DESCRIPTION

The block diagram of the PV system equipped with the MPPT command, power strip, load and the regulator is shown in Fig1. This system is designed to charge the stationary batteries from the PV panels. It contains:

A. Photovoltaic Panels And Battery

They consist of two PV Shell assembled in parallel to form a module. Two batteries are connected in series, according to the wattage of the panel being installed.

B. Block Of Power

It ensures adaptation and transfer of energy provided by panels to the solar batteries. It is composed of a DC/DC boost type converter, to operate in continuous mode. The power switch of converter is controlled by a PWM (Pulse Width Modulation) signal, generated by the regulator and controlled by microcontroller, which can vary with duty cycle.

C. MPPT Regulator

It ensures the control of state of charge by an algorithm for setting control of Threshold values for state of charge of the batteries to struggle against causes of ageing, degradation and also to charge battery by the MPPT algorithm.

D. Control Block And Acquisitions

It contains mainly a control and treatment unit of data, using PIC microcontroller. The PIC includes and manages all tasks predefined by the program injected. Its main role is to make treatment of captured values, generation of PWM and square signal for pulsed charging current[2]. As shown in the Fig.1, the acquisition of the data of system is carried out by voltages dividers for capturing the voltage, and the amplifiers for capturing the image of current by shunt resistors. The measured values are Send to mobile through wireless communication.

E. Protection Block

It is inserted to protect the converter and ensure the charging battery when the MPPT control is faulty. In the complete stop of the MPPT control; this detects the failure and connects the panels directly to the batteries.

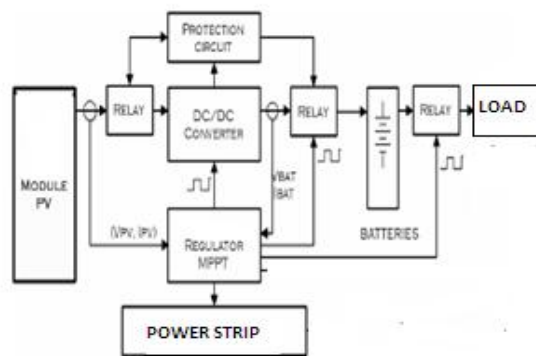


Fig 1. Synoptic diagram of an autonomous photovoltaic system equipped with regulator, MPPT ,power strip and interface of acquisition and control.

F. Relays

Three powers relays (I, II and III) supporting high currents, controlled by microcontroller are used in the system. The first relay connects the converter to the battery during the charging process . When the battery is charged, it disconnects the PV system to reconnect to the other battery and continues the charging cycles. The second relay connects (disconnects) the battery to the load, when the rate of discharge (DoD) Or V_{BAT} (voltage of battery) is higher (lower) than the thresholds(fixed by the user) .The threshold $V_{BAT} = V_D$ is voltage limit of discharge, which depends upon the rate of discharge current V_D . The DoD rate is of 50% for the opened lead acid batteries with thin plates, 80% for battery electrolyte gel. The third relay ensures the connection of protection block to the relay I when the MPPT is failing.

G. Power Strip

The principle of this device is to impose to the consumer to control and manipulate the whole system through GSM (global system for mobile communications) which is an open, digital cellular technology used for transmitting mobile voice and data services. This programmable power strip constructed with the relays and GSM technology is controlled by the microcontroller through a graphical user interface from MPPT controller.[1]

III. CHARGE CYCLE

In this work, we used the algorithm , adapted for ensuring charge balance in the batteries and maintaining load balance in AC loads as in Fig 2. The improvement is to set the appropriate parameters (Voltage Regulator V_R , Floating Voltage V_{FLT} .) after tests and measurements on batteries, and use the maximum power supplied by the PV panels through the MPPT control during the phases of charging process. The different stages are:

A. Boost charge

This phase is characterized by a battery voltage $V_{bat} < V_R$ (Voltage Regulator) and fast recovery of capacity. This is charged by the maximum current supplied by the PV panels after running the MPPT algorithm as in Fig 4. Usually the capacity of the battery recovered in this phase is about 80% - 90%. As shown in Fig 4 the principle of the MPPT [4] is based on the calculation of the derivative of the power that determines its sign, and the execution of the conditional structure

If the power derivative is positive, a variable named “Var” in our program will be evaluated, to increase the duty cycle if Var equal to 1, or decrease it if Var equal to 0. If the derivative power is negative, we have to determine the variable H status (status of the timer).

Var change its statue if the variable H equal to 1, and then we initialize the variable H to 0. If not, no operation is performed. Then, Var will be determined to increase the duty cycle if Var equal to 1 or decreased if Var equal to 0.

B. Absorption charge:

when the battery voltage reaches V_R to avoid overcharging, the regulator complete the charge by regulating the voltage of the battery around V_R , by applying current pulses variable. The end of this phase is determined when the charging current reaches 5% to 10% of the maximum charging current ($I_{CH(MAX)}$)

C. Floating charge:

To keep the battery entirely charged and avoid deep discharge when the battery does not power the load, the regulator applies to the battery a floating voltage V_{FLT} . The charging current pulsated become very weak and just needed to keep the battery voltage around V_{FLT} .

The variation of state of charge SoC, and depth of charge DoD with open circuit voltage (V_{oc}), is obtained using equations (1) and (2)

$$V_{oc} = n * (2.116 - DoD * (2.116 - 1.95)) \quad (1)$$

$$\text{state of charge} = 1 - DoD \quad (2)$$

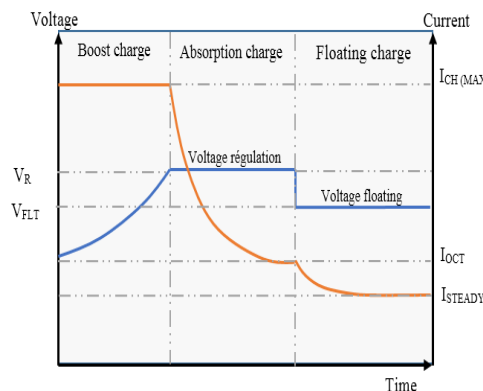


Fig.2. Strategy of control the state of charge of the battery with three phases.

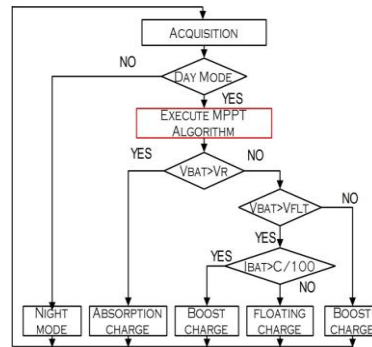


Fig. 3 Algorithm of control and management the state of charge of battery.

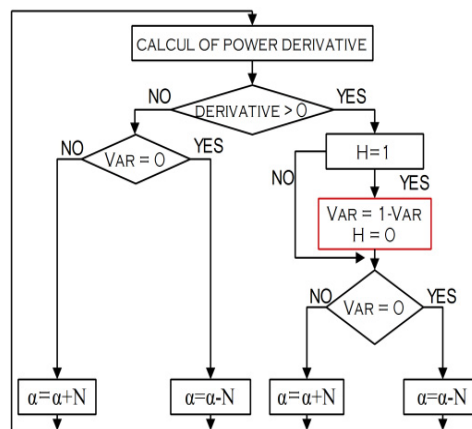


Fig. 4 MPPT Algorithm [4]

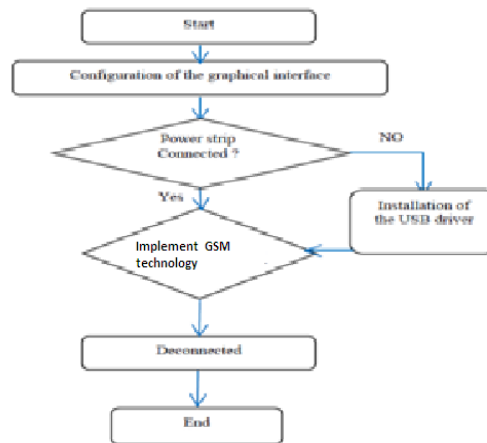


Fig. 5. The algorithm of power strip.[1]

IV. RESULTS AND DISCUSSION

In the program execution, we set the parameters for our batteries as per the panel and battery being used. The statement of the typical values (V_{BAT} , I_{BAT}) during a charge cycle is shown in Fig 6. Which appears as a functioning dependent on time designed using protues software:

When $t_0 < t < t_1$: This phase is characterized by an increase of V_{bat} , and the battery is charged with maximum current supplied (Boost charge) until $V_{bat} = V_R$. This voltage characterizes a SoC about 80%. During this phase, the control MPPT intervenes to maximize the power delivered by the PV panels.

When $t_1 < t < t_2$: To improve charging and protect the batteries against overcharging when $t > t_1$, V_{BAT} is regulated around V_R by pulsed currents during increasing time intervals. This shows the charging current decreases average value, until it reaches the value $I_{BAT} = I_{OCT}$, and the SoC is greater than 90%.

When $t_2 < t < t_3$: during this period of time, the batteries are completely charged, and the floating charge is activated to compensate for self-discharge by application of a current pulses, increasingly short and spaced, the V_{BAT} is stabilized at V_{FLT} . This phase manifests when the batteries are used as backup power source. Once the battery is charged the regulator can be let connect without risk of overcharge.

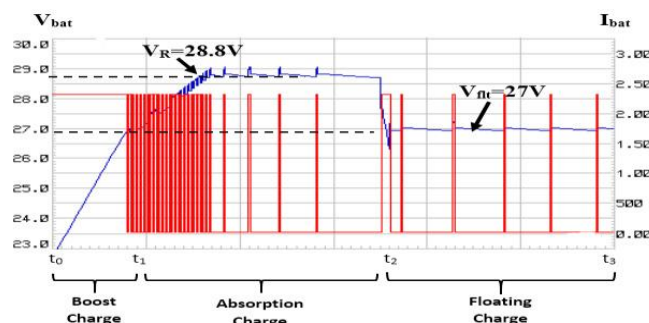
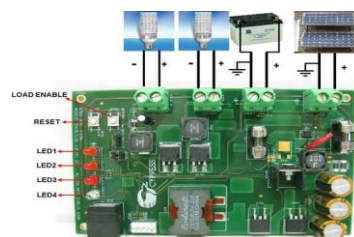


Fig. 6. Voltage (V_{bat}) and current (I_{bat}) of battery charge

To validate the set of blocks of the regulator designed in this work,, during cloudy days when irradiance undergoes rapid changes during charging solar batteries. In the control algorithm, we have set the parameters for our batteries as 100Ah capacity for a 50W panel, the system management control using unit transfer of data using 8051 microcontroller designed powerstrip as in fig 7.



Fig7 A) power strip message display unit B) power strip sim insertion unit



C) MPPT charge controller

We represented the typical statements of results: electrical quantities battery (V_{BAT} , I_{BAT} and SoC) using protues software, the typical result and setup of powerstrip, electrical quantities PV panels (Panel Photovoltaic Voltage V_{pv} , Panel Photovoltaic Current I_{pv} , and power by PV panel P_{pv}) the losses of PV panels and efficiencies of converter and the complete PV system.

In these plots, we have taken into account the power losses caused by parallel connection of PV panels. These losses of about 10 to 15%. The expressions of converter and the global system efficiencies are given by:

$$\eta_{conv} = \frac{P_{bat}}{P_{PV}} \quad (3)$$

$$\eta_{sysPV} \approx \eta_{panel} \cdot \eta_{conv} \quad (4)$$

$$\eta_{panel} = \frac{P_{PV}}{L_e S} \quad (5)$$

All these results show:

The batteries charge in three phases:

When time varies from 0 to 14 h: the voltage $V_{BAT}=28.2$ V increases to V_R and the current I_{BAT} , is substantially constant= 2 . The tracing of the state of charge SoC, shows that more than 85% of capacity is been recovered with maximum charging current. This is the phase Boost charge.

When the time varies from 14 to 19 h: the $V_{BAT}=28.2$ V reaches the voltage V_R (regulation voltage)and the regulator increases the battery by current pulses of variable duration to reach the SoC higher than 95%. In this case, the current means of charge decreases to the value $I_{OCT} = 0.7A$ (phase of absorption).

When the time varies from 19 h to 22 h: the regulator maintains the battery voltage around $V_{FLT} =27V$ by current pulses of variable duration around 0.4 A. .This is achieved by the regulator to compensate self-discharge. This is the phase: floating charge During functioning of the PV panels, an optimal experimental ones on electrical quantities panel, and the duty cycle α of the PWM signal, generated by the MPPT control. During the phase of the floating charge, since the output current is very low , then the converter functioning in discontinuous regime. MPPT control optimizes the function of PV panels in discontinuous regime.

□ During these phases, the losses of power supplied by the PV panels are less than 8%, the efficiencies of converter and the global system are very satisfactory (90% and 9%). During the floating charge (time greater than 19 h), since the battery is important, the charge current is low. so the efficiencies of the converter and the global system degrades.

All these results show that the battery is charged according to determined by the Algorithm , taking into account parameters of our batteries. The battery is completely charged (over than 95%) by the maximum power supplied by the PV panels. Moreover, to protect the battery against the electrolysis of water, the regulator reduces the voltage at the end of charging to the V_{FLT} and simultaneously compensated a self-discharge. The power strip act as a control for the whole system to control ,coordinate, report fault through message in mobile,in accordance with the algorithm. The low losses of power supplied by the PV panels (<8%), good efficiencies of the converter and global PV system (90% and 8%) show the good functioning of the MPPT control algorithm and maintain energy consumption.

V. CONCLUSION

The design, the realization and the experimentation of an autonomous PV system equipped with a solar regulator,digital MPPT and power strip ensures the following of MPP with a MPPT command and controls of the state of charge of batteries with the regulator. The results show that: The MPPT regulator ensures and controls the state of charge of the batteries. The presence of adaptation between the PV generator and batteries allows quick charging and reduces the losses caused by the direct connection. Thus, a gain in time and efficiency resulting from improvement strategy and control algorithm. The power strip equipped with the system allows to control, coordinate, report fault independently all the operation of the system through wireless transmission. The low losses of power supplied by the PV panels show the feasibility and energy consumption of the PV system designed and realized during this work

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