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Solar Charge Controller with a Data Acquisition System Based on Arduino

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Abstract. This paper presents the design of a solar charge controller with the Maximum Power Point Tracking (MPPT). The proposed design uses a microcontroller (Arduino Nano) which is able to acquire the current and voltage measurements, of the panels and the battery and to apply a certain algorithm which allows to deduce the PWM cycle that will power the converter DC-DC (buck converter) to control the charge and discharge of the battery. The system incorporates a WiFi module for data acquisition and can be used to study the state of the battery and help for maintenance. The results obtained from the implemented on hardware demonstrate the change of the duty cycle with the change in load and thus mean the variation of the buck converter output voltage and current controlled by the algorithm of charge.

Keywords: Solar energy, MPPT, Charge controller, DC-DC converter, Battery, Microcontroller.

1 Introduction

Global demand for energy is rapidly evolving and natural energy resources such as uranium, petroleum and gas decreased due to a great diffusion and development of the industry in recent years. The increase in energy costs and environmental constraints are pushing for the development of technological solutions allowing better control of the resources and the exploitation of the renewable energies in specific photovoltaic energy. Photovoltaic energy is a clean and renewable energy resource. Moreover, solar panels are a silent energy producer because there is absolutely no noise when converting sunlight into electricity, [1].

In order to exploit solar energy to power the DC loads and to store electricity, a solar charge controller is needed to monitor the State of charge of the batteries and protect them from overcharging and full discharge (deep discharge). This monitoring and this permanent protection helps to extend significantly the performance and life of the batteries. This controller is used in many areas such as systems not connected to the electric network, ensure the autonomy of an embedded system, monitor solar installations...

This paper includes a MPPT circuit in order to extract the maximum power from the solar panel using the algorithm P&O (perturbation & Observation) and the DC /DC Converter.

2 PROPOSED SYSTEM

The block diagram shown in the figure 1 represents the complete system. It contains a solar panel, DC-DC buck converter, Arduino Nano, battery, and Loads. The solar panel is used to generate the current and voltage from which the voltage will be converted by a DC-DC converter. After calculating the power from the data transmitted by the current and voltage sensors, we used perturb and observe algorithm to calculate the maximum power point.

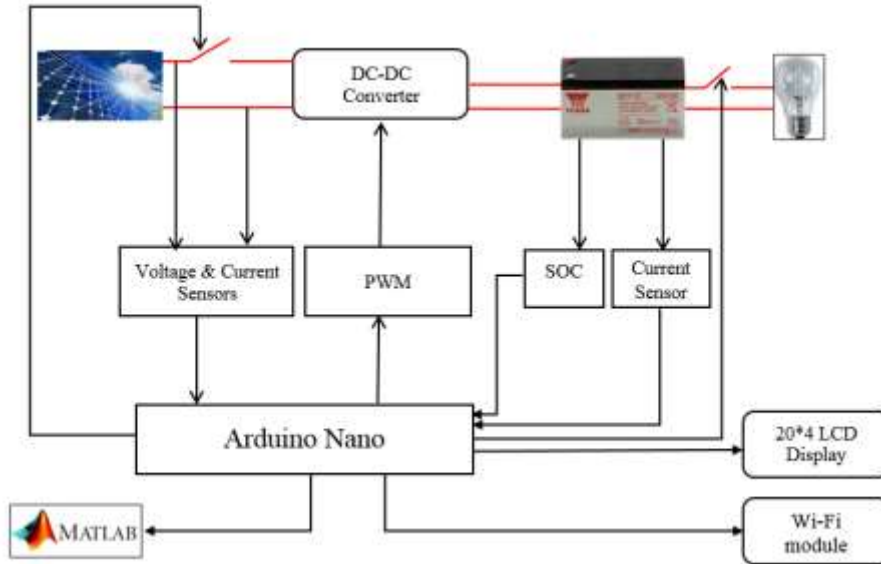


Fig. 1.Block diagram of the whole system.

2.1 DC-DC Buck Converter

The buck converter is used to convert the higher DC input voltage from PV Panel to lower or equal DC output voltage suitable for charging the battery and supplying the DC loads. The DC-DC buck converter circuit is shown in Figure 2.

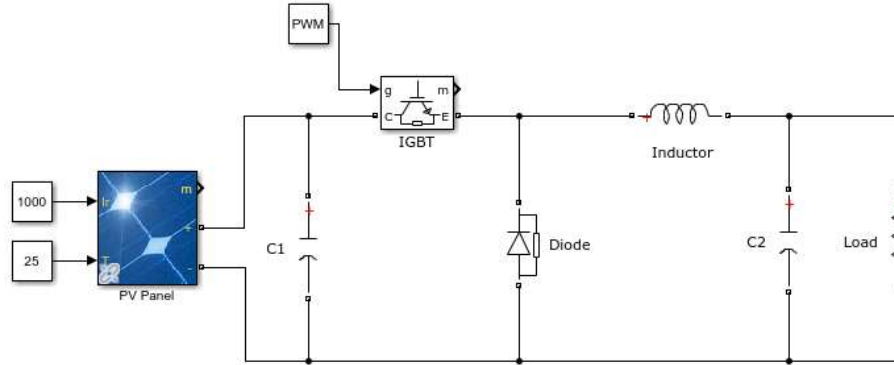


Fig. 2.DC-DC Buck converter

After designing the buck converter, we need to find the values of the inductor and the capacitor. It is most critical part in designing as the efficiency of the converter depends on these values. For a solar panel of 50W and a 12V battery, the value of the inductance $L = 33\mu\text{H}$ and the capacitance value $C2 = 220\mu\text{F}$, [2].

2.2 MPPT Algorithm

Maximum Power Point Tracking (MPPT) algorithms are needed to maximize the power output at any moment. Many MPPT techniques have been proposed in the literature. In this controller we chose worked with the method perturb and observe due to its easy implementation. Note that the point of maximum power $P(n) = V(n) I(n)$ is obtained when the condition $\frac{dP}{dV} = 0$ is accomplished, regardless of the sun irradiance, [3]. In this work polycrystalline Silicon panel is used. Electrical characteristics of the PV Panel (Values at STC (AM1.5, 1000W/m², 25°C)).

- Maximum Power (Pmax): 60W
- Open-circuit voltage (Voc): 26.4V
- Short-circuit Current (Isc): 3.00A
- Maximum Power voltage (Vmp):22.0V
- Maximum Power current (Imp):2.73A
- Tolerance (Tol): +3/-3%

The figure 4 show the Flowchart of the Perturb and Observe method.

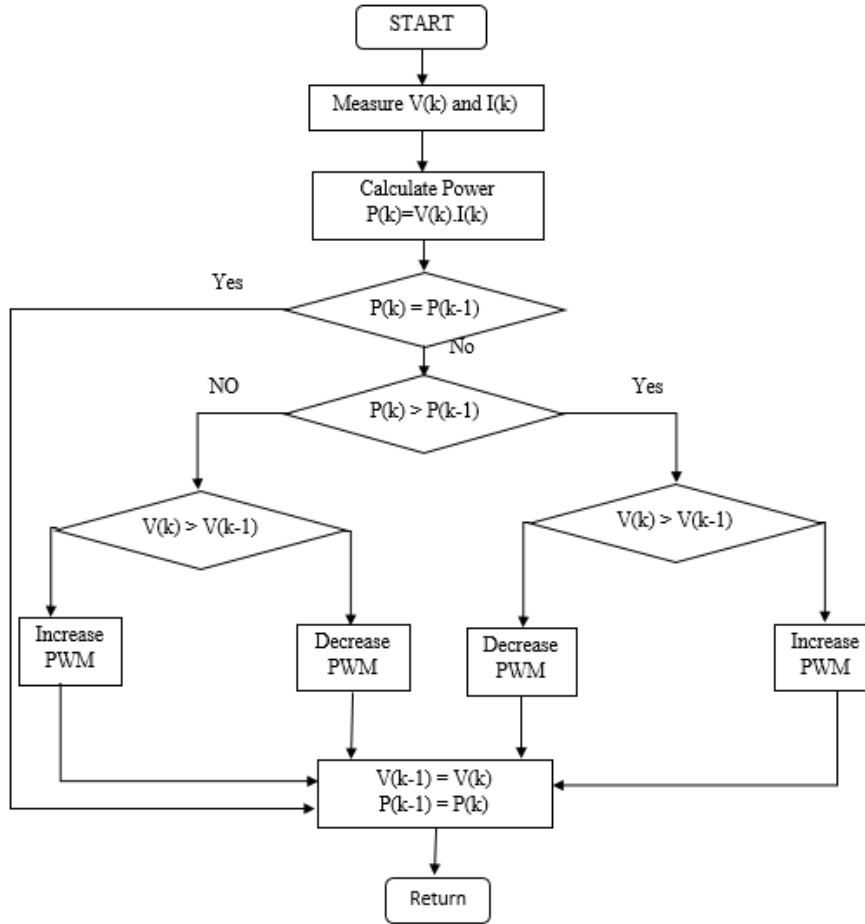


Fig. 3.The flowchart of the P&O method

3 EXPERIMENTAL RESULTS

A prototype was built using various electronic components, this prototype was tested block by block before the realisation of the global circuit. The DC-DC converter is the most critical part, the experimental results are presented in the figures 5 and 6. The LCD screen was used to display the results obtained. The observations ahead show the results of the hardware implementation.



Fig. 4.Hardware Prototype

3.1 Buck Converter

In order to verify the design efficiency of the solar charge controller system, an experimental DC-DC Buck converter was built. The PV array was replaced by a battery of 12V. The PWM signal was generated with Arduino Nano board.

For V_{in} an input voltage and to obtain an output voltage V_{out} , the duty cycle is:

$$\alpha = \frac{V_{out}}{V_{in}}$$

Figures 5 and 6 illustrate the PWM signal and the output voltage of the DC-DC converter for the different Duty cycle.

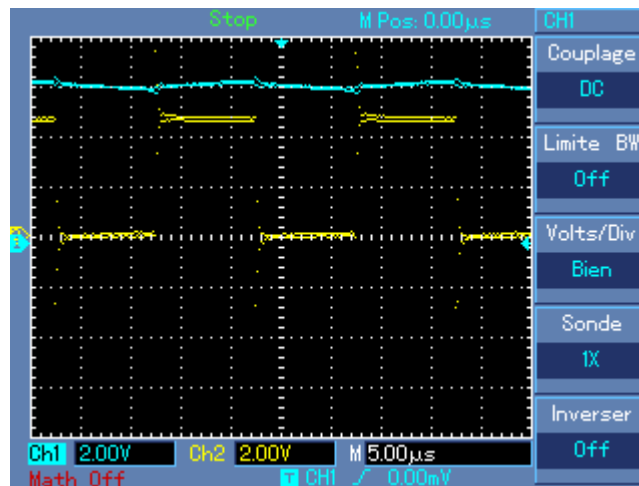


Fig. 5.Output voltage of the DC-DC converter and the PWM signal with duty cycle equal to 0.5

3.2 Charge Controller

[illegible]

Fig. 7. Flowchart the proposed control strategy for the battery charger

ON State - the solar watts input is between the low and minimum solar power but not low enough to go into the off state. In this state the Load turns OFF and the Battery charging turns ON.

OFF State - The charger controller goes into this state when there is no more power being generated by the solar panels. In this state the Battery charging turns OFF and the Load turns ON if the battery voltage is higher than the minimum value.

BULK State – The Solar energy is greater than the minimum value. This is where we do the bulk of the battery charging and when we execute the Peak Power Tracking algorithm. In this state, we try to run the maximum current that the solar panels generate in the battery. The Load turns ON and the Battery charging go into the Bulk state.

FLOAT State – the battery voltage gets to the maximum Value. In this state we try and keep the battery voltage at maximum by adjusting the PWM value. The Load is turned ON and the Battery charging go into the Float state.

Figure 9 and 8 shows the experimental results of the charge controller in Matlab.

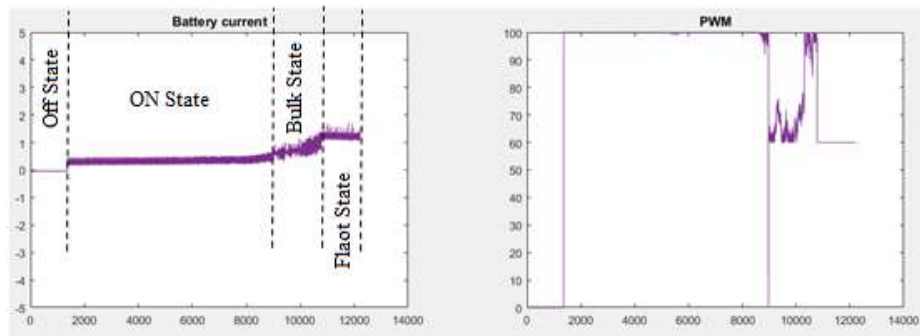


Fig. 8.Battery Current and PWM signal curves

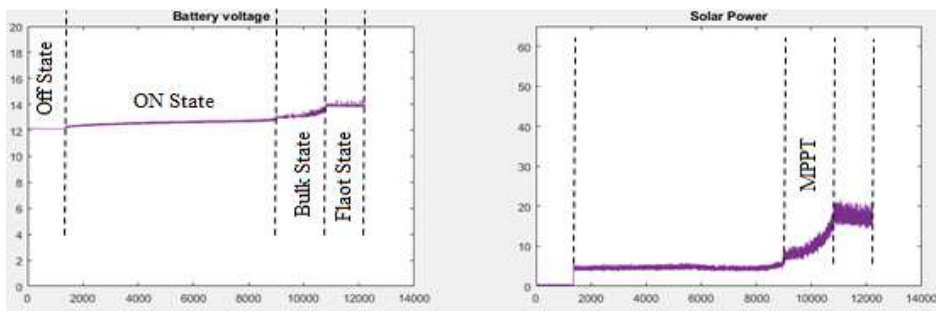


Fig. 9. Battery Voltage and Solar Power curves

Data acquisition system helps to collect data about solar PV system and battery for many purposes. Figure 10 illustrates variation of PV power and battery voltage with time.

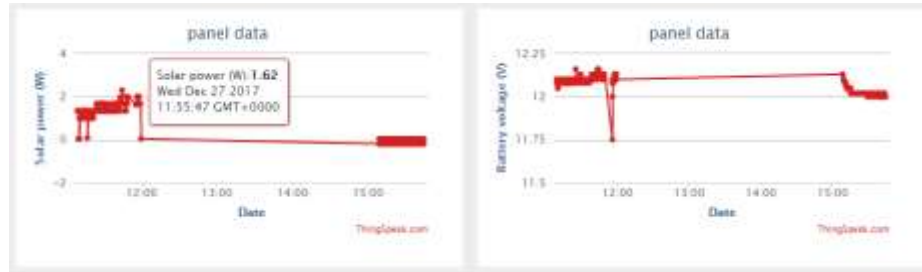


Fig. 10. Solar Power and Battery voltage curves with time.

4 Conclusion

The realisation of this solar charge controller using Arduino was done at low cost but effective for small DC loads, and we can use this controller to implement other algorithms or to make comparisons. In this paper we have presented the experimental results using the Matlab environment (panel power, current and voltage of the battery, state of charge controller, PWM signal).

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