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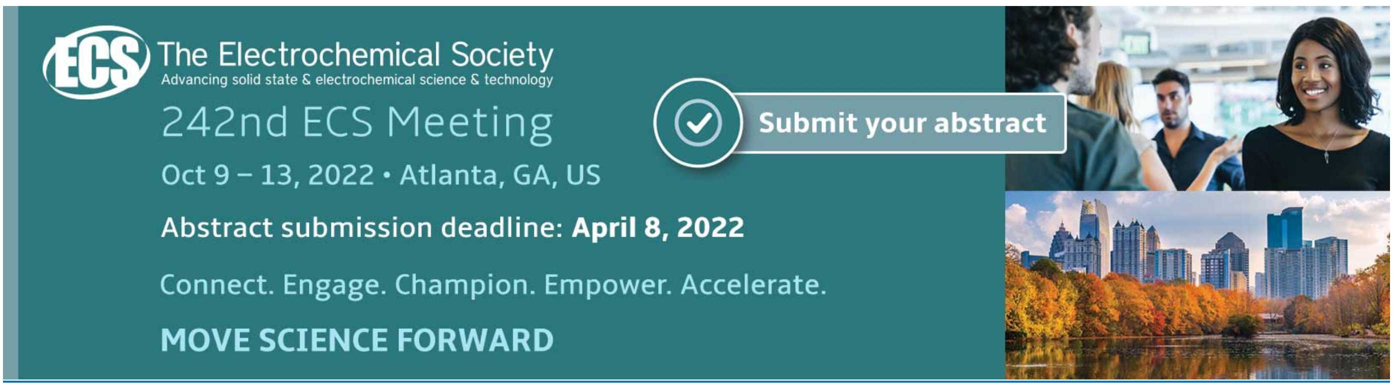

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Implementation of Maximum Power Point Tracking (MPPT) Solar Charge Controller using Arduino

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Abstract— the platform Arduino with a number of sensors standard can be used as components of an electronic system for acquiring measures and controls. This paper presents the design of a low-cost and effective solar charge controller. This system includes several elements such as the solar panel converter DC/DC, battery, circuit MPPT using Microcontroller, sensors, and the MPPT algorithm. The MPPT (Maximum Power Point Tracker) algorithm has been implemented using an Arduino Nano with the preferred program. The voltage and current of the Panel are taken where the program implemented will work and using this algorithm that MPP will be reached. This paper provides details on the solar charge control device at the maximum power point. The results include 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 MPPT algorithm.

Keywords — Solar Energy, MPPT, Charge controller, Arduino Nano, Battery.

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 help 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...

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This paper includes an 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 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 use perturb and observe algorithm to reach the maximum power point.

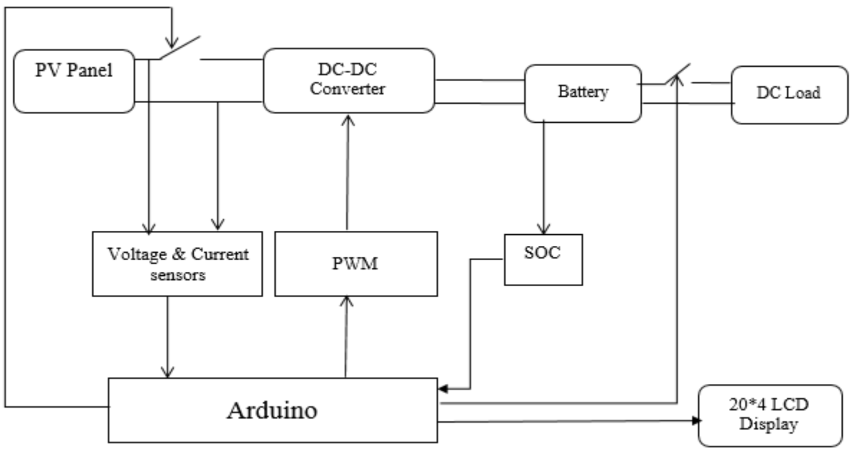


Figure 1. Block diagram of the whole system

2.1 DC-DC Buck Converter

The buck converter produces a lower average output voltage than DC input voltage for charging the battery and supplying the DC loads. The DC-DC buck converter circuit is shown in Figure 2.

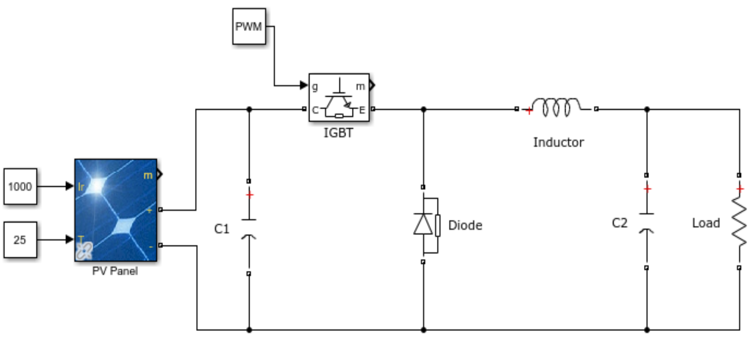


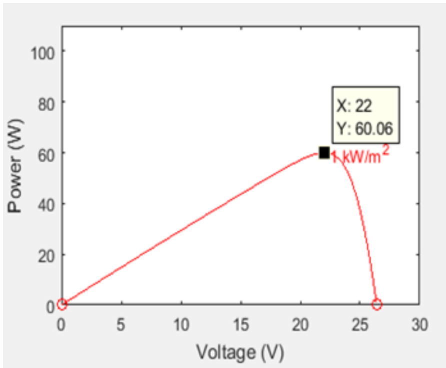
Figure 2. DC-DC Buck converter

After designing the buck converter, we need to find the values of the inductor and the capacitor. It is most critical part as the efficiency of the converter depends on these values. For a solar panel of 60W and a 12V battery, the value of the inductance L = 33uH and the capacitance value C = 220uF, [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. It uses the P-V characteristics P = f (V) of the PV module shown in fi gure 3. 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 solar 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%



gure 3. P-V characteristic curve Ppv = f (V) of PV modules

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

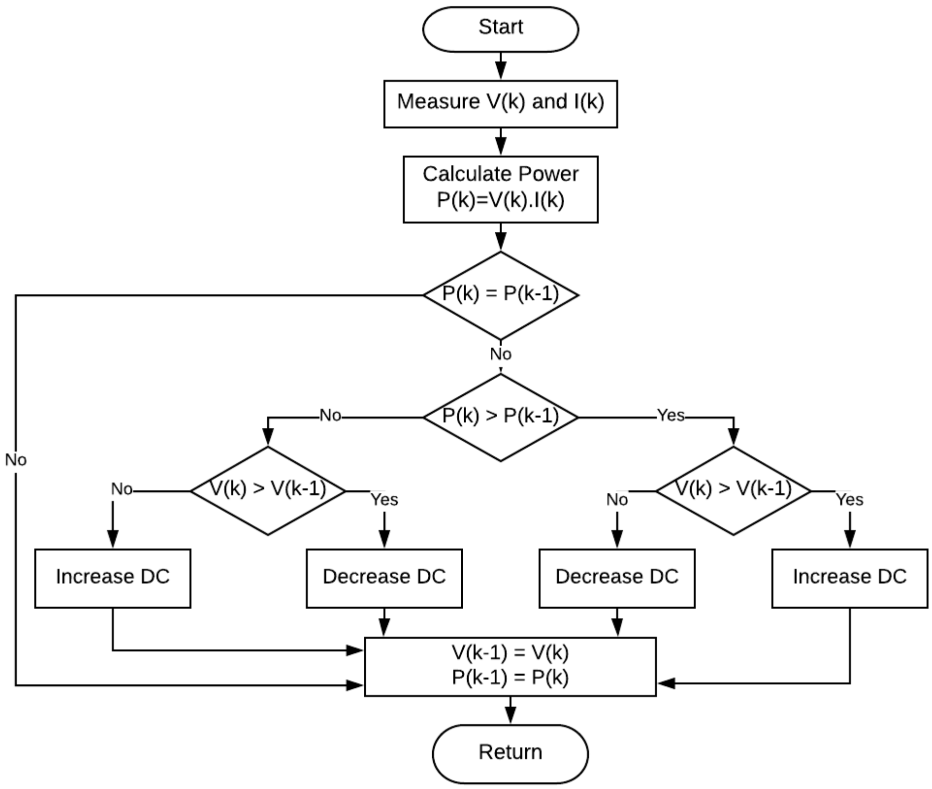


Figure 4. The flowchart of the P&O method

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3. Experimental Results

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

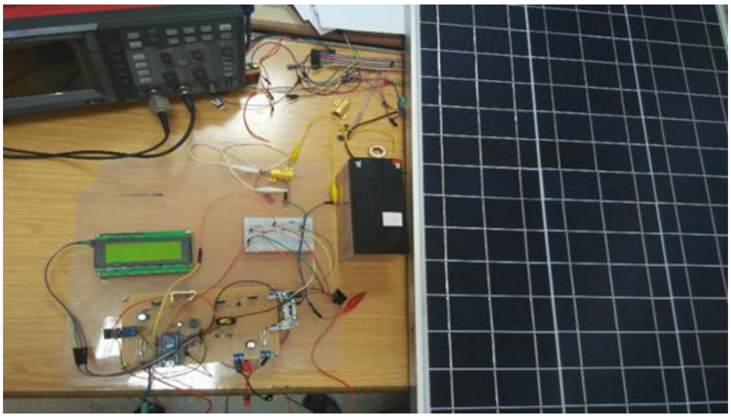

Figure 5. Hardware Prototype

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.

The output voltage can be controlled by the duty cycle with the following expression: $\alpha = \frac{Vout}{Vin}$
Figure 6 shows the PWM signal and the output voltage of the DC-DC converter for the different Duty cycle.

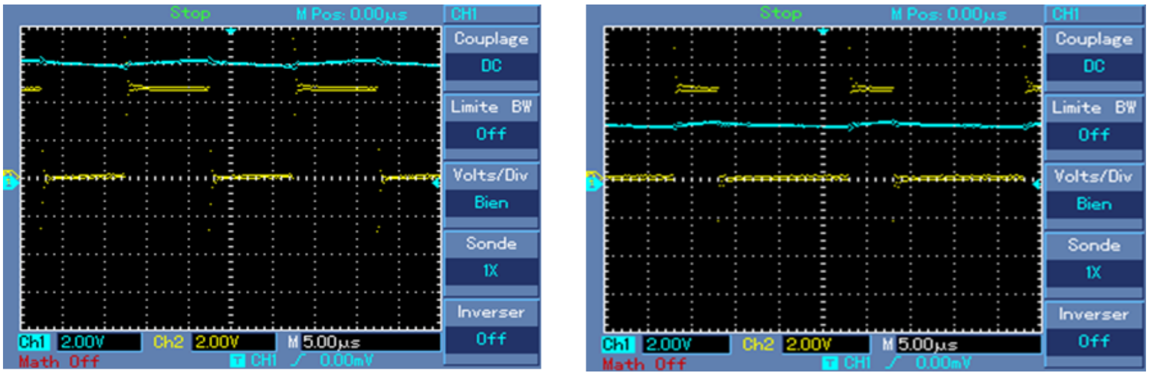

Figure 6. a) Output voltage of the DC-DC converter and the PWM signal with a duty cycle equal to 0.5 and b) Output voltage of the DC-DC converter and the PWM signal with a duty cycle equal to 0.5

3.2 Charge Controller

Table 1, shows the experimental results of the solar charge controller. It has four states on, off, bulk and float, details of the four states are shown in the table below.

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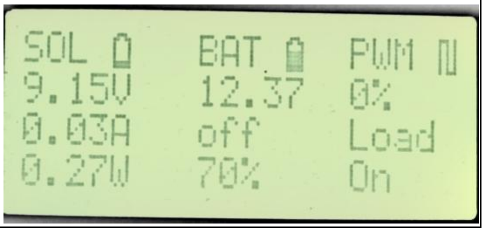
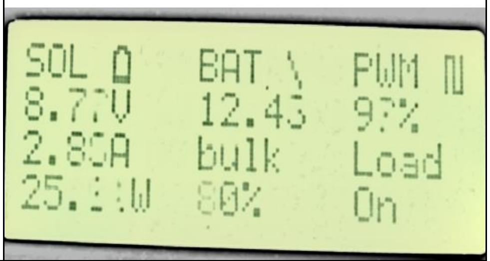
Table 1. Charge controller results

State	conditions required	result	observations
ON	sol_power > Low_sol_power & sol_power < Min_sol_power	Load On & Battery charging On	
OFF	solar watts < Low_SOL_WATTS	Load On & Battery charging Off	
Bulk	solar watts > MIN_SOL_WATTS & bat_volts < BATT_FLOAT	Load On & Battery charging Bulk	
Float	bat_volts > BATT_FLOAT	Load On & Battery charging Float	

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 for the battery. The Load turns ON and the Battery charging goes 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 goes into the Float state.

4. Conclusion

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The realization 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. This paper contains a battery charging system for laboratory using a direct connection between the photovoltaic solar panel and the battery system. With the help of this charge controller, the authors used solar power effectively and prolonged battery lifetime. In this paper, we have presented the experimental results using the LCD display (panel power, state of charge of the battery, state of the charge controller, duty cycle ....).

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