DESIGN AND DEVELOPMENT OF AUTOMATIC BATTERY CHARGER WITH CONTROLLER FOR BATTERY CHARGING STATION

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ABSTRACT

The study aimed to design and construct a locally-made battery charge controller for the Battery Charging Station (BCS) project implemented by Central Philippine University-Affiliated Non-conventional Energy Center (CPU-ANEC). The battery charge controller was designed only to protect the battery from over-charging. The functionality of the charge-controller was tested using a solar panel and a battery. The charging current was controlled by the PWM circuit. During charging, the output of the PWM circuit was both set approximately to ten percent (10%) duty cycle for charging ninety percent (90%) duty cycle for trickle charging. The output waveform and the duty cycle of the PWM circuit were checked using the oscilloscope. Testing of the charge-controller was done for four days of continuous operation to ensure the reliability of the system. Based on the test results, when the duty cycle was ten percent (10%), the green LED lighted-up and the ammeter indicated maximum charging current, while for the ninety percent (90%) duty cycle, a yellow LED light-up indicating minimum current. The red LED light-up when the polarity of the battery was reversed, while the orange LED lighted-up only when the battery state of charge was empty. These test results show that the battery charge-controller worked as expected by meeting the required design parameters. The unit is now ready for use.

INTRODUCTION

Solar energy is one of the renewable energy sources being promoted by the Department of Energy (DOE) to replace fossil fuels in generating electricity. The CPU-Affiliated Non-conventional Energy Center (CPU-ANEC), established in 1989 under the College of Engineering, is one of the ANEC agencies in the country tasked by DOE to tap this renewable power source to be utilized for areas which could not be reached by grid electricity. In its 16 years of existence, the CPU-ANEC has undertaken more than 70 projects utilizing micro-hydro and photovoltaic (PV) cell technology. Of these projects, 46 solar charging stations were constructed to allow charging batteries in the community.

All of the 46 solar charging station projects of CPU-ANEC, have no equipment to protect the battery from being subjected to overcharging. Due to this, the people in the community utilizing the battery charging station (BCS) complained about the short life span of their battery.

Solar charging stations must be provided with a charge controller to prevent the overcharging of batteries. Overcharging is the condition where a fully charged battery is continuously charged by a normal charging current and if this is frequently done, it will shorten the battery life. It must also protect the solar charging station from reversal of connections of the battery polarities, thus, resulting in the damage of the blocking diode on the solar panels. Blocking diode is an electronic component that is used to protect each panel when it is connected in parallel. This controller must be made from local components and materials so that maintenance and after sales services can easily be provided to the customers. It will also be designed by considering the current, voltage, and power rating of the solar charging station.

The charge-controller is an essential component in protecting both the battery and the charging station from problems caused by incorrect usage of the facility. In solar charging stations, it is important to make use of the full potential of the power being delivered by the sun during peak hours without compromising the battery life. Another thing that needs to be considered is the ability of the charging station to fully charge the battery within one day so that its utilization during nighttime can be guaranteed.

This low-cost automatic battery charger with controller is primarily designed for a solar battery charging station. This system is designed based on its specifications and limitations. The maximum charging current is set to 8 A. The controller can be connected to either two (2) solar panels with a rating of 75 Watt-peak (75 W-p) or three (3) 50 W-p panels connected in parallel. Most BCS installed were composed of sixteen (16) 75 Watt-peak panel. Charging nine (9) plates of N50 battery requires two (2) of these panels for normal operation and therefore needs eight (8) charge controllers are sets for each BCS.

This controller was made from readily and locally available components and materials so that the maintenance and other after-installation services can easily be provided. It was also designed with considerations on the current, voltage, and power rating requirements of the solar charging station. Thus, these consumptions study will benefit the CPU-ANEC and the communities with solar charging station. This will help CPU-ANEC to continuously operate their projects and to save cost from the operation and maintenance of these devices. Moreover, through this project, the communities can be provided with a controller for their battery charging, thus, guaranteeing smoother and continuous operation of the system through prevention of sudden damage of their batteries caused by overcharging.

METHODOLOGY

The Design of the Charger

The design of the battery charge-controller was based on the block diagram of the given system shown in Figure 1. The simplified diagram is composed of 15 blocks, properly labeled to correspond to each block's specific function and operation. These blocks include solar panel, blocking diode, shunt control-element, trickle charge indicator, pulse width modulator (PWM), high voltage reconnect (HVR), high voltage disconnect (HVD), charge indicator, battery, low voltage disconnect (LVD), low voltage reconnect (LVR), load controller, full charge indicator, reverse polarity protection, and the load.

The solar panel or photovoltaic cell (PV) is used to supply power to the circuit in order to charge the battery during daytime. The shunt control element controls the charging of the battery. The HVR senses the voltage level of the battery; if the battery voltage is less than 13 V, the HVR triggers the control element to reconnect the PV to charge the battery. The HVD triggers the control element to disconnect the PV from the battery terminals to stop the PV from charging the battery if the battery voltage reaches 14.4 V.

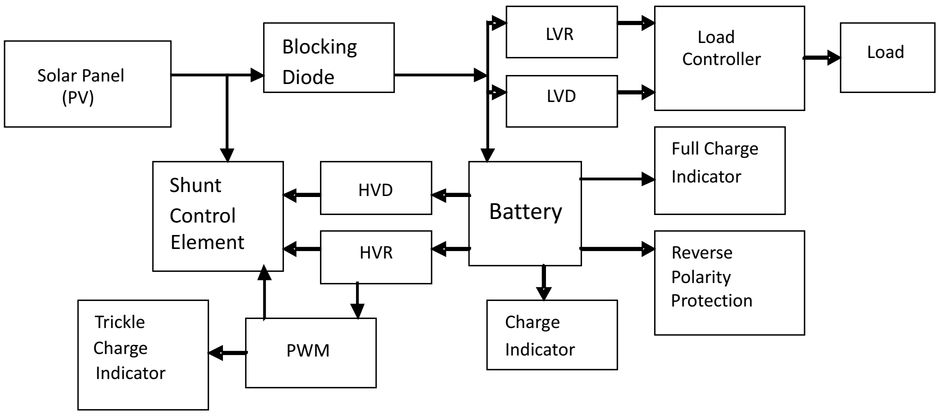

Figure 1. Block diagram of a battery charge-controller

The LVD triggers the load controller to disconnect the load if the battery voltage is less than 11.7 V. The LVR triggers the load controller to reconnect the load if the voltage of the battery reaches 12.7 V. The blocking diode is used to block battery voltage when the PV output voltage is less than the battery voltage to protect the PV panel. The charge indicator shows that the charger is in the process of charging the battery and the full charge indicator suggests that the battery is full, while the trickle charge indicator indicates that it is in the process of trickle charging. The PWM is used for trickle charging to compensate for the loss in the battery when the battery is already full. The reverse polarity protection is used to protect the system from reverse polarity.

Construction of the Battery Charger

The construction of the battery charger was done at Electronics Laboratory Room located at room 204 of the College of Engineering (EN204), by the designers and the technician assigned in the laboratory. The construction had two phases: construction using breadboard for pre evaluation and the construction of the system for final testing and evaluation.

Testing the Circuit Design and Pre-evaluation

The testing of the charger was conducted at the En 204, College of Engineering, Central Philippine University. The parameters tested were the maximum charging current, short circuit current, LVD, LVR, HVD, HVR and the pulse width of the PWM. The final testing and evaluation was done also in the College using two 75 watt-peak solar panels to simulate the actual BCS.

Final Evaluation and Testing of the Finished Design

The final evaluation of the battery charger was performed at the College of Engineering. It was tested by the personnel from the CPU-ANEC and the designers for four days of continuous operation. During the evaluation and testing of the battery charger, the following instruments were used:

1. *DMM (Digital Multimeter)*. METEX model M380 is a multimeter instrument used to measure the Voltage, Current, and Resistance of a given circuit and component.
2. *Solar Panel.* This was used to supply the battery charger to charge the battery.
3. *9-plate Battery.* This was used to test the functionality of the battery charger.

Data Gathered

During the performance evaluation of the battery charger, the following data were gathered:

1. Maximum charging current
2. Short circuit current
3. LVD
4. LVR
5. HVR
6. HVD
7. Pulse and frequency of the PWM

Parameters Analyzed

The parameters analyzed included:
1. the duty cycle of pulse width of the PWM.
2. the charging current at specific duty cycle.

RESULTS AND DISCUSSION

System Overview

The function of the battery charge controller is to protect the battery from overcharging, over discharging and reverse polarity for the protection of the bypass diode. The problem with the existing BCS (Battery Charging Station) of CPU-ANEC is that it has no charge controller to regulate the charging of the battery and to protect the battery and the bypass diode from reverse polarity. This designed controller will solve the problem of a given system and prolong the life span of the battery and the bypass diode. The block diagram in Figure 2 shows how the system is interconnected. The BCS which is made of two panels is connected to the charge controller and the charge controller in turn, is connected to the battery.

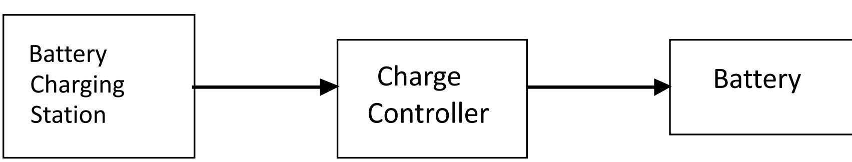

Figure 2. System operation block diagram

The battery charge controller for battery charging station has a maximum charging current of 8 A, HVD of 14.4V, HVR of 13V, LVR of 12.7V, and LVD of 11.7V. The charge controller uses the principle of pulse width modulation techniques to control the battery charging. Also included are indicators to show the status of the charging, and a battery voltage with reverse polarity protection.

Testing and Evaluation Procedure

To test the functionality and operation of the charge controller, the battery was connected first to the charge controller followed by the solar panel as shown in Figure 3. After the system is connected, the charge controller, which is provided with a reset button, started at the initial condition. While charging, the charge controller, through the LEDs, indicated the status of charging and that of the battery voltage. When the battery polarity was reversed, the charge controller automatically disconnected the circuit and the red LED lit up to indicate that the battery polarity was reversed. For the normal operation of the system, the charge controller indicated the status of charging depending on the initial condition and the status of the battery whether it is charging or only trickle charging. The green LED was used to indicate charging while the yellow LED was used for trickle charging.

To test the functionality of the charge controller, the nine-plate, 12 V battery was allowed to discharge below 11.7 V before connecting it to the charge controller. In response, the charge controller disconnected the load (the load is turned off) and the solar panel charged the battery because the voltage was less than the HVR. On the other hand, the ammeter indicated a maximum charging current. The charging current is dependent on the solar insulation; the higher the solar insulation, the higher is the charging current.

To test the functionality of the overcharging protection, the battery was allowed to be fully charged by letting its voltage reached approximately 14.4 V. When the voltage of the battery was approximately equal to 14.4 V, the ammeter indicated a very small charging current, indicating trickle charging. The charge controller indicated that the battery was fully charged. This process was repeated four times to ensure that the system would operate consistently.

Results and Discussion of Testing and Evaluation

The set-point voltages are shown in Table 1. The circuit system was provided with four trimmer resistors to set the HVR, HVD, LVR, and LVD. To set the HVD, the battery voltage was adjusted to 14.4 V and the trimmer resistor was attuned to have a reference voltage of 6.18 V. This voltage is required to trigger the trickle charge function of the charge controller. For HVR setting, the battery voltage was set to 13 V and adjusted another trimmer to have a reference voltage of 3.01 V. This voltage is required to trigger charge function of a charge controller. For the LVD, the battery voltage was adjusted to 11.7 V while setting another reference voltage to approximately 3.03 V. This voltage is required to trigger the disconnect function of the charge controller which is to disconnect it from the load terminal. In order to activate the LVR function, the battery voltage was set to 12.7 V and the reference voltage was set to approximately 6.19 V. This voltage is required to trigger the reconnect function of the charge controller, connecting it back to the load terminal.

Table 1. Set point reference voltages

Setting Voltages	SPRV (Set Point Reference Voltages)
HVR (High Voltage Reconnect)	SPRV for HVR
HVR=13.05 V	SPRV=3.011V
HVD (High Voltage Disconnect)	SPRV for HVD
HVD = 14.32 V	SPRV=6.18
LVR (Low Voltage Reconnect)	SPRV for LVR
LVR = 12.76 V	SPRV=6.19
LVD (High Voltage Disconnect)	SPRV for LVD
LVD=11.76 V	SPRV=6.19

The PWM parameters were set to approximately 100 Hz output frequency with ten percent (10%) duty cycle for charging, and ninety percent (90%) duty cycle for trickle charging. The results of the tests are shown in Figures 3 and 4. The waveform in the oscilloscope (Figure 3) shows approximately ninety percent (90%) duty cycle with both yellow and green LEDs lit up. This indicates that the charge controller is trickle charging. The ammeter reads small amount of current. Figure 4 shows ten percent (10%) duty cycle with the green LED lit up. This indicates that the charge controller is charging the battery. The ammeter, in this case, reads maximum charging current.

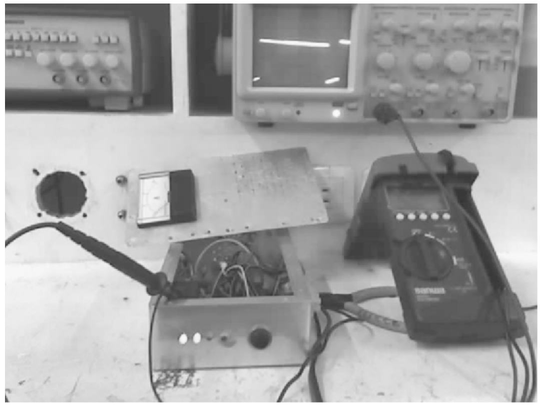

Figure 3. The oscilloscope showing 90% duty cycle with the green and the yellow LEDs lit up indicating trickle charging.

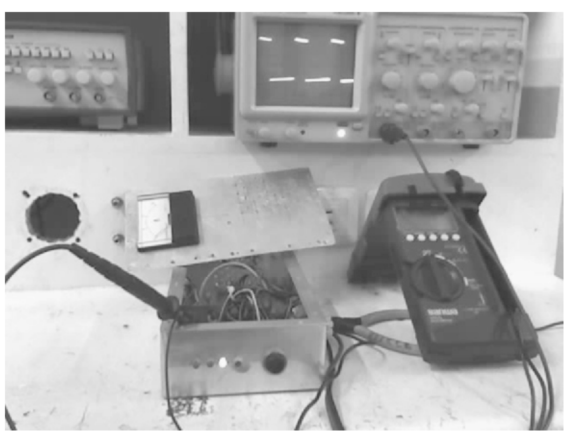

Figure 4. The oscilloscope showing 10% duty cycle with the green LED lit up indicating it is charging.

CONCLUSIONS

Based on the findings of the study, it is apparent that the design and construction of the automatic charger with controller were successful. Using locally available components, the best circuit option for the functionality and reliability of the charge controller was developed. The PWM (Pulse Width Modulator) circuit successfully produced approximately 100 Hz output frequency with 10% duty cycle for charging and 90% duty cycle for trickle charging. The functionality of the charge controller was tested, and was found to be operating normally and is ready for use.

RECOMMENDATIONS

For continuous operation like using this charge controller in the solar house system, it is recommended that a temperature sensor be incorporated to sense the battery temperature to prolong battery life.

A much lower device cost, however, may be also realized by employing only the HVR and HVD functions and eliminating the PWM function.

For high current application, Insulated Gate Bipolar Junction Transistor (IGBJT) could be used for the shunt control element.

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The Researchers