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DESIGN OF A PULSE WIDTH MODULATION (PWM) OR STANDARD CHARGE CONTROLLER FOR A PHOTOVOLTAIC SYSTEM IN AWKA, NIGERIA

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ABSTRACT

This paper proposes the design of a low cost pulse width modulation (PWM) charge controller for a standalone PV lighting system in Awka, Anambra State, Nigeria with a microcontroller to control and coordinate the functions properly. The charge controller was designed to protect the battery from both the solar panel and the LED lamps. The charging current was controlled by the PWM circuit. Moreover, battery can be disconnected from solar cells when over-charged and reconnected while discharging. The LED lamps which are the loads can be disconnected according to the excess current and under flow current limit for both battery and PV. The PWM charge controller should be equipped with LEDs to display the battery charging/discharging status, charge level and short circuit condition by the aid of the microcontroller. The LED lamps make it possible for our standalone PV system to operate on direct current (dc) all through from solar panels to battery to output light source.

Keywords: Battery, charging, discharging, LED lamps, standalone solar PV system.

INTRODUCTION

Recently, energy has become an integral part of our daily life all around the world. The use of energy ranges from cooking our food, cooling our spaces, transportation of goods and services, water pumping even to space traveling. The needed energy do come from either the renewable or non-renewable energy sources. The non-renewable energy sources are finite in nature and cause environmental pollution. In Nigeria, every citizen does not get sufficient amount of energy that he/she requires. There is a huge shortage of energy supply. Most households in rural Nigeria do not get sufficient electricity which hinders the growth of rural Nigeria both at social and economic front. There is either lack of sufficient infrastructure to supply energy to all or sufficient fuel is not available at reasonable cost. Hence, there are efforts to use the renewables that are continuously produced by natural processes and forces occurring in our environment which include solar radiation, wind and biomass *etc.* Any amount of solar energy can be harnessed without affecting the availability of solar energy for the next day, and therefore, it is termed I renewable energy source.

Background

Electricity supply that can lead to sustainable development has to be reliable, affordable, economically viable, socially acceptable and environmentally sound for the socioeconomic well being of all. Reliable electricity access is the life wire of any country. Without energy there is no economy. Nigeria is presently faced with the challenge of providing sustainable, adequate, reliable and efficient electricity supply to residential, commercial and industrial consumers. This situation has adversely affected the social and economic life of the citizenry.

The contemporary deteriorating power condition in which the nation is entangled, is as a result of the over dependence on fossil fuels to fuel the electricity generation plants. Consequently sustainable renewable energy resources, in spite of their abundance were relegated to the back, contributing little to the overall supply of energy in Nigeria.

Successive Nigerian governments have made some giant efforts to solve this dreadful energy crisis that threatens the economic growth of the nation, but all efforts have proved abortive. The present government has set an energy policy that seeks to exploit the abundant renewable energy sources to complement fossil fuel, with the hope of improving the current power supply in the country. Solar radiation represents the largest energy flow entering the earth, thus solar energy has the potential of becoming a major component of a sustainable energy portfolio, with constrained greenhouse gas emissions. Solar radiation is abundantly present in Nigeria hence it is one area of focus among the renewable energy resources that can be harnessed to solve Nigerian power crisis. Nigeria receives an average solar radiation of about 7.0kW/m^2 (25.2MJ/m^2 per day) in the far North and about 3.5kWh/m^2 (12.6MJ/m^2 per day) in the coastal latitudes. The estimate of the potential solar energy in Nigeria with 5% device conversion efficiency is 5.0 x 10^{14}kJ of useful energy annually. This is equivalent to about 258.62million barrels of oil produced annually and about 4.2 x 10^5GWh of electricity production annually in the country.

Given an average solar radiation level of about 5.5kWh/m^2 per day and the prevailing efficiencies of commercial solar electric generators, then if solar collectors or modules were used to cover 1% of Nigeria's land area of 923,773kJm^2, it is possible to generate 1850 x 10^3GWh of solar electricity per year, which is over one hundred times the current grid electricity consumption level in the country. The solar PV modules produce electricity only when sunlight shines on modules and for night time applications, electrical energy storage in the form of batteries may be required if there is no other supply. These batteries used in standalone solar PV systems require frequent charging or refilling of charge they need to be protected. The protection of battery is required to ensure that the batteries are not over-charged or over-discharged as both of these damage the batteries and reduce their lifetime. A device called charge controller is required in PV system to protect the batteries.

PWM Charge Controller

Charge controllers, as the name implies, control the flow of charge from the battery and to the battery. They protect the battery by preventing over-charge or deep discharge of batteries to preserve their life and performance. When the battery gets overcharged by solar PV modules, a charge controller will cut it off from the circuit so that no more charging is possible. Similarly, if a battery goes into a deep discharge (or over-discharge) due to excessive use of batteries by the load, a charge controller detects and disconnects the battery from the circuit so that no current can be drawn from the battery. In this way, a charge controller protects the battery. In this paper, we desire to design the Pulse Width Modulation (PWM) charge controller to be used in our tropical country. The PWM charge controllers have same nominal voltage across battery bank and PV array while the Maximum Power Point Tracking (MPPT) which is more electronically sophisticated and functions best at low temperature conditions.

The PWM controls, adjusts the duty ratio of the switches as the input changes to produce a constant output voltage. The DC voltage is converted to a square-wave signal, alternating between fully on and zero. PWM is a way of digitally encoding analog signal levels. It also controls the amount of current charging the battery and provides trickle charging. We have the voltage mode PWM controller which contains all of the features necessary for basic voltage mode operation. This PWM controller has been optimized for high frequency primary side control operation. This type of controller has its unique features with benefits which include;

- A sink/source gate drive for high efficiency operation.
- Up to 1MHz Fsw which helps to optimize for size or efficiency.
- External voltage reference also gives reduced component count.

Mode of Operation

The PWM charge controller also has programmable Pulse-By-Pulse overcurrent protection and overvoltage protection with programmable hysteresis. Fig 1 is a complete circuitry diagram that shows the mode of operation of the PWM charge controller. The Fig 1 also shows how PWM controller is capable of being configured as Forward, boost or battery charge controller.

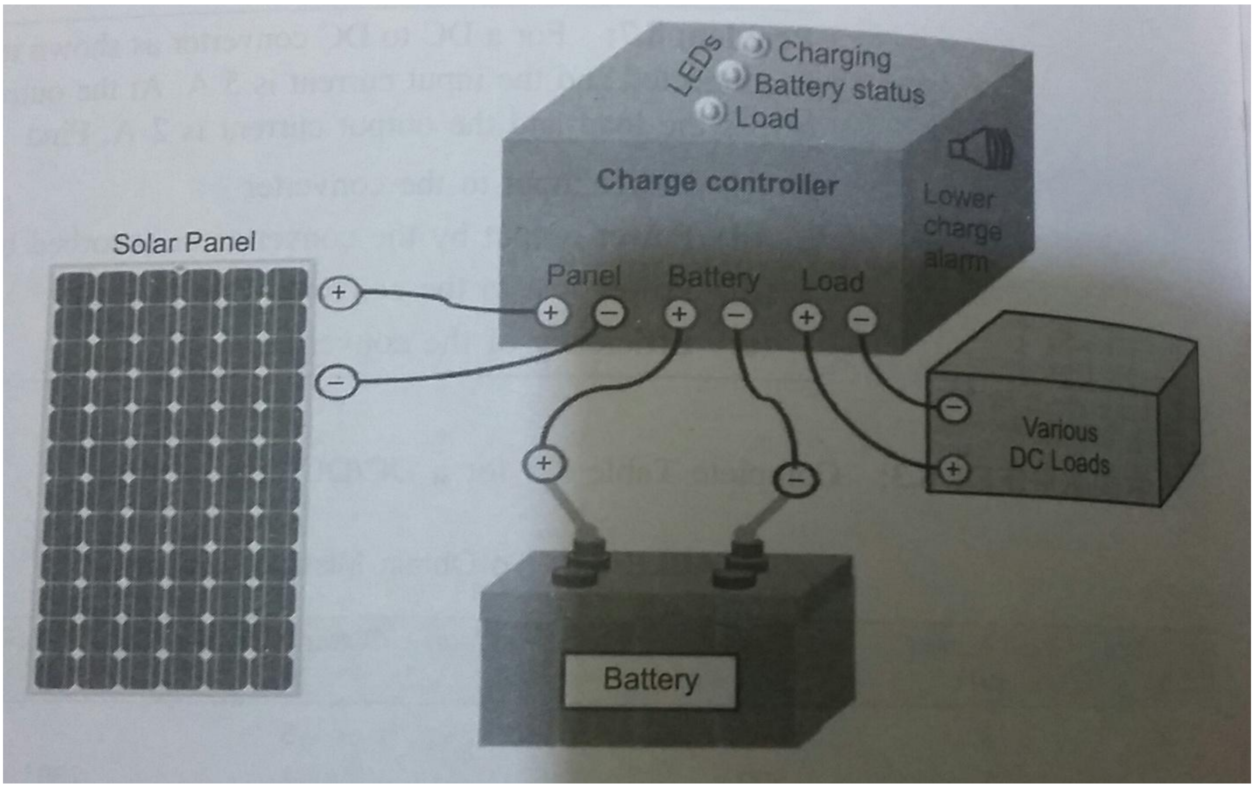

Fig 1: Complete circuit diagram of a PWM charge controller.

Design

The PWM solar charge controller should be chosen as per the required input and output voltage and current of load and battery. The charge controller was designed to effectively handle the current and voltages that are likely to be flowing in the system. Hence for our PV system, the PWM should be chosen with output voltage and current handling capacity approximate to 12V and 34A respectively. While designing the charge controller for our PV Standalone System for the 3 LED 30W lights. We considered the fact that all the loads were powered simultaneously using two parallel connected modules. Each module has a peak current of 8.05A and short circuit current of 8.28A.

We chose the appropriate charge controller using the following estimation:

- Total load estimation - 30W x 3 = 90W.
- Nominal system voltage of charge controller:- same as rated voltage of load and PV array, i.e. 12V.
- Nominal PV array current – 2 x 8.28 = 16.56A

Therefore at the input side, the charge controller should be able to handle 17A current.

- Nominal load current - Total DC load/ Nominal system voltage = 90/12 = 7.5A.

Therefore, the output side, the charge controller should be able to handle about 8A.

OBSERVATIONS/RESULTS

From the design it was observed that the charge controller would function better if the voltage output is fixed on 14.3V from the current booster block of the PWM charge controller so that the test data will include reading from 200Ah, 12V battery charged for approximately 12 hrs. under varying weather conditions. Based on the proper design of the PWM controller to both the solar panel and the battery, the power and undercharging LEDs will turn ON to show battery charging. After about 12 hours of charge the optimum charge LED will turn ON to show full charge. The circuit is expected to perform satisfactorily.

CONCLUSION

The design of a low cost, functional and effective PWM charge controller with locally sourced components was successful. The design when constructed will effectively fit a standalone PV system in Awka. This is expected to solve the inherent problems that challenge the effective use of photovoltaic systems in Nigeria. The charge controller set points trigger functions such as charge regulation or load control, which are key to maximizing battery health and system performance.

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