Analysis Design and Construction of a Pulse width Modulated Charge Controller

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Abstract:

Erratic power supply has caused serious problems in the Nigerian environment resulting in the extensive use of small generating plants in the first instance. Frequent and unpredictable fuel scarcity has further exacerbated the problem of power that previously untouchable solar solutions have begun to look attractive.

This paper presents a brief review of the evolution of prices of solar panels and examines various options that can improve the local value added of the solutions. One component that lends itself to relatively easy realization locally is the charge controller. One such design employing the pulse-width modulation principle is analyzed, designed, realized and the results of tests performed on it are presented in this paper. It is shown that an efficient product can be manufactured with a high level of reliability.

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1. Introduction:

Electric power is the most important source of energy in modern societies in the twentieth century. It provides a very efficient means for the transportation, conversion and utilization of vast amounts of energy in a relatively clean and safe manner. As a result it has become indispensable to the modern person. While problems exist in the supply of electrical power in all societies, the situation in many developing countries is not encouraging. In Nigeria for example, power generated and connected to the grid is more noted for its absence than its efficiency. The result has been the adoption of personal generators which are also plagued by fuel scarcity and the high prices of petrol or diesel used to run them.

In recent times, many institutions have been subjected to serious shortages that their out is greatly curtailed and the cost of supplying alternate power so crippling that hitherto neglected renewal energy sources are beginning to appear quite attractive. This is the situation in particular for solar voltaic in Nigeria. What began as a fad is beginning to gain strong following as the price of fuels escalates and the cost of solar panels gradually decline. In the past five years, the cost of solar panels has dropped from an unaffordable $20/ Watt to under $2/ Watt. Although the full impact is still to be felt, solar powered devices are beginning to appear in some strategic applications such as for street lights and information technology centers in tertiary institutions.

The wide spread adoption of solar voltaic would be greatly facilitated by a process whereby the local content of the resulting systems are increased. Unfortunately, the technology for the fabrication of the solar panels is still evolving, highly capital intensive and requires physical and technical infrastructure that is beyond te capabilities of the developing nations. All the same there are aspects of the solar power systems that are within reach and hence should be addressed with the utmost urgency in order to further reduce the burden on the economy and generate some employment.

A study of the solar voltaic system indicates that apart from the panels, the most important parts are the batteries and the charge controllers. This paper presents the results of the design and construction of a pulse-width modulated charge controller.

2. Basic Principles of Charge Control:

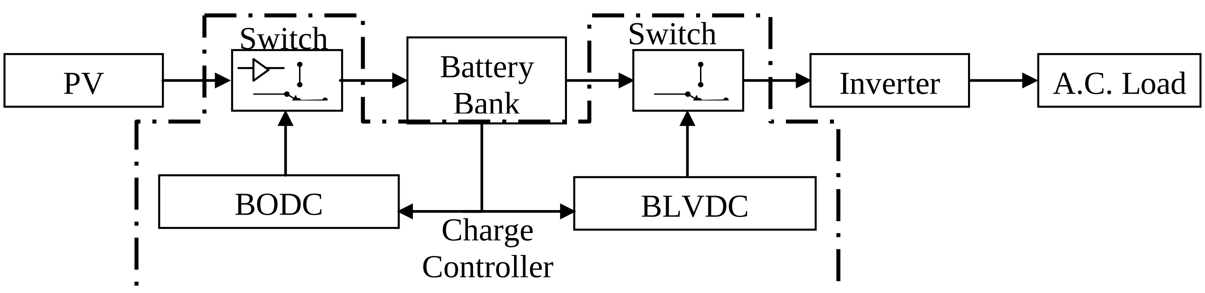
A basic photo-voltaic system consists of principally the solar arrays, which convert solar energy into electricity in the form of a current, a bank of batteries which serve as the energy store, an inverter which converts the direct current energy into AC energy for direct use by equipment and other applications. This arrangement requires a number of control functions that prevent:

i. the solar panels from over-charging and hence shortening the life of the batteries in the bank;
ii. the back feeding of the solar panels by the batteries in the night or under low light intensity conditions; and
iii. the batteries from being discharged beyond their lowest point.

An arrangement capable of performing these functions can be configured as shown in figure 1.

In terms of investment costs, the battery is presently the next most important cost center and even under the best circumstances seldom have a life in excess of five years when the batteries have to be replaced. As a result there is a need to put in place all precautions that will automatically safeguard the investment. The charge controller is the device which can perform the functions listed above.

Solar battery chargers differ from the traditional battery chargers because the solar panels retain their semi-conducting properties. As a result, the solar power is a high impedance DC source which is equivalent to charging the batteries using a current source (Kriszina and Ewen, 2008). Ordinary battery chargers tend to be serviced by near voltage sources which as a consequence are almost self-regulating since the current charging the battery will decrease as its voltage increases and approaches that of the source. There is thus a much greater tendency to over-charge the batteries and subsequently reducing the useful life.



BODC – Battery Overcharge Disconnect Circuit
BLVD – CBattery Low Voltage Disconnect

Figure 1: Block Diagram of a Stand-Alone Solar Voltaic Power System

There are many approaches that have been developed for controlling the charging features of solar voltaic energy sources. A detailed review of the methods can be found in

Eric and Michael (1998). They may be summarized as shown in table 1. What is clear is that all methods have their advantages although experience has shown that the pulse-width modulated controllers tend to ensure that the batteries are charger to more than 90% of their rated voltages without overcharging and actually do so in a trickle manner so that the charging action occurs in a switched manner.

3. Design of a PWM Solar Charge Controller:

The PWM charge controller can be represented as a feedback controlled system as shown in figure 2.

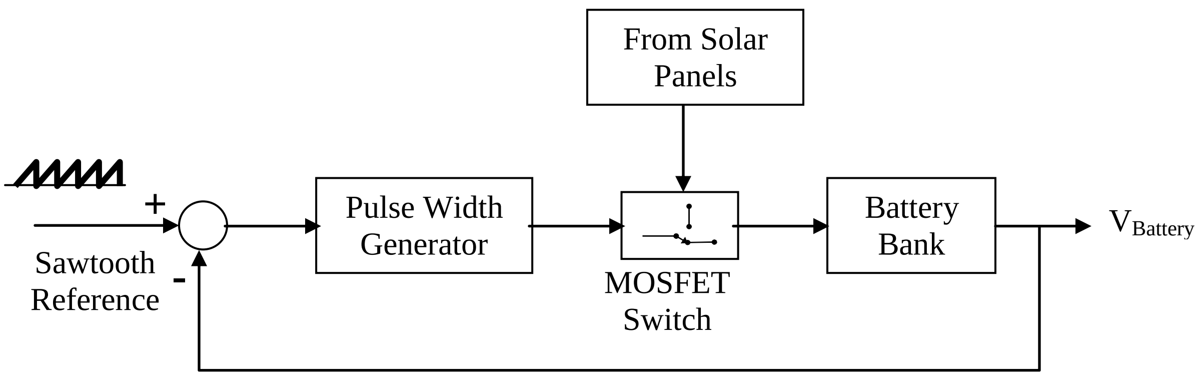


Figure 2: Feedback Model of a Pulse-Width Modulated (PWM) Charge Controlled System

In this arrangement, the battery voltage is compared with a saw-tooth voltage source so that pulses are generated with widths equal to the duration for which saw-tooth voltage is greater than the battery voltage. A switch/ relay can then be activated to connect and disconnect the solar power from the battery as required.

The design process can then be decomposed into the following stages:

i. design a saw-tooth generator of a suitable frequency and amplitude; and
ii. design a comparator circuit with a booster stage for driving a control switch

The realization of the saw-tooth circuit adopted in this design employs a current source to charge a capacitor connected controlled by a 555-timer configured for a-stable operation.

The full details of the design of this circuit are presented fully in Ikhide (2006).

The saw-tooth output from the capacitor is then connected through a buffer stage to the non-inverting input of an LM 710 follower integrated circuit (ON Semiconductors, 1999). The inverting input is connected to a sample of the battery voltage as shown in figure 3.

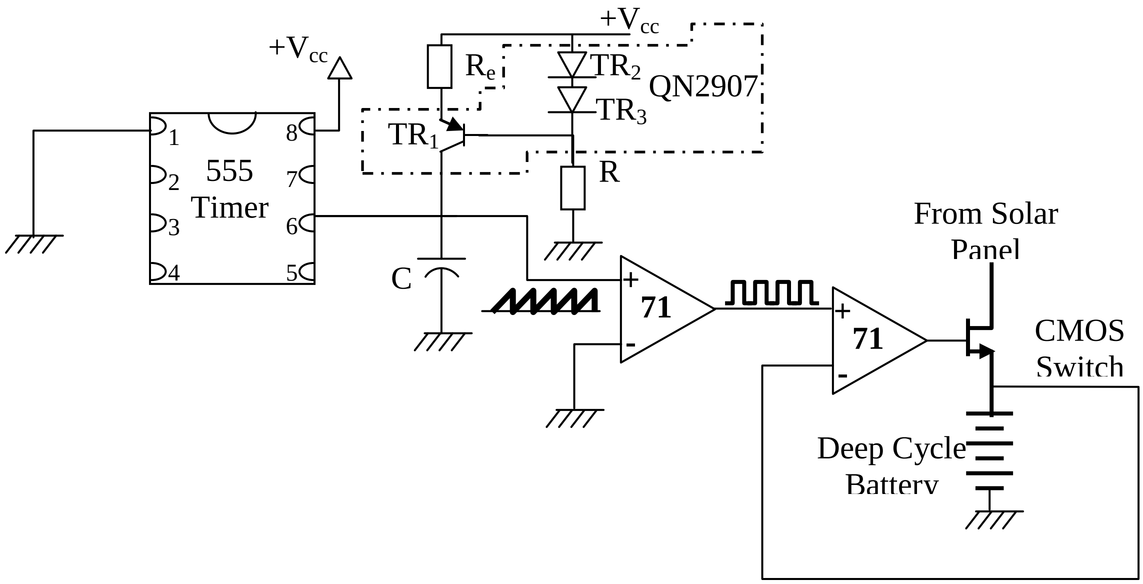


Figure 3: Circuit Diagram of a 555-based PWM Solar Charge Controller

4. Results:

The circuits described above were fully designed, constructed and tested. The saw-tooth output obtained from the pin 6 of the timer gave an output as shown in Figure 4 and the frequency could be varied over a wide range. The choice of operating frequency will depend on the switching device selected. Clearly solid state relays or CMOS analog switches must be used unless the frequency of the saw-tooth is reduced to a fraction of a Hertz. In that case an electro-mechanical relay may be used but the resulting arrangement would require changing of the relays as the contacts wear out.

The effect of the battery was simulated by using an external source and varying the voltage between 10 volts and 13.5 volts which is the typical operating range of batteries.

5. Conclusions:

The tests indicate that charge controllers can be designed for different types of charging regimes. The component count can be greatly reduced with the use of quad comparators like the LM 2901 and quad 2N2907 transistors. The printed circuit boards required can also be readily produced locally so that should the potential large-scale deployment of solar voltaic systems in the tropics (where most developing countries are to be found) materialize, this could become a very viable project in the not so distant future.

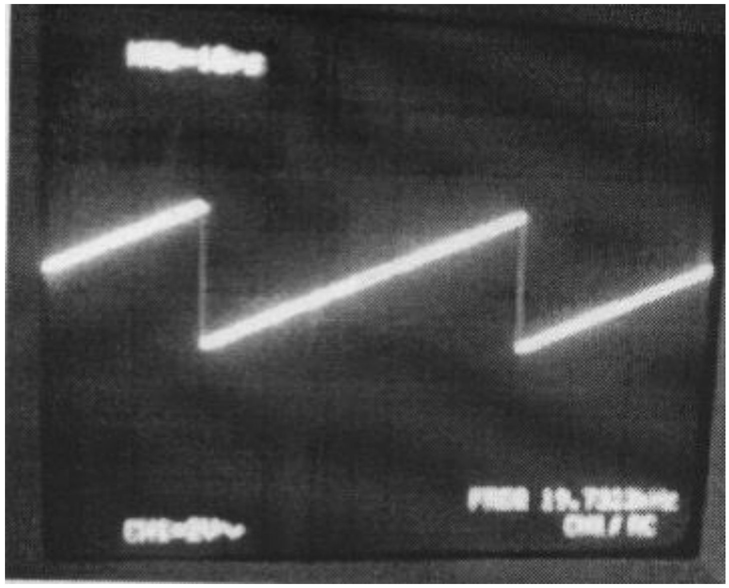


Figure 4: Saw-tooth Output at Pin 6 of the 555-Timer

6. References:

Azooz, P. A. and Sulayman, J. M. (2005)."Electronic Control Circuit for Solar Battery Charging." Romanian Reports in Physics, Vol. 59, No 1, pp 101-111

Eric, P.U. and Michael, M.D. (1998). Recommended Practices for Controllers. Report of International Energy Agency Implement Agreement on Photovoltaic Power Systems. Report IEA PVPS T3-05:1998, PP 7 -35.

Ikhide, M. A. (2006): "Studies and design Considerations of a %%%-Timer Based Function Generator", pp. 31 – 33, Unpublished B. Eng Thesis, The Federal University of Technology, Akure, Ondo State, Nigeria.

Kriszina, L. and Ewen, R. (2008). "Selecting an Accurate Solar Panel Simulation Model." Nerdie Workshop on Power and Industrial Electronics. pp 2-5

ON Semiconductors (1999):" LM 339 Data Sheets", www.alldatasheets.com

Appendix I:

Table 1: Controller Configuration Comparison

Controller Type	Charging Method	Advantages	Disadvantages
Shunt-Interrupting	On/Off	- lower voltage drop across controller than series configuration - often simple, cheap and reliable	- significant power dissipation in switching element in large systems - blocking diode required - can cause hot spots in high voltage arrays - may have difficulty fully charging at high currents
Shunt-Linear	CV	- tapered current charging - lower voltage drop across controller than series configuration	- significant power dissipation in switching element in large systems - blocking diode required - can cause hot spot in in high voltage arrays
Series-Linear	CV	- tapered current charging	- power dissipation required - voltage drop across controller
Series/Shunt Pulse Width Modulated	CV	- tapered current charging - lower power dissipation than other CV methods	- voltage drop across controller - generally more complex than series or shunt on/off controllers - sometimes causes electromagnetic interference in sensitive equipment nearby
Sub – Array switching	Stepped	- pseudo-tapered current charging - can control large arrays	- not cost effective with small arrays
None	Self-regulated	- low-cost	- charge regulation strongly temperature dependent - Charging never completely terminates