MICROPROCESSOR-BASED CHARGE CONTORLLER FOR HOME PHOTOVOLTAIC SYSTEM

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Abstract

The charge controllers currently in use in most solar home systems (SHS) in Africa require intensive manual battery monitoring and maintenance regimes for the user or field technicians. In addition, the most widely used charge controllers in the African set-up are analogue systems, which are very rigid in the adaptation for local conditions such as temperature compensation or seasonal irradiation variation. From the maintenance point of view, this presents some significant technical problems for the end-user, particularly our villagers in the rural and remote communities. Reliability and compatibility due to circuit complexity and use of non-available components have also meant repair and maintenance in the field has been a major problem. Costs involved in the hardware development of such charge controllers are quite large. In this work, we design a charge controller based on the microprocessor, which offers increased reliability, reduced cost, reduced complexity in the number of electronic components and increased monitoring and regulative functions. This controller is designed for simplicity by using a commonly applied domestic embedded systems microcontroller - the Motorola 6811 series. The advantage of using a microprocessor based system is that it is possible to alter the general parameters and specifications of the charge controller by simply altering the voltage parameters in the software via a user interface. For researchers and maintenance technicians the controller is designed for easy interface to a data logger or a portable computer to check for battery and panel performance history whilst away from the site.

1. Introduction

The predominant use of lead acid batteries in home photovoltaic systems in remote areas, where this energy resource is widely used, is due to their easy availability and low cost. However, these batteries require an aggressive charging and discharging regulation regime. System failures due to battery failure have led to high system cost and maintenance problems making the technology unattractive. An effective charge control system to prevent battery damage is necessary to counter these negative perceptions.

Charge controllers currently in use are mostly analogue based controllers and in the African setting suffer from the following problems:

- Most of the charge controllers manufactured in developed countries have complex hardware and are difficult to repair. Throwing away or sending back the controller to the manufacturer for repair is not a practical solution, especially in rural areas where the majority of the users are.
- System performance cannot be monitored with analogue charge controllers.
- Monitoring of battery abuse by the consumer in small Energy Supply Companies is difficult. This is especially so when dealing with scattered villages.

Difficulty in adjusting control parameters since the control system is hardware and not software based.

Experiences in the field have also shown that microprocessor based system currently on the market have not addressed these problems adequately. Problems related to repair, durability, monitoring and local conditions optimisation still remain. However, under the programme of providing solar photovoltaic (PV) electricity services through energy services companies (ESCOs) in rural areas, local community technicians are now being trained in the skills of installing, maintaining and repairing solar PV systems.

2. Motivation

In this work, we design a charge controller based on the microprocessor, which offers increased reliability and monitoring functions, and reduced cost and complexity. This controller is designed for simplicity by using a commonly applied domestic embedded systems microcontroller, the Motorola 68HC11 and easily replaceable power MOSFET transistors for switching. The estimated retail cost of this new model to the consumer is of the order of US$ 40.00 which fares comparably well to current market charge controllers at an average cost of US$ 100.00. In addition, circuit complexity is transferred to the software, which is easier to redesign, and the analogue circuit is confined to switching. An added incentive of using a microprocessor-based system is the possibility to alter the general parameters and specifications of the charge controller to suite local conditions by simply altering the voltage parameters in the software via a user interface.

For researchers and maintenance technicians, the design incorporates easy interface to a data logger or a portable computer to check for battery and panel performance history whilst away from the site.

3. System overview

Figure 1 below gives an overview of the system of a solar home system. The solar panel converts solar radiant energy into electrical energy, which is stored in chemical form by using batteries. Appliances such as radio, television and light bulbs are connected to the battery. The charge controller serves the duo process of managing the system so that the battery is protected from overcharging and over discharging. Lead acid batteries suffer from effects of sulphation of the plates if abused by over discharging resulting in a shorter life span. The charge controller manages to achieve the task of regulating the system by monitoring the battery state of charge, which is related to the voltage levels of the battery. When the battery is overcharged the panel is disconnected and when over discharged the load is disconnected. The controller operates with four set points, which are voltage levels triggering action. These are load disconnect, load reconnect, panel disconnect and panel reconnect.Fig. 1. General solar home system

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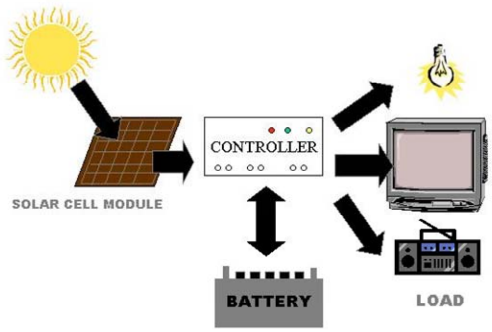
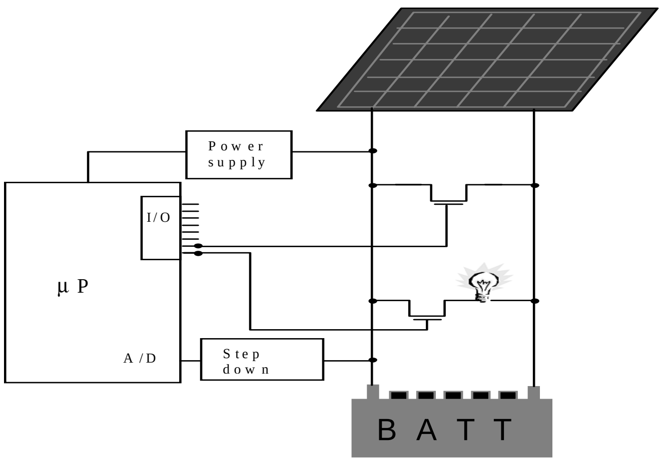


Figure 2. General charge controller function



4. Hardware design

4.1 General function

Figure 2 below represents a block diagram of the hardware design of the microprocessor based charge controller. The microcontroller monitors the voltage of the battery through its analogue to digital (A/D) port imbedded in the chip. To match the reference voltage specification of the A/D, a step down circuit matching the maximum voltage of the battery to that of the A/D is used. The microcontroller then decides on the action to be taken based on the battery voltage it records by checking the set points recorded in its memory.

If the voltage is such that the panel is to be cut off, it sends a high signal via one of the pins on the input/output (I/O) port. This in turn switches the Power MOSFET connected to the two terminals of the solar panel, thus effectively short circuiting the solar panel. The resultant is effectively divert the charging current that flows to the battery. If the microcontroller signals a low to the power MOSFET, the solar panel is open circuited. Therefore, the current from the panel charges the battery.

In the case of the discharge control, the power MOSFET acts as a switch with the signal from the microprocessor as the control. If the battery is overly discharged, the transistor is sent a LOW, cutting off the load. If the load is to be reconnected, the transistor is sent a HIGH.

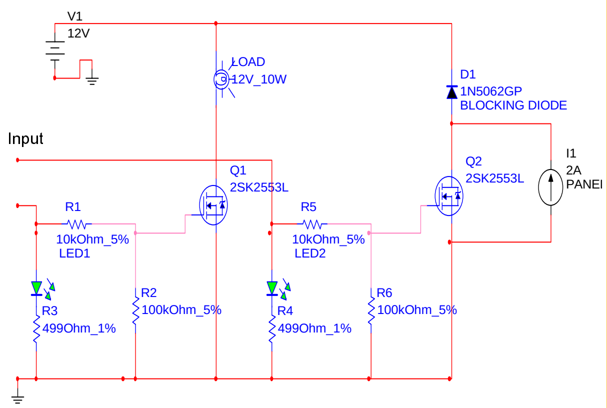
The panel or the battery supplies power for the charge controller. A power supply circuit has to be incorporated in order for the microprocessor to operate according to its specifications. Since the supply from the two sources is already DC, a voltage divider and a Zener diode arrangement are enough to attain the desired regulated power supply.

4.2 Switching Circuit

The analogue circuit in Figure 3 is the switching circuit required to control the charging and discharging. Two power MOSFETS are used as switching devices for both the panel and load control. Each transistor is controlled by a digital 0 to 5 volt signal from the microcontroller to its gate. The use of MOSFETs prevents the need of incorporating buffer circuits between the digital and analogue circuit because current is not drawn into the gate. Resistors on the input are set at values that correctly bias the gates and in this case the situation is identical for both switching circuits.

For the discharge control, the load is in series with the transistor while in the charging control the solar panel is in parallel. To prevent short circuiting the battery or damaging the panel with reverse current from the battery, a blocking diode D1 is included. Of particular importance is the use of MOSFETs, which are easily replaceable because they are the highest cause of failure in most charge controllers. To protect the MOSFET from excess

Figure 3. Circuit diagram of switching circuit



current, one needs to insert a fuse between the load and the power transistor.

4.3 Controlling circuit

The Motorola 68HC11 microcontroller, which is widely used in embedded systems, is ideal for the task of both monitoring the battery and controlling the system. Important features include an on board analogue to digital converter, imbedded input and output interface ports, on chip EPROM and RAM. The circuit is simply an interface between the microcontroller and the components of the system. The battery is monitored through the analogue to digital port, whilst the control signals are output through bits 0 and 1 of the output port B. Inputs by the user are interfaced through the input port A, using a keypad. An LCD display is connected for the user to monitor the status of the system.

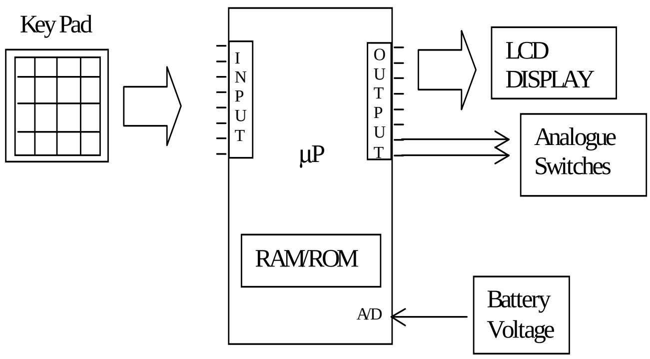
5. Software design

The programme running the system is simply a monitor programme of the various inputs and outputs. On power up, a hardware initialisation routine checks and initialises the hardware status before settling into standby mode. Once it is switched to control mode, it performs a continuous loop of checking the battery voltage and deciding on what course of action to take as a result. This is accomplished by comparing the battery voltage with the preset values stored in the memory. A control vector is then sent to the output port, switching the appropriate transistor into the required state. The algorithm can be summarised by the following:

1. Check battery voltage
2. If battery is overly discharged then disconnect load, loop to 1.
3. Check if load is disconnected
4. If load is disconnected check if reconnection criteria is met

   4.1 If criteria is met, reconnect load, loop to 1

Figure 4. µP control circuit schematic



   4.2 Loop to 1

5. If battery is overcharged, disconnect panel, loop to 1
6. Check if panel is disconnected
7. If panel is disconnected, check if reconnection criteria is met

   7.1 If criteria is met, reconnect panel, loop to 1

   7.2 Loop to 1

8. Loop to 1.

Other features incorporated into the software include data logging in which routinely and automatically checks the voltage at noon, every day, and stores the result in RAM for future retrieval. Set points can be changed via the user interface and stored in the allocated memory location. The number of cycles a particular battery has gone through and an estimation of lifetime based on history is an option. For the purpose of system maintenance, the programme records all disconnections and reconnections thus giving an indication of the state of the battery or user abuse.

The programme was developed in C and converted into assembly using the Windows based Integrated Development Environment. In this environment, a step by step execution using dummy output ports is possible before loading the programme on to the EPROM of the kit.

6. Implementation

The charge controller, in design stage, has been tested for functionality. The switching circuit, when interfaced to a microcontroller, successfully performs all the necessary functions using the digital signals. A variety of similar power MOSFETS were used in the same circuit without appreciable deficiency in the performance. This ensures that finding replacement parts for the most vulnerable part of the controller, the transistors, will be easier than in most commercial controllers. The microprocessor system was implemented using a simulator kit, which was fed to the programme via an adaptor connected to a PC. Programme execution for the basic monitoring routine managed to detect battery voltage and control the system. For this test, the panel, battery and load used were at the roof of the physics building at the University of Zambia.

Incorporation of special features software has been achieved. However long term monitoring and data acquisition tests will require a complete prototype and longer periods of time to test.

7. Conclusions

A microprocessor based charge controller has been designed and tested. The benefits of this design are to have a charge controller easy to maintain and repair, but still with the functional sophistication imbedded in the software to allow for monitoring of the performance of the entire solar electric system. In addition, this design enables easy parameter adjustment for local conditions and can be adapted for remote control monitoring.

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In The News

ITER: The need for cheaper, reliable and clean energy

The International Thermonuclear Experimental Reactor (ITER), an international collaborative project involving China, the European Union, Japan, Russia, Korea and the United States, promises to deliver cleaner and cheaper energy. The plant which France will host is estimated to cost of about 10 billion euros, generate 10,000 jobs and will serve as a demonstrative plant for development of commercial plants, possibly by the mid of this century.

Nuclear fusion, mimicking the process the sun uses to produce energy, is perceived as a cleaner approach to production energy than nuclear fission and fossil fuels. The deal reached on Tuesday may accelerate national research efforts on nuclear fusion.

Why the farce?

First, it will mark a technological milestone. In order to fuse light atoms (hydrogen isotopes) to make heavier ones, heat in excess of several millions of degree Celsius is required.

Secondly, about 1 kg of fusion fuel will produce energy equivalent to that generated by 10 million kilograms of fuel.

Thirdly, unlike nuclear fission, the waste decays much faster.

Not everyone agrees it is the best way to spend the money or that it will work. However, if it does not work this time, it will surely work one day. (28 June 2005.

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The Upgrade of Kenya's oil refinery

The upgrade of the Kenya Petroleum Refineries Limited (KRPL) may increase the prices of oil products. The plant, which is owned by the Government (50%) and BP, Shell and ChevronTexaco, would cost about $200 million to modernize.

The Mobil Oil Kenya Managing Director Robert D Paterson said the investment will increase the cost of fuel as KRPL has a low processing capacity and can not match the larger and modern plant in the Gulf region. However, KRPL is partially protected by a rule that requires oil marketer to purchase 70% of their oil requirements from KRPL. (Eastern Standard- 30 June, 2005)

Indeed, it is estimated that KRPL processing cost per ton increased from about $2.7 (1993-1998) to about $5 (1999-2003), making imports cheaper than locally refined oil products.