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Microcontroller Based Solar Smart Charge Controller using MPPT

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Abstract: Photovoltaic is one of the renewable energy resources that recently has become broader in nowadays technology. The electricity generations of photovoltaic (PV) panels are strongly related with insolation and temperature. The insolation and temperature are not stable, since the electricity generations of the PV panels are not stable. In PV systems, insolation and temperature continuous vary. Therefore, the maximum power point tracking (MPPT) techniques are used to give the highest power to the loads/batteries. The MPPT process is performed with a power electronic circuit and it overcomes the problem of voltage mismatch between the PV panels and the batteries/loads. In this system, a microcontroller is employed to develop battery charge control system for PV panels. The system is composed of a microcontroller PIC16F877A, boost type DC-DC converter, a resistive load, and lead acid battery. In the system, MPPT, charge control, and discharge algorithms are executed by a program embedded within the microcontroller. Furthermore, this smart charge controller is developed to reduce the current market price of charge controller to an affordable level. This system deals with the design of an intelligent charge controller using PIC microcontroller to control and coordinate the activity in charge controller. The proposed charge controller is equipped with LCD to display the temperature, battery voltage and current flow through the battery. Output of these 3 inputs are used to obtain the accurate and efficient disconnecting/reconnecting action which is capable of protecting the battery and the load whereas LED indicator is featured to show the status of the systems.

Keywords: Boost Converter, MPPT, Mikroc Photovoltaic.

I. INTRODUCTION

PV (Photovoltaic) generation has constraints on the amount of sunlight, temperature, and other environmental conditions. Moreover, the energy conversion efficiency of PV generation is fairly low. In order to supplement for these weaknesses, there are many researches going on to increase the efficiencies of the solar cell and the electric power conversion device [5]. Photovoltaic sources are used today in many applications. They have the advantage of being maintenance and pollution-free but their installation cost is high and, in most applications; they require a power conditioner (dc/dc or dc/ac converter) for load interface. Since PV modules still have relatively low conversion efficiency, the overall system cost can be reduced using high efficiency power conditioners which, in addition, are designed to extract the maximum possible power from the PV module [maximum power point tracking (MPPT).

A very common MPPT technique is to compare the PV array voltage (or current) with a constant reference voltage (or current), which corresponds to the PV voltage (or current) at the maximum power point, under specific atmospheric conditions. Simple relay-operated charge controllers allow relatively coarse adjustment of the current flow and seldom meet the exact requirements of PV systems [2]. Microcontroller-based designs are able to provide more intelligent control with an internal computer program. Various control algorithms may be enacted with the same devices imply by changing the program parameters and/or adding more sensors and by matching it to the various stages of charge of the battery.

II. MAXIMUM POWER POINT TRACKING

The efficiency of a solar cell is very low. In order to increase the efficiency, methods are to be undertaken to match the source and load properly. One such method is the Maximum Power Point Tracking (MPPT). According to maximum power point theorem, output power of any circuit can be maximize by adjusting source impedance equal to the load impedance, so the MPPT algorithm is equivalent to the problem of impedance matching. This is done by utilizing a boost converter whose duty cycle is varied by using a MPPT algorithm. Output voltage of the converter is depend on the duty cycle, so MPPT is used to calculate the duty cycle for obtain the maximum output voltage because if output voltage increases than power also increases. In this system, Perturb and Observe (P&O) is used, because these require less hardware complexity and low-cost implementations [3].

A. Perturb & Observe MPPT Algorithm

Perturb and Observe algorithm is used for MPP tracking. Perturb and observe algorithm has a simple feedback structure and fewer measured parameters. It operates by periodically perturbing (i.e. incrementing or decreasing) the array terminal voltage and comparing the

PV output power with that of the previous perturbation cycle. If the perturbation leads to an increase (decrease) in array power, the subsequent perturbation is made in the same (opposite) direction. In this manner, the peak power tracker continuously seeks the peak power condition. Moreover, in rapidly changing atmospheric conditions, the MPPT takes considerable time to track the MPP. Figure 1 shows the flow chart of the Perturb and Observe Algorithm [4].

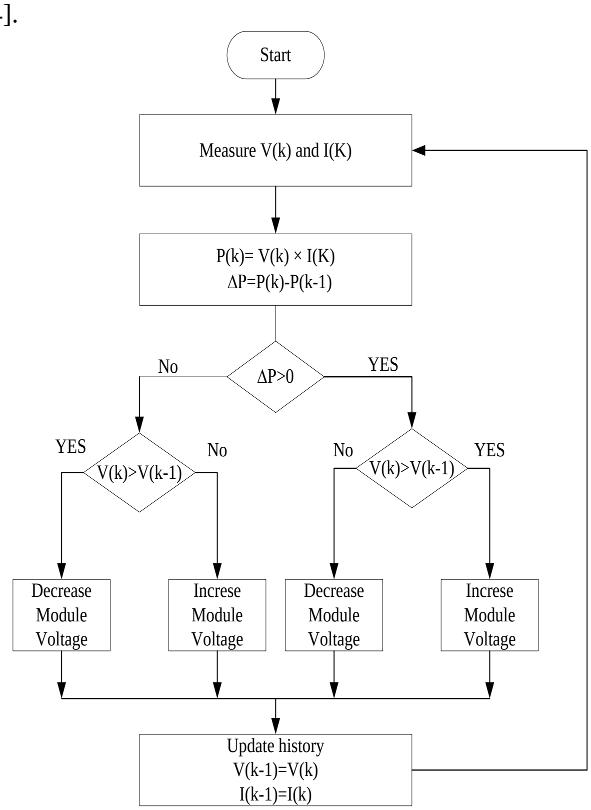

Figure 1: Flow chart for P&O MPPT.

B. DC\DC Converter

The boost converter is used to truly track the maximum power point rather than maximizing the voltage[7]. The basic circuit of the boost converter designed and developed is shown in Figure 2. It is well known that the relationship between the input voltage and the output voltage of the boost converter is given by the relationship (1).

$$V_{out} = V_{pv}/(1-\propto) \qquad \textbf{(1)}$$

Where, $\propto = t_{on}/T$ is defined as the converter duty cycle. This means that the converter output voltage can be simply controlled by the variation of the duty cycle. The duty cycle $\propto$ is changed continuously in order to track the maximum pour point of the photovoltaic. The inductor value, L, required to operate the converter in the continuous conduction mode is calculated such that the peak inductor current at maximum output power does not exceed the power switch current rating. Hence, L is calculated as

$$L \geq V_{PV} \propto / f \Delta I_{PV} \qquad \textbf{(2)}$$

Where, f = 1/ T is the switching frequency, $\propto$ is the duty cycle at maximum converter output power, V_{PV} the input voltage and ΔI_{PV} is the peak-to-peak inductor ripple current. The choice of the converter inductor value and the switching frequency is a compromise between converter efficiency, cost, power capability and weight. The output capacitor value calculated to give the desired peak-to- peak output voltage ripple is given by the relationship (3).

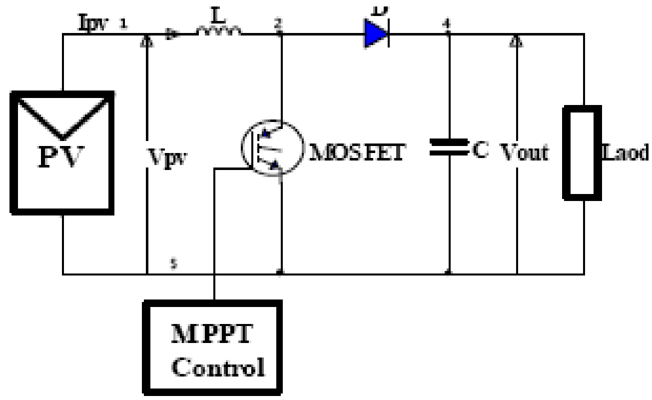

Figure 2. Boost converter.

$$C \geq I_{PV} \propto / f \Delta V_{PV} \qquad \textbf{(3)}$$

Where, f = 1/ T is the switching frequency, I_{out} is the output current and ΔV_{out} is the peak-to-peak ripple of the capacitor output voltage.

III. MICROCONTROLLER BASED CHARGE CONTROLLER

Microcontroller based charge controller design is feasible for performing complex task. PlC16F877A microcontroller used in this charge controller is the central of coordinating all system's activity. It is designed in 40 pin DIP package (Dual In Line Package) and it is the member from microcontroller 8-bit "Reduced Instruction Set Computer Central Processing Unit family" (RISC CPU) which implement the Harvard architecture by separating code and data spaces. Here, PlC16F877A microcontroller is used to control the operation of charging control and data acquisition task in this project. PlC16F877A contains 5 I/O ports which are suitable for the development of the charge controller. Port A is used to perform the analog to digital conversion which is used in input parts like temperature sensing circuit, battery voltage sensing circuit and current sensing circuit. Port B is used to interface with the LCD module whereas port C controls disconnect or reconnect operations for photovoltaic panel or load and also triggering the buzzer and generating the PWM signal to control the boost converter. Port D is used as input part for switching control and as output part for LED indicator. Block diagram of charge controller is shown in Figure 2.

Generally, charge controller is divided into 3 main portions, which are PIC16F877A microcontroller, input parts and output parts. The input parts for the charge controller are current sensing circuit, battery voltage sensing circuit and temperature sensing circuit. They are used to detect the voltage and current of the circuit and send the data to the PIC microcontroller to analyze and PIC microcontroller will operate according to the program written inside its memory. For the output part, it consists panel-battery connect/ disconnect circuit, sources load connect/ disconnect circuit, LCD module, PWM signal low voltage warning circuit, status indicator circuit. The 20MHz crystal is used as clock frequency of the microcontroller. The power of microcontroller is used from solar with 78L05 voltage regulator. Battery voltage is sensed across a potential divider which dropped it to less than 5V and a LED is used to give warning when this was low. An LM35 temperature sensor sensed the ambient temperature. Two power MOSFETs (IRF540) are used as solid-state switch for the panel-battery line and battery-load line. LEDs of differing colors are used to display the system status. The third power MOSFET is derived as boost converter switching transited by PWM signal that is came from microcontroller.

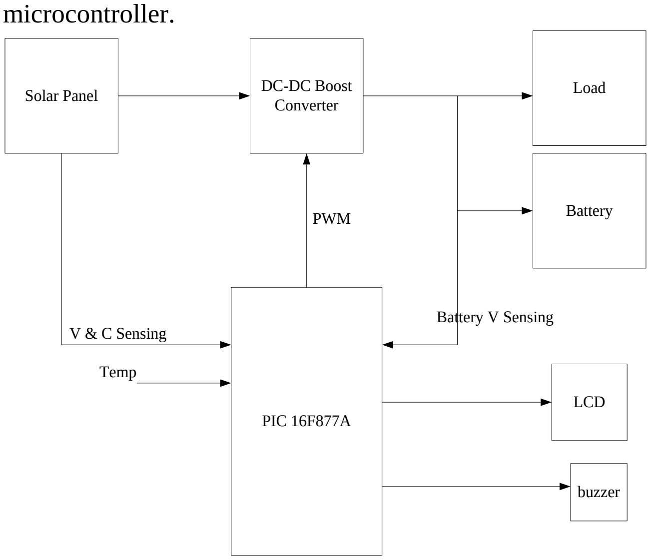

Figure 2. Block Diagram for Charge Controller.

One of the special features of this charge controller is it can be used with or without the existence of the battery in the stand alone photovoltaic system. The other features of this designed charge controller are listed as below.

- Solar charging current: 0 to 3 Amps continuous
- Nominal battery voltage: 12V
- Photovoltaic panel voltage ratings: 12 to 16V (85W)
- PWM battery charging for boost mode
- Battery type: lead-acid
- Reverse current flow prevention at night
- Overvoltage and under voltage protection
- Excess temperature protection
- Charge equalization
- Featured with LCD to display battery voltage, temperature and current flow to battery
- 3 LED indicators to show the status of the charge controller which are load disconnect, battery disconnect, and PWM charging.

IV. RESULTS AND DISCUSSION

A. Pulse-Width Modulation Charging Method

With pulse-width modulation (PWM) a voltage or current signal is switched on and off with a variable duty cycle, {3. The average output voltage is {3Vs, where {3=To,,!(Ton + Toff), Ton is the on-time and Toff is the off-time of the switch and Vs is the supply voltage. PWM is produced by a power MOSFET transistor switched through channel RC2 of the microcontroller via a transistor. Charging from the lower set point take place at full panel current (f3=1). When normal gassing occurs, {3 is progressively decreased almost to zero until the upper set point is reached.

B. Voltage control algorithm

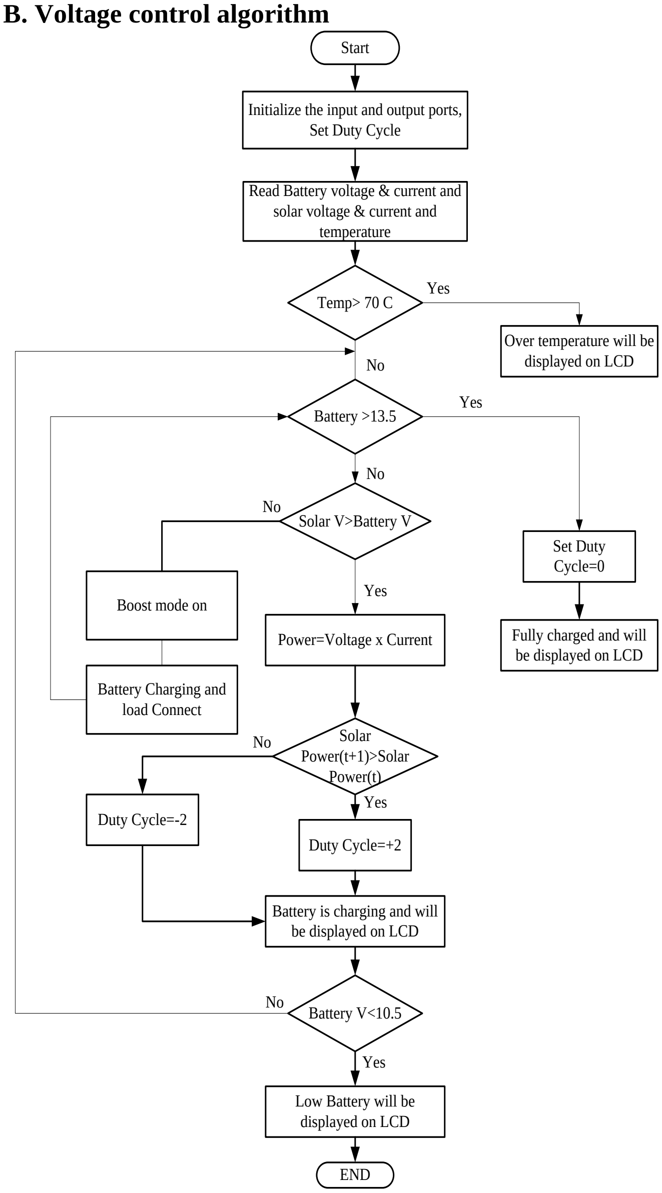

Figure 3. Flow charge for Software Development.

Software is crucial element in the development of solar charge controller. The main objective of the software development is to give instruction, control and coordinate the PIC16F877A to execute various tasks. In this case, mikroC code is written for the software development of solar charge controller. Microcontroller based designs are able to provide more intelligent control with the same device simply by changing the program parameters and/ or adding more sensors and by matching it to the various stages of charge of the battery. If the surrounding temperature is higher than 70°C, the system will be turn off. Figure 3 illustrates the flow chart for the software development of charge controller. The complete schematic diagram of the proposed charge controller is shown in figure 4.

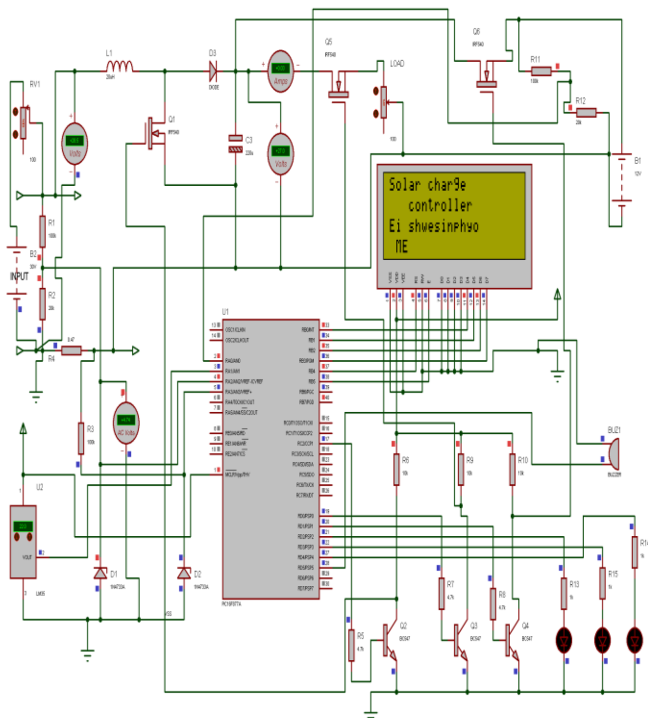

Figure 4. Charge controller schematic diagram.

V. CONCLUSION

The PV output power delivered to a load can be maximized using MPPT control systems, which consist of a power conditioner to interface the PV output to the load, and a control unit, which drives the power conditioner such that it extracts the maximum power from a PV array. The system consists of a high-efficiency, Boost-type dc/dc converter and a microcontroller-based unit which controls the dc/dc converter directly from the PV array output power measurements. PIC microcontrollers are easy to be used with mikro C code and there are many types of PIC microcontroller in the market that can perform better than PIC16F877A. Therefore, there is a potential for further research and future work on application of high end PIC microcontroller to further improve the performance of charge controller with some cost effective designs.

VI. ACKNOWLEDGMENT

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