Arduino Based Solar Powered Battery Charging System For Rural SHS

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***Abstract*— Solar Energy is a clean and renewable power resource and is on its way to high level penetration in the world electricity energy basket. However, there are several challenges associated with Solar Energy, like intermittency, limited dispatch ability and non-storability. Non-storability in a standalone PV system can be mitigated by incorporating energy storage devices like battery to store the electrical energy produced by solar panel when the sun is shining and to supply power when the sun is not shining. Batteries are, therefore, one of the critical component in the standalone PV system. And often the weakest link in PV systems as it influences the maintenance cost and reliability of the system. This paper involves designing and development of a low cost, microcontroller based, solar powered battery charging system. The developed system incorporates (i) MPPT (ii) Arduino Uno interface for battery management functions Arduino Uno interface , (iii) LCD display for information to the user about the system regarding the systems overall capacity to charge at any given time, (iv) data storage and incorporates Wi-Fi module for remote surveillance and uploading live data which can further be used for studying the health of the battery and help in maintenance of battery. The developed solar powered battery charging system for DC loads has been designed for use in Solar Home Systems (SHS). The individual SHS can be connected to form a low voltage DC micro grid for the remotely located rural population for sustainable provision of electric energy services.**

Keywords— Battery; Charge controller; Arduino Uno; Solar PV Panel

I. INTRODUCTION

Increasing energy demand, depleting fossil fuels, new load types, rural electrification, energy security are some of the drivers for power sector to embark on to a journey of sustainable energies. Renewable energies will play a key role in this journey. Solar Energy is expected to contribute to the energy mix in a large measure because it is abundant and clean. Solar PV systems involve no fuel cost, are silent in operation, require less maintenance and have long life. In India the Solar Mission is supported by MNRE and MoP. 100 GW of solar power is envisaged by 2022. Out of this 40 GW of Rooftop PV and 60 GW of Solar Thermal will be generated according to report of JNNSM (Jawaharlal Nehru National Solar Mission) MNRE, India. Decentralized Distributed Generation (DDG) scheme envisage provision of electricity to villages from conventional or renewable sources on a standalone basis [1]. In order to provide access to electricity to rural population with low energy consumption in remote and off grid areas, a low, voltage DC distribution network where in individual Solar Home Systems (SHS) can be interconnected, is an attractive option [2]. However such standalone renewable energy solutions need energy storage devices for making the power available without interruption over a number of days. Lead acid batteries currently provide the best cost to benefit ratio amongst various energy storage technologies [3]. In this paper a low cost Arduino Uno based solar powered battery charging system for SHS has been designed and developed.

II. CONVENTIONAL METHODS AND PROBLEMS

The major components in standalone solar PV system Solar PV panels, batteries and power conditioning devices .The solar PV panels produce DC power which was later on converted to AC using converter devices. The use of power electronics converters increase the complexity and decrease efficiency of the power system [4]. Nowadays, increasing number of devices which use DC, such as laptops, mobile phones and other power electronic devices used in our daily life are being incorporated. Such applications need to convert AC back to DC. This conversion increases the losses and complexity of the power system. This concept is particularly useful for rural and sparsely populated areas where in low voltage DC network can supply electricity generated by solar PV to cater to the load constituting of LED lamps, DC fan, TV and mobile charging stations. To improve the efficiency of such a power network, instead of using multiple conversions, the whole power system can be represented in figure 1. The DC based power system helps to eliminate the requirement of converters systems, reducing converter cost, power system complexity, improve efficiency and reliability. The batteries are used to store the energy from solar panels as an energy bank for emergency and night hour usage in domestic and industrial applications. To charge these batteries from the sun light rated amount of current for rated time duration is required. If excess current is supplied, the battery can be damaged. If battery is overcharged or discharged for a long duration of time, batteries life span will come down. The conventional battery chargers available in market have limited features. And some time they do not monitor the battery health properly, and may let the battery to undergo deep discharge or overcharge. If a battery goes into deep discharge, it is very difficult to recharge it using battery charger since the electrode plates of battery will be fully sulphated, resisting the charging.

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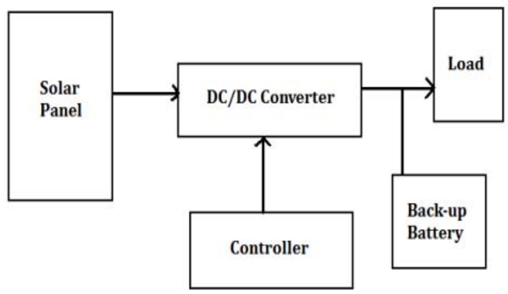

Fig. 1. Block diagram of the proposed solar system

To charge a deep discharge battery, a large current to reverse the chemical reactions which took place during discharging is required.

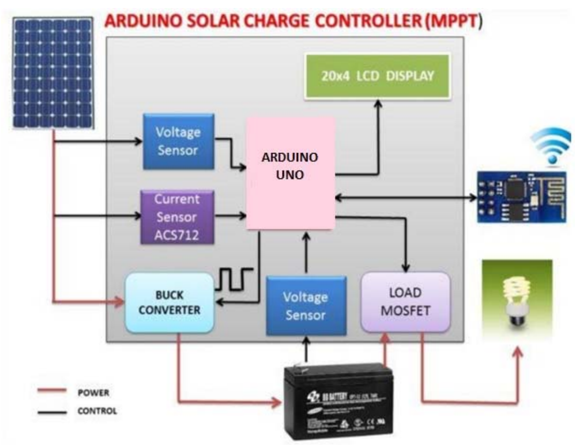

Fig. 2. Block diagram of the proposed solar system

If we supply huge current to a deep discharged battery, battery will get damaged. And if we let a battery to be in charging process for a long duration (over charging), gassing of hydrogen and oxygen occurs at the electrode plates and wash away the active material coated on the plates this again leads failure of battery hence an intelligent battery charging system is necessary to take care of these problems. In this work, a low cost solar powered battery charger for DC loads (DC lighting i.e. LEDs, DC gadgets like laptops, telephones, satellite TV controllers etc.) has been designed and developed. The developed system has the capability of logging and storing data for remote surveillance, leading to better maintenance of the battery, thereby increasing the life of the battery. Figure 2 gives the block diagram of the proposed system. The overall solar PV standalone system consist of a solar panel, Arduino interfaced MPPT charge controller, Wi- Fi module battery bank, and load to deliver usable power to the end user [5,8].

III. BASIC DESCRIPTION OF THE SYSTEM

A. PV Cell Chemisteries

The solar panel consist of a number of Si based PV cells combined in series and in parallel depending on the required voltage and the current. Presently the commonly used different types of PV cells are polycrystalline Silicon, mono crystalline Silicon, copper-indium selenide and amorphous silicon. The efficiencies vary from 6% to 25%. A Mono crystalline silicon PV cell has higher conversion efficiency (approx. 22%) as well as higher cost. In this work mono crystalline Silicon panel is used. Electrical characteristics of the PV Panel (Values at STC (AM1.5, 1000W/m², 25°C))

- Max Power P_{max} : $50W_p$ +/-3%
- Panel Voltage : 12 V
- Nominal Current I_{mp} : 2.77A
- Nominal Voltage V_{mp} : 17.20V
- Cell Efficiency : 17%
- Open–Circuit Voltage V_{oc} : 21.6 V
- Module Efficiency : 14.6%
- Short-Circuit Current I_{sc} : 3.23 A

The I-V characteristic of solar cell under varying sunlight is shown in Figure 3. The knee point where the dropping voltage line meets the vertical power line shows the optimal power available.

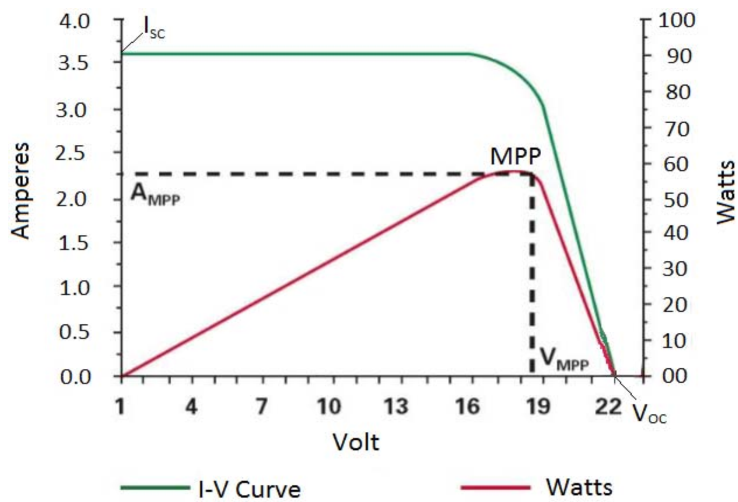

Fig. 3. Standard I-V Characteristics of PV Cell

B. Batteries for Energy Storage

Energy storage devices are required for ‘power applications’ and ‘energy applications’. In energy applications, the discharging process of energy is slow as compared to power applications and generally takes ten minutes to hours. In case of power applications discharging of the stored energy take place at very high rate, from seconds to minutes [7]. In power applications the energy storage medium is flywheel, battery, hydrogen and electrochemical capacitors (ECs). Most common used energy storage technology is lead-acid battery because of its main advantage over the other rechargeable batteries is that power ratio is superior. Generally there are two categories of lead–acid batteries flooded lead acid (FLA) batteries and valve regulated lead-acid (VRLA). VRLA is further categorized as Absorbed Glass Mat (AGM) and Gel. VRLA batteries are also known as sealed batteries. Sealed batteries, though costly, have the advantage of less maintenance and longer life span. In the present work AGM battery is used.

C. Charge Controller

A battery charging system is not complete without a charge. Mainly it is type of regulator that prevents the batteries from overcharging. The charge controller converts the incoming DC voltage from the solar panels to the exact voltage range suitable for battery charging. The charge controller unit must work for the given range of the voltage and should cut automatically if SPV voltage falls below desire value [13]. As the intensity of light reduced, the charge controller automatically turns off and switches on when adequate amount of light is restored again. Most of the available charge controllers can operate only on ideal lighting conditions. Due to this shortcoming, the use of such charge controllers is limited. The developed charge controller use maximum power point tracking (MPPT) to track and adjust the voltage and current to follow the maximum power with prevailing light conditions. However, MPPT controllers are costly [8]. Figure 4 depicts the Tracking Algorithm of Maximum Power Point Tracker used.

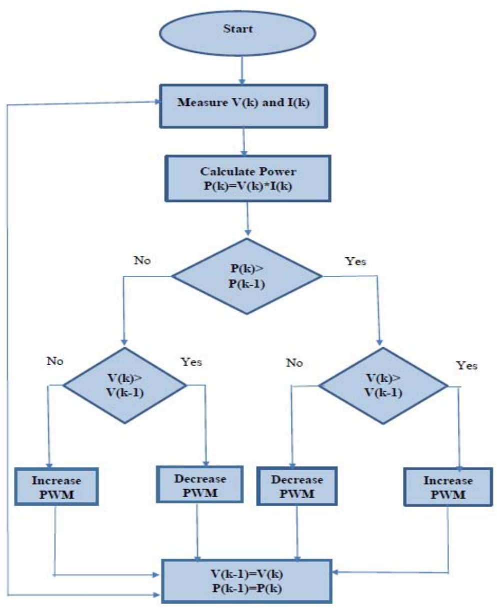

Fig. 4. Tracking Algorithm of Maximum Power Point Tracker.

Pulse width charge controller use high frequency pulses to control the current from the source depending upon the state of charge of battery. Pulse width charge controller checks the magnitude and time of pulse to reduce battery overcharging. During peak when the batteries are discharged a signal is received by the PWM charger and full current pulses remain continuous, as it becomes charged and this stage is called bulk stage of charging.

Absorption is the next step of charging which occurs when batteries are near to the full state of charge (SOC). The battery bank voltage is held constant by the controller for certain period of time. Further, the off time of the pulses increased to slowly decrease the current level when power bank is topped off. The full capacity of the batteries is referred to as float charging stage. The developed battery charger can be in one of the following four states:

- On State: Is the charger state for solar power value in between minimum solar power value and low solar power value (minimum solar power < solar power <low solar power) [12]. In this state, for bulk charging state the solar watts input are very low but not so much low to go into the off state. To get low amount of power pulse width modulation is set to be 99.9%.
- Bulk State: Is the charger state in which solar power is greater than the minimum solar power. In this state, the Peak Power Tracking algorithm is used for the bulk of the battery charging by running the maximum amount of current in the circuit that the solar panels are generating into the battery.
- Float State: In this stage, voltage is rise till maximum battery voltage is achieved . So this state is known as float state. In this state, by adjusting the PWM value the battery voltage is maintained at its maximum. If PWM attain its 100%, then the battery is being drawn down by some load because battery voltage can't be kept at maximum.
- Off State: When no power is generated by the solar panels the charger goes into Off state (solar power < minimum solar power). In this situation power from the battery can reflect into the solar panel, so all the MOSFETs are turned off to avoid this situation. If the solar panel isn't producing power then it's probably night time. Therefore, the load state will be on which means that the load connected will take supply from the battery and there is no supply from the solar panel. The final code of the Arduino circuit used for MPPT was developed.

D. DC to DC Converter

A DC-to-DC converter is required to increase (Boost) or decrease (Buck) the input panel voltage to the required battery level. The main parameters of the buck circuit are the inductor, capacitor, and MOSFET. In this work IRFZ44N MOSFET is used as a switch.

E. Microcontroller

Arduino Uno (ATmega 328P) microcontroller is used as easy to program. It has 14 digital input/output pins. Out of these these 14 pins, 6 are used as PWM outputs and 6 are used for analog inputs. It is powered by USB connection to computer and has a reset button. Operating voltage is 5 V.

IV. INTERFACE BETWEEN THE CONTROLLER AND WI-FI MODULE

Wi-Fi module (ESP8266) is used to accomplish the monitoring task. It is a self-contained SOC which stands for (System on Chip) support integrated TCP/IP protocol stack which provides any microcontroller with an access to any Wi-

Fi network. The ESP8266 is able to host or offload an application from another application processor doing all Wi-Fi networking functions. Every ESP8266 module comes pre-programmed with a firmware, AT command set, so we can simply connect it to Arduino device and get about as much Wi-Fi-ability as a Wi-Fi Shield offers. In this work, the data is sent through AT commands from a computer to serial adapter by an USB. The working of Wi-Fi module is tested with and firmware installed in the ESP8266 module Arduino Uno, in order to integrate in the main circuit (Fig. 5).

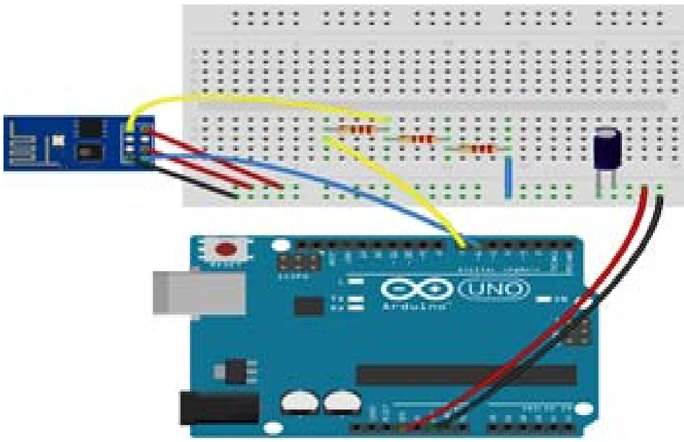

Fig. 5. Interfacing of Wi-Fi module with Arduino

Firmware is basically a set of instructions uploaded directly into the ESP8266 module by connecting it to the laptop directly. For this, USB to TTL logic convertor has been used to establish communication between the developed system and Wi-Fi module. Flasher is then used to flash the firmware into ESP module. Through AT commands, communication is facilitated between the module and internet. After establishing the connections, this circuit (Wi-Fi module) is implemented into our main circuit (Fig. 6).

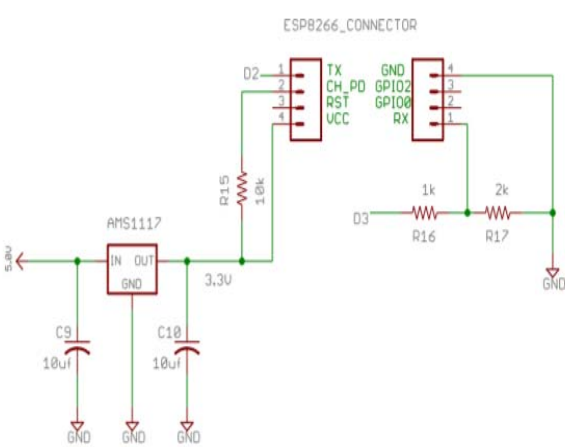

Fig. 6. Wi-F interfacing with main Circuit

Data Logging helps to gather data about solar PV system and battery for many purposes. Figure 7 depicts variation of PV voltage with time.

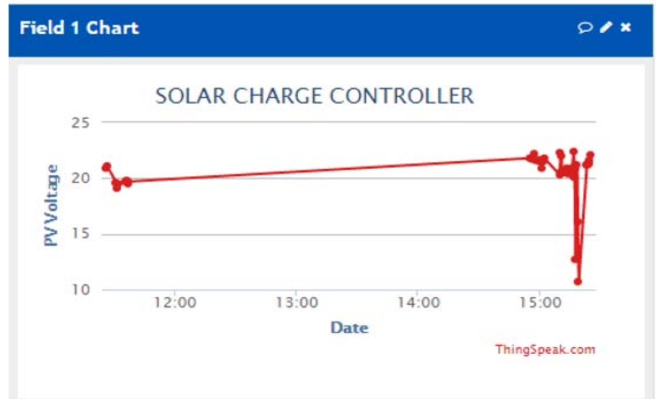

Fig. 7. Solar PV voltage Vs Time

The data can also be send to the locations of the nearest solar tree system for the users' smart phones. All this can lead to a designing of a better, efficient, IoT (Internet of Things) integrated and better connected PV systems. Table 1 gives the list of main components used.

Table 1. List of component used

Component	Specifications
Solar PV Panel	Rated Power – 50W; Cell Type – Monocrystalline; Open Circuit Voltage: 21.6V; Short Circuit Current: 3.23 A; Max. Power Voltage: 17.20 V
Battery	Absorbent Glass Mat (AGM) ; Nominal Voltage :12V; Internal Resistance- Fully Charged battery 770F-30 mΩ
Mosfet Driver	Gate drive supply - 10 to 20V; V_{OFFSET} - 600V (max) V_{OUT} - 10 - 20V; IO+/- - 130 mA / 270 mA
Buck Converter	Resistance–220Ω; Inductance–33micro Henry; Capacitance– 0.1microFarads
Boost Converter	Inductance – 90 micro Henry Capacitance – 220 micro Farads
Load	Lamp; Voltage – 12 V; Rated Power - 6W
Microcontroller	Arduino Uno
WI Fi Module	ESP8266; Module operates at 3.3V; 240mA peak current; 100M for max transmitting distance ;+20Dbm power
Current and Voltage Sensors; LCD display	

V. CONCLUSIONS

In this paper, design and development of a low cost Arduino based Advance Solar powered Battery Charge Controller is presented. The charging of battery is implemented using MPPT algorithm. Thus extra energy harvest is obtained by operating at PV peak power point instead of output voltage of PV at any given time. The charge controller has an battery management system in built along with LCD display and Wi Fi module for data logging and storing. The in and out voltage and current flow in the battery, the state of charge of battery and cut off the battery when various limits are reached are indicated by display. The developed battery charger will help better monitoring of battery performance and reliability of the system. It can also be used for remote surveillance of battery connected to PV standalone systems.

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