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Solar Power Based Approach for Charging of VRLA Batteries and Mobile Phones for Street Vendors

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Abstract:
Street vendors in India make use of battery and LED lamps to illumine their cart. They generally charge their cart batteries on every alternate day, by paying fees to the charging point. In solar rich countries like India, the green solar energy can be utilized for this purpose, at virtually no cost. This is, to best of our knowledge, first ever attempt to bring ease in the life of street vendors by providing them with solar cart lighting solution, at minimal initial cost. This paper presents a low power,low maintenance, highly efficient method for charging VRLA battery using Maximum Power Point Tracking. There are a number of Maximum Power Point Tracking (MPPT) algorithms available for PV system operations, the proposed system utilizes indirect voltage method algorithm for its numerous advantages. The systems designed is subjected to various test conditions including environmental conditions and experimental result indicates that output voltage remains constant at 14.2 V with input power variations from 12.10W to 15.45W. A PWM signal of microcontroller controls switching of MOS transistors, which in turn adjusts charging voltage of a battery precisely at 14.2V.

Keywords: Solar PV System, MPPT, Indirect voltage Algorithm, Microcontroller, Low power application, street cart vendors.

I. INTRODUCTION:

Solar energy is one of the most evident renewable energy sources available that is gaining increased attention in recent years [4]. Throughout the world, photovoltaic power generation is becoming increasingly popular due to a combination of factors: low maintenance, minimal wear and tear of components due to the absence of moving parts, lack of audible noise, the absence of fuel cost and pollution-free operation after installation [3]. Solar energy is clean and free of emissions since it does not produce pollutants or by-products harmful to nature. The conversion of solar energy into electrical energy has many applications in various fields. When a solar panel is used without a charge controller which can perform Maximum Power Point Tracking (MPPT), it will often result in loss of power, ultimately resulting in the need to install more panels for the same power requirement [2]. Recently, research and development of low cost flat solar panels, thin-film devices, concentrator systems, and many innovative concepts have increased. In the near future, the costs of small solar-power units and solar-power plants will be economically feasible for large-scale production and use of solar energy [4]. This paper presents an efficient operation of the PV panel. The PV systems show nonlinear behavior, in which the maximum power point (MPP) varies with insolation, and there is a unique PV panel operating point at which the output power is maximum. In order to maintain the Maximum Power Point (MPP), a power electronics system that significantly increases the system's efficiency. By using it, the system operates at the Maximum Power Point (MPP) and produces efficient output [6]. Thus, an MPPT maximizes the PV array's efficiency and thereby reducing the overall system's cost [4]. Furthermore, an attempt to design the MPPT by using the "Indirect voltage" algorithm is done. It's implementation by using a DC to DC Converter is done [4]. Various types of DC-DC converter were studied and among them "BUCK-BOOST" converter is used for the design. The buck-boost converter is used since it has a linear voltage transfer function when operating in Continuous Conduction Mode (CCM). PV generation systems generally use a microcontroller based charge controller connected to a battery and the load [4]. As the input voltage from the solar array varies, the charge controller regulates the charge to the batteries preventing any overcharging [4]. So a good, solid and credible PV charge controller is an essential component of any PV battery charging system to achieve system's utmost efficiency. It is known that microcontroller based designs are able to provide more creative control and thereby an increase in the adeptness of the system can be achieved [4]. The system is developed based on the requirements of the street vendors to light up their stalls economically without costing much. Along with the MPPT, system also includes a mobile battery charger, an LCD to display the status of charging of the battery and overcharging protection.

II. REVIEWED LITERATURE:

MPPT technique:

Tracking the Maximum Power Point (MPP) of a photovoltaic array is an essential stage of a PV system. As such, many MPPT methods have been introduced and numerous variants of each method have been proposed to overcome specific disadvantages. The large number of methods proposed can make it difficult to determine the best technique to adopt when implementing a PV system. All the methods vary in complexity, number of sensors required, digital or analog implementation, convergence speed, tracking ability, and cost effectiveness. In addition, the type of utilization can have a denoting impact on the selection of MPPT algorithm. In this regard, this paper outlines the method best suitable for efficiently charging the battery at a constant voltage [3].

Algorithm (Indirect voltage)
The requirement of the system is to charge a battery for the street vendors who mostly use the used up car batteries. In order to charge such batteries, a constant voltage with appropriate current is necessary as due to varying voltage, the life of the battery is affected and may damage it further. The algorithm used is simple and effective in this case. The microcontroller is fed with the output from the voltage sensor which is sensing the panel's voltage. The battery used is 12V, 7Ah therefore, for efficient charging needs a constant supply of 14.2V. Also, the microcontroller continuously keeps tracking the maximum power point The algorithm focuses on providing the voltage of 14.2 to the battery. The microcontroller generates PWM signal according to the adjustment required. If the sensed voltage is less than 14.2V the duty cycle of the pulse is incremented by 5% every time till 14.2V is achieved. If the voltage exceeds the required value, in the same way, the duty cycle is decremented till the required voltage is achieved [3].

Table.1. Comparison between different MPPT techniques [5]

Techniques	Implementation and complexity	Convergence speed	Sensed parameters
Neural Network	High	Fast	Variable
Fuzzy Logic control	High	Fast	Variable
Perturb and Observe	Low	Variable	Voltage
Fractional Vsc	Low	Medium	Voltage
Fractional Isc	Medium	Medium	Current
Incremental conductance	Medium	Variable	Voltage and current
This method	Low	Medium	Voltage

PROPOSED SYSTEM:
Fig. 1 indicate block diagram of proposed system's which includes PV panel, controller circuit and a battery. The voltage and current of PV array is sensed and fed as an input to the microcontroller. In order to display solar panel & battery voltage, a 16x4" LCD display along with a toggle switch is used. The microcontroller generates PWM signal to operate the buck-boost converter which provides constant voltage and appropriate current to the battery for its charging[3].

Fig.1. System's block diagram including PV panel and battery

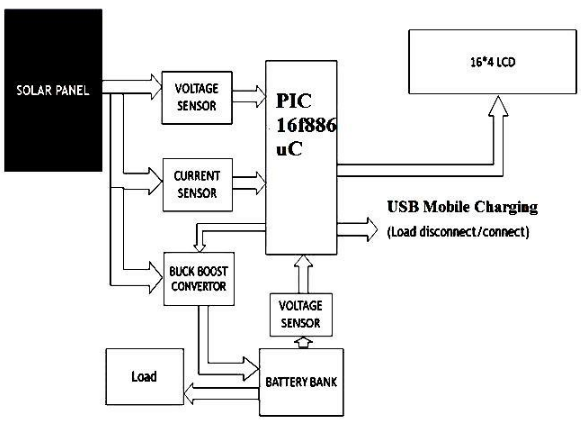

Figure.1. System's block diagram including PV panel and battery

The objective of the paper is to present a novel, cost-effective and efficient microcontroller based MPPT system for the solar photovoltaic system to ensure the maximum power point operation at all changing environmental conditions for the street vendors [4]. This algorithm is executed by employing an PIC16f886 controller that utilizes the PV voltage and current data to control the duty cycle of a pulse width modulation signal applied to a DC/DC converter.

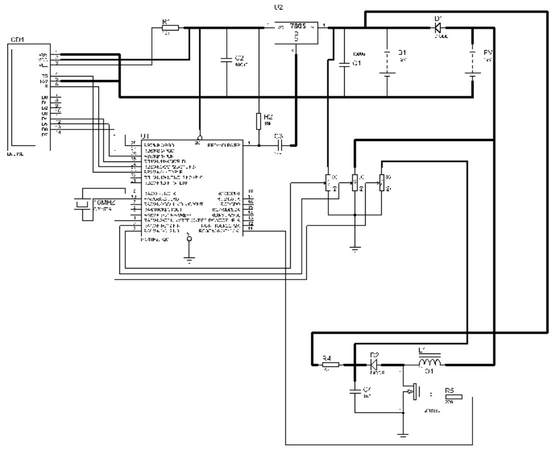

Figure. 2. Circuit schematic

Microcontroller: The MPPT control circuit is implemented in a microcontrollerPIC16f866, an 8 bit CMOS microcontroller. The DC to DCconverter is controlled by the microcontroller. It reads the voltage of the solar panels through the A/D port of controller. It also reads the voltage of battery side in the same way and send a corresponding control signal to the DC to DC converter and controls the duty cycle of the PWM signal through the controller to accordingly increase, decrease or turn off the DC to DC converter [4]. The PIC16f886 is a perfect combination of performance, features, and low power consumption for this application also it is observed that this microcontroller is capable of providing an accurate PWM pulse [8].
DC-DC converter: There are several topologies available for a DC-DC converter. Among them, the buck-boost converter is in an increasingly popular topology, particularly in battery powered applications, as the level of the output voltage can be changed with respect to input voltage [8]. The commonly used converter in PV systems is a DC/DC power converter. It ensures thorough control action and transfer of the maximum electrical power to the load. The construction of the converter is determined in accordance with the load to be equipped. In this article we focus on the step-down as well as step-up DC/DC converter (Buck-boost converter). MPPT handles the related converter for a distinct scope, such as modulating the input voltage at the Maximum Power Point and maintaining load matching for the maximum power transfer [4].

Circuit Operation:
Phase 1: The duration of phase 1 is from 10 a.m. to 4 p.m.
The PV array is the source driving the system. A diode incorporated at the input side prevents the reverse flow of current from the system to the PV array, thereby, protecting the PV array from damage. The voltage from the PV array is fed to the microcontroller via a voltage sensor and MPPT circuitry. The microcontroller thus has the data regarding the input voltage. This is checked in the algorithm mentioned earlier. The PWM input signal is given to the MOSFET by the

PIC IC regulating the required voltage by varying the current accordingly. The battery and the loads are connected in parallel. The voltage from the MPPT converter drives them. The battery's voltage is continuously checked by the PIC microcontroller so as to protect the battery from overcharging and discharging. A bulky resistor rated 100ohm, 50W is connected in series with PV array and battery, this ensures PV array protection from reverse current of battery during discharge.

Phase 1 system in operation

Phase 2: The duration is from 6p.m to 11p.m

The source is battery in phase 2 driving the system. The PV array is disconnected during this phase. The battery is used to drive a LED lamp ranging from 4W-24W.

Phase .2. system in operation

The system designed includes,

1. Battery reverse discharge protection circuitry
2. Over-current current protection circuitry
3. Load switchable between battery and PV array
4. Deep discharge and over-charge protection circuit
5. Portable mobile charger port

Table 2. Observation of the output of PV array of 40W at 42°C

Time	Voltage(V)	Current(A)	Power(W)	Output Voltage from the circuit(V_o)	Output Current from the circuit(I_o)
1100 hours	20.9	1.31	29.22	14.2	1.58
1200 hours	21.3	1.37	30.46	14.2	1.60
1300 hours	21.7	1.38	30.90	14.2	1.63
1400 hours	20.2	1.42	30.22	14.2	1.61
1500 hours	20.1	1.37	28.56	14.2	1.57
1600 hours	19.6	1.21	24.20	14.2	1.52

III. CONCLUSION:

This research paper proposes a simple low-cost method for the charging of VRLA battery used by street vendors for lighting of their carts. This is, to best of our knowledge, first ever attempt to bring ease in the life of street vendors by providing them with solar cart lighting solution, at minimal initial cost. Proposed system utilizes indirect voltage method algorithm for efficient charging of battery. Charging of the battery is carried out during the daylight when there is appreciable radiation intensity. Apart from that, the system has mobile charging port as an additional facility. The systems have been in-depth analyzed and tested for various test conditions including environmental conditions such as clouds, low/high wind, rain and experimental results indicates that battery charging voltage was constant at 14.2 V with input power variations from 12.10W to 15.45W. Presently, designed system prototype is being used by street cart in the region.

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