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Solar PV FED Current Pumped Battery Charger

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Abstract: Solar Energy is inexhaustible and available abundant in nature. The Photo Voltaic (PV) power generation system can be used for wide range of applications. Since the output of solar PV panel is random in nature, there is a need to store excess power in batteries. Traditionally the solar PV battery system is charged using conventional DC-DC converter. In this paper charging is experimented with solar PV fed current pumped battery charger that improves the charging performance of a lead-acid battery. The solar PV fed Current Pumped Battery Charger (CPBC) is built using DC-DC converter interfaced with a current pumped battery charger circuit. The output of DC-DC converter is fed to the Phase Locked Loop (PLL) IC 4046 which consists of Two Phase Frequency Comparators (PFC) and Voltage Control Oscillator (VCO). A Voltage to current converter operation is performed by the operational amplifier and the power MOSFET is used to transfer the current into the pumping current which charges the battery quickly. Test results shows that the charging time is considerably reduced compared to traditional DC-DC converter for a Lead Acid battery.

Key words: SolarEnergy · DC-DC Converter · Lead-acid Battery · Current pumped battery charging system.

INTRODUCTION

Energy is the predominant force, which determines the growth of any nation. Enormous amount of energy is being produced and it is consumed in the global context. Energy depleting resources of fossil fuels indicates that there is a need to conserve energy for the future. There is ever growing demand for energy from resources like solar, wind, tidal etc. India has a rich potential of renewable energy market [1]. The Evolution of renewable energy resources has gained much importance due to the depletion of non-renewable energy resources. As the power demand tends to increase, there is a need to go with renewable energy resources along with the traditional sources of power generation to meet out the demand. Solar Energy is preferred mostly as it is available with free of cost and it is easy to extract the solar energy by installing the solar panels [2-3].

This paper makes use of solar energy as the source of power to charge the 12V, 7Ah Lead-Acid battery. As it takes longer time to charge the battery using DC-DC converter, the proposed method of current pumped battery charging system is used to charge the battery [4]. It uses the concept of pulsed current charging method which pumps the current to the battery and makes it to charge the battery quickly. As there will be fluctuations in the output voltage of the solar panel, this paper gives us the DC-DC Converter. It produces the constant voltage of 12V to reduce the voltage fluctuations. The battery is allowed to charge and discharge using traditional DC-DC Converter. The corresponding characteristics are noted.

The CPBC circuit is interfaced with the traditional DC-DC Converter. Again the battery is allowed to charge and discharge with the above circuit. The charging and discharging characteristics of the battery are noted. The comparison is made between the traditional method and proposed method to prove the efficiency of the current pumped battery charging system.

Batteries and Charging System: An electric battery is a device consisting of one or more electrochemical cells that convert stored chemical energy into electrical energy. Each cell contains a positive terminal, or cathode and a negative terminal, or anode. Electrolytes allow ions to move between the electrodes and terminals, which allows current to flow out of the battery to perform work.

Battery and its Types: Most of the batteries used in our hobby today are the rechargeable type. There are several kinds of rechargeable batteries and these includes NiCd (Nickel Cadmium), NiMH (Nickel Metal Hydride), Li-Po (Lithium Polymer), Lead Acid, Sea Lead Acid and Gel-cell

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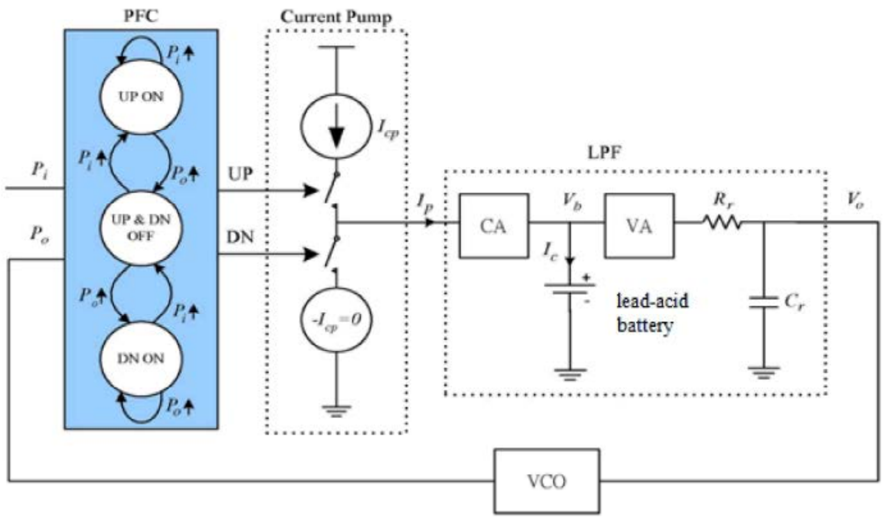


Fig. 1: Block diagram of Current pumped battery charger

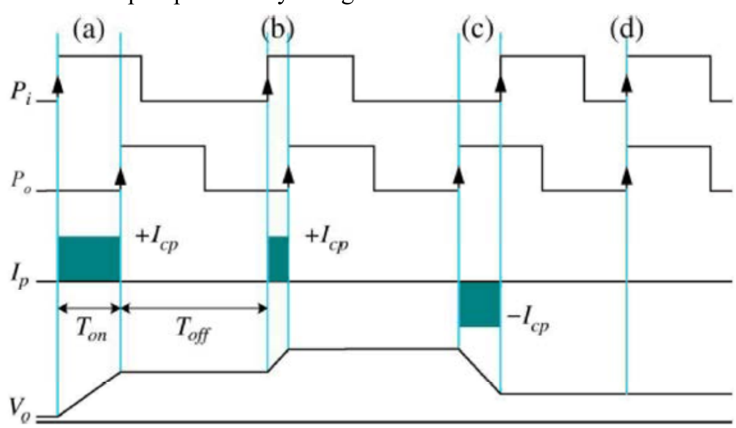


Fig. 2: Waveforms of CPLL

and among others. NiCd's are used to run our radio systems as well as power our model cars, boats and planes [5]. Generally they are wired together in pack of four or more cells depending on their application. NiMH is relatively new and is being widely accepted for the same application as NiCd's. Li-Po cells are a new technology that quickly finds its way into model applications. The other types of batteries mentioned are usually 6 or 12V and used to power flight boxes and large scale boats.

The Lead Acid Storage batteries is an important energy storage device which is most widely used secondary storage cell by automobiles and other industries. Storage cells are the devices which release the flow of electrons through an external circuit as a result of reactions occurring between the active electro material and ions transported by the electrolyte. The cells in which the reactions are reversible are called secondary cells. In these cells the active materials can be returned to their original state by applying electrical current from an external source in the opposite direction to the flow of cells discharge current.

Proposed System and Description: This paper uses the method of current pumped battery charger circuit to charge the battery quickly. The block diagram of CPBC system is shown in Figure 1. The proposed system consists of Phase Frequency Comparator (PFC), Current pumping circuit, Current amplifier, Lead-acid battery, Voltage amplifier and Voltage Controlled Oscillator (VCO).

A.current Pumped Phase-Locked Loop (CPPLL): The waveform of a typical Current pumped phase –locked loop is shown in Figure 2. It consists of a PFC, current pumping circuit, Low-Pass Filter (LPF) and VCO. The PFC checks the input phase P_i and the feedback phase P_o, outputs UP and DOWN control signals to control the current pump circuit which produces pumping current I_p.

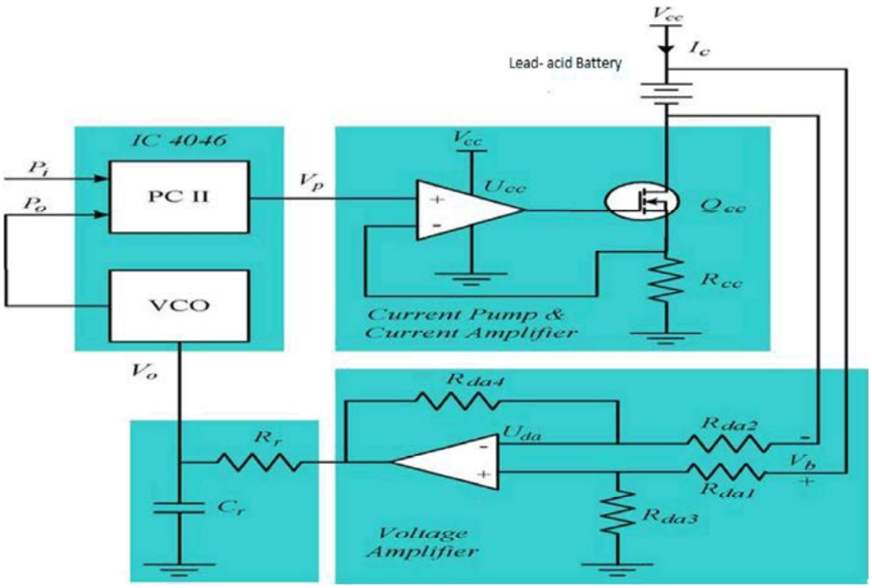


Fig. 3: Circuit diagram of Current pumped battery charger

The pumping current I_p adjusts the driving voltage V_o through LPF. The VCO oscillates at a frequency that varies with the V_o to minimize the frequency and phase error. After many cycles of operation the frequency and phase error will be zero.

The state diagram of the PFC is drawn in the PFC block in Fig. 1. When the feedback phase Po lags the input phase Pi, the UP control signal is maintained ON for a time corresponding to the phase difference. In this state, as shown in periods (a) and (b) in Fig. 2, the CP outputs the positive constant current +Icp to pump the LPF. When the feedback phase Po leads the input phase Pi, the DOWN control signal is maintained ON for a time corresponding to the phase difference. In this state, as shown in period (c) in Fig. 2, the CP outputs the negative constant current -Icp to pump the LPF. When the feedback phase Po is equal to the input phase Pi, which is shown as time (d) in Fig. 2, UP and DOWN remain OFF and thus, PFC output becomes an open circuit and holds the VCO driving voltage Vo constant for locking the feedback phase Po as the input phase Pi. From Fig. 2, it can be seen that the CPPLL inherently provide pulsed current to pump the LPF. If the LPF is replaced by batteries and the pumping current is large enough, a novel battery pulse charge system will be developed by using the CPPLL technique.

Current Pumped Battery Charger: The functions of the PFC, CP and VCO in the proposed CPBC are all the same as those in a typical CPPLL. The circuit diagram of CPBC is shown in Figure 3. In particular, the negative constant current -Icp is set to zero in the proposed CPBC. The Current Amplifier is used to amplify the pumping current Ip to a high-power current (i.e., battery charging current) Ic to charge the battery. The Voltage Amplifier is used to amplify the measured Lead-Acid battery voltage Vb to adapt the input voltage scale of the VCO. The capacitor Cr and resistor Rr acts as a ripple suppressor to the VCO driving voltage. In the proposed CPBC, the Current Amplifier, Lead-Acid battery, VA and ripple suppressor work together as LPF [6]. This is shown in the dotted block in Fig. 1. It can be clearly seen that the circuit topology of the proposed CPBC is the same as that of the CPLL, which means that the CPBC can have lots of inherent abilities that CPLLs have, such as proving a pumping current to the LPF. The working process of the proposed CPBC is briefly described as follows. First, the Lead-Acid battery voltage Vb is measured and amplified by the VA and then sent to the VCO. Next, the VCO oscillates a feedback phase Po that corresponds to measured Lead-Acid battery voltage Vb and feeds back to the PFC.

This implies that the proposed CPBC works as a pulsed current charging process in the phase-tracking state. It should be noted that the pulsed charging frequency is equal to the input frequency fi. Finally, when the feedback phase Po is almost the same as the input phase Pi, the CPBC works as a pulsed float charging process to maintain the battery at a preset voltage. In practical applications, a pulsed charging current is regarded as a pulsed float charging process when its duty ratio is smaller than or equal to 5%. After the above

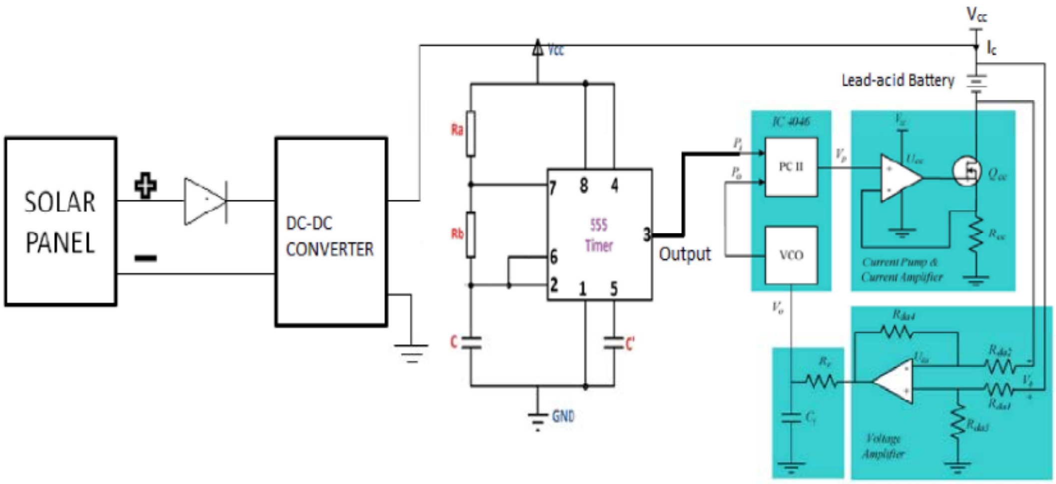


Fig. 4: Block diagram of the solar PV fed CPBC

Table 1: Specifications of DC-DC Converter

Output		
DC Voltage	12 volts	
Current range	125-1250 mA	
Rated power	15w	
Input		
Voltage Range	(9-18)volts DC	
DC Current	Full load	1700mA
No load	20mA	
Protection	Fuse recommended	
Environment		
Working temperature	+25 -- +71°c	
Working humidity	-25 -- +105°c	

description, it can be seen that there are three inherent charging processes in this CPBC, namely, bulk current charging, pulsed current charging and pulsed float charging.

Complete Block Diagram Current Pumped Battery Charger: The Figure 4 shows the solar PV fed current pumped battery charger. It is composed of solar as source of power, interfacing circuit with timer and the current pumped battery charger (CPBC). The output of the solar panel depends upon the sun radiation, it produce high voltage at noon and low voltage at morning and evening. The fluctuation in the output of the solar panel affects the battery and the other circuits. In order to avoid this problem a dc-dc converter is used to produce the constant output of 12 volt. The converted output from the dc-dc converter is fed to the timer circuit; it converts the direct dc voltage to pulsed dc voltage. The pulsed output from the timer circuit is given as the input to the current amplifier circuit.

The pulsed dc voltage is given as the one input (Pi) of the phase comparator and the output of the Vco (Po) is given as another input of the phase comparator. The phase comparator compares both the input and produces the output with respect to the phase difference of the inputs. The output of the phase comparator is given to the input of the current pump and current amplifier circuit which pumps the current to the battery and decreases the charging time of the battery. The feedback of the battery is fed to the voltage amplifier. This stabilizes the voltage and this voltage is fed to input of the Vco [7-11].

The Vco oscillates the voltage to adjust the error of the phase comparator. The output of the Vco is fed to the phase comparator. The phase comparator again compares both the inputs and produces the output with respect to the phase difference of the inputs. This process continues and works as a phase locked loop.

DC-DC Converter: A dc-dc converter is an electronic circuit which converts a source of direct current (DC) from one voltage level to another. The specifications of DC-DC converter is shown in Table 1. Among various DC-DC converters SKA15A-12 DC-DC CONVERTER is used in this paper.

Timer Circuit: This circuit comprises of NE555 as astable multivibrator which converts the direct voltage to pulsed voltage. This circuit is used to interface the DC-DC converter and the current pumped battery charger.

A form of relaxation oscillator which comprises two stages that are coupled so that the input of one is derived from the output of the other. Basically two amplifiers are cross-coupled with regenerative feedback, in its most

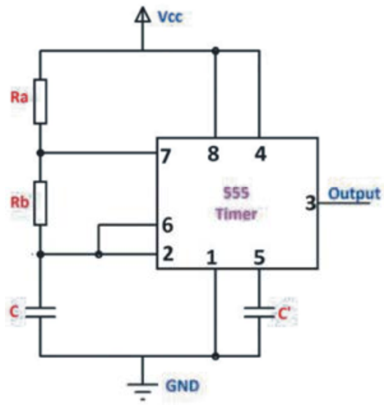


Fig. 5: Timer Circuit

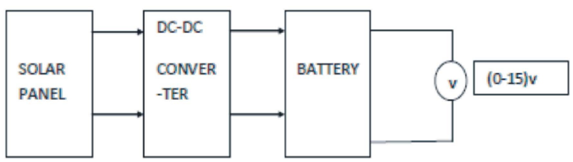


Fig. 6: Charging circuit of the battery without current pumped battery charger

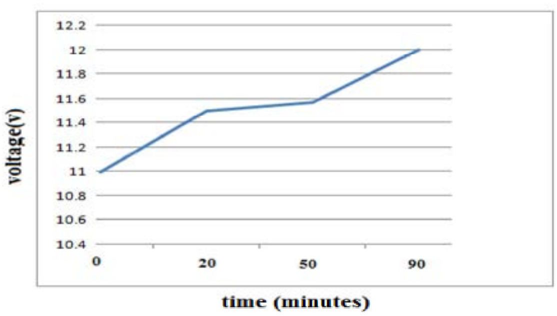


Fig. 7: Charging characteristics of the battery without current pumped battery charger

Table 2: Charging characteristics of the battery with dc-dc converter

TIME (minutes)	VOLTAGE(volts)
0	11
20	11.5
50	11.57
90	12

simplistic form. One of the amplifiers is always conducting while the other amplifier is in cut off mode. In this case both amplifier circuits are contained within a single IC 555. In this case IC 555 timer is configured as an Astable multivibrator in Figure 5. It has output having a 50% duty cycle, a square wave [t1 and t2 are equal time periods].

The Astable multivibrator generates a square wave, the period of which is determined by the circuit external to IC 555. The astable multivibrator does not require any external trigger to change the state of the output. Hence the name free running oscillator. The time during which the output is either high or low is determined by the two resistors and a capacitor which are externally connected to the IC 555 timer. The above figure shows the IC 555 timer connected as an astable multivibrator. Initially, when the output is high capacitor C starts charging towards Vcc through RA and RB [12]. However as soon as the voltage across the capacitor equals 2/3 Vcc, comparator1 triggers the flip-flop and the output switches to low state. Now capacitor C discharges through RB and the transistor Q1. When voltage across C equals 1/3 Vcc, comparator 2 output triggers the flip- flop and the output goes high. Then the cycle repeats.

Testing of Proposed System: The performance of CPBC system is tested by charging and discharging characteristics of 12v, 7Ah battery. The charging and discharging characteristics of battery with and without CPBC are compared.

Charging Characteristics Without Current Pumped Battery Charger: The charging of battery is done without the current amplifier circuit. The output of the solar panel is fed to the regulator circuit which maintains the constant voltage of 12 volts, then it is fed to the battery. A voltmeter is connected across the battery to measure the charging voltage across the battery. The test circuit is shown in Figure 6. The charging characteristics are plotted and tabulated in Figure 7 and Table 2 respectively.

Discharging Characteristics without current Pumped Battery Charger: The discharging of the battery is done by connecting a dc lamp across the battery. A dc lamp is connected across the battery. An voltmeter is connected across the battery and an ammeter is connected across the charged battery. The noted current and time are used to plot the discharging characteristics. The test circuit is shown in Figure 8 and discharging characteristics tabulated in Table 3. Discharging characteristics of the battery without current pumped battery charger is shown in Figure 9.

Charging Characteristics with Current Pumped Battery Charger: The regulated output from the regulator IC is fed to the timer circuit. The pulsed output from the timer circuit is given as the input to the current amplifier circuit. The voltmeter is connected across the battery and the corresponding readings are noted. The charging circuit and the corresponding characteristics for a CPBC are

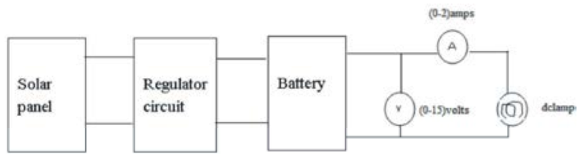


Fig. 8: Discharging circuit of the battery without current pumped battery charger

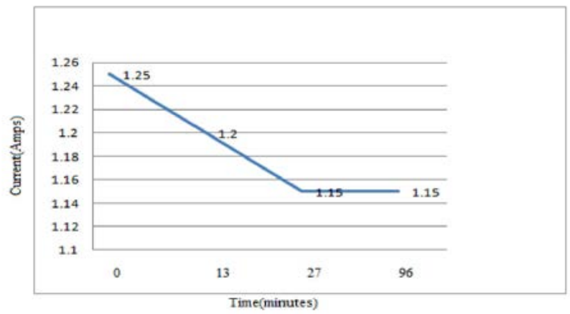


Fig. 9: Discharging characteristics of the battery without current pumped battery charger

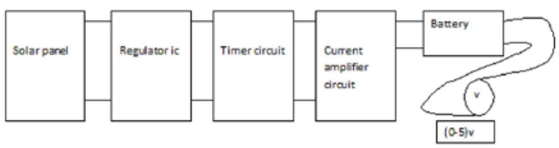


Fig. 10: Charging circuit of the battery with current pumped battery charger

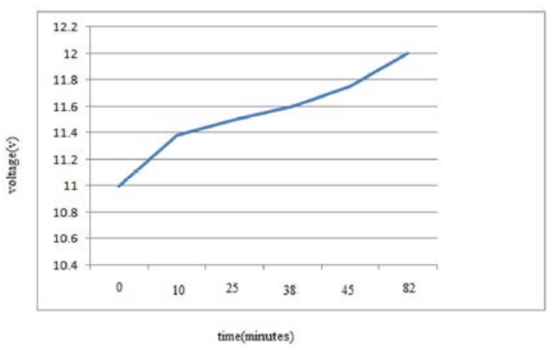


Fig. 11: Charging characteristics of the battery with current pumped battery charger

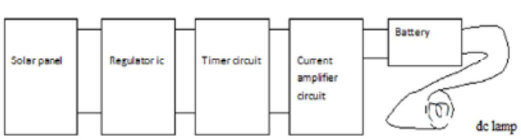


Fig. 12: Discharging circuit of the battery with current pumped battery charger

shown in Figure10 and Figure 11. The charging characteristics of the battery with CPBC are tabulated in Table 4.

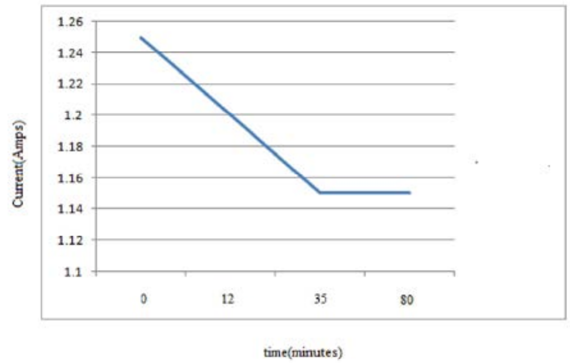


Fig. 13: Discharging characteristics of the battery with current pumped battery charger

Table 3: Discharging characteristics of the battery with dc-dc converter

TIME (minutes)	CURRENT(amps)
0 1.25	
13 1.2	
27 1.15	
96 1.15	

Table 4: Charging characteristics of the battery with Current pumped battery charger

TIME (minutes)	VOLTAGE (volts)
0	11
10	11.38
25	11.50
38	11.60
45	11.75
82	12

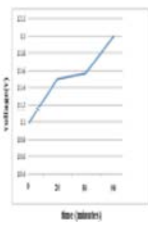
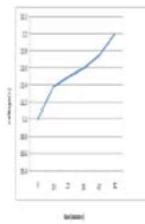
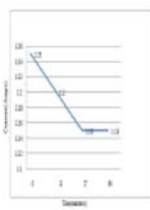
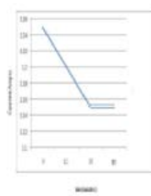
Table 5: Discharging characteristics of the battery with Current pumped battery charger

TIME(minutes)	CURRENT(amps)
0	1.25
12	1.2
35	1.15
80	1.15

Discharging Characteristics with Current Pumped Battery Charger: The regulated output from the regulator IC is fed to the timer circuit. The pulsed output from the timer circuit is given as the input to the current amplifier circuit. The Dc lamp is connected across the battery and corresponding circuit is shown in Figure 12. The discharging characteristics with CPBC are shown in figure 13 and tabulated in Table 5 respectively.

Comparison of Test Results: The charging and discharging characteristics without and with CPBC are compared. The results show that the battery gets charged faster with current pumping and the charging time is reduced by 8 minutes. The performance comparison is tabulated in Table 6.

Table 6: Performance Comparison

Process	With Conventional DC-DC Converter	With Current pumped battery charger (CPBC)
Charging of the battery		
Discharging of the battery		
Charging time	90 minutes	82 minutes

CONCLUSION

In this paper, a novel solar PV fed current pumped battery charger has been successfully implemented for charging a Lead-acid battery. The considered lead acid battery is tested and compared with a traditional DC-DC converter for charging process of the battery. The solar PV fed current pumped battery charger improves the system performance of a lead acid battery, the charging time is also reduced to 8 minutes compared to traditional DC-DC converter for a 12volt, 7Ah lead acid battery.

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