Li-ION BATTERY CHARGER FOR MOBILE REFIGERATOR

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Abstract — Among existing battery technologies, Lithium ion batteries are very efficient due to their extremely large charge capacity for a given volume and weight, long life cycle, no memory effect and low self discharge. Charging methods have important role in battery management system. Among all charging methods pulse charging method is more efficient compared to others. The rest periods between pulses give battery electrolyte ions the opportunity to be distributed evenly to obtain better battery charge efficiency. The charging structure has low power efficiency due to large deviation between supply voltage and battery voltage. To overcome this drawback DC-DC converter is used. It generates variable supply voltage changing in response to battery voltage during the charging process. In islanded power systems, interfacing of multiple sources allows for improved reliability, flexibility, and utilization of preferred energy sources.. A charger circuit for Li ion battery is proposed which consist of pulse charger circuit and uses flyback type two input dc-dc converter, in which a solar array and a commercial ac line are exploited as two input power sources. Proposed system provides fast charging and high efficiency. Its performances are examined using MATLAB Simulink.

Keywords — *Li- ion battery; Pulse Charger Circuit; DC-DC Flyback Converter.*

I. INTRODUCTION

Storing energy has been the world's most active research area in recent years. Since 19th century, electric batteries have been the most common devices for storing electric energy. In batteries the stored chemical energy gets converted into electric energy, which in turn produces electric current. Once the internal capacity of this device runs short, the battery is discarded. Scientists have always looked for a more economic and eco-friendly type batteries that can be recharged after discharging. Different rechargeable batteries have been discovered such as lead acid battery, Nickel cadmium batteries, Nickel metal hydride batteries, Li-ion battery. Among existing rechargeable batteries, Lithium ion batteries are considered most efficient due to its extremely large charge capacity for a given volume and weight, long life cycle, no memory effect and low self discharge[1].

A battery system consists of battery and battery management system (BMS). Battery charging plays an important role in the BMS, where the charging currents over time, have a strong influence on the battery performance and life cycles[2]. Many charging algorithms have been developed such as constant current-constant voltage (CC-CV), multi-step charging method, boost charging method, pulse charging method. The algorithms varying with charging time, charging efficiency and impact on the battery life cycles as well as implementation complexity, sensors required, cost and popularity[3]. Typically constant current constant voltage is the standard method of charging. If we increase charging current during the constant current stage and increase the voltage above a specified value, charging time can be reduced. But both these method degrade the performance of the battery. Another disadvantage of this method is temperature is uncontrolled. Life cycle can be improved by five step charging pattern.

Boost charger is faster compared to CC-CV due to high charging voltage at starting. But it is required to fully discharge the battery before charging; hence it requires a discharge circuit. This result in high cost, and low efficiency[4]. All these drawbacks can be eliminated by pulse charging method. Charging and suspension of charging are repeatedly alternated, hence it prevents degradation of battery performance and charging time is reduced. It aims to obtain an even distribution of ions in the battery electrolyte, speed up the charging process and slow down the polarization of the battery and increase life cycles. In Duty Cycle Varied- Pulse Charge (DCV- PC) we can detect suitable pulse duty cycle and supply the suitable charge pulse to battery to increase charge speed and charge efficiency[5]. Frequency Varied- pulse Charge (FV-PC) is similar to DCV- PC, the only difference is that, instead of changing the duty cycle of the pulse it changes the frequency of the pulse to achieve the highest charging current. But in these methods it cannot handle the low output power of micro energy harvesting system for battery charging[6]. These drawbacks are eliminated by new system which has following advantages such as pulse charger which efficiently charges battery via either an ac adapter or energy harvesting system. All charging phases are user programmable. It provides safety mechanisms such as external battery temperature sensing and over voltage protection circuit. It supports micro energy harvesting system[7].

The charging structure has low power efficiency due to large deviation between supply voltage and battery voltage. To overcome this drawback, we use switching mode power supply converter. Most electrical systems are supplied by one kind of energy source, whether it is batteries, wind, solar, utility etc. Certain special cases are powered by two sources, such as, uninterruptible power supplies. In this project a flyback type two-input dc-dc converter is used, in which a solar array and a commercial ac line are exploited as two input power sources and are combined by two input winding of the energy-storage reactor[8].

This paper aims to develop a pulse charger circuit and multiple input flyback converter topology for Li- ion battery charging.

II. METHODOLOGY

Block diagram of system shown in fig. 1. System consist of two input sources such an ac power line and solar panel. A battery charger is basically a DC power supply source. If the input source is ac mains, then it is converted to dc by using bridge rectifier, and is further smoothed by a high value electrolytic capacitor. After that we get corresponding dc voltage. Here flyback dc-dc converter is used to step down the input dc voltage to the required level as per the rating of battery. This voltage given to pulse charger circuit which charges the battery. Depending on battery voltage, battery charger circuit operates in three phases such as trickle charge phase, fast charge phase, slow charge phase.

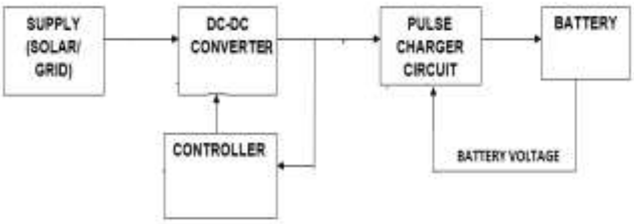

Fig. 1 Block Diagram of Proposed System

III. SYSTEM COMPONENTS

A. DC-DC Converter

Fig. 2 shows the circuit configuration of flyback-type two-input dc-dc converter. The input side is divided into two main blocks; one is solar-array block referred to as CONV.1 and the other is the commercial-ac-line power-source block referred to as CONV.2. CONV.1 consists of a solar-cell module, an inverse current blocking diode D1, a voltage smoothing capacitor, the main power switch S1, and one input winding of the energy storage reactor T. CONV.2 consistsof a commercial-ac-line voltage source bridge rectifier, main power switch S2, and another input winding of T. The output side is composed of one output winding of T, a rectifier, a voltage smoothing capacitor, and a load. When the light intensity is relatively high, the output power is mainly sent from CONV.1. When light intensity is low then the output power is fed from CONV.2

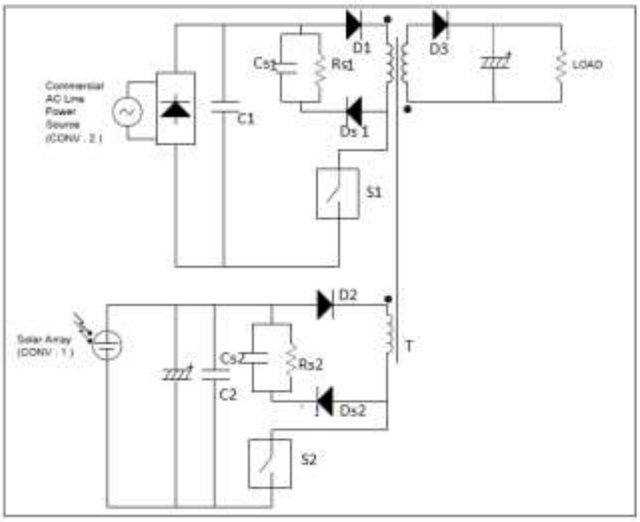

Fig. 2 Circuit diagram of a multiple input flyback converter

B. Pulse charger circuit

Fig. 3 shows the circuit configuration of the pulse charger circuit. It consists of mainly TC and PC comparators which helps charger circuit for operating in different charging phases. PC comparator helps the circuit from over voltage protection. A external temperature sensor used for high temperature protection. If the battery temperature higher than nominal value then circuit provide a signal for stop all charging phases. EC comparator used for detect that battery voltage reached its maximum value or not. If battery voltage reaches its maximum value then circuit stops charging. It consist of 2 current sources. For trickle charging only 10 % of charging current flows through battery. For pulse charging full charge current flows through battery. Charging current is limited by using Rset.

Pulse charger operates in three charge phases: trickle charge (TC), fast charge, and slow charge. A charge phase is selected based on the battery state during charge. If the battery is determined to be deeply discharged, the TC phase is initiated. The trickle charging phase charge rate is usually below a charge rate of C/10 during charging. This is necessary for the preconditioning of deeply discharged Li-ion cells. If a Li-ion battery is in a deeply discharged state and a high current is initially used for charging, it could be damaged. The fast charge phase is initiated once the battery is out of the deeply discharged state but less than the nominal voltage Vnom. As the battery approaches full charge voltage, where full charge denotes a state of charge (SoC) of 100%, the slow charge phase is initiated. With the battery approaching its full charge, it is necessary for the battery to absorb charge efficiently to prevent it from overcharging due to increased concentration of Lithium ions Li+ at the electrodes during this phase. The fast and slow charge phase seeks to combine fast charging with increased battery charge efficiency.

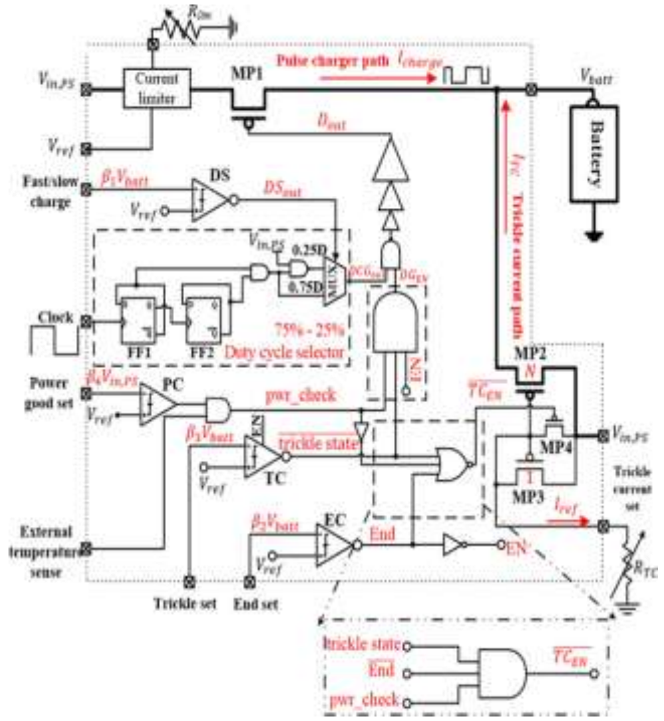

Fig. 3 Pulse charger circuit [6]

IV. SIMULATION AND RESULTS

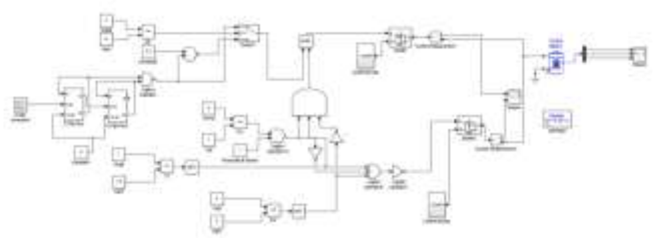

Fig. 4 Complete MATLAB simulink model of charger circuit

The proposed system is simulated using MATLAB software Proposed system consists of two stages. Firstly, multiple input converter was simulated with solar panel and ac grid as input and then proposed pulse charging method is simulated. It has two input solar panel and grid. Solar panel voltage is set to be 36V and grid voltage is set to be 240V. Instead of solar panel dc voltage source is used. As explained in proposed system, pulse charger operates charging different charging phases such as trickle charging phase, fast charging and slow charging. The charging phases selected in accordance with battery voltage. Here different comparators are present. Control logic of multiple input dc-dc converter developed in MATLAB. PI controller is used here. Reference voltage for PI controller is developed as in calculation. Depending on the control logic mosfet switches are fired. First compare reference voltage and output voltage. Then corresponding error signal is given to PI controller block. PI controller calculates duty of PWM signal and update duty of PWM cycle. Switching frequency is selected as 30 KHz.

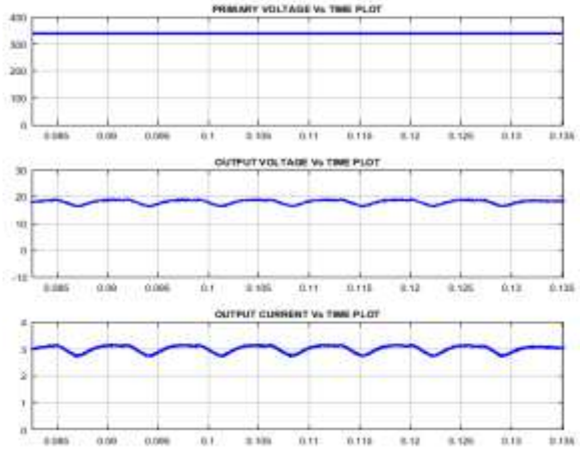

Fig.4 Waveforms of converter 2

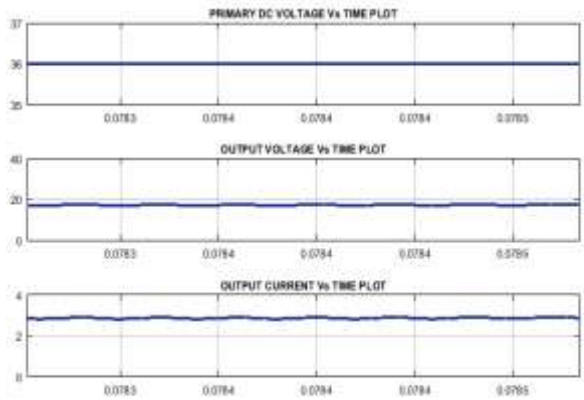

Fig.5 Waveforms of converter 1

Fig 4 shows input voltage, output voltage and output current of converter 2. For converter 2 when gate pulse is high then voltage across switch is zero and no current flow through the secondary. When gate pulse is low then voltage across switch is nearly two times input voltage. During off condition diode is reverse biases and no current flows through it. In on condition diode is forward biased. Primary dc voltage is 340V, which is filtered AC voltage. Output voltage is 18V, and output current nearly 3.3 A. Fig 5 shows input voltage, output voltage and output current of converter 1. Input voltage of converter 1 is 36V. Output voltage is 18 V.

In pulse charger circuit, each comparator compares reference voltage with battery voltage. The PC comparator checks input power supply is there or not. The EC comparator compares battery voltage with its maximum value. If its output is high then charging takes place. If battery voltage is less than cut of voltage then trickle charge current flow through the battery. Trickle charge current is 10 % of full charge current. If battery battery voltage is higher than cut off voltage and less than nominal voltage then it operates in fast charging phase. In fast charging phase pulses with 75 % duty cycle is flow through the battery. If battery voltage is higher than rated voltage and less than maximum voltage then it operates in slow charging phase. In slow charging phase, pulses with 25 % duty cycle flow through the path. When battery voltage reaches its maximum value then EC comparator terminates the charging process. Switching frequency of clock pulse is 1 KHz. Different modes of operation of pulse charger were analyzed. Charging current waveform of each charging phase is shown in fig 6 - 8. Pulse charger simulated for 14.6 V, 3.3 Ahr battery.

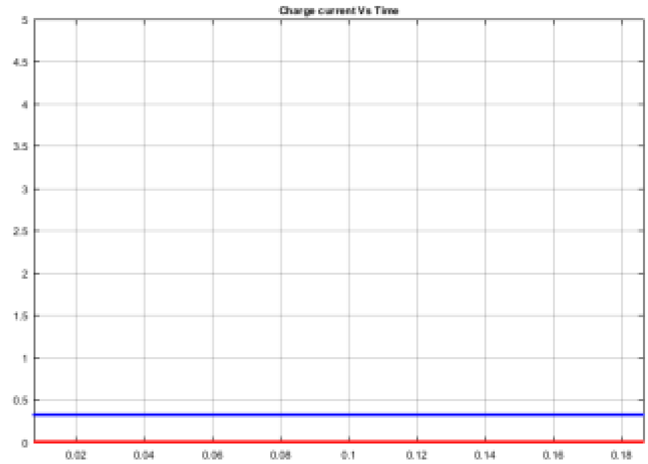

Fig.6 Trickle charge phase

During trickle charge phase 300mA current flows through battery.

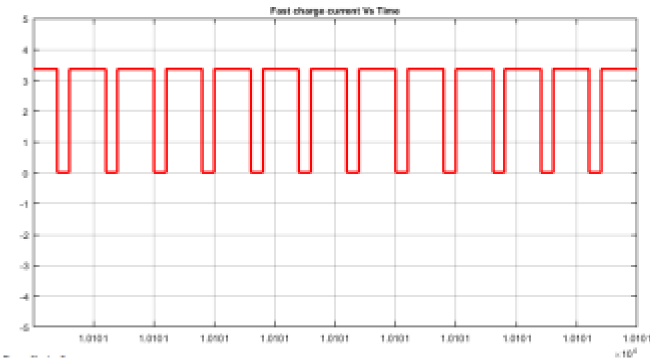

Fig.7 Fast charge phase

During fast charge phase 3A current flows through battery. It has pulses with 75% duty cycle.

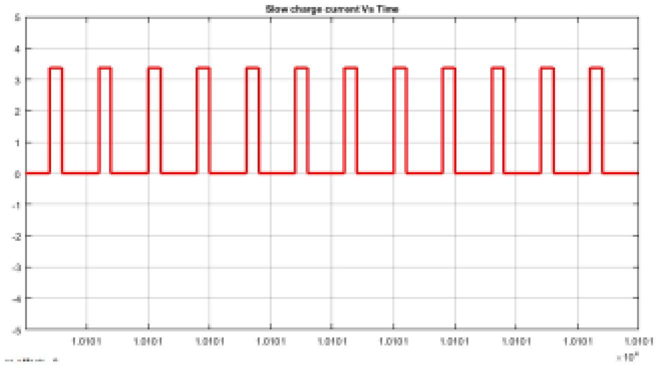

Fig. 8 Slow charge phase

During fast charge phase 3.3A current flows through battery. It has pulses with 25% duty cycle

V. CONCLUSION

This paper mainly demonstrate a charger circuit for Li-ion battery which provide good performance by considering the safety and operational concerns. Different charging methods were studied. From the literature survey pulse charger method was taken which is more efficient. Pulse charger method provides fast charging and efficiently charges battery via either an ac adapter or EHS. All charging phases are user programmable. It provides safety mechanisms such as external battery temperature sensing and over voltage protection circuit. Designed multiple input flyback converter and pulse charging circuit and simulated using MATLAB simulink.

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