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An Charging Interface for Lithium ion Batteries Compatible with Current in-use UPS System

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Abstract**—**This work put forward the use of Lithium ion batteries as an energy storage medium with the existing uninterrupted power supplies, design for lead acid batteries by introducing an interface which takes care of different necessary parameters of Lithium Ion batteries is proposed. Li-ion battery has different voltage level per cell and demands more sophisticated control and safety measures as compare to Lead Acid battery. The interface will take its input from the UPS and will accordingly adjust its output for the Li-ion battery. The interface consists of a converter and a battery management system (BMS) for safe charging and discharging of Li-ion battery. A Li-ion battery pack topology is also proposed in the work, which ensures maximum energy extraction from the battery pack being used in UPS without compromising the life of battery pack and other constraints.

Keywords**—** Li-ion, BMS, Uninterrupted power supply, lead acid battery,

I. BACKGROUND

Fast track development going on in the automotive field side and other immobile applications such as stand-alone and grid tied micro grid system; all requires a reliable energy storage system. Batteries been an important source of energy storage become an integral part of these systems. The battery units offer manageability and high energy, power density for many space, military and vehicles industry applications.

There is also a huge market for batteries in the Electrical energy system. In many developing countries power outages and load shedding is a common occurrence. The present situation of loading shedding and energy outages in Pakistan requires a need for long lasting sustainable efficient energy system tackling the energy loses and other issues. Different approaches and systems are proposed to curb the energy shortages and meet the growing energy demands.

Taking the case of developing countries like Pakistan, Bangladesh, Sri Lanka etc. regarding energy crisis, all are bearing huge energy shortages. The current generation and demand gap of energy in Pakistan is very serious; the situation is alarming with growing concerns in the industrial sectors, which are considered as the backbone of country's economy. The short fall reaches to 10 MW in the previous year's pushing back the country's economic situation resulting in shifting of industries, unemployment and inflation.

The fast track technological development and increasing population future energy demands are growing with a rapid pace, the future energy demand requirement are very high, the fear of depletion of conventional energy sources and the growing concern over the environment protection requires a need for some renewable clean, cheap Eco-friendly resources. The toxic emission from the burning of conventional energy sources are of great concern for the future of this planet and mankind. The greenhouse gases emission and other increased carbon proportion by products are contaminating the environment [1].

Renewable energy resources are environment friendly, clean, cheap and replenish able, having the capability of fulfilling the future energy demands. But the intermittent natures of renewable resources i.e. wind and solar highlights the need for a sustainable reliable energy storage system.

The Micro grid concept provides best suitable available option for energy shortages with the advent of incorporating renewable resources Uninterrupted Power Supplies (UPS) are used largely in micro grids to enhance local reliability and energy security [2]. The development in the transportation system with Electric vehicles EV having hybrid (HEV) and plug in hybrid (PHEV) vehicles, also requires large capacity storage system [3]. In the coming years widespread usage of EV would call for decreased cost, volume and weight of the storage package while maintaining the assortment and protection aspects for the on-road automobiles [4].

II. INTRODUCTION

In the energy sector the uninterrupted power supplies store energy in battery when grid is available and in case of grid outages and load shedding delivers back the stored energy. Energy storage system not only recompenses for the intermittent nature of the renewable resources and grid outages but also regulates system voltage and frequency. Different types of batteries are used in energy storage system .These batteries differ from each other in terms of chemistries and internal structure manufacturing. Lead acid battery is the most mature and commonly used battery for energy storage in UPS systems but it has some shortcomings in terms of lifecycle ,temperature tolerance, charging and discharging limitations and energy density [5].Different other battery chemistries have their own limitation aspects. The recent developments and lower cost of Lithium ion batteries are making their way to replace the out dated lead acid batteries by overcoming the limitations of lead acid battery system. As lead acid and lithium ion are two different types of batteries having dissimilarities in chemistry contributing to difference in voltage per cell, charging and discharging current requirements and other parametric differences. It's not that we simply just take out the existing lead acid batteries and put Lithium ion batteries in place of them, to the existing running system specifically design for Lead acid batteries. Uninterrupted power supplies (UPS) are basically design keeping in view the different parameters of Lead acid, so it's not appropriate to connect them directly to lithium ion batteries which are having different voltage per cell, different charging and discharging requirements and diverse safety issues. As the new lithium ion (Li-ion) batteries are better than the lead acid batteries in terms of lifecycles, energy and power density and many other features and they are the most suitable candidate to replace them [6]. There is a need for an interface that enables the current UPS systems to replace lead acid batteries with Li-ion, without any major changes. We are proposing an interface which enables the UPS system to be compatible with Li-ion batteries though they are specifically designed for lead acid batteries. This interface will ensure safe and fast charging of Li-ion batteries and will take care of some critical aspects which are of importance while using Li-ion batteries. The use of power electronic provides the best available choice in terms of efficiency. The interface will be power electronic based keeping in view the system efficiency, it will take lead acid charging parameters as an input and will deliver Li-ion charging parameters at the output. The Li-ion battery different voltage/cell as compared to lead acid battery requires proper battery management system which enables safe charging and discharging .The key issues like battery cell voltage measurement, battery state estimation, battery uniformity and temperature sensing should be taken into consideration [7]. The purpose of the study is to contribute towards the compatibility of existing UPS system to Lithium ion batteries, which are specifically designed for Lead acid batteries. Lead acid batteries almost dominate the current energy storage solutions, but there exist various issues in form of variability in the quality of batteries and ineffective use of available technology grounded on poor design solutions. Battery evaluation is done on their total storage capacities which far exceed the usable energy capacity for optimal utilization of this affluent resource, making room for new smart battery solutions based on emerging technologies in the space. The recent research and development in the Li-ion battery mark them the evolving technology having potential to overcome many weaknesses of other storage batteries. [8-10]. Li-ion batteries have high specific energy and power densities making them suitable choice for energy storage systems. The conventional system having batteries as energy storage system are mainly design keeping in view the different parameters i.e. voltage, charging and discharging current, state of charge etc. of Lead acid battery[11-12]. To replace Lead acid batteries with Li-ion in conventional uninterrupted power supply system (UPS), a conversion unit architecture and design is implemented to conventional UPS systems to interface Li-ion based battery banks with them.

The conversation unit manages for safe, effective and optimal charging and discharging of Li-ion battery bank through chargers design for Lead-Acid batteries [13-15].

Besides these a Li-ion battery topology is also proposed, keeping in view the conventional UPS systems parameters. The proposed topology ensures full energy extraction from the battery cells without causing any adverse effect on the cell life and system reliability. The safe range operations of the battery cell are maintained which contribute to maximum life cycles and efficiency.

III. DESIGN METHODOLOGY

Battery technology is a complex field. The battery itself is always a sub-component of a larger system that utilizes them to both draw energy during the discharge cycle and store energy during the charging cycle. The charging and discharging cycles of the batteries differ for different battery categories and replacement of Lead-acid batteries with Li-ion batteries is not as straight forward as matching the terminal characteristics of voltage, current and capacity requires an in-depth understanding of the various ways in which the batteries are interfaced with the overall electrical system and requires design of an intermediate power processing interface that can simultaneously address the requirements of both the electrical system and the internal battery processes.

The recent improvements and advancements in Li-ion battery technology in terms of safety, lifetime, energy storage and power delivery capabilities, energy efficiency and sharply decreasing trend in the cost makes it an ideal replacement for the lead acid battery based systems [16-19]. Currently lithium ion batteries are globally used for new advance applications and no focus is given to retrofit the existing lead acid based solution with more advanced and better Li-ion.

The replacement can be enhanced/implemented in two ways; first way is to introduce a suitable interface by which we can retrofit this new battery based on Li-ion in existing lead acid battery based UPS systems allowing an up gradation at a lower cost and the second way is to design new UPS systems relying solely on Li-ion for first time installation foe new users.

This work provides retrofitting of existing UPS system with Li-ion batteries. The UPS system is design for lead acid batteries, to replace Li-ion with lead acid batteries an intermediate power processing interface is introduced between Li-ion battery and the existing UPS system, which takes care of the necessary parameters and condition for proper working of UPS system. The interface takes UPS output parameters as input and accordingly adjusts its output for Li-ion batteries. The UPS output parameters are maintain for lead acid while the interface output is maintain in safe operating range of Li-ion battery. A battery management unit is also placed which helps in monitoring and balancing of individual cells parameters. Charging is done through the interface which converts UPS terminal voltage to 5V for safe charging of Li-ion cells, the BMS monitor overcharge and undercharge conditions, keeping cell voltage within allowable range of 4.2V. A 5V DC bus is provided with BMS, which charge the cells in parallel scheme. Discharging is done directly bypassing the interface and BMS. The UPS cut off voltage is 10.8V which is in due safe operating range of Li-ion battery.

IV. SIMULATION

Buck Converter Simulation is done in PowerSim. Due to absence of battery model in PowerSim, a configuration of capacitor in series with resistor is considered as a battery. A constant 14 volt DC supply is maintained at the input of converter. To acquire suitable duty cycle C block is used. For required PWM generation, output of C block and saw-tooth wave are fed into comparator.

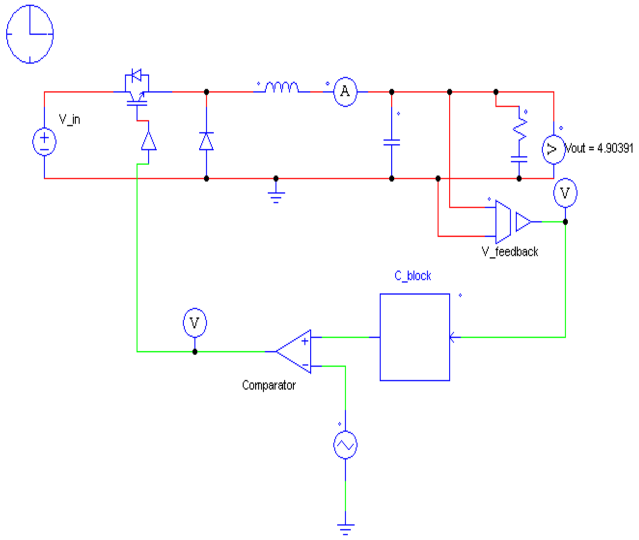

Figure 1. Buck converter

The results of simulation of Buck converter are shown below. The switching frequency is Selected 25k. The fig 8 show a DC input V_in 14V. The voltage at the output of converter is used to charge the battery. A 5V output is maintained with the help of adjusting PWM. A feedback voltage sensor is used at the output and fed into C block to check the voltage level at the output and adjust PWM accordingly to maintain constant voltage for the battery. The inductor and capacitor values are selected to operate the converter in CCM .The inductor value is calculated for a ripple 10% of the maximum current through the inductor which is about 0.8 ampere in this case as the maximum current is about 9 ampere. The simulation result verifies inductor current ripple value. The battery voltage increases gradually, as the charge accumulated into it. A voltage of 5V is maintained at the output.

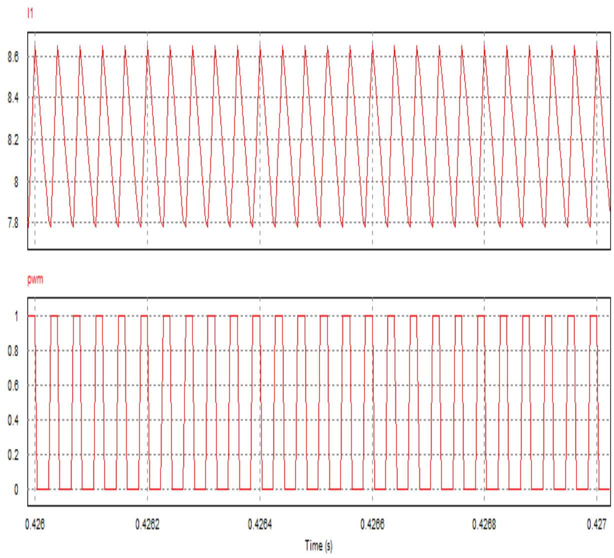

Figure 2. Simulation results of the circuit

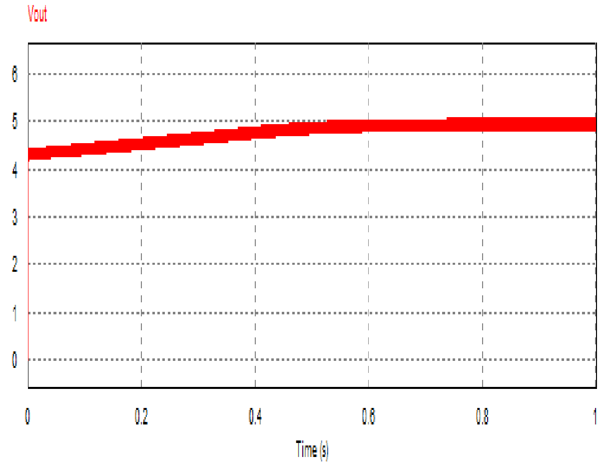

Figure 3. Output voltage

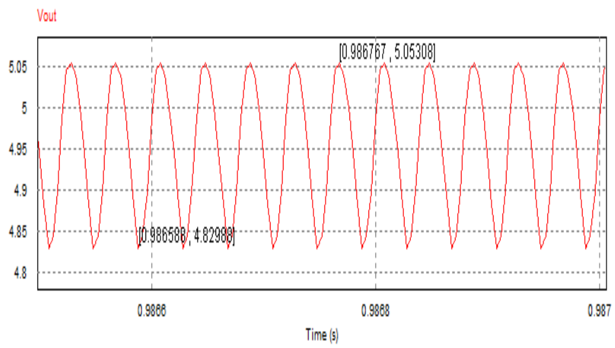

Figure 4. Output voltage ripple

The simulation result shows in fig.2, 3, 4 a voltage ripple of about 0.24V which is in accordance to the calculation done in above section. The overall results finding from the simulation show complete compliance with the theoretical calculation done in Buck converter design section.

V. RESULTS

The circuit was practically implemented and tested in the laboratory. The required objective results were achieved with the help of below hardware setting.

Figure 5. PWM and Current results from the hardware

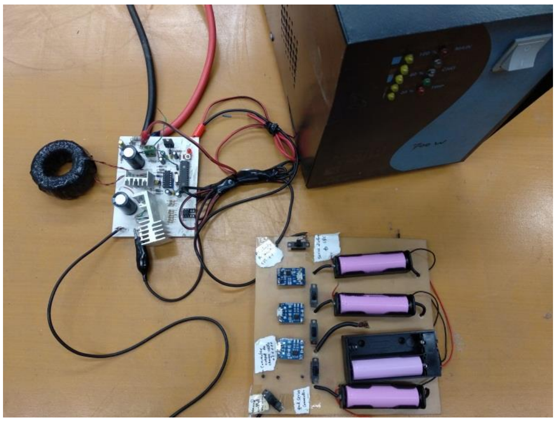

Figure 6. Hardware for the circuit

The inductor current ripple is show in greater detail in fig 23. Taraz current sensor is used for the measurement. According to the calibration of the sensor, an output voltage of 10mv is equivalent to 1 ampere. Therefore maximum ripple through the inductor is 19.2/2 which is equal to 0.96amp. The fig 5 also verifies the CCM mode of operation of converter.

CONCLUSION

The suggested idea of substituting Li-ion battery with lead acid in conventional UPS system is successfully implemented by introducing an interface between UPS and Li-ion battery pack. The acquired simulation results are effectively realized by the implementation of hardware.

The charging of Li-ion cells with UPS system is achieved through the interface. The interface is basically a DC to DC buck converter providing an appropriate charging scheme for Li-ion cells. The voltage at the output of converter is maintained constant for controlled charging. The Battery management system (BMS) is also incorporated with the converter. The elementary safety protection of Li-ion cells is maintained by the BMS, by monitoring voltage and charging current within limits.

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