Design of Digitally Controlled Battery Charging System Using DC-DC Converter

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Abstract. This initiative proposes a new battery charging device. The fundamental concept is to keep this project up-to-date by restricting charge time. The new constant loading technique is proposed and it has a digitally operated loader. Also, the adapter transfers control mode to continuous voltage charging with the battery voltage increasing to the default voltage mark. For battery charging applications, a digitally controlled charger is developed and introduced. A digitally controlled charger for battery charging applications is developed and introduced. The operation of the loader is subject to the proposed software control system. The closed-loop PID control also guarantees optimum electricity voltage. Three stages are used with the digitally controlled charger. The first step is to change the electric volume of 50 Hz to the DC volume with an appropriate power factor. The second phase is the DC-DC fly-back converter, changing the battery to its level and generating galvanic insulation. Step 3 uses digital power to keep the current and voltage stable. The project's key aim is to maintain a steady voltage and current. The simulation is performed using Simulink with the MATLAB file Experimental findings show design and execution efficiency.

1. Introduction

As a result of increase in global warming, pollution and exhaustion of fossil fuels has led to the prompt need of electric vehicles and other electrical application which has better performance and zero direct emissions [1]. A DC-DC converter plays an inevitable role in charging system of an electric vehicle.

The DC-DC Converter can handle the dynamic power transfer from the DC source to load using a power semiconductor switch by connecting the source to the load for an advanced period. The transformers are used in high-performance energy supply systems for automobile and aeronautical applications, battery banking charges, renewable energy sources [2], LED lighting, DC motor drives, and DC micrometry systems. The DC-DC converter in the input voltage is mainly known as the down and up-converter based on the degree of DC output voltage. Frequently used as an independent and not insulated transformer. Included in the Isolated Converter List are Buck[4], Boost, and Buck-Boost.

DC-DC converters that are not injected with insulation are the full-bridge and push-pull DC-DC converters. Based on the interconnections, voltage, and power levels of their circuit elements, different topologies may be used for specific or multiple applications. Any topologies are strong and have high voltage. Figure 1 shows different converter topologies and input voltage and power level. For several input volts and a high degree of power handling, the isolated surface of the whole Bridge DC-DC converter [3]. But a semi-bridge topology is just a broad input and does not have high capacity.
Figure 1. Various topologies with voltage and power level

The controller's primary feature in a DC-DC converter is to keep the rated output tension and reduce the input current. DC-DC converters are operated in peak current and voltage mode by the main control techniques.

The Controller processes the error value of actual values to get the desired value to provide an accurate control signal for the pulse generator. The Pulse Generation Unit produces the right PWM signal for switching the control signal to active power switches relative to the ramp signal in the switching frequency. Many algorithms and automated controls may be added to improve the efficiency of converters across these main control techniques.

In compliance with applications' requirements and guidelines, the DC-DC converter controllers play a significant part. For incorporating green energy sources in the Grid, the reliability of the pumped electricity through the front-end DC-DC converter is critical. The energy management workshop also provides DC-DC converter control for additional uses including energy storage systems, solid-state and hybrid vehicles [5]. Without losing the rating of working power switches and diodes, DC-DC converter controls must enable and disable automatically. Intelligent, efficient, and effective controls increase the overall efficiency of DC-DC converters. Controllers play their prominent role in making the DC-DC converters more suitable for various applications with the expected desirable performance.

Since Ziegler and Nichols invented proportional and integral (PI) tuning, this controller was used successfully in many industrial control systems. The key element of this controller is its basic shape and it is easier to understand the PI control principle. The PI controller is seen in Figure 2. In most industrial applications, PI controllers guarantee their guaranteed performance with good stability. These key factors make it possible to use PI controllers as process controls in industrial applications. PI controllers serve a good job in DC-DC converters to preserve the correct and safe values in converter voltage and current levels. There are several qualities for the high voltages DC-DC converter: constant rip free input currents, low power losses, and stable output voltage, even under different input and charge conditions. The converter is more reliable and efficient than the quality of the DC-DC converter.

Figure 2. Proportional integral (PI) controller
The optical loader with the proposed continuous current charge technology (a fly-back converter). The charger is a Cin input condenser, TR, a power transmission operated with Q, D-sided correction, cut, R1, and batteries. A Cin output condenser is mounted in the charger.

DC-grid applications, unbroken energy supplies, micro inverters, and fuel units have been studied, due to the increasing demands on applications like EV, high-level DC-DC transformers with various topologies. High voltage gains can be calculated under several conditions by high-level DC-DC converters. Soft-switch function, high efficiency, continuous input current: Low Voltage by switches; DC-DC converters have different characteristics for special applications with similar high-voltage circuits topologies [6]. Sustainable and renewable energy sources such as solar panels and fuel cells have been leading players, battery sources [7], and superficial transporters respectively. DC-DC converter families for high power transmission between the DC buses at different voltage levels have been compared and analyzed. The DC-DC converter, used as a multi-level converter DC source, provides constant low voltage ribs, a high voltage ratio, and reduced switching tension.

The multiplier in voltage Cockcroft-Walton (CW). Used for the low input voltage is the n-stage CW multifunction. DC-DC Converter boost shares the latest load delivery. Two switches were used to swap currencies, in addition to two inductors. The quadratic converter type DC-DC, which has high effectiveness and a constant input current. Inside the transformerless DC-DC converters, high voltage gains were suggested, offering a high voltage gain without a significant duty ratio. For one high voltage unisolated switch, a DC-DC boost converter with combined voltage rise and multiplier circuits is offered. Diode, condenser, and inductor N-stages have been developed for the low-duty high voltage increase. Uninsulated converters did not have isolation between input and load and unnecessary in some applications, such as battery charging, DC grid systems, and drive applications. However, because the control switch is hard to switch, the input current and output are discontinuous. The quadratic boost converter is combined to form a new topology of converters for micro inverter applications [8].

2. Proposed System Design
An online UPS prototype is used for the proposed digital-controlled charger Figure 3. Complete digital battery charger operated.

![Figure 3. Fully digital controlled battery charger](image)

2.1. The proposed battery charger

Figure 4 shows the planned onboard loader. This charger includes a front-end power factor converter and a fly-back converter dc-dc converter in the second level.

A. Front-End First Stage AC-DC PFC Rectifier
Two parallel CCM booster converters operating 180° out of phase are used for the interleaved PFC.
The current input is the sum of the LB1 and LB2 inductor currents. As the inductor ripples are out of motion, the current trends to be abolished and to be reduced.

**B. Front-End First Stage AC-DC PFC Rectifier**

With output voltage shielded from the main supply, the Fly-back is the most frequent low-capacity SMPS circuit. There will be between a few and under 100 Watts of peak power on SMPS flyback circuits. This converter is much simpler than other SMPS circuits. The topology of this converter. The input for the system is usually unregulated by dc voltage, and a simple condenser filter is provided by the ac power supply. It may have one or more isolated tensions and operate with a wide range of input tension variations. Power supplies fly-back are lower than many other SMPS systems in terms of power performance, but their basic topology and low cost make them popular with low power levels.

![Circuit diagram for Digital Control Battery Charger](image)

**Figure 4.** Circuit diagram for Digital Control Battery Charger

**C. Fly-Back Converter Basic Topology**

The topology of a back flight circuit is the basic one below. The input into the circuit could be dc voltage from the AC supply after correction and some filtering. A fast switching system ("S") like MOSFET is applied with simple and dynamic switching control for the desired output voltage (on-time to time-changing ratio). This transformer is used to isolate the pressure in Figure 5 and to align the voltage v input and output with the current specifications in better order. The fly-back section of flight-back transformers is slightly easier to correct the voltage and the filtration output than most other power supply systems. The secondary twisting voltage is rectified and processed by just one diode and condenser. The voltage through this condenser filter is an SMPS output voltage.

![Circuit diagram of Fly-back Converter](image)

**Figure 5.** Circuit diagram of Fly-back Converter

**D. Operational Principle**
MODE 1:

If the 'S' switch is ON, the main winding of the transformer is connected to the input supplies by linking the pointed end to the positive side. The diode voltage 'D' is now paired in series with a secondary winding due to secondary mediated voltage (dotted end potential being higher).

However, the current in the secondary winding is interrupted by the back biassed diode. The flow developed in the transformer center and the windings are completely associated with the principal winding present. The figure 6 shows the present portion of the circuit. The driving switch or diode will be regarded as a short circuit switch, and the driving device will be taken as an opened switch. This picture of the turn corresponds to our observation that the buttons and diodes are considered optimal, with zero voltage drops during conduction and nil current during off state.

MODE 2:

The 'S' key is turned off for a moment as shown in figure 7. The key course of winding current is blocked and the stress polarities are reversed by windings according to the laws of magnetic induction. Return of polarity allows the diode in the secondary circuit to become polarized. The condenser is loaded by the secondary winding present. However, the condenser's output voltage is usually high enough throughout multiple cycles to prevent any noticeable difference in its voltage in the same switching period. The secondary winding starts to turn the electricity back into energy supply when recharging the output of the magnetic field of the transformer. The secondary current is held to zero, and the magnetic field energy transfer to the source and load is completed. The secondary current is kept to nil. The Mode-2 circuit ends with 'S' turned on and then the circuit goes again into Mode-1 and repeats the series.

Figure 6. Mode 1 equivalent circuit

Figure 7. Mode 2 equivalent circuit

2.2. Digital Controller

A small signal model is drawn for the charger to set up the digital controller. Figure 8 shows the limited signal model without taking into account the battery model DCM chargers. The battery model is, however, only used in continuous voltage mode in the suggested charging technique. The controller is bypassed and the tariff limit controller's duties regulated in the continuous current mode. The battery is then modelled on this paper as a continuous voltage resistor. The model comprises two compounds: the condenser and the other inductive. The controller works only in constant voltage mode in the proposed charging technique. The constant input voltage is provided as shown in figure 9. The controller is bypassed and the tariff limit controller's duties regulated in the continuous current mode. The battery is then modelled on this paper as a continuous voltage resistor. There are two dynamic elements in the model: one condenser and the other inductive. The vector is the induct modelled condition and condenser intensity current. Here the procedure for PID and Pulse
generation is used; the PID controller measures a value for error as the discrepancy between a calculated method vector and a target set point. The term for proportional feedback management remains as shown in Equations (1)-(5)

$$u = K_P e$$ \hspace{1cm} (1)

Where,

\(e = "\text{mistake}"\);

\(K_P = \text{proportional benefit}\);

$$u = K_I \int e d\tau$$ \hspace{1cm} (2)

Integral feedback is defined as

$$u = K_P e + K_I \int e d\tau$$ \hspace{1cm} (3)

There, \(K_I\) is the benefit factor for integration.

We have a combination of P and I power in the PI controller, ie:

$$u = K_P e + \frac{1}{\tau_I} \int e d\tau$$ \hspace{1cm} (4)

$$u = K_P (e + \frac{1}{\tau_N} \int e d\tau)$$ \hspace{1cm} (5)

Where,

\(\mu_I = "\text{Time of inclusion}" \text{ [s]}\)

\(\mu_N = "\text{Time reset}" \text{ [s]}\)

The controller attempts to minimize the error by setting process control inputs for constant power and voltage charges. The output of the dc-dc converter is provided to the controller. A perfected gate pulse and a service period of less than 33 percent are given by the controller. Figure 11 represents the gate signals provided for the battery charger. Since the controller provides constant current and voltage battery charging.

The pulse generator can generate scalar, vector, or matrix signals of any actual data type. Figure 10 depicts the PWM signals generated for the circuit. Using scalars, the waveform parameters can be set such that a block can emit a scalar signal. Use the type of pulse to indicate whether the block is time-based or sample-based. The block calculates the output by a sample model at given intervals. The Simulink software measures the block output only when the output changes when you choose time-based. The effect of this alternative is less computation for computing the block's simulation contribution.

3. Results and Discussion

Without current feedback, the results of the simulations reveal continuous voltage and current charging. The constant output voltage required to charge the battery is shown in Figure 12. The first step is a corrector of the power factor used to convert the electrical quantity 50Hz into DC with a strong input power factor.

The second phase is a fly-back dc-dc converter, which adapts the levels to the battery value and also provides an insulation galvanic. The third stage is the technology of digital control used to maintain a continuous charging of electricity and voltage.
Figure 8. Digital controlled battery charger

Figure 9. Input Voltage and Current waveform

Figure 10. Control signal (pulse width modulation)
4. Conclusion
This modern era which has a fast moving environment always needs devices and products with good and fast performance. Converters with high efficiency are required for battery charging. They have the ability of reducing power consumption of the system (e.g. EV/HEV) by reducing the overall weight of the vehicle. Therefore, a battery charger is designed to provide a constant current charge for UPS applications, electric vehicle battery charging stations, and simulation results verify the proposed topology. The results of the simulation allow it to be applied with highly effective batteries with less switching losses to the renewable energy system and the electric vehicle.

References
[1] J. Rodríguez, J. Pontt, C. A. Silva, P. Correa, P. Lezana, P. Cortés, and U. Ammann, Predictive current control of a voltage source inverter, IEEE Trans. Ind. Electron., 54(1), pp. 495–503, Feb. 2007.
[2] Y. C. Chuang, Y. L. Ke, H. S. Chuang, and H. K. Chen, Implementation and analysis of an improved series-loaded resonant DC-DC converter operating above resonance for battery chargers, IEEE Trans. Ind. Appl., 45(3), pp. 1052–1059, May/Jun. 2009.
[3] M. B. Camara, H. Gualous, F. Gustin, A. Berthon, and B. Dakyo, dc/dc converter design for supercapacitor and battery power management in hybrid vehicle applications- polynomial control strategy, IEEE Trans. Ind.Electron., 57(2), pp. 587–597, Feb.2010.
[4] Y. C. Chuang, High-efficiency ZCS buck converter for rechargeable batteries, IEEE Trans. Ind. Electron., 57(7), pp. 2463–2472, Jul.2010.
[5] Haldorai, A. Ramu, and S. Murugan, Social Aware Cognitive Radio Networks, Social Network Analytics for Contemporary Business Organizations, pp. 188–202. doi:10.4018/978-1-5225-5097-6.ch010

[6] R. Arulmurugan and H. Anandakumar, Region-based seed point cell segmentation and detection for biomedical image analysis, International Journal of Biomedical Engineering and Technology, vol. 27, no. 4, p. 273, 2018.

S.Lalouni,D.Rekioua, T.Rekioua, E.Matagne, Fuzzy logic control of Stand-alone photovoltaic system with battery storage, Journal of Power Sources 193(2009)899-907.

[7] Keshav Patidar and Amod C. Umarikar, A Step-up PWM DC-DC Converter for Renewable Energy Applications, Int. Journal of Circuit Theory and Applications, 44(4), pp.819-832, June 2015.