www.ijraset.com Volume 3, Special Issue-1, May 2015
IC Value: 13.98 ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Design and Implementation of Battery Charger Using Flyback Converter for Constant Current and Voltage Control

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Abstract—This paper presents the design and implementation of battery charger using flyback converter for constant current and voltage control without current feedback. This constant current charging control can be done by limiting the duty cycle of charger. So, the current feedback signal is not necessary and in that way reducing the cost of A/D converter, current sensor, and computation complexity necessary for current control. Additionally, when the battery voltage is improved to the preset voltage level by means of constant current charge, the charger changes the control mode to constant voltage charge. A flyback converter based charger is designed and employed for Uninterrupted Power Supply (UPS) system. The proposed system is designed using MATLAB Simulink. Experimental results show the success of the design and implementation.

Keywords—Charger, constant current charge, constant voltage charge, flyback converter and UPS

I. INTRODUCTION

Currently, rechargeable battery has been broadly applicable in different kind of electronic device, such as portable devices, uninterrupted power supply (UPS) system, electrical vehicle, etc. So, battery charger [1]–[3] plays a vital role in recharging batteries professionally and extending the battery life. Conventional type chargers are controlled by analog controller, such as UC384x, L6561 ... etc. control ICs; these controllers can adjust charge voltage and also achieve current control. Though, in analog controller, compensation parameters are composed of resistor and capacitors, where the components are highly dependent on temperature variation and with aging issues.

In the proposed system, the compensation parameters are employed digitally, therefore, temperature and aging issues can be neglected. Also, it has some benefits including implementing difficult control methods [4]–[7], robustness to noise, programmable compensator, short-time to market, and on-the-fly parameter tuning [8]. Therefore, in this paper, a digital controlled charger is implemented to charge the batteries [9] in UPS system [10]–[19] as shown in Fig. 1.

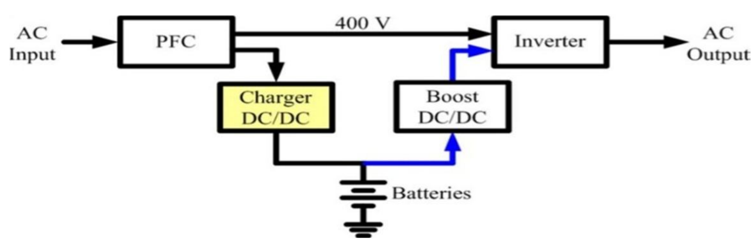

Fig. 1. Proposed UPS system

The charging characteristics have three stages [23], [24] as shown in Fig. 2. The first stage is constant current charging. The second one is constant voltage charging. The third one is floating charge. To achieve constant current charging, conventional charging control needs current sensor to feedback the current information [16], [17], [20]–[22]. There are numerous types of current sensing techniques, the most frequently used methods include shunt resistor, Hall sensor, and current transformer. Though, these three methods will cause additional power loss, cost, and component count to the system. For constant voltage charge and floating charge, the control is recognized by output voltage feedback and temperature compensation. Temperature compensation approaches have been presented by many authors [25]–[27].

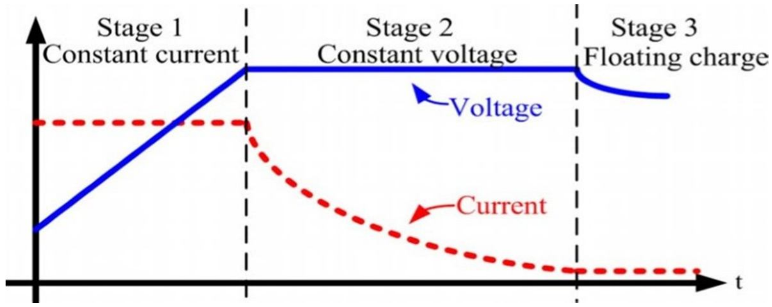

Fig. 2. The charging characteristics

In this paper, a digital controlled UPS system with proposed battery charging technique is presented as shown in Fig. 3. The proposed charging method can achieve constant current/voltage charging without the requirement of current sensor. In some cases, digital controller is already employed in the UPS system; thereby, sharing some resources of the digital controller to control the charger with the proposed technique will not bring more cost to the whole system.

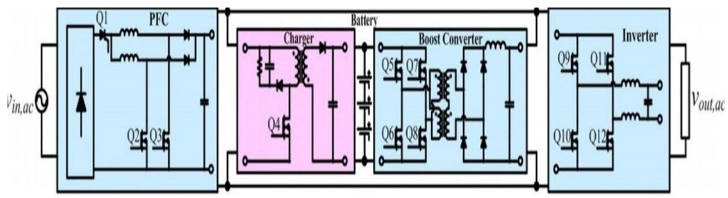

Fig. 3. The schematic view of UPS system with proposed battery charging technique

II. UPS SYSTEM WITH PROPOSED CHARGER

The flyback converter based controller with the proposed constant current charging technique is shown in Fig. 4. The charger contains of an input capacitor C_{in}, a high frequency transformer TR, a controlled power switch Q, a secondary rectifier diode D, a output capacitor C_{out}, voltage divide resistors R_1, R_2, and batteries. The digital controller contains A/D converter, voltage controller, the proposed duty cycle limit controller, and digital PWM generator. As presented in Fig. 4, no current sensor and the related A/D converter are necessary for the presented constant current control. The proposed digital controlled constant current charging method for UPS battery charger aims at providing constant current control without current sensor. Fig. 5 shows the basic idea of the control scheme. As shown in Fig. 5, at the beginning of charging, the constant current is controlled by duty cycle limitation. As battery voltage is charged up to its nominal value, the control is dominated by voltage controller, where the current will decrease gradually.

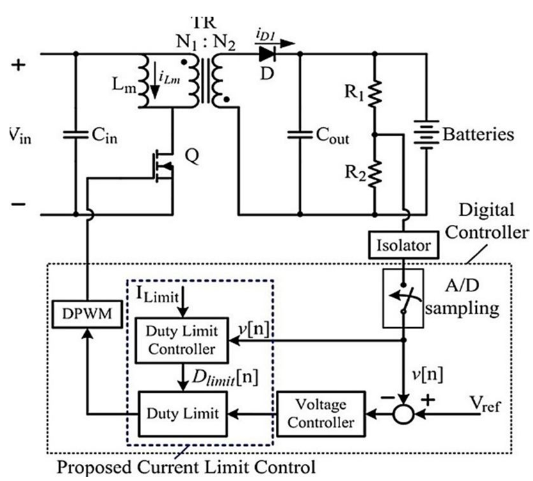

Fig. 4. The flyback converter based controller with the proposed constant current charging technique.

Volume 3, Special Issue-1, May 2015
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

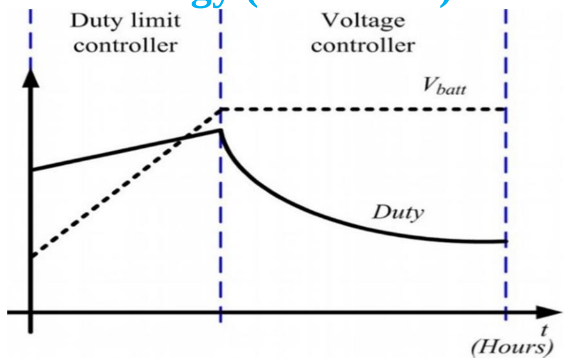

Fig. 5. Basic idea for the proposed control scheme

A. Design of flyback converter

More than half of the external power supplies produced are used for portable electronics, such as: smart phones, tablets, and MP3 players that require constant output voltage and current regulation for battery charging. For applications requiring precise Constant-Current (CC) regulation, current sensing in the secondary side is always necessary, which results in sensing loss. For power supply designers faced with stringent energy-efficiency regulations, output current sensing is a design challenge. The advanced PWM controller FAN104W can alleviate the burden of meeting international energy efficiency regulations in charger designs. This application note presents practical design considerations for flyback battery chargers employing the FAN104W. It includes instructions for designing the transformer and output filter, selecting the components, and implementing Constant Current (CC) / Constant Voltage (CV) control. The design procedure is verified through an experimental prototype converter.

B. Basic CV / CC Control Principle

Fig. 6 shows the basic circuit diagram of a PSR flyback converter with typical waveforms shown in Fig. 8 Generally, Discontinuous Conduction Mode (DCM) or Boundary Conduction Mode (BCM) operation is preferred for primary-side regulation because it allows better output regulation.

C. Constant Voltage (CV)

When the rectifier diode current reaches zero, the transformer auxiliary winding voltage (V_{Aux}) begins to oscillate by the resonance between the primary-side inductor (L_m) and the effective capacitor loaded across MOSFET. For BCM operation, this period does not exist.

During the rectifier diode conduction time, the sum of output voltage and diode forward-voltage drop is reflected to the auxiliary winding side as $(V_o+V_F) \times N_{Aux} / N_s$. Since the diode forward-voltage drop decreases as current decreases, the auxiliary winding voltage reflects the output voltage best at the end of diode conduction time, where the diode current diminishes to zero. By sampling the winding voltage at the end of the diode conduction time, the output voltage information can be obtained. The internal error amplifier for output voltage regulation (V_{sah}) compares the sampled voltage with internal precise reference to generate an error voltage ($V_{EA.V}$), which determines the duty cycle of the MOSFET in CV mode.

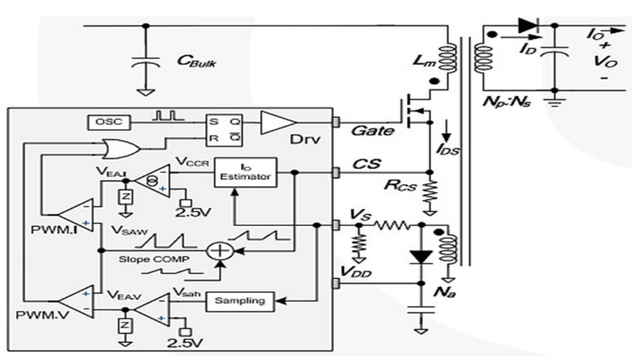

Fig. 6. Basic circuit diagram of a PSR flyback

D. Constant Current (CC) Regulation

CC regulation is implemented internally without directly sensing the output current. The output current estimator reconstructs output

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ISSN: 2321-9653

current information (V_{CCR}) using the transformer primary-side current and diode current discharge time. V_{CCR} is then compared with a reference voltage (2.5 V) by an internal error amplifier and generates a $V_{EA.I}$ signal to determine the duty cycle. $V_{EA.I}$ and $V_{EA.V}$ are compared with an internal sawtooth waveform (V_{SAW}) by PWM comparators PWM.I and PWM.V, respectively, to determine the duty cycle. As seen in Figure 6, the outputs of two comparators (PWM.I and PWM.V) are combined with the OR gate and used as a reset signal of flip-flop to determine the MOSFET turn-off instant. The lower signal, $V_{EA.V}$ or $V_{EA.I}$, determines the duty cycle, as shown in Fig. 7. During CV regulation, V $_{EA.V}$ determines the duty cycle while $_{VEA.I}$ is saturated to HIGH.

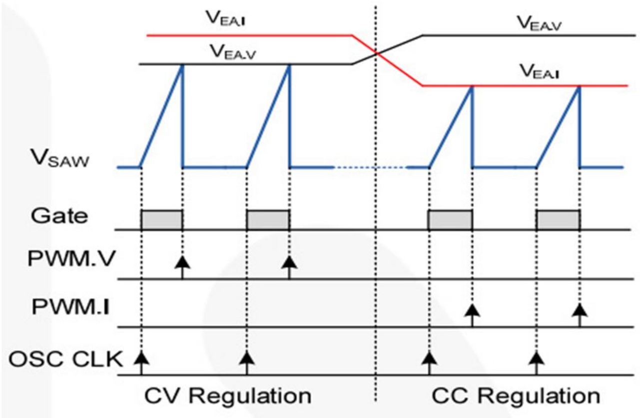

Fig. 7. PWM Operation for CV and CC Modes

During CC regulation, V $_{EA.I}$ determines the duty cycle while $V_{EA.V}$ is saturated to HIGH. FAN104W internal circuits identifies the peak value of the drain current with a peak-detection circuit and calculates the output current using the inductor discharge time (t_{DIS}) and switching period (t_S). This output information (V_{CCR}) is compared with an internal precise reference to generate an error voltage ($V_{EA.I}$), which determines the duty cycle of the MOSFET in CC Mode. Meanwhile, the output current is obtained by averaging the triangular output diode current area over a switching cycle, as calculated by:

$$I_0 = I_D^{AVG} = \frac{1}{2} I_{PK} \frac{N_P}{N_S} \frac{t_{DIS}}{t_S} \qquad (1)$$

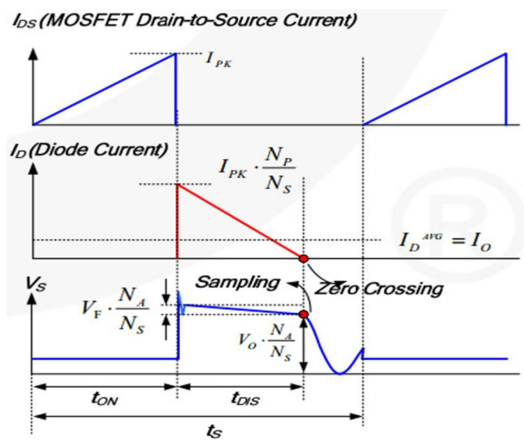

Fig. 8. Key Waveforms of DCM Flyback Converter.

III. DESIGN OF FLYBACK CONVERTER BASED CONTROLLER IN UPS SYSTEM

The flyback converter based controller to achieve constant current and voltage control is designed using MATLAB Simulink model and it is shown in Fig. 9.

Volume 3, Special Issue-1, May 2015
ISSN: 2321-9653
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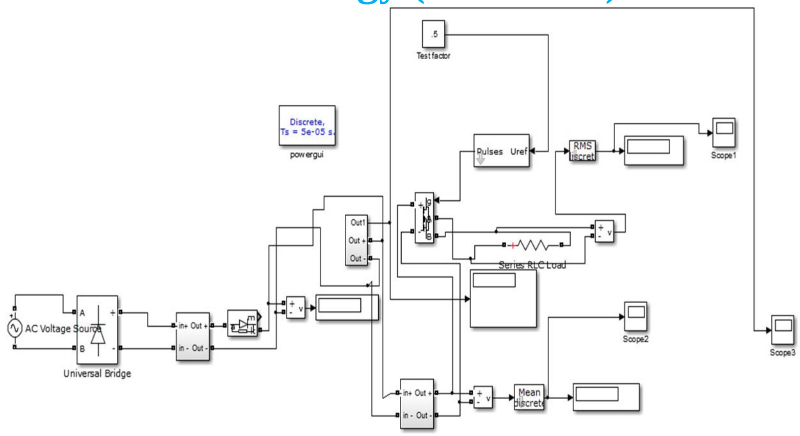

Fig. 9. Simulink model of proposed controller.

IV. RESULT AND DISCUSSIONS

The output values of current and voltage taken at the battery. It shows that the current and voltage values are constant for all the time duration. The constant current and voltage output waveforms taken from Simulink model are shown Fig. 10 and Fig. 11 respectively.

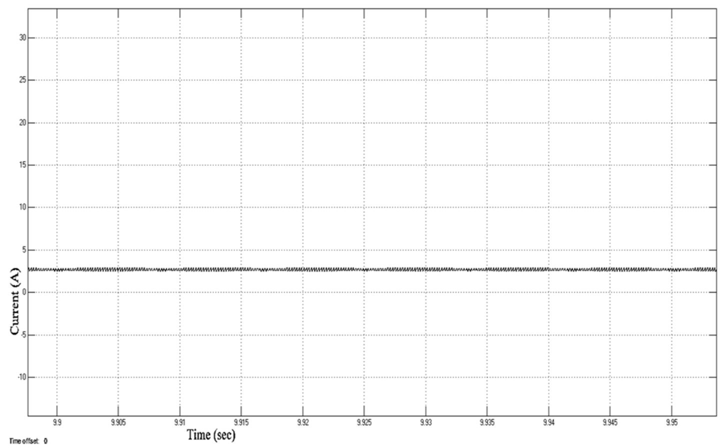

Fig. 10. Constant current output waveform

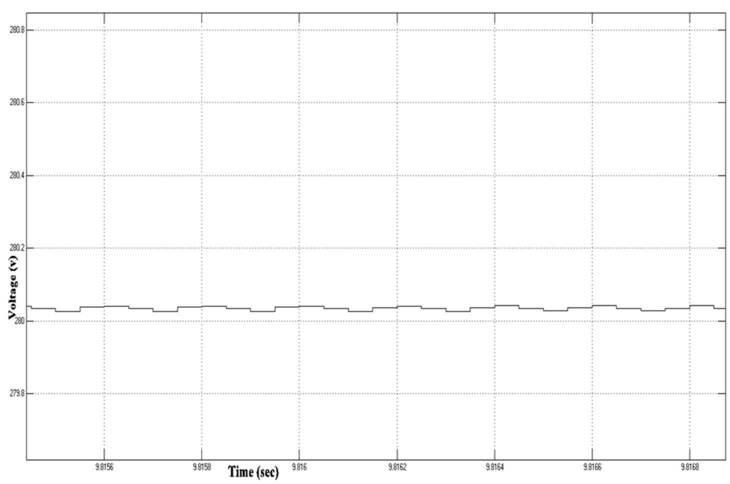

Fig. 11. Constant voltage output waveform

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ISSN: 2321-9653

The hardware model designed to implement the proposed controller in UPS system is shown in Fig.12. Two 6V-4.5Ah batteries are used in the hardware which having the maximum charging current of 1.35A each. The charger performance is given in Table I.

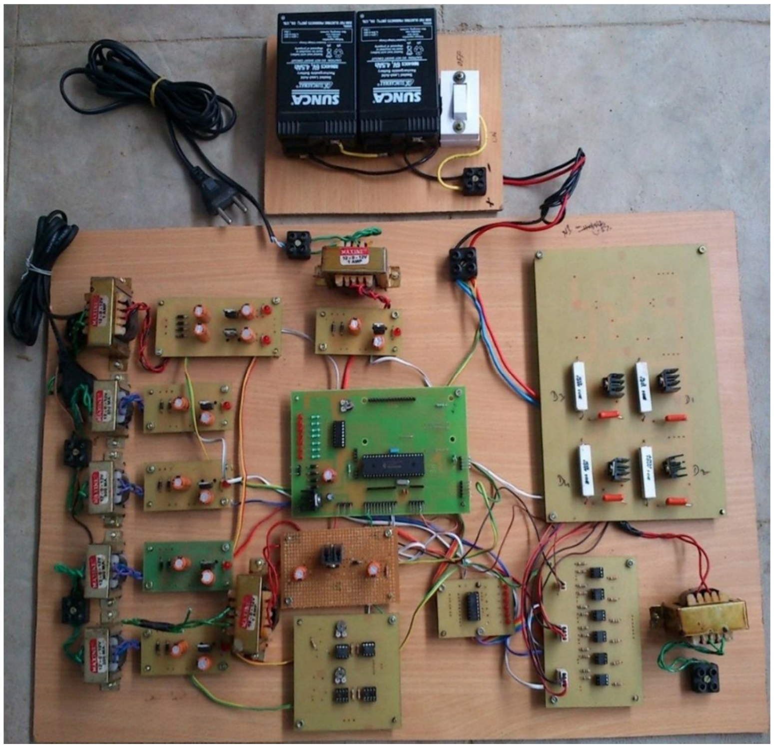

Fig.12. Hardware model of proposed controller based UPS system.

TABLE I. PERFORMANCE OF BATTERY CHARGER.

Hours of charge	Battery voltage (V)	Average charging current (A)
1	11.8	1.31
2	11.8	1.31
3	11.9	1.30
4	12	1.29
5	12	1.29
6	12	1.29
7	12.1	1.00
8	12.2	0.85
9	12.2	0.85
10	12.2	0.85

V. CONCLUSION

The design and implementation of battery charger using flyback converter for constant current and voltage control without current feedback is presented in this paper. This constant current charging control can be done by limiting the duty cycle of charger. Additionally, when the battery voltage is improved to the preset voltage level by means of constant current charge, the charger changes the control mode to constant voltage charge. A flyback converter based charger is designed and employed for Uninterrupted Power Supply (UPS) system. The proposed system is designed using MATLAB Simulink. Experimental results show the success of the design and implementation that is the constant current and voltage is achieved all over the time duration.

REFERENCES

[1] Y. C. Chuang, “High-efficiency ZCS buck converter for rechargeable batteries,” IEEE Trans. Ind. Electron., vol. 57, no. 7, pp. 2463–2472, Jul. 2010.
[2] P. A. Cassani and S. S. Williamson, “Design, testing, and validation of a simplified control scheme for a novel plug-in hybrid electric vehicle battery cell equalizer,” IEEE Trans. Ind. Electron., vol. 57, no. 12, pp. 3956– 3962, Dec. 2010.
[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., vol. 57, no. 2, pp. 587–597, Feb. 2010.
[4] 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., vol. 54, no. 1, pp. 495–503, Feb. 2007.
[5] P. Cortés, M. P. Kazmierkowski, R. Kennel, D. E. Quevedo, and J. Rodríguez, “Predictive control in power electronics and drives,” IEEE Trans. Ind. Electron., vol. 55, no. 12, pp. 4312–4324, Dec. 2008.
[6] J. Chen, A. Prodic,´ R. Erickson, and D. Maksimovic,´ “Predictive digital current programmed control,” IEEE Trans. Power Electron., vol. 18, no. 1 , pp. 411–419, Jan. 2003.
[7] P. Athalye, D. Maksimovic, and R. Erickson, “Variable-frequency predictive digital current-mode control,” IEEE Power Electron. Lett, vol. 2, no. 4, pp. 113–116, Dec. 2004.
[8] Y. T. Chang and Y. S. Lai, “Online parameter tuning technique for predictive current-mode control operating in boundary conduction mode,” IEEE Trans. Ind. Electron., vol. 56, no. 8, pp. 3214–3221, Aug. 2009.
[9] 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., vol. 45, no. 3, pp. 1052–1059, May/Jun. 2009.
[10] C. G. C. Branco, C. M. T. Cruz, R. P. Torrico-Bascopé, and F. L. M. Antunes, “A non-isolated single-phase UPS topology with 110 V/ 220 V input-output voltage ratings,” IEEE Trans. Ind. Electron., vol. 55 , no. 8, pp. 2974–2983, Aug. 2008.
[11] G. Zanei, E. Cevenini, H. Ruff, and O. Ulibas, “Integrated systems for UPS: New solutions in the power quality chain,” in Proc. IEEE 29th Int. Telecommun. Energy Conf., 2007, pp. 582–586.
[12] L. A. Flores, O. Garcia, A. Roman, and M. S. Esparza, “Isolated DC-DC UPS based in a forward-forward converter analysis and design,” in Proc. IEEE 34th IECON, Nov. 2008, pp. 802–807.
[13] N. Vazquez, J. Villegas-Saucillo, C. Hernandez, E. Rodriguez, and J. Arau, “Two-stage uninterruptible power supply with high power factor,” IEEE Trans. Ind. Electron., vol. 55, no. 8, pp. 2954–2962, Aug. 2008.
[14] K. W. Ma and Y. S. Lee, “An integrated flyback converter for DC uninterrupted power supply,” IEEE Trans. Power Electron., vol. 11, no. 2, pp. 318–327, Mar. 1996.
[15] F. Luo, Y. Kang, S. X. Duan, and X. L. Wei, “A novel digital controlled battery charger for high power UPS application,” in Proc. IEEE 5th Int. Power Electron. Motion Control Conf., 2006, pp. 1 – 5.
[16] L. Schuch, C. Rech, H. L. Hey, H. A. Grundling, H. Pinheiro, and J. R. Pinheiro, “Evaluation of a digital control system for a high-efficiency battery charger UPS,” in Proc. IEEE Int. Symp. Ind. Electron, 2003, pp. 956–961.
[17] G. J. M. de Sousa, C. M. T. Cruz, C. G. C. Branco, L. D. S. Bezerra, and R. P. Torrico-Bascope, “A low cost flyback-based high power factor battery charger for UPS applications,” in Proc. IEEE Brazilian Power Electron. Conf., 2009, pp. 783–790.
[18] E. Rodriguez, N. Vazquez, C. Hernandez, and J. Correa, “A novel AC UPS with high power factor and fast dynamic response,” IEEE Trans. Ind. Electron., vol. 55, no. 8, pp. 2963–2973, Aug. 2008.
[19] A. Nasiri, N. Zhong, S. B. Bekiarov, and A. Emadi, “An on-line UPS system with power factor correction and electric isolation using BIFRED converter,” IEEE Trans. Ind. Electron., vol. 55, no. 2, pp. 722–730 , Feb. 2008.
[20] H. J. Chiu, L. W. Lin, P. L. Pan, and M. H. Tseng, “A novel rapid charger for lead-acid batteries with energy recovery,” IEEE Trans. Power Electron., vol. 21, no. 3, pp. 640–647, May 2006.
[21] L. R. Chen, J. J. Chen, N. Y. Chu, and G. Y. Han, “Current-pumped battery charger,” IEEE Trans. Ind. Electron., vol. 55, no. 6, pp. 2482–2488 , Jun. 2008.
[22] S. J. Chiang, H. J. Shieh, and M. C. Chen, “Modeling and control of PV charger system with SEPIC converter,” IEEE Trans. Ind. Electron., vol. 56, no. 11, pp. 4344–4353, Nov. 2009.
[23] Buchmann, Charging the Lead-Acid Battery, 2003. [Online]. Available: http://batteryuniversity.com
[24] J. Chen, F. C. Yang, C. C. Lai, Y. S. Hwang, and R. G. Lee, “A high-efficiency multimode Li-Ion battery charger with variable current source and controlling previous-stage supply voltage,” IEEE Trans. Ind. Electron., vol. 56, no. 7, pp. 2469–2478, Jul. 2009.
[25] P. K. Ng and K. Wolf, “Effect of temperature compensation on battery temperature as predicted by a thermal model,” in Proc. IEEE INTELEC, 1996, pp. 33–38.
[26] S. S. Misra and A. J. Williamson, “On temperature compensation for lead acid batteries in float service: Its impact on performance and life,” in Proc. IEEE INTELEC, 1996, pp. 25–32.
[27] M. Cugnet, J. Sabatier, S. Laruelle, S. Grugeon, B. Sahut, A. Oustaloup, and J. M. Tarascon, “On lead-acid-battery resistance and crankingcapability estimation,” IEEE Trans. Ind. Electron., vol. 57, no. 3, pp. 909 – 917, Mar. 2010.