

DSP Based 20kW Generator/Lithium Battery Management System and Application of Parallel Hybrid Electric Vehicles

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ABSTRACT

The generator and lithium battery management system plays an important role in many electromechanical devices. In a hybrid electric vehicles (HEV), the generator and lithium battery management system is not only the core unit of high performance but also the decisive unit of energy-conservation and reduce carbons. In this thesis, we develop an adaptive battery charge system and energy management strategy for HEV. They both cooperate with each other and turn into key unit of energy-conservation and reduce carbons. The adaptability battery charge system can immediately regulate optimum charge for lithium battery according to energy of power source. Based on this method, we design many suitable automation charge mode. It is able to charge the lithium battery on the condition of ultra-low energy source. Hence, it reaches these functions of improving the storing efficiency and reducing energy losses. Moreover, it can also equilibrium charge at the same time to lengthen the battery life. We will apply this adaptability battery charge system in the HEV platform. Because the power of generator and lithium battery is possible more than 10 kW, the circuit design and stability operation of this system are not an easy task. We consider power of generator modulation, charging and discharging reacting of lithium battery and safety norm to accomplish the adaptability battery charge system of HEV. Besides, we also achieved the construction of the prototype vehicle to real application and test in this research. Through the real experiments, we have proved the exactitude of theory and the practicability of the novel method. The adaptability battery charge system can not limits the application to the kind of particular battery and vehicle system, it can also apply to any kind of real-time electricity generation system of the frequently change energy.

Keywords : Integrated motor/generator (IMG) ; Lithium battery ; Battery charge system ; Charge equalization ; Hybrid electric vehicle (HEV)

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REFERENCES

[1] T. Gottwald, Z. Ye, T. Stuart, " Equalization of EV and HEV Batteries with a Ramp Converter ", IEEE Trans. on Aerospace and Electronic

Systems, Vol.33, No.1, Jan., 1997, pp. 307-311.

[2] B. Lindemark, " Individual Cellvoltage Equalizers (ICE) for Reliable Battery Performance ", 13th International Telecommunications Energy Conference 1991, INTELEC ' 91, pp. 196-201.

[3] C. Pascual, and P. T. Krein, " Switched Capacitor System for Automatic Series Battery Equalization ", 12th Applied Power Electronics Conference and Exposition 1997, APEC ' 97, pp. 848-854.

[4] G. A. Kobzev, " SwitchedCapacitor Systems for Battery Equalization ", Modern Techniques and Technology 2000, MTT 2000, pp. 57-59.

[5] H. Sakamoto, K. Murata, E.Sakai and K. Nishijima, " Balanced Charging of Series Connected Battery Cells ", Telecommunications Energy Conference 1998, INTELEC ' 98, pp. 311-315.

[6] N. H. Kutkut, H. L. N. Wiegman, D. M. Divan and D. W. Novotny, " Design Considerations for Charge Equalization of an Electric Vehicle Battery System ", IEEE Transactions on Industry Applications, Vol.35, Jan.Feb.1999, pp. 28-35.

[7] N. H. Kutkut, H. L. N. Wiegman, D. M. Divan, D. W. Novotny, " Charge Equalization for Series Connected Battery Strings ", IEEE Trans. On Industry Applications, Vol.31, No.3, May/June, 1995, pp.562-568.

[8] N. H. Kutkut, H. L. N. Wiegman, D. M. Divan, D. W. Novotny, " Charge Equalization for an Electric Vehicle Battery System ", IEEE Trans. On Aerospace and Electronic Systems, Vol.34, No.1, Jan., 1998, pp. 235-245.

[9] N. H. Kutkut, " Nondissipative Current Diverter Using a Centralized Multiwinding Transformer ", 28th IEEE Power Electronics Specialists Conference, 1997. PESC '97, pp. 648-654.

[10] Nasser H. Kutkut, " A Modular Non Dissipative Current Diverter for EV Battery Charge Equalization ", APEC 1998, Conference Proceedings 1998, 13 rd, Vol. 2, 1998, pp. 686-690.

[11] S. T. Hung, D. C. Hopkins, and C. R. Mosling, " Extension of Battery Life via Charge Equalization Control ", IEEE Trans. On Industrial Electronics, Vol. 40, No. 1, Feb., 1993, pp. 96-104.

[12] D. C. Hopkins, C. R. Mosling, and S. T. Hung, " Dynamic Equalization During Charging of Serial Energy Storage Elements ", IEEE Trans. On Industry Applications, Vol. 29, No.2, Mar./Apr. 1993, pp. 363-368.

[13] M. Tang, T. Stuart, " Selective Buck-Boost Equalizer for Series Battery Packs ", IEEE Trans. on Aerospace and Electronic Systems, Vol.36, No.1, Jan., 2000, pp. 201-211.

[14] Z. Ye, T. A. Stuart, " Sensitivity of a Ramp Equalizer for Series Batteries ", IEEE Trans. on Aerospace and Electronic Systems, Vol.34, No.4, Oct., 1998, pp. 1227-1236.

[15] Y. S. Lee, M. W. Chen, K. L. Hsu, J. Y. Du, and C. F. Chuang, " Cell Equalization Scheme with Energy Transferring Capacitance for Series Connected Battery Strings ", IEEE Conference on Computers, Communications, Control and Power Engineering 2002, TENCON '02, pp. 2042-2045.

[16] C. Karnjanapiboon, Y. Rungruengphalanggul and I. Boonyaroonate, " The Low Stress Voltage Balance Charging Circuit for Series Connected Batteries Based on Buck-Boost Topology ", International Symposium on Circuits and Systems 2003, ISCAS ' 03, pp. 284-287.

[17] Cheng-Liang Cheng, " Preparation of Porous,Chemically Crosslinked PVdF-HFP Based Polymer Electrolytes for Lithium Secondary Batteries and Study of Their Thermal Shutdown Behaviors " NTHU dissertation.

[18] Z. Yang Pan and F. Lin Luo, " Novel Soft-Switching Inverter for Brushless DC Motor Variable Speed Drive System ", IEEE Trans. on Power Electronics, Vol. 19, no. 2, Mar. 2004.

[19] R.W. Erickson and D. Maksimovic, " Fundamentals of power electronics " Kluwer Academic Publishers, 2nd, 2001.

[20] Juan W. Dixon and Iva'n A. Leal, Current Control Strategy for Brushless DC Motors Based on a Common DC Signal, IEEE Trans 2002, pp. 232-240.

[21] Taiwan Trade Centre Ltd., " Taipei International Automobile Electronics Show, " Auto Tronics Taipei 2007. Apr, pp. 25-28, 2007.