WiP Abstract: Charge Scheduling for Large-Scale Battery Management Systems

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1. WORK-IN-PROGRESS ABSTRACT

Introduction. A large-scale Battery Management System (BMS) used in Electric Vehicles (EVs) and energy storage systems is a typical Cyber-Physical System (CPS) application in that scheduling of battery charge, discharge, and rest (i.e., cyber part) can significantly improve BMS performance under understanding and controlling battery characteristics (i.e., physical part). Therefore, the CPS community has paid attention to BMSes, e.g., ICCPS [4, 5, 3] and the CPS track in RTSS [7, 2, 6, 1].

Most studies on BMSes from the CPS community have focused on a situation where a BMS supplies power to target systems. This entails determining which batteries are discharged (while others are rested) and how much individual batteries are discharged. To schedule battery discharge and rest, we should understand interesting non-linear characteristics of batteries, e.g., *rate capacity effects* and *recovery effects*. Rate capacity effects mean the higher discharge rate, the less efficient deliverable power; for example, provided that a battery can serve 60 minutes with 1-unit discharge rate, the battery only serves 28 (not 30) minutes with 2-unit discharge rate [7]. By recovery effects, we mean that the voltage dropped by deep discharge can be recovered after some rest time. These non-linear behaviors play an important role for performance improvement potentially achieved by scheduling of battery discharge and rest.

However, only a few existing CPS research on BMSes dealt with a situation where power is sporadically generated within target systems. For example, many EVs are equipped with a regenerative breaking system, which generates power whenever the brake decelerates the EV. To manage this situation, we conjecture two battery properties for charge process: (a) deciding *which batteries and how much individual batteries are charged* is as important as that for discharge process; and (b) there exist *non-linear characteristics for battery charge process* corresponding to those for discharge process. Provided that the two hypotheses are valid, scheduling of battery charge and rest can potentially improve BMS performance.

Preliminary Results and Ongoing Work. We performed simulations using a popular battery simulator *Dualfoil*, and demonstrated that the two hypotheses are correct. For example, we observed that there exists a behavior regarding battery charge process, which corresponds to recovery effects regarding discharge process. As shown in Figure 1, the voltage peaked at 4.0 V right after 48-minute-long charge process with 1-unit charge rate will be dropped down to 3.94 V after some rest period. In addition, the figure shows that the dropped voltages vary with charge rate, e.g., 3.94, 3.88, 3.86, and 3.84 V with 1-, 2-, 3-, and 4-unit charge rate, respectively. This behavior is another factor we should consider for scheduling of battery charge and rest.

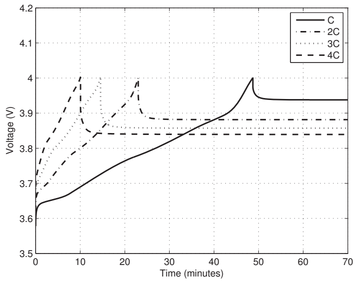

Figure 1: Battery charge behavior

Now, we are working on understanding physical characteristics of battery charge process more thoroughly; in addition to above-mentioned battery characteristics, we believe that there are more interesting behaviors that should be addressed for efficient charge scheduling. Once we investigate the characteristics, we will develop scheduling framework for battery management systems, handling a situation where power is intermittently generated within target systems.

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2. REFERENCES

[1] W. Chang, A. Prbstl, D. Goswami, M. Zamani, and S. Chakraborty. Battery- and aging-aware embedded control systems for electric vehicles. In *RTSS 2014*.

[2] L. He, L. Gu, L. Kong, Y. Gu, C. Liu, and T. He. Exploring adaptive reconfiguration to optimize energy efficiency in large-scale battery systems. In *RTSS 2013*.

[3] L. He, L. Kong, S. Lin, S. Ying, Y. Gu, T. He, and C. Liu. Reconfiguration-assisted charging in large-scale lithium-ion battery systems. In *ICCPS 2014*.

[4] E. Kim, J. Lee, and K. G. Shin. Real-time prediction of battery power requirements for electric vehicles. In *ICCPS 2013*.

[5] E. Kim, K. G. Shin, and J. Lee. Real-time battery thermal management for electric vehicles. In *ICCPS 2014*.

[6] E. Kim, K. G. Shin, and J. Lee. Real-time charge/discharge rate management for hybrid energy storage in electric vehicles. In *RTSS 2014*.

[7] H. Kim and K. G. Shin. Scheduling of battery charge, discharge, and rest. In *RTSS 2009*.