The algorithm has the capability to manage and organize the different modes of operation in smart homes. Simulation results show that the proposed algorithm can improve the life cycle of the battery by controlling its SOC and cell temperature within the safe range. The minimum SOC will not exceed its limit under different load levels irrespective of the irradiance variation during the sunny and cloudy day. The battery temperature is continuously increased either during discharging or charging mode and is kept within the safe temperature range during the different operation conditions. The simulation result shows the energy management algorithm will operate correctly for the battery charging/discharging mode to minimize the power exchange by the grid.

The impact of storage batteries on the electricity bills has to be studied in future. First, the cost saving due to reduction in peak demand charge and the participating in regulation market will be estimated. Second, as electric vehicle number continues to increase, the proposed model needs to be extended to consider the additional constraints by charging and discharging of electric vehicle batteries.

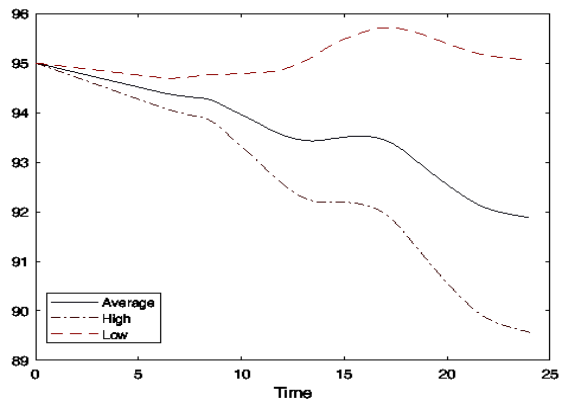

Fig. (10) Variation of battery SOC for average, low and high load during cloudy day

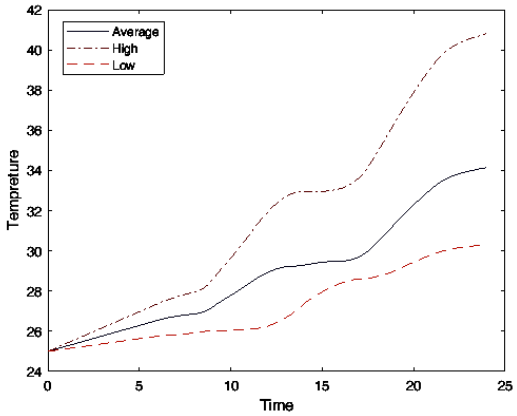

Fig. (11) Variation of battery temperature for average, low and high load during cloudy day

References

[1] Bach, B., Willhelmer, D. and Palensky, P. (2010), "Smart buildings, smart cities and governing innovation in the new millenium", 8th IEEE International Conference on Industrial Informatics (INDIN), IEEE, Osaka, pp. 8-14

[2] A. Abdon, X. Zhang, D. Parra, M.K. Patel, C. Bauer, J. Worlitschek, "Techno-economic and environmental assessment of stationary electricity storage technologies for different time scales", Energy, Jul. 2017.

[3] Liu, W.-H.E.; Liu, K.; Pearson, D.," Consumer-centric smart grid ", IEEE PES Innovative Smart Grid Technologies (ISGT), 2011, Page(s): 1 – 6.

[4] S. Saponara and T. Bacchillone. Network architecture, security issues, and hardware implementation of a home area network for smart grid. Journal of Computer Networks and Communications, 2012,

[5] K. Mets, M. Strobbe, T. Verschueren, T. Roelens, F. De Turck, and C. Develder. Distributed multi-agent algorithm for residential energy management in smart grids. In Network Operations and Management Symposium (NOMS'2012), pages 435- 443, 2012.

[6] M. Ahangari Hassas , K. *Pourhossein*, Control and Management of Hybrid Renewable Energy Systems: Review and Comparison of Methods, Journal of Operation and Automation in Power Engineering Vol. 5, No. 2, Dec. 2017, Pages: 131-138

[7] Wang, Z., Wang, L., Dounis, A.I. and Yang, R. (2012), "Multi-agent control system with information fusion based comfort model for smart buildings", Applied Energy, Vol. 99, pp. 247-254.

[8] Tarun Huria, Massimo Ceraolo , Javier Gazzarri, Robyn Jackey , High Fidelity Electrical Model with Thermal Dependence for Characterization and Simulation of High Power Lithium Battery Cells, 4-8 March 2012, 2012 IEEE International Electric Vehicle Conference, Greenville, SC, USA

[9] G. Fortino and A. Guerrieri. Decentralized management of building indoors through embedded software agents. Computer Science and Information Systems, 9(3):1331{1359, 2012.

[10] Soares A., A. Gomes, and C.H. Antunes. 2012. Integrated management of residential energy resources. *EPJ web of conferences*. 33:05005.

[11] Mohamed A. El-Sayed, Steven Leeb, Evaluation of Maximum Power Point Tracking Algorithms for Photovoltaic Electricity Generation in Kuwait, Renewable Energy and Power Quality Journal (RE&PQJ) ISSN 2172-038 X, No.12, April 2014

[12] Mohamed A. El-Sayed, Steven Leeb, Fuzzy Logic Based Maximum Power Point Tracking Using Boost Converter for Solar Photovoltaic System in Kuwait", Renewable Energy and Power Quality Journal (RE&PQJ) ISSN 2172-038 X, No.13, April 2015

[13] Ryu Ishizaki, Lei Lin, Naoki Kawarabayashi, Masahiro Fukui, "An SOC Estimation System for Lithium ion Batteries Considering Thermal Characteristics", The 19th Workshop on Synthesis And System Integration of Mixed Information technologies, *SASIMI 2015*, 16 - 17 March, 2015. Yilan, Taiwan.

[14] A. L. Emelina, M. A. Bykov, M. L. Kovba, B. M. Senyavin, E. V. Golubina, "Thermochemical properties of lithium cobaltate". Russian Journal of Physical Chemistry, volume 85, issue 3, pp 357–363, (2011).

[15] Cong Zhu, Xinghu Li, Lingjun Song, Liming Xiang, Development of a theoretically based thermal model for lithium ion battery pack, Journal of Power Sources, Volume 223, 1 February 2013, Pages 155-164.

[16] P. Kreczanik, P. Venet, A. Hijazi and G. Clerc, "Study of Supercapacitor Aging and LifetimeEstimation According to Voltage, Temperature, and RMS Current," in IEEE Transactions on Industrial Electronics, vol. 61, no. 9, pp. 4895-4902, Sept. 2014.