# HYBRID POWER MANAGEMENT FOR FUEL CELL-SUPERCAPACITOR POWERED HYBRID ELECTRIC VEHICLE

SRI SATYA VEERENDRA BABU ARIGELA

DOCTOR OF PHILOSOPHY

UNIVERSITI MALAYSIA PAHANG

**SUPERVISOR'S DECLARATION**

We hereby declare that We have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

(Supervisor's Signature)

Full Name : DR. MOHD RUSLLIM BIN MOHAMED

Position : ASSOCIATE PROFESSOR

Date : 01 JANUARY 2022

(Co-supervisor's Signature)

Full Name : DR. MOHD HERWAN BIN SULAIMAN

Position : ASSOCIATE PROFESSOR

Date : 01 JANUARY 2022

## STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

(Student's Signature)

Full Name : SRI SATYA VEERENDRA BABU ARIGELA

ID Number : PES18003

Date : 01 JANUARY 2022

# HYBRID POWER MANAGEMENT FOR FUEL CELL-SUPERCAPACITOR POWERED HYBRID ELECTRIC VEHICLE

SRI SATYA VEERENDRA BABU ARIGELA

Thesis submitted in fulfillment of the requirements
for the award of the
Doctor of Philosophy

College of Engineering

UNIVERSITI MALAYSIA PAHANG

JANUARY 2022

## ACKNOWLEDGEMENTS

First, I would like to take this opportunity to express my sincere gratitude to my supervisor Assoc. Prof. Mohd Rusllim Bin Mohamed for his continuous support, patience, motivation, enthusiasm and immense knowledge imparted during my Ph.D. study. I am always illuminated from talking with Dr. Mohd Rusllim Bin Mohamed about solving problems encountered in my research.

Besides my supervisor, I would like to thank my co-supervisor Assoc. Prof Mohd Herwan Sulaiman for his encouragement, insightful comments and constructive suggestions. I also would like to thank Dr. K. Sudhakar for his support and help in my study. He is very kind and helpful. His professional suggestions and comments were very important to improve my scientific papers.

My sincere thanks also go to Universiti Malaysia Pahang representatives not only for their financial support under doctoral research scheme as well as PGRS (Grant No: PGRS200321) during my research, but also their constructive and positive feedbacks on regular basis.

I wish to express my appreciation to all individuals who supported me during the completion phases of the thesis including all my friends and department professors and staff.

I would like to express my warmest thanks to my parents, my son, my sister, and parent in laws for their unconditional love and support more than I could ever expect. A special thank you to my parents Venkateshwara Rao and Lakshmi Kumari. They believed in me and that my dream would become a reality one day.

*Finally,*

*To my loving wife Lakshmi, for tolerating my eccentric ways the past three years, and for agreeing to stand by me till the end of time…*

**ABSTRAK**

*Fuel Cell* (FC) dengan kombinasi kenderaan elektrik hibrid dengan *supercapacitor* (SC) berpotensi menyelesaikan sistem pengangkutan masa depan. Hal ini kerana kemampuan hasil wasap sifar, peningkatan daya sementara, kemampuan menyerap tenaga pengereman regeneratif, kecekapan tinggi, dan jarak jauh. Namun, ciri keluaran yang tidak linear menyebabkan sistem FC mempunyai kelemahan kekangan dalaman seperti kandungan air membran dan suhu sel. Oleh itu, pengurusan keluaran tenaga semaksimum mungkin adalah penting bagi mengelakkan penggunaan bahan bakar berlebihan dan kecekapan sistem yang rendah. Sebaliknya, walaupun SC mempunyai kelebihan sistem penyimpanan tenaga tambahan, penyambungan sel SC sesiri menyebabkan masalah ketidakseimbangan sel, berpunca dari ciri sel yang tidak setara yang berlaku semasa proses pembuatan dan keadaan persekitaran. Perbezaan voltan sel ini dalam modul SC menyebabkan penurunan kecekapan kombinasi sel dan jangka hayatnya. Tambahan, batasan sumber kuasa di atas dan keadaan caj awal SC mempengaruhi pengurusan kuasa bagi agihan kuasa di antara pelbagai sumber. Oleh itu, tesis ini bertujuan untuk mengusulkan kawalan dan pengurusan hybrid tenaga FC-SC untuk kenderaan elektrik hibrid sambungan sesiri bagi menyelesaikan 3 permasalahan di atas. Pertama, tesis ini berfokuskan pada pengawal penjejakan titik maksimum kuasa (MPPT) dengan topologi pengubah meningkat 4-kaki berselang-seli (M-FLIBC) yang diubahsuai untuk sistem FC. Keberkesanan IBC dibandingkan dengan 2 sistem kawalan lain dengan topologi tradisional FLIBC. Seterusnya, penyeimbang modular global untuk imbangan voltan dalam SC dihubungkan secara sesiri bagi sistem HEV. Rekaan pengimbangan modular global menggunakan pendekatan penukaran depan, yang mengintegrasikan pengimbangan sel, pengimbangan modul, dan operasi bagi frekuensi berbeza, memberi impak pengurangan kapasiti serta kerumitan pelaksanaan. Akhir sekali, tesis ini menilai pengurusan kuasa hibrid (HPM) untuk membolehkan pengagihan sumber kuasa dengan berkesan, bagi membolehkan pengurangan penggunaan hidrogen dan peningkatan ekonomi bahan bakar kenderaan. Dalam hal ini, model litar setara SC dibangunkan untuk sistem penyimpanan tenaga. Kombinasi kaedah penapis Kalman (EKF) dan penghitungan tradisional coulomb (CC) digunakan untuk melakukan penganggaran keadaan pengecasan SC, yang meningkatkan keberkesanan HPM. Bagi memastikan kajian pengukuran ekonomi bahan bakar dalam keadaan pemanduan yang realistik, kitaran ujian gabungan agensi perlindungan alam sekitar (EPA) untuk bandar dan lebuh raya dipertimbangkan. Hasil perbandingan prestasi pengawal yang berbeza berdasarkan teknik MPPT dari segi voltan, arus, kuasa, masa penyelesaian, dan kecekapan FC menunjukkan bahawa pengawal MPPT dengan RBFN dan M-FLIBC mengungguli pengawal berasaskan PID dan Fuzzy. Dalam hal pengawalan SC dalam HEV, topologi SC yang dicadangkan menunjukkan pengimbangan voltan berkesan selain pengurangan penggunaan komponen, dengan lingkungan operasi frekuensi yang berbeza pada 10 - 70 kHz, dan kelebihan bilangan sel SC modular tanpa had dalam Analisa prestasi HEV. Akhirnya, dengan semua topologi kawalan yang dicadangkan dan gabungan pengurusan tenaga berdasarkan EKF-CC untuk FC-SC dalam Siri HEV, ekonomi bahan bakar kenderaan dapat dinaikkan kepada 93.38 km/kg berbanding dengan pengurusan kuasa berasaskan tradisional CC sebanyak 86.53 km/kg dan peningkatan pecutan kenderaan 0-100 km/jam dalam masa 9.0 saat. Hasil kajian menunjukkan kawalan dan pengurusan kuasa hibrid FC dan SC dapat meningkatkan prestasi kenderaan dalam sudut utama perbandingan. Cadangan pengembangan kajian masa depan diketengahkan.

## ABSTRACT

Fuel cell (FC) with a combination of supercapacitor (SC) based hybrid electric vehicles have been regarded as a potential solution in the future transportation system. This is due to their zero-emission, enhancement of transient power demand, ability to absorb the energy from the regenerative braking, high efficiency, and long mileage. Nevertheless, the nonlinear output characteristics of the FC system are a feeble point owing to internal constraints such as membrane water content and cell temperature. Hence it is essential to extricate as much power as possible from the stack to avert excessive fuel usage and low system efficiency. Conversely, despite the advantages of the SC as an auxiliary energy storage system, the series connection of SC cells causes a cell imbalance problem due to uneven cell characteristics that occur during the manufacturing process and its ambient conditions. This discrepancy of cell voltages in a supercapacitor module leads to reduce the stack's efficiency and its lifetime. Furthermore, the above limitations of the power sources and initial state of SC's charge affect the power management's distribution of power among the multiple sources. Therefore, the aim of this thesis is to propose a hybrid power management for fuel cell-supercapacitor powered hybrid electric vehicles to solve the three identified problems. Firstly, this thesis focuses on a maximum power point tracking (MPPT) controller with a modified 4-leg interleaved boost converter (M-FLIBC) topology for the FC system. The effectiveness of the proposed IBC with a controller for the FC is compared with the two additional controllers couples with the conventional FLIBC topology. Next, a global modular balancer for voltage balancing of multiple supercapacitor cells is connected in series for an HEV system. The global modular balancing architecture is proposed based on forward conversion, which integrates cell balancing, module balancing, and operating for different frequencies. Thus, greatly reducing the volume and implementation complexity. Finally, the thesis evaluates hybrid power management (HPM) for effective power sources distribution, in order to reduce hydrogen consumption and enhance the vehicle's fuel economy. In this case, an equivalent circuit model of SC is developed for the energy storage system. The combination of an extended Kalman filter (EKF) and traditional coulomb counting (CC) method is used to estimate the SC state of charge in improving the effectiveness of the HPM. To evaluate the fuel economy under realistic driving conditions, the combined environmental protection agency (EPA) test cycles for a city and highway are considered. The outcome of performance comparison of the different controllers based on MPPT technique in terms of voltage, current, power, settling time, and efficiency of the FC indicates that the radial basis function network (RBFN) based MPPT controller with the M-FLIBC outperforms the PID and Fuzzy based controllers. With respect to controlling of SC in HEV environment, the proposed topology of SC presents effective voltage balancing with a lower component count, able to operate at different frequencies, i.e., 10 to 70 kHz, as well opens to unlimited stackable modular numbers of SC cells for the HEV performance analysis. Ultimately, with all the proposed control topologies and combined EKF-CC based power management for the FC-SC in Series HEV, the vehicle's fuel economy is increased to 93.38 km/kg as compared to traditional CC based power management of 86.53 km/kg, besides it improves the vehicle's acceleration within 0-100 km/h in 9.0 seconds respectively. Finally, the research shows that the hybrid power management of FC and SC powered HEV leads to improved performance of the vehicle in terms of the key measures. Suggestions for future research are also highlighted.

## TABLE OF CONTENT

# REFERENCES


Abdul-Hak, M., & Al-Holou, N. (2009). ITS based predictive intelligent battery management system for plug-in hybrid and electric vehicles. *Vehicle Power and Propulsion Conference, 2009. VPPC'09. IEEE*, 138–144.

Ahmad, S., Nasir, M., Dąbrowski, J., & Guerrero, J. M. (2020). Improved topology of high voltage gain DC-DC converter with boost stages. *International Journal of Electronics Letters*, 1–13.

Ahmadi, S., & Bathaee, S. M. T. (2015). Multi-objective genetic optimization of the fuel cell hybrid vehicle supervisory system: Fuzzy logic and operating mode control strategies. *International Journal of Hydrogen Energy*, *40*(36), 12512–12521. https://doi.org/https://doi.org/10.1016/j.ijhydene.2015.06.160

Ahmadi, S., Bathaee, S. M. T., & Hosseinpour, A. H. (2018). Improving fuel economy and performance of a fuel-cell hybrid electric vehicle (fuel-cell, battery, and ultra-capacitor) using optimized energy management strategy. *Energy Conversion and Management*, *160*, 74–84.

Akhil, A. A., Huff, G., Currier, A. B., Kaun, B. C., Rastler, D. M., Chen, S. B., Cotter, A. L., Bradshaw, D. T., & Gauntlett, W. D. (2013). *DOE/EPRI 2013 electricity storage handbook in collaboration with NRECA*. Sandia National Laboratories Albuquerque, NM.

Ali, A., & Soffker, D. (2018). Towards Optimal Power Management of Hybrid Electric Vehicles in Real-Time: A Review on Methods, Challenges, and State-Of-The-Art Solutions. *Energies, 11*(3), 476.

Alloui, H., Becherif, M., & Marouani, K. (2013). Modelling and frequency separation energy management of fuel Cell-Battery Hybrid sources system for Hybrid Electric Vehicle. *Control & Automation (MED), 2013 21st Mediterranean Conference On*, 646–651.

Amjad, S., Neelakrishnan, S., Rudramoorthy, R. (2010). Review of design considerations and technological challenges for successful development and deployment of plug-in hybrid electric vehicles. *Renewable and Sustainable Energy Reviews, 14*(3), 1104–1110.

Anno, T., & Koizumi, H. (2015). Double-input bidirectional DC/DC converter using cell-voltage equalizer with flyback transformer. *IEEE Transactions on power Electronics, 30*(6), 2923–2934.

Arias, M., Sebastián, J., Hernando, M. M., Viscarret, U., & Gil, I. (2014). Practical application of the wave-trap concept in battery–cell equalizers. *IEEE Transactions on Power Electronics*, *30*(10), 5616–5631.

Arulmurugan, R., & Suthanthiravanitha, N. (2015). Model and design of a fuzzy-based Hopfield NN tracking controller for standalone PV applications. *Electric Power Systems Research, 120*, 184–193.

Aso, S., Kizaki, M., (2007). Development of fuel cell hybrid vehicles in TOYOTA. In *2007 Power Conversion Conference - Nagoya, Vols 1-3*. <Go to ISI>://WOS:000250405500243

Azib, T., Bethoux, O., Remy, G., & Marchand, C. (2011). Saturation management of a controlled fuel-cell/ultracapacitor hybrid vehicle. *IEEE Transactions on Vehicular Technology, 60*(9), 4127–4138.

Azri, M., Khanipah, N. H. A., Ibrahim, Z., & Abd Rahim, N. (2017). Fuel cell emulator with MPPT technique and boost converter. *International Journal of Power Electronics and Drive Systems*, *8*(4), 1852.

Babaei, E., & Saadatizadeh, Z. (2017). A new interleaved bidirectional dc/dc converter with zero voltage switching and high voltage gain: analyses, design and simulation. *International Journal of Circuit Theory and Applications*, *45*(11), 1773–1800. https://doi.org/10.1002/cta.2360

Baccouche, I., Jemmali, S., Mlayah, A., Manai, B., & ben Amara, N. E. (2018). Implementation of an Improved Coulomb-Counting Algorithm Based on a Piecewise SOC-OCV Relationship for SOC Estimation of Li-Ion Battery. *International Journal of Renewable Energy Research*, *8*(1), 178–187. <Go to ISI>://WOS:000429607600018

Bahri, H., & Harrag, A. (2021). Ingenious golden section search MPPT algorithm for PEM fuel cell power system. *Neural Computing and Applications*, 1–24.

Bayat, P., & Baghramian, A. (2018). Implementation of hybrid electric vehicle energy management system for two input power sources. *Journal of Energy Storage*, *17*, 423–440. https://doi.org/10.1016/j.est.2018.03.019

Bendib, B., Belmili, H., Krim, F. (2015). A survey of the most used MPPT methods: Conventional and advanced algorithms applied for photovoltaic systems. Renewable and Sustainable Energy Reviews, *45*, 637–648.

Benyahia, N., Denoun, H., Badji, A., Zaouia, M., Rekioua, T., Benamrouche, N., & Rekioua, D. (2014). MPPT controller for an interleaved boost dc-dc converter used in fuel cell electric vehicles. *International Journal of Hydrogen Energy*, *39*(27), 15196–15205. https://doi.org/10.1016/j.ijhydene.2014.03.185

Bhattacharjee, A. K., & Batarseh, I. (2021). An Interleaved Boost and Dual Active Bridge-Based Single-Stage Three-Port DC-DC-AC Converter With Sine PWM Modulation. *IEEE Transactions on Industrial Electronics*, *68*(6), 4790–4800. https://doi.org/10.1109/tie.2020.2992956

Bui, T., Kim, C. H., Kim, K. H., & Rhee, S. (2018). A modular cell balancer based on multi-winding transformer and switched-capacitor circuits for a series-connected battery string in electric vehicles. *Applied Sciences, 8*(8), 1278.

Bui, T. M., Bae, S. (2015). Active Clamped Forward based Active Cell Balancing Converter. *Indian Journal of Science and Technology, 8*(26).

Burke, A., & Miller, M. (2011). The power capability of ultracapacitors and lithium batteries for electric and hybrid vehicle applications. *Journal of power sources, 196*(1), 514–522.

Campanari, S., Manzolini, G., & de la Iglesia, F. G. (2009). Energy analysis of electric vehicles using batteries or fuel cells through well-to-wheel driving cycle simulations. *Journal of power sources, 186*(2), 464–477.

Caspar, M., Eiler, T., & Hohmann, S. (2014). Comparison of active battery balancing systems. *Vehicle Power and Propulsion Conference (VPPC), 2014 IEEE*, 1–8.

Chakraborty, S., Vu, H. N., Hasan, M. M., Tran, D. D., el Baghdadi, M., & Hegazy, O. (2019). DC-DC Converter Topologies for Electric Vehicles, Plug-in Hybrid Electric Vehicles and Fast Charging Stations: State of the Art and Future Trends. *Energies*, *12*(8). https://doi.org/10.3390/en12081569

Chan, C. C. (2007). The state of the art of electric, hybrid, and fuel cell vehicles. *Proceedings of the IEEE, 95*(4), 704–718.

Chang, W. Y. (2013). The state of charge estimating methods for battery: A review. *International Scholarly Research Notices*, *2013*.

Changizian, S., Ahmadi, P., Raeesi, M., & Javani, N. (2020). Performance optimization of hybrid hydrogen fuel cell-electric vehicles in real driving cycles. *International Journal of Hydrogen Energy*. https://doi.org/https://doi.org/10.1016/j.ijhydene.2020.01.015

Chatzikomis, C., Sorniotti, A., Gruber, P., Bastin, M., Shah, R. M., & Orlov, Y. (2017). Torque-Vectoring Control for an Autonomous and Driverless Electric Racing Vehicle with Multiple Motors. *SAE International Journal of Vehicle Dynamics Stability and Nvh*, *1*(2), 338–351. https://doi.org/10.4271/2017-01-1597

Chau, K. T., Chan, C. C., & Liu, C. (2008). Overview of permanent-magnet brushless drives for electric and hybrid electric vehicles. IEEE Transactions on Industrial Electronics, *55*(6), 2246–2257.

Chau, K. T., Wong, Y. S., Chan, C. C. (1999). An overview of energy sources for electric vehicles. *Energy Conversion and Management, 40*(10), 1021–1039.

Chen, B. C., Wu, Y. Y., & Tsai, H. C. (2014). Design and analysis of power management strategy for range extended electric vehicle using dynamic programming. *Applied Energy, 113*, 1764–1774.

Chen, H., Cong, T. N., Yang, W., Tan, C., Li, Y., & Ding, Y. (2009). Progress in electrical energy storage system: A critical review. *Progress in Natural Science, 19*(3), 291–312.

Chen, Y., Hu, X., & Liu, J. (2019). Life Cycle Assessment of Fuel Cell Vehicles Considering the Detailed Vehicle Components: Comparison and Scenario Analysis in China Based on Different Hydrogen Production Schemes. *Energies*, *12*(15), 3031.

Chen, Y., Liu, X., Cui, Y., Zou, J., & Yang, S. (2015). A multiwinding transformer cell-to-cell active equalization method for lithium-ion batteries with reduced number of driving circuits. *IEEE Transactions on Power Electronics*, *31*(7), 4916–4929.

Chen, Y. T., Lu, Z. X., & Liang, R. H. (2018). Analysis and Design of a Novel High-Step-Up DC/DC Converter With Coupled Inductors. *IEEE Transactions on Power Electronics*, *33*(1), 425–436. https://doi.org/10.1109/tpel.2017.2668445

Costa, L. F., Mussa, S. A., & Barbi, I. (2014). Multilevel Buck/Boost-Type DC-DC Converter for High-Power and High-Voltage Application. *IEEE Transactions on Industry Applications*, *50*(6), 3931–3942. https://doi.org/10.1109/tia.2014.2313715

Cotterman, T. (2013). Energy Storage Technologies: Transforming America's Intelligent Electrical.

Cui, W. H., Wang, J. S., & Chen, Y. Y. (2018). Equivalent Circuit Model of Lead-acid Battery in Energy Storage Power Station and Its State-of-Charge Estimation Based on Extended Kalman Filtering Method. *Engineering Letters*, *26*(4). <Go to ISI>://WOS:000449494300014

Daoud, M. I., Massoud, A. M., Abdel-Khalik, A. S., Elserougi, A., & Ahmed, S. (2016). A flywheel energy storage system for fault ride through support of grid-connected VSC HVDC-based offshore wind farms. *IEEE Transactions on Power Systems, 31*(3), 1671–1680.

Daowd, M., Omar, N., van den Bossche, P., & van Mierlo, J. (2011). Passive and active battery balancing comparison based on MATLAB simulation. *2011 IEEE Vehicle Power and Propulsion Conference*, 1–7.

Das, H. S., Tan, C. W., & Yatim, A. H. M. (2017). Fuel cell hybrid electric vehicles: A review on power conditioning units and topologies. *Renewable & Sustainable Energy Reviews*, *76*, 268–291. https://doi.org/10.1016/j.rser.2017.03.056

Davis, K., & Hayes, J. G. (2019). Fuel cell vehicle energy management strategy based on the cost of ownership. *IET Electrical Systems in Transportation*, *9*(4), 226–236. https://doi.org/10.1049/iet-est.2019.0021

De Santiago, J., Bernhoff, H., Ekergard, B., Eriksson, S., Ferhatovic, S., Waters, R., & Leijon, M. (2012). Electrical Motor Drivelines in Commercial All-Electric Vehicles: A Review. *IEEE Transactions on Vehicular Technology*, *61*(2), 475–484. https://doi.org/10.1109/Tvt.2011.2177873

Deniz, E. (2017). ANN-based MPPT algorithm for solar PMSM drive system fed by direct-connected PV array. *Neural Computing and Applications*, *28*(10), 3061–3072.

Deshpande, R. P. (2015). Capacitors. McGraw-Hill Education.

Dincer, I., & Rosen, M. (2002). Thermal energy storage: systems and applications. John Wiley & Sons.

Dong, B., Li, Y., & Han, Y. (2014). Parallel architecture for battery charge equalization. *IEEE Transactions on Power Electronics*, *30*(9), 4906–4913.

Dubal, D. P., Ayyad, O., Ruiz, V., & Gomez-Romero, P. (2015). Hybrid energy storage: the merging of battery and supercapacitor chemistries. *Chemical Society Reviews, 44*(7), 1777–1790.

Eberhard, M., & Tarpenning, M. (2006). The 21 st century electric car tesla motors. *Tesla Motors*, *17*.

Ehsani, M., Gao, Y., & Emadi, A. (2010). Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design, 2nd Edition. In *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design, 2nd Edition*. <Go to ISI>://WOS:000353915100019

Ehsani, M., Gao, Y., Longo, S., & Ebrahimi, K. (2018). Modern electric, hybrid electric, and fuel cell vehicles. CRC press.

Elsied, M., Oukaour, A., Chaoui, H., Gualous, H., Hassan, R., & Amin, A. (2016). Real-time implementation of four-phase interleaved DC–DC boost converter for electric vehicle power system. *Electric Power Systems Research*, *141*, 210–220.

Enang, W., Bannister, C. (2017). Modelling and control of hybrid electric vehicles (A comprehensive review). *Renewable and Sustainable Energy Reviews,74*, 1210–1239.

Ettihir, K., Boulon, L., & Agbossou, K. (2016). Optimization-based energy management strategy for a fuel cell/battery hybrid power system. *Applied Energy*, *163*, 142–153. https://doi.org/10.1016/j.apenergy.2015.10.176

Fernandez, L. M., Garcia, P., Garcia, C. A., & Jurado, F. (2011). Hybrid electric system based on fuel cell and battery and integrating a single dc/dc converter for a tramway. *Energy Conversion and Management*, *52*(5), 2183–2192. https://doi.org/10.1016/j.enconman.2010.12.028

Forse, A. C., Merlet, C., Griffin, J. M., & Grey, C. P. (2016). New Perspectives on the Charging Mechanisms of Supercapacitors. *Journal of American Chemical Soceity*, *138*(18), 5731–5744. https://doi.org/10.1021/jacs.6b02115

Ge, X., Ahmed, F. W., Rezvani, A., Aljojo, N., Samad, S., & Foong, L. K. (2020). Implementation of a novel hybrid BAT-Fuzzy controller based MPPT for grid-connected PV-battery system. *Control Engineering Practice*, *98*, 104380. https://doi.org/https://doi.org/10.1016/j.conengprac.2020.104380

Geng, C., Jin, X., & Zhang, X. (2018). Simulation research on a novel control strategy for fuel cell extended-range vehicles. *International Journal of Hydrogen Energy, 44(1)*, 408-420.

Gur, T. M. (2018). Review of electrical energy storage technologies, materials and systems: challenges and prospects for large-scale grid storage. *Energy & Environmental Science*, *11*(10), 2696–2767.

Han, Y., Chen, W., Li, Q., Yang, H., Zare, F., & Zheng, Y. (2019). Two-level energy management strategy for PV-Fuel cell-battery-based DC microgrid. *International Journal of Hydrogen Energy*, *44*(35), 19395–19404. https://doi.org/https://doi.org/10.1016/j.ijhydene.2018.04.013

Hannan, M. A., Hoque, M. M., Mohamed, A., Ayob, A. (2017). Review of energy storage systems for electric vehicle applications: Issues and challenges. *Renewable and Sustainable Energy Reviews, 69*, 771–789.

He, H. W., Xiong, R., Zhao, K., & Liu, Z. T. (2013). Energy management strategy research on a hybrid power system by hardware-in-loop experiments. *Applied Energy*, *112*, 1311–1317. https://doi.org/10.1016/j.apenergy.2012.12.029

Hiroshima, N., Hatta, H., Nagura, Y., Koyama, M., Sakai, T., & Kogo, Y. (2016). Spin test of three-dimensional composite rotor using polymer ring as a connection device for high-speed flywheel. *Mechanical Engineering Journal, 3*(4), 16-00261-16–00261.

Hoque, M. M., Hannan, M. A., Mohamed, A., Ayob, A. (2017). Battery charge equalization controller in electric vehicle applications: A review. *Renewable and Sustainable Energy Reviews, 75*, 1363–1385.

Hsieh, Y.-C., Cai, Z.-X., & Wu, W.-Z. (2014). Switched-capacitor charge equalization circuit for series-connected batteries. *Power Electronics Conference (IPEC-Hiroshima 2014-ECCE-ASIA), 2014 International*, 429–432.

Hua, C., & Fang, Y.-H. (2015). A charge equalizer with a combination of APWM and PFM control based on a modified half-bridge converter. *IEEE Transactions on Power Electronics*, *31*(4), 2970–2979.

Huang, Y. H., Surawski, N. C., Organ, B., Zhou, J. L., Tang, O. H. H., & Chan, E. F. C. (2019). Fuel consumption and emissions performance under real driving: Comparison between hybrid and conventional vehicles. *Science of the Total Environment*, *659*, 275–282. https://doi.org/10.1016/j.scitotenv.2018.12.349

Huang, Y., Wang, H., Khajepour, A., He, H., & Ji, J. (2017). Model predictive control power management strategies for HEVs: A review. *Journal of Power Sources, 341*, 91–106.

Huangfu, Y. G., Zhuo, S. R., Chen, F. X., Pang, S. Z., Zhao, D. D., & Gao, F. (2018). Robust Voltage Control of Floating Interleaved Boost Converter for Fuel Cell Systems. *IEEE Transactions on Industry Applications*, *54*(1), 665–674. https://doi.org/10.1109/tia.2017.2752686

Ibrahim, H., Ilinca, A., Perron, J. (2008). Energy storage systems—Characteristics and comparisons. Renewable and Sustainable Energy Reviews, *12*(5), 1221–1250.

Imtiaz, A. M., & Khan, F. H. (2013). "Time shared flyback converter" based regenerative cell balancing technique for series connected Li-ion battery strings. *IEEE Transactions on Power Electronics*, *28*(12), 5960–5975.

İnci, M., & Caliskan, A. (2020). Performance enhancement of energy extraction capability for fuel cell implementations with improved Cuckoo search algorithm. *International Journal of Hydrogen Energy*, *45*(19), 11309–11320. https://doi.org/https://doi.org/10.1016/j.ijhydene.2020.02.069

Jeon, S., Kim, M., & Bae, S. (2017). Analysis of a Symmetric Active Cell Balancer with a Multi-winding Transformer. *Journal of Electrical Engineering & Technology*, *12*(5), 1812–1820. https://doi.org/10.5370/jeet.2017.12.5.1812

Jose, C. P., & Meikandasivam, S. (2017). A Review on the Trends and Developments in Hybrid Electric Vehicles. In *Innovative Design and Development Practices in Aerospace and Automotive Engineering* (pp. 211–229). Springer.

Kamran, M., Mudassar, M., Fazal, M. R., Asghar, M. U., Bilal, M., & Asghar, R. (2020). Implementation of improved Perturb & Observe MPPT technique with confined search space for standalone photovoltaic system. *Journal of King Saud University - Engineering Sciences*, *32*(7), 432–441. https://doi.org/https://doi.org/10.1016/j.jksues.2018.04.006

Kascak, S., Prazenica, M., Jarabicova, M., & Konarik, R. (2018). Four Phase Interleaved Boost Converter: Theory and Applications. *WSEAS Transactions on Power Systems*, *13*, 272–282.

Keil, P., Englberger, M., & Jossen, A. (2016). Hybrid energy storage systems for electric vehicles: An experimental analysis of performance improvements at subzero temperatures. *IEEE Transactions on Vehicular Technology, 65*(3), 998–1006.

Khaligh, A., & Li, Z. (2010). Battery, ultracapacitor, fuel cell, and hybrid energy storage systems for electric, hybrid electric, fuel cell, and plug-in hybrid electric vehicles: State of the art. *IEEE Transactions on Vehicular Technology, 59*(6), 2806–2814.

Khalilzadeh, M., Asaei, B., & Nikzad, M. R. (2017). A novel interleaved DC-DC converter with reduced loss for fuel cell vehicle application. *Iranian Journal of Electrical and Electronic Engineering*, *13*(1), 89–99.

Khayyam, H., Kouzani, A., Nahavandi, S., Marano, V., & Rizzoni, G. (2010). Intelligent energy management in hybrid electric vehicles. In *Energy management*. InTech.

Kim, C.-H., Kim, M.-Y., Park, H.-S., & Moon, G.-W. (2012). A modularized two-stage charge equalizer with cell selection switches for series-connected lithium-ion battery string in an HEV. *IEEE Transactions on Power Electronics*, *27*(8), 3764–3774.

Kim, J. W., & Ha, J. I. (2016). Cell Balancing Method in Flyback Converter without Cell Selection Switch of Multi-Winding Transformer. *Journal of Electrical Engineering & Technology*, *11*(2), 367–376. https://doi.org/10.5370/jeet.2016.11.2.367

Kisacikoglu, M. C., Uzunoglu, M., & Alam, M. S. (2009). Load sharing using fuzzy logic control in a fuel cell/ultracapacitor hybrid vehicle. *International Journal of Hydrogen Energy*, *34*(3), 1497–1507.

Kolli, A., Gaillard, A., de Bernardinis, A., Bethoux, O., Hissel, D., & Khatir, Z. (2015). A review on DC/DC converter architectures for power fuel cell applications. *Energy Conversion and Management*, *105*, 716–730. https://doi.org/10.1016/j.enconman.2015.07.060

KoteswaraRao, K. v, & Srinivasulu, G. N. (2019). Modeling, downsizing, and performance comparison of a fuel cell hybrid mid-size car with FCEV for urban and hill road driving cycles. *International Journal of Green Energy*, *16*(2), 115–124. https://doi.org/10.1080/15435075.2018.1549996

Koubaa, R. (2017). Double layer metaheuristic based energy management strategy for a Fuel Cell/Ultra-Capacitor hybrid electric vehicle. *Energy*, *133*, 1079–1093.

Kumar, S., & Shaw, B. (2019). Design of off-grid fuel cell by implementing ALO optimized PID-based MPPT controller. In *Soft Computing in Data Analytics* (pp. 83–93). Springer.

Kuncham, S. K., Annamalai, K., & Nallamothu, S. (2019). A new structure of single-phase two-stage hybrid transformerless multilevel PV inverter. *International Journal of Circuit Theory and Applications*, *47*(1), 152–174. https://doi.org/10.1002/cta.2580

Lee, S.-Y., Choi, K.-H., Choi, W.-S., Kwon, Y. H., Jung, H.-R., Shin, H.-C., Kim, J. Y. (2013). Progress in flexible energy storage and conversion systems, with a focus on cable-type lithium-ion batteries. *Energy and Environmental science, 6*(8), 2414–2423.

Lee, Y., Jeon, S., Bae, S. (2016). Comparison on Cell Balancing Methods for Energy Storage Applications. *Indian Journal of Science and Technology, 9*(17).

Lee, Y. S., & Cheng, G. T. (2006). Quasi-resonant zero-current-switching bidirectional converter for battery equalization applications. *IEEE Transactions on Power Electronics*, *21*(5), 1213–1224. https://doi.org/10.1109/tpel.2006.880349

Lemofouet, S., & Rufer, A. (2006). Hybrid energy storage system based on compressed air and super-capacitors with maximum efficiency point tracking (MEPT). *IEEJ Transactions on Industry Applications, 126*(7), 911–920.

Li, H., Ravey, A., N'Diaye, A., & Djerdir, A. (2018). A novel equivalent consumption minimization strategy for hybrid electric vehicle powered by fuel cell, battery and supercapacitor. *Journal of Power Sources*, *395*, 262–270. https://doi.org/10.1016/j.jpowsour.2018.05.078

Li, H., Zhou, Y., Gualous, H., Chaoui, H., & Boulon, L. (2020). Optimal Cost Minimization Strategy for Fuel Cell Hybrid Electric Vehicles Based on Decision Making Framework. *IEEE Transactions on Industrial Informatics*.

Li, J., Zhang, M., Yang, Q., Zhang, Z., & Yuan, W. (2016). SMES/battery hybrid energy storage system for electric buses. *IEEE Transactions on Applied Superconductivity*, *26*(4), 1–5.

Li, Q., Chen, W., Li, Y., Liu, S., Huang, J. (2012). Energy management strategy for fuel cell/battery/ultracapacitor hybrid vehicle based on fuzzy logic. *International Journal of Electrical Power and Energy Systems, 43*(1), 514–525.

Li, S., Mi, C. C., & Zhang, M. (2012). A high-efficiency active battery-balancing circuit using multiwinding transformer. *IEEE Transactions on Industry Applications*, *49*(1), 198–207.

Li, T. Y., Liu, H. Y., Zhao, D. X., & Wang, L. L. (2016). Design and analysis of a fuel cell supercapacitor hybrid construction vehicle. *International Journal of Hydrogen Energy*, *41*(28), 12307–12319. https://doi.org/10.1016/j.ijhydene.2016.05.040

Li, Y., Samad, S., Ahmed, F. W., Abdulkareem, S. S., Hao, S., & Rezvani, A. (2020). Analysis and enhancement of PV efficiency with hybrid MSFLA–FLC MPPT method under different environmental conditions. *Journal of Cleaner Production*, *271*, 122195. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.122195

Lim, E., Jo, C., Kim, H., Kim, M.-H., Mun, Y., Chun, J., Ye, Y., Hwang, J., Ha, K.-S., & Roh, K. C. (2015). Facile synthesis of Nb2O5@ carbon core–shell nanocrystals with controlled crystalline structure for high-power anodes in hybrid supercapacitors. ACS Nano, *9*(7), 7497–7505. https://pubs.acs.org/doi/10.1021/acsnano.5b02601

Lin, J. Y., Wang, C. F., Lin, C. Y., Chen, J. L., & Wang, J. M. (2015). An active-clamping zero-voltage-switching flyback converter with integrated transformer. *International Journal of Circuit Theory and Applications*, *43*(10), 1351–1366. https://doi.org/10.1002/cta.2009

Ling, R., Dan, Q., Wang, L., & Li, D. (2015). Energy bus-based equalization scheme with bi-directional isolated Cuk equalizer for series connected battery strings. *2015 IEEE Applied Power Electronics Conference and Exposition (APEC)*, 3335–3340.

Liu, W., Kang, D., Zhang, C., Peng, G., Yang, X., & Wang, S. (2016). Design of a High-TC Superconductive Maglev Flywheel System at 100-kW Level. *IEEE Transactions on Applied Superconductivity, 26*(4), 1–5.

Lukic, S. M., Cao, J., Bansal, R. C., Rodriguez, F., & Emadi, A. (2008). Energy storage systems for automotive applications. *IEEE Transactions on Industrial Electronics, 55*(6), 2258–2267.

Luta, D. N., & Raji, A. K. (2019). Fuzzy rule-based and particle swarm optimisation MPPT techniques for a fuel cell stack. *Energies*, *12*(5), 936.

Mirzaei, A., Rezvanyvardom, M., & Najafi, E. (2019). A fully soft switched high step-up SEPIC-boost DC-DC converter with one auxiliary switch. *International Journal of Circuit Theory and Applications*, *47*(3), 427–444. https://doi.org/10.1002/cta.2595

Montazeri-Gh, M., & Mahmoodi-K, M. (2016). Optimized predictive energy management of plug-in hybrid electric vehicle based on traffic condition. *Journal of Cleaner Production, 139*, 935–948.

Odeim, F., Roes, J., Wulbeck, L., & Heinzel, A. (2014). Power management optimization of fuel cell/battery hybrid vehicles with experimental validation. *Journal of Power Sources*, *252*, 333–343. https://doi.org/10.1016/j.jpowsour.2013.12.012

Offer, G. J., Howey, D., Contestabile, M., Clague, R., & Brandon, N. P. (2010). Comparative analysis of battery electric, hydrogen fuel cell and hybrid vehicles in a future sustainable road transport system. *Energy Policy, 38*(1), 24–29.

Ogata, M., Matsue, H., Yamashita, T., Hasegawa, H., Nagashima, K., Maeda, T., Matsuoka, T., Mukoyama, S., Shimizu, H., Horiuchi, S. (2016). Test equipment for a flywheel energy storage system using a magnetic bearing composed of superconducting coils and superconducting bulks. *Supercnductor Science and Technology, 29*(5), 54002.

Okonkwo, P. C., Belgacem, I. ben, & Zghaibeh, M. (2020). MPPT Control of an Interleaved Boost Converter for a Polymer Electrolyte Membrane Fuel Cell Applications. *2020 International Conference on Electrical and Information Technologies (ICEIT)*, 1–5.

Pan, A. v, MacDonald, L., Baiej, H., & Cooper, P. (2016). Theoretical consideration of superconducting coils for compact superconducting magnetic energy storage systems. *IEEE Transactions on Vehicular Technology, 26*(3), 1–5.

Park, H. S., Kim, C. H., Park, K. B., Moon, G. W., & Lee, J. H. (2009). Design of a charge equalizer based on battery modularization. *IEEE Transactions on Vehicular Technology*, *58*(7), 3216–3223.

Park, S. H., Park, K. B., Kim, H. S., Moon, G. W., & Youn, M. J. (2011). Single-magnetic cell-to-cell charge equalization converter with reduced number of transformer windings. *IEEE Transactions on Power Electronics*, *27*(6), 2900–2911.

Prajapati, K. C., Patel, R., & Sagar, R. (2014). Hybrid vehicle: a study on technology. *International Journal of Engineering Research and Technology*, *2*, 10–20.

Rahman, K. M., Fahimi, B., Suresh, G., Rajarathnam, A. v, & Ehsani, M. (2000). Advantages of switched reluctance motor applications to EV and HEV: Design and control issues. *IEEE Transactions on Industry Applications*, *36*(1), 111–121. https://doi.org/10.1109/28.821805

Rajabzadeh, M., Bathaee, S. M. T., & Golkar, M. A. (2016). Dynamic modeling and nonlinear control of fuel cell vehicles with different hybrid power sources. *International Journal of Hydrogen Energy*, *41*(4), 3185–3198. https://doi.org/10.1016/j.ijhydene.2015.12.046

Rana, K. P. S., Kumar, V., Sehgal, N., & George, S. (2019). A novel dPdI feedback based control scheme using GWO tuned PID controller for efficient MPPT of PEM fuel cell. *ISA Transactions*, *93*, 312–324.

Rashid, M. H. (2011). Power electronics handbook*: Devices*. *handbook, CRC Press, 3*.

Ren, G., Ma, G., Cong, N. (2015). Review of electrical energy storage system for vehicular applications. *Renewable and Sustainable Energy Reviews, 41*, 225–236.

Rivera-Barrera, J. P., Muñoz-Galeano, N., & Sarmiento-Maldonado, H. O. (2017). SoC estimation for lithium-ion batteries: Review and future challenges. *Electronics*, *6*(4), 102.

Sabri, M. F. M., Danapalasingam, K. A., Rahmat, M. F. (2016). A review on hybrid electric vehicles architecture and energy management strategies. *Renewable and Sustainable Energy Reviews, 53*, 1433–1442.

Saju, C., Lydia, M., (2018). A Comprehensive Review On Hybrid Electric Vehicles: Power Train Configurations, Modelling Approaches, Control Techniques. In *Proceedings of the 2018 Second International Conference on Inventive Communication and Computational Technologies*. <Go to ISI>://WOS:000456251700185

Salkind, A. J., Cannone, A. G., & Trumbure TB Reddy, F. A. (2001). Handbook of batteries. *Fuel and Energy abstracts,* 23e70.

Salkind, A. J., Fennie, C., Singh, P., Atwater, T., & Reisner, D. E. (1999). Determination of state-of-charge and state-of-health of batteries by fuzzy logic methodology. *Journal of Power Sources*, *80*(1–2), 293–300.

Samsudin, N. A., Ishak, D., & Ahmad, A. B. (2018). Design and experimental evaluation of a single-stage AC/DC converter with PFC and hybrid full-bridge rectifier. *Engineering Science and Technology-an International Journal-JESTECH*, *21*(2), 189–200. https://doi.org/10.1016/j.jestch.2018.03.003

Sato, S., & Kawamura, A. (2002). A new estimation method of state of charge using terminal voltage and internal resistance for lead acid battery. *Proceedings of the Power Conversion Conference-Osaka 2002 (Cat. No. 02TH8579)*, *2*, 565–570.

Schiffer, J., Bohlen, O., de Doncker, R. W., Sauer, D. U., Ahn, K. Y., (2005). Optimized energy management for fuelcell-supercap hybrid electric vehicles - VPP track 4: Energy storage components/systems. *2005 IEEE Vehicle Power and Propulsion Conference (VPPC)*, 716–723. https://doi.org/10.1109/vppc.2005.1554637

Semadeni, M. (2003). Energy storage as an essential part of sustainable energy systems: a review on applied energy storage technologies. *CEPE working Paper, 24*.

Sergeant, P., Demircali, A., Koroglu, S., Kesler, S., Ozturk, E., & Tumbek, M. (2016). Energy management system for battery/ultracapacitor electric vehicle with particle swarm optimization. *International Conference on Recent Advances in Electrical Systems (ICRAES)*, 23–27.

Seyezhai, R., & Mathur, B. L. (2012). Design and implementation of interleaved boost converter for fuel cell systems. *International Journal of Hydrogen Energy*, *37*(4), 3897–3903.

Shang, Y., Xia, B., Zhang, C., Cui, N., Yang, J., & Mi, C. (2017a). A modularization method for battery equalizers using multiwinding transformers. *IEEE Transactions on Vehicular Technology*, *66*(10), 8710–8722.

Shang, Y., Xia, B., Zhang, C., Cui, N., Yang, J., & Mi, C. C. (2017b). An automatic equalizer based on forward–flyback converter for series-connected battery strings. *IEEE Transactions on Industrial Electronics*, *64*(7), 5380–5391.

Sharma, B., Dahiya, R., & Nakka, J. (2019). Capacitor voltage balancing in cascaded H-bridge multilevel inverter and its modelling analysis for grid integrated wind energy conversion system application. *International Journal of Circuit Theory and Applications*, *47*(8), 1323–1339. https://doi.org/10.1002/cta.2644

Shaw, B. (2019). Comparison of SCA-optimized PID and P&O-based MPPT for an off-grid fuel cell system. In *Soft Computing in Data Analytics* (pp. 51–58). Springer.

Shen, C., Shan, P., & Gao, T. (2011). A comprehensive overview of hybrid electric vehicles. *International Journal of Vehicular Technology, 2011*.

Sid, M. N., Nounou, K., Becherif, M., Marouani, K., & Alloui, H. (2014). Energy management and optimal control strategies of fuel cell/supercapacitors hybrid vehicle. *Electrical Machines (ICEM), 2014 International Conference On*, 2293–2298.

Sidhu, N., Patnaik, L., & Williamson, S. S. (2016). Power electronic converters for ultracapacitor cell balancing and power management: A comprehensive review. *Industrial Electronics Society, IECON 2016-42nd Annual Conference of the IEEE*, 4441–4446.

Spanos, C., Turney, D. E., Fthenakis, V. (2015). Life-cycle analysis of flow-assisted nickel zinc-, manganese dioxide-, and valve-regulated lead-acid batteries designed for demand-charge reduction. *Renewable and Sustainable Energy Reviews*, *43*, 478–494.

Srinivasan, S., Tiwari, R., Krishnamoorthy, M., Lalitha, M. P., & Raj, K. K. (2021). Neural network based MPPT control with reconfigured quadratic boost converter for fuel cell application. *International Journal of Hydrogen Energy*, *46*(9), 6709–6719. https://doi.org/https://doi.org/10.1016/j.ijhydene.2020.11.121

Stuart, T. A., Zhu, W. (2009). Fast equalization for large lithium ion batteries. *IEEE Aerospace and Electronic Systems Magazine, 24*(7), 27–31.

Sun, F., Hu, X., Zou, Y., & Li, S. (2011). Adaptive unscented Kalman filtering for state of charge estimation of a lithium-ion battery for electric vehicles. *Energy*, *36*(5), 3531–3540.

Sun, Y., Liu, N., & Cui, Y. (2016). Promises and challenges of nanomaterials for lithium-based rechargeable batteries. *Nature Energy, 1*(7), 16071.

Tie, S. F., Tan, C. W. (2013). A review of energy sources and energy management system in electric vehicles. *Renewable and Sustainable Energy Reviews*, *20*, 82–102.

Torreglosa, J. P., Jurado, F., Garcia, P., & Fernandez, L. M. (2011). Hybrid fuel cell and battery tramway control based on an equivalent consumption minimization strategy. *Control Engineering Practice*, *19*(10), 1182–1194. https://doi.org/10.1016/j.conengprac.2011.06.008

Umetani, S., Fukushima, Y., & Morita, H. (2017). A linear programming based heuristic algorithm for charge and discharge scheduling of electric vehicles in a building energy management system. *Omega, 67*, 115–122.

Un-Noor, F., Padmanaban, S., Mihet-Popa, L., Mollah, M. N., & Hossain, E. (2017). A comprehensive study of key electric vehicle (EV) components, technologies, challenges, impacts, and future direction of development. *Energies, 10*(8), 1217.

Uno, M., & Tanaka, K. (2013). Single-switch multioutput charger using voltage multiplier for series-connected lithium-ion battery/supercapacitor equalization. *IEEE Transactions on Industrial Electronics, 60*(8), 3227–3239.

Uno, M., & Toyota, H. (2008). Equalization technique utilizing series-parallel connected supercapacitors for energy storage system. *Sustainable Energy Technologies, 2008. ICSET 2008. IEEE International Conference On*, 893–897.

Uzunoglu, M., & Alam, M. S. (2007). Dynamic modeling, design and simulation of PEM fuel cell/ultra-capacitor hybrid system for vehicular applications. *Energy Conversion and Management*, *48*(5), 1544–1553. https://doi.org/10.1016/j.enocnman.2006.11.014

Wang, H., Gaillard, A., & Hissel, D. (2019). A review of DC/DC converter-based electrochemical impedance spectroscopy for fuel cell electric vehicles. *Renewable Energy*, *141*, 124–138.

Wegmann, R., Doege, V., Becker, J., & Sauer, D. U. (2017). Optimized operation of hybrid battery systems for electric vehicles using deterministic and stochastic dynamic programming. *Journal of Energy Storage, 14*, 22–38.

Weigert, T., Tian, Q., & Lian, K. (2011). State-of-charge prediction of batteries and battery–supercapacitor hybrids using artificial neural networks. *Journal of Power Sources*, *196*(8), 4061–4066.

Wen, H. Q., & Su, B. (2016). Hybrid-mode interleaved boost converter design for fuel cell electric vehicles. *Energy Conversion and Management*, *122*, 477–487. https://doi.org/10.1016/j.enconman.2016.06.021

Wu, T.-H., Moo, C.-S., & Hou, C. H. (2017). A Battery Power Bank with Series-Connected Buck–Boost-Type Battery Power Modules. *Energies, 10*(5), 650.

Xing, Y., Ma, E. W. M., Tsui, K. L., & Pecht, M. (2011). Battery management systems in electric and hybrid vehicles. *Energies, 4*(11), 1840–1857.

Xu, K., Wu, D., Jiao, Y. L., Zheng, M. H. (2016). A fully superconducting bearing system for flywheel applications. *Superconductor Science and Technology, 29*(6), 64001.

Xu, L., Ouyang, M., Li, J., Yang, F., Lu, L., & Hua, J. (2013). Application of Pontryagin's Minimal Principle to the energy management strategy of plugin fuel cell electric vehicles. *International Journal of Hydrogen Energy, 38*(24), 10104–10115.

Xu, L., Wang, J., & Chen, Q. (2012). Kalman filtering state of charge estimation for battery management system based on a stochastic fuzzy neural network battery model. *Energy Conversion and Management*, *53*(1), 33–39.

Yang, X.-S., & Deb, S. (2013). Multiobjective cuckoo search for design optimization. *Computers & Operations Research*, *40*(6), 1616–1624.

Yang, Y., Arshad-Ali, K., Roeleveld, J., & Emadi, A. (2016). State-of-the-art electrified powertrains-hybrid, plug-in, and electric vehicles. *International Journal of Power Trains, 5*(1), 1–29.

Ye, Y., & Cheng, K. (2016). An automatic switched-capacitor cell balancing circuit for series-connected battery strings. *Energies*, *9*(3), 138.

Yin, H., Zhou, W., Li, M., Ma, C., & Zhao, C. (2016). An adaptive fuzzy logic-based energy management strategy on battery/ultracapacitor hybrid electric vehicles. *IEEE Transactions on transportation electrification, 2*(3), 300–311.

Yu, H. F., & Stuart, A. L. (2017). Impacts of compact growth and electric vehicles on future air quality and urban exposures may be mixed. *Science of the Total Environment*, *576*, 148–158. https://doi.org/10.1016/j.scitotenv.2016.10.079

Yuan, Y., Sun, Y., & Huang, Y. (2015). Design and analysis of bearingless flywheel motor specially for flywheel energy storage. *Electronics Letter, 52*(1), 66–68.

Zakeri, B., Syri, S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. *Renewable and Sustainable Energy Reviews, 42*, 569–596.

Zeltser, I., Kirshenboim, O., Dahan, N., & Peretz, M. M. (2016). ZCS resonant converter based parallel balancing of serially connected batteries string. *Applied Power Electronics Conference and Exposition (APEC), 2016 IEEE*, 802–809.

Zeng, Y., Hu, J., Ye, W., Zhao, W., Zhou, G., & Guo, Y. (2015). Investigation of lead dendrite growth in the formation of valve-regulated lead-acid batteries for electric bicycle applications. *Journal of Power Sources, 286*, 182–192.

Zhang, H. T., Zhou, M., & Lan, X. D. (2019). State of Charge Estimation Algorithm for Unmanned Aerial Vehicle Power-Type Lithium Battery Packs Based on the Extended Kalman Filter. *Energies*, *12*(20). https://doi.org/10.3390/en12203960

Zhang, J., & Xia, C. (2011). State-of-charge estimation of valve regulated lead acid battery based on multi-state Unscented Kalman Filter. *International Journal of Electrical Power & Energy Systems*, *33*(3), 472–476.

Zhang, L., Wang, Z. P., Sun, F. C., Dorrell, D. (2014). Ultracapacitor modelling and parameter identification using the Extended Kalman Filter. In *2014 IEEE Transportation Electrification Conference and Expo*. <Go to ISI>://WOS:000349676800013

Zhang, L., Xu, D., Li, H., Shen, G., & Chen, M. (2015). Three-phase interleaved high step-up boost converter with voltage multiplier for fuel cell power system. *2015 IEEE Energy Conversion Congress and Exposition (ECCE)*, 4804–4811.

Zhang, L. Y., Zhang, L., Papavassiliou, C., & Liu, S. (2018). Intelligent Computing for Extended Kalman Filtering SOC Algorithm of Lithium-Ion Battery. *Wireless Personal Communications*, *102*(2), 2063–2076. https://doi.org/10.1007/s11277-018-5257-9

Zhang, S., Xiong, R., & Sun, F. (2017). Model predictive control for power management in a plug-in hybrid electric vehicle with a hybrid energy storage system. *Applied Energy*, *185*, 1654–1662.

Zhang, W., Li, J., Xu, L., & Ouyang, M. (2017). Optimization for a fuel cell/battery/capacity tram with equivalent consumption minimization strategy. *Energy Conversion and Management*, *134*, 59–69. https://doi.org/https://doi.org/10.1016/j.enconman.2016.11.007

Zhang, Z., Gui, H., Gu, D.-J., Yang, Y., & Ren, X. (2016). A hierarchical active balancing architecture for lithium-ion batteries. *IEEE Transactions on Power Electronics*, *32*(4), 2757–2768.

Zhao, H., & Burke, A. (n.d.). Fuel Cell Powered Vehicles. *Encyclopedia of Automotive Engineering*, 1–18. https://doi.org/https://doi.org/10.1002/9781118354179.auto066

Zhao, H., & Burke, A. F. (2010). Fuel Cell Powered Vehicles Using Supercapacitors–Device Characteristics, Control Strategies, and Simulation Results. *Fuel Cells, 10*(5), 879–896.

Zhou, Z., Benbouzid, M., Charpentier, J. F., Scuiller, F., Tang, T. E. (2013). A review of energy storage technologies for marine current energy systems. *Renewable and Sustainable Energy Reviews, 18*, 390–400.