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Comparison Analysis Between PI and Adaptive Controllers for DC-DC Converter of Hybrid Energy Storage Systems in Electric Vehicles
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Abstract
A power converter is one of the important components in a hybrid electric vehicle (HEV), where it has a strong nonlinear dynamic due to the variation of load demand from different driving modes, namely acceleration, braking and cruising. To adapt with the nonlinearities, this work proposes the use of direct model reference adaptive control (DMRAC) to regulate its operation in tracking the load and current demand of the HEV. To validate the response, the control performance is benchmarked with the commonly used traditional PI controller. The system model includes a battery with a supercapacitor, and its controller was constructed using the MATLAB Simulink platform. Simulation results show that DMRAC provides better performance as compared to the PI controller in two cases, which are tracking the current and load demands according to the root mean square error (RMSE) analysis. Nevertheless, in the presence of disturbance, it is noted that DMRAC is only effective in tracking the current demand while requiring some time to adapt and surpass the PI controller in tracking the load demand. Based on these findings, it can be justified that the DMRAC has the potential to become a good alternative approach to control the HEV power converters, specifically in the presence of disturbance. © The Authors 2023. Published by Universiti Malaysia Pahang Publishing. This is an open access article under the CC BY-NC 4.0 license

Author Keywords
Adaptive control; DC-DC converter; Electric vehicle; PI controller; Supercapacitor

Index Keywords
Acceleration, Control nonlinearities, Controllers, DC-DC converters, Electric loads, Hybrid vehicles, MATLAB, Mean square error, Model reference adaptive control; Adaptive Control, Adaptive controllers, Comparison analysis, Current demands, Direct modelling, Driving mode, Hybrid energy storage systems, Load demand, Model-reference adaptive controls, PI Controller; Supercapacitor

References

- Paraschiv, S., Paraschiv, L. S.
  Trends of carbon dioxide (CO2) emissions from fossil fuels combustion (coal, gas and oil) in the EU member states from 1960 to 2018
  (2020) *Energy Reports*, 6, pp. 237-242.
  [1]

- Kreps, B. H.
  The rising costs of fossil-fuel extraction: an energy crisis that will not go away
  (2020) *American Journal of Economics and Sociology*, 79 (3), pp. 695-717.
  [2]

- Yong, J. Y., Ramachandaramurthy, V. K., Tan, K. M., Mithulananthan, N.
  A review on the state-of-the-art technologies of electric vehicle, its impacts and prospects
  (2015) *Renewable and sustainable energy reviews*, 49, pp. 365-385.
  [3]

- Ghorbani, R., Bibeau, E., Filizadeh, S.
  On conversion of hybrid electric vehicles to plug-in
  (2010) *IEEE Transactions on Vehicular Technology*, 4 (59), pp. 2016-2020.
  [4]

- Emadi, A., Lee, Y. J., Rajashekara, K.
  Power electronics and motor drives in electric, hybrid electric, and plug-in hybrid electric vehicles
  (2008) *IEEE Transactions on Industrial Electronics*, 55 (6), pp. 2237-2245.
  [5]

- Amjadi, Z., Williamson, S. S.
  Power-electronics-based solutions for plug-in hybrid electric vehicle energy storage and management systems
  (2009) *IEEE Transactions on Industrial Electronics*, 57 (2), pp. 608-616.
  [6]

- Bayindir, K. Ç., Gözüküçük, M. A., Teke, A.
  A comprehensive overview of hybrid electric vehicle: Powertrain configurations, powertrain control techniques and electronic control units
  (2011) *Energy Conversion and Management*, 52 (2), pp. 1305-1313.
  [7]

- Ghosh, A.
  Possibilities and challenges for the inclusion of the electric vehicle (EV) to reduce the carbon footprint in the transport sector: A review
  (2020) *Energies*, 13 (10), p. 2602.
  [8]

- Lundin, J.
  (2011) *Flywheel in an all-electric propulsion system*,
  [9] Ph.D Thesis, Uppsala Universitet, Sweeden

- Ostadi, A., Kazerani, M.
  A comparative analysis of optimal sizing of battery-only, ultracapacitor-only, and battery–ultracapacitor hybrid energy storage systems for a city bus
  (2014) *IEEE Transactions on Vehicular Technology*, 64 (10), pp. 4449-4460.
  [10]

- Ju, F., Zhang, Q., Deng, W., Li, J.
  Review of structures and control of battery-supercapacitor hybrid energy storage system for electric vehicles
  (2016) *Advances in Battery Manufacturing, Service, and Management Systems*, pp. 303-318.
  [11]

- Liu, K., Li, K., Peng, Q., Zhang, C.
  A brief review on key technologies in the battery management system of electric vehicles
  (2019) *Frontiers of Mechanical Engineering*, 14, pp. 47-64.
  [12]

- Hasan, M. K., Mahmud, M., Habib, A. A., Motakabber, S., Islam, S.
  Review of electric vehicle energy storage and management system: Standards, issues, and challenges
  (2021) *Journal of Energy Storage*, 41, p. 102940.
  [13]

- Horn, M., MacLeod, J., Liu, M., Webb, J., Motta, N.
  Supercapacitors: A new source of power for electric cars?
  (2019) *Economic Analysis and Policy*, 61, pp. 93-103.
  [14]

- Naseri, F., Karimi, S., Farjah, E., Schaltz, E.
  Supercapacitor management system: A comprehensive review of modeling, estimation, balancing, and protection techniques

(2022) *Renewable and Sustainable Energy Reviews*, 155, p. 111913.
[15]

- Wai, R.-J., Shih, L.-C.
  Design of voltage tracking control for DC–DC boost converter via total sliding-mode technique
  (2010) *IEEE Transactions on Industrial Electronics*, 58 (6), pp. 2502-2511.
  [16]

- Yazici, İ., Yaylaci, E. K.
  Fast and robust voltage control of DC–DC boost converter by using fast terminal sliding mode controller
  (2016) *IET Power Electronics*, 9 (1), pp. 120-125.
  [17]

- Nizami, T. K., Mahanta, C.
  An intelligent adaptive control of DC–DC buck converters
  (2016) *Journal of the Franklin Institute*, 353 (12), pp. 2588-2613.
  [18]

- Sahin, E., Ayas, M. S., Altas, I. H.
  A PSO optimized fractional-order PID controller for a PV system with DC-DC boost converter
  (2014) *2014 16th International Power Electronics and Motion Control Conference and Exposition*, pp. 477-481.
  [19]

- Adnan, M. F., Oninda, M. A. M., Nishat, M. M., Islam, N.
  Design and simulation of a DC-DC boost converter with PID controller for enhanced performance
  (2017) *International Journal of Engineering Research & Technology (IJERT)*, 6, pp. 27-32.
  [20] 09

- Po, L., Ruiyu, L., Tianying, S., Jingrui, Z., Zheng, F.
  Composite adaptive model predictive control for DC–DC boost converters
  (2018) *IET Power Electronics*, 11 (10), pp. 1706-1717.
  [21]

- David, B. M., Sreeja, K.
  A Review of sliding mode control of DC-DC converters
  (2015) *International Research Journal of Engineering and Technology*, 2 (4), pp. 1382-1386.
  [22]

- Utkin, V.
  Sliding mode control of DC/DC converters
  (2013) *Journal of the Franklin Institute*, 350 (8), pp. 2146-2165.
  [23]

- Massaoudi, Y., Elleuch, D., Gaubert, J. P., Mehdi, D., Damak, T.
  A new backstepping sliding mode controller applied to a dc-dc boost converter
  (2016) *International Journal of Power Electronics and Drive Systems*, 7 (3), p. 759.
  [24]

- Benbaha, N., Zidani, F., Nait-Said, M.-S., Zouzou, S. E., Boukebbous, S., Ammar, H.
  DSPACE validation of improved backstepping optimal energy control for photovoltaic systems
  (2018) *2018 6th International Renewable and Sustainable Energy Conference (IRSEC)*, pp. 1-6.
  [25]

- Saadatmand, S., Shamsi, P., Ferdowsi, M.
  The heuristic dynamic programming approach in boost converters
  (2020) *2020 IEEE Texas Power and Energy Conference (TPEC)*, pp. 1-6.
  [26]

- Abjadi, N., Goudarzian, A., Arab Markadeh, G. R., Valipour, Z.
  Reduced-order backstepping controller for POESLL DC–DC converter based on pulse width modulation
  (2019) *Iranian Journal of Science and Technology, Transactions of Electrical Engineering*, 43, pp. 219-228.
  [27]

- Islam, M., Abdul Ghaffar, A. F., Sulaeman, E., Ahsan, M. M., Kouzani, A. Z., Mahmud, M. P.
  Performance analysis of PI and DMRAC algorithm in buck–boost converter for voltage tracking in electric vehicle using simulation
  (2021) *Electronics*, 10 (20), p. 2516.
  [28]

- Liu, J., Ming, W., Gao, F.
  A new control strategy for improving performance of boost DC/DC converter based on input-output feedback linearization
  (2010) *2010 8th World Congress on Intelligent Control and Automation*, pp. 2439-2444.
  [29]

- Yi, L.-K., Zhao, J., Ma, D.
  Adaptive backstepping sliding mode nonlinear control for buck DC/DC switched power converter
  (2007) *2007 IEEE International Conference on Control and Automation*, pp. 1198-1201.
  [30]

- Ghosh, S. K., Roy, T. K., Pramanik, M. A. H., Mahmud, M. A.
  Design of nonlinear backstepping double-integral sliding mode controllers to stabilize the DC-bus voltage for DC–DC converters feeding CPLs
  (2021) *Energies*, 14 (20), p. 6753.
  [31]

- Song, Z., Hou, J., Hofmann, H., Li, J., Ouyang, M.
  Sliding-mode and Lyapunov function-based control for battery/supercapacitor hybrid energy storage system used in electric vehicles
  (2017) *Energy*, 122, pp. 601-612.
  [32]

- Fatah, B., Chokri, M., Hamed, Y., Naceur, H., Hassan, H.
  Hybrid modelling of energy management system in electric traction
  (2012) *International Conference on Control, Engineering & Information Technology*, 1, pp. 192-197.
  [33]

- Blaud, P. C., Dessaint, L.-A.
  Supercapacitor Model
  MathWorks,
  [34] [Online]. Available: [Accessed July 7, 2023]

- Ranjan, A., Bodkhe, S. B.
  Modified energy management strategy for HESS in electric vehicle
  (2021) *2021 9th IEEE International Conference on Power Systems (ICPS)*, pp. 1-6.
  [35]

- Hadartz, M., Julander, M.
  (2008) *Battery-supercapacitor energy storage*,

[36] Chalmers University of Technology Gothenburg, Sweden

- Allegre, A.-L., Bouscayrol, A., Trigui, R.
  Influence of control strategies on battery/supercapacitor hybrid energy storage systems for traction applications
  (2009) *2009 IEEE Vehicle Power and Propulsion Conference*, pp. 213-220.
  [37]

- Song, Z., Hofmann, H., Li, J., Hou, J., Han, X., Ouyang, M.
  Energy management strategies comparison for electric vehicles with hybrid energy storage system
  (2014) *Applied Energy*, 134, pp. 321-331.
  [38]

- Hannan, M., Azidin, F., Mohamed, A.
  Multi-sources model and control algorithm of an energy management system for light electric vehicles
  (2012) *Energy Conversion and Management*, 62, pp. 123-130.
  [39]

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