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A Study of Advanced Efficient Hybrid Electric Vehicles, Electric Propulsion and Energy Source

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Abstract

Recently global warming and the depletion of fuel resources have accelerated researchers' efforts to produce more efficient and clean alternatives. This research presents a comprehensive review of the different adjustments/con figurations of electric vehicles (EVs) and hybrid electric vehicles (HEVs), traction motors for power systems, and wireless speed control of traction drive. Electronic installation of technology can reduce pollution efficiently and effectively. The efficient operation has always been one of the most common investigators' objectives in the automotive industry and academic areas. There are several renewable energy resources for hybrid vehicles that will replace depleted gasoline worldwide. The purpose of this paper is the development of more efficient pure EVs, HEVs, and fuel cell electric vehicles (FCEV) present both a challenge and a definite solution to current mobility issues. Fuel consumption in cars is a concern due to the harmful effects on the environment. Among other battery sources, fuel cells (FC), super capacitors (SC), and photovoltaic cells are studied for vehicle application. A combination of these renewable energy sources can be used for hybrid electric vehicles (HEV) in the next generation of transportation. With the significant progress of automobile technology, the hybrid electric vehicle has already become the main achievement of transportation electrification due to its excellent fuel-saving performance.

Keywords

Alternative Energy Resources, Hybrid Electric Vehicle (HEV), Electrification

1. Introduction

An emphasis on green technology is extensively demanded of modern cities. Electric vehicles (EV) is a real vehicles involved with electric propulsion. With the rapid development of the economy and people's living standards, the total number of vehicles is continuously increasing day by day. With the rapid growth of the economy and people's living standards, the total number of vehicles is constantly increasing day by day. Research and development focus on energy efficiency and reduction of use and pollution control and expansion of various electric vehicles (EVs) is increasing worldwide [1] [2] [3]. Currently, the most common vehicle type is still the conventional vehicles (CVs) powered only by an internal combustion engine (ICE) [4] [5]. Many social problems are coming, such as the overuse of oil resources and extreme pollution [6]. The above issues have raised international attention and brought significant challenges to the automotive industry [7]. Therefore, automobile companies all over the world are dedicated to developing efficient new energy vehicles. Therefore, automobile companies all over the world are dedicated to developing efficient new energy vehicles. Since the sale of lithium-ion batteries (LIBs), significant progress has been made in increasing energy efficiency, reducing costs, and improving battery performance. Since EVs can help remove automotive emissions and reduce fuel dependence, almost all car manufacturers have introduced EV production. Various countries have declared policies to prevent internal fire vehicles (ICE) from overcoming 10 - 30 years.

The paper begins by reviewing the status of EV and HEV, then focuses on the engineering philosophy of EV development. The following mentioned vehicles are new energy vehicles which are hybrid electric vehicles/plug-in electric vehicles (HEVs/PHEVs), electric batteries (BEVs), and fuel cell vehicles (FCVs) [8]. BEVs featuring new energy vehicles will be the best option to improve air quality and reduce fuel consumption and future emissions. However, BEV performance is severely limited by battery capacity due to immature battery technology. Currently, BEVs are not yet well-known. Applications on a large scale still require older fuel cells, cost-effectiveness, and full support resources in FCVs. They think the combination of ICE and electric vehicle (EM) is the most likely way to detect hybrid topology. HEV/PHEV technology can be a different approach to CVs that are widely used in urban transport [9]. HEV/PHEV essential part is its hybrid powertrain. A hybrid powertrain has two energy sources.

The manuscript is arranged as follows. Section 2 defines the design space of HEV size when all electric mode is not required. Section 3 describes the bandwidth based control strategy. Section 4 presents experimental work. Section 5 defines the optimization problem and constraints and presents the Pareto Frontier applicable to the controller algorithm studied. Section 6 provides the conclusions of this work.

Hybrid powertrain configuration is commonly divided into three basic forms based on the different topology combinations of electric traction and mechanical traction: series, parallel, and series-parallel [10] [11].

a) Series; b) Parallel; c) Series Parallel.

EM, G, and BAT show electric-motor, gearbox, and battery, accordingly, in the structure diagrams of these three powertrain structures shown in **Figure 1**.

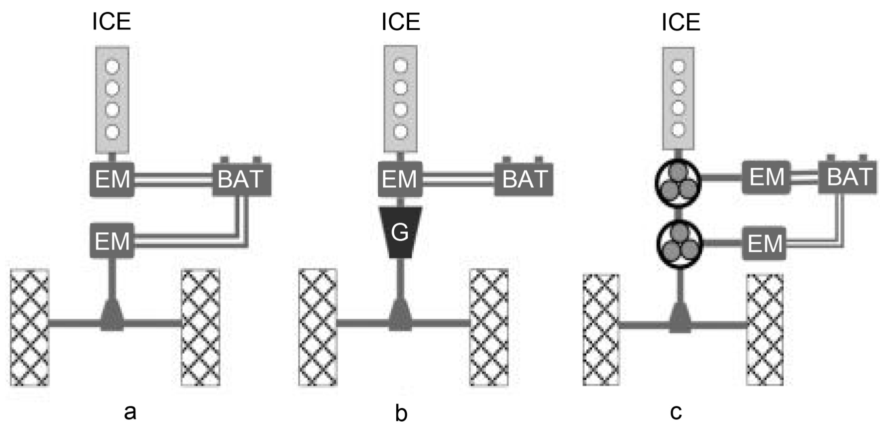

Figure 1. Configurations of hybrid powertrains.

As shown in Figure 1(a), in a series hybrid powertrain, the EM acts as the driving force source. In contrast, the engine-generator set provides the electric energy, allowing the engine to operate in its high-efficiency zone. Figure 1(b) portrays the parallel hybrid powertrain configuration.

One EM will generally fulfill five standard HEV working modes in a parallel hybrid powertrain, including electric driving mode, engine driving mode, hybrid driving mode, engine active charging mode, and regenerative braking mode. As compared to the powertrain of CVs, the parallel design allows for a lot of versatility in part selection. A power-split hybrid powertrain, as shown in Figure 1(c), is a series-parallel hybrid powertrain with one engine and two EMs. It combines a serial hybrid powertrain with a parallel hybrid powertrain, both typical in passenger cars. The fuel-saving theory of a hybrid powertrain can easily be deduced from the above definitions. The HEV switches between various working modes regularly, and then the electro-mechanical energy is transformed into a hybrid powertrain. In order to design an effective HEV, an energy management strategy (EMS) that is embedded in the vehicle controller and governs the energy flows in the hybrid powertrain is needed. Hybrid electric vehicle research is expected to become more prevalent in the coming years with advancements in battery technology, control techniques, and government funding for car owners and manufacturers. So far, this paper has concentrated on the classification, history, benefits and disadvantages, vehicle types, and energy usage of HEVs.

2. EV Topology Exploration

Recently different researches have focused on EV topology exploration, emission-reduction, efficiency maximization strategies, cost-minimization, and power conversion technologies and their integration into the electric power grid. As shown in Figure 2, three major interconnected branches of EV technology have piqued the interest of academic and industrial R&D researchers: 1) Advanced electric drive system (EDS) [12]-[18], 2) Power generation and energy storage system (ESS) [19]-[24], 3) EV Construction.

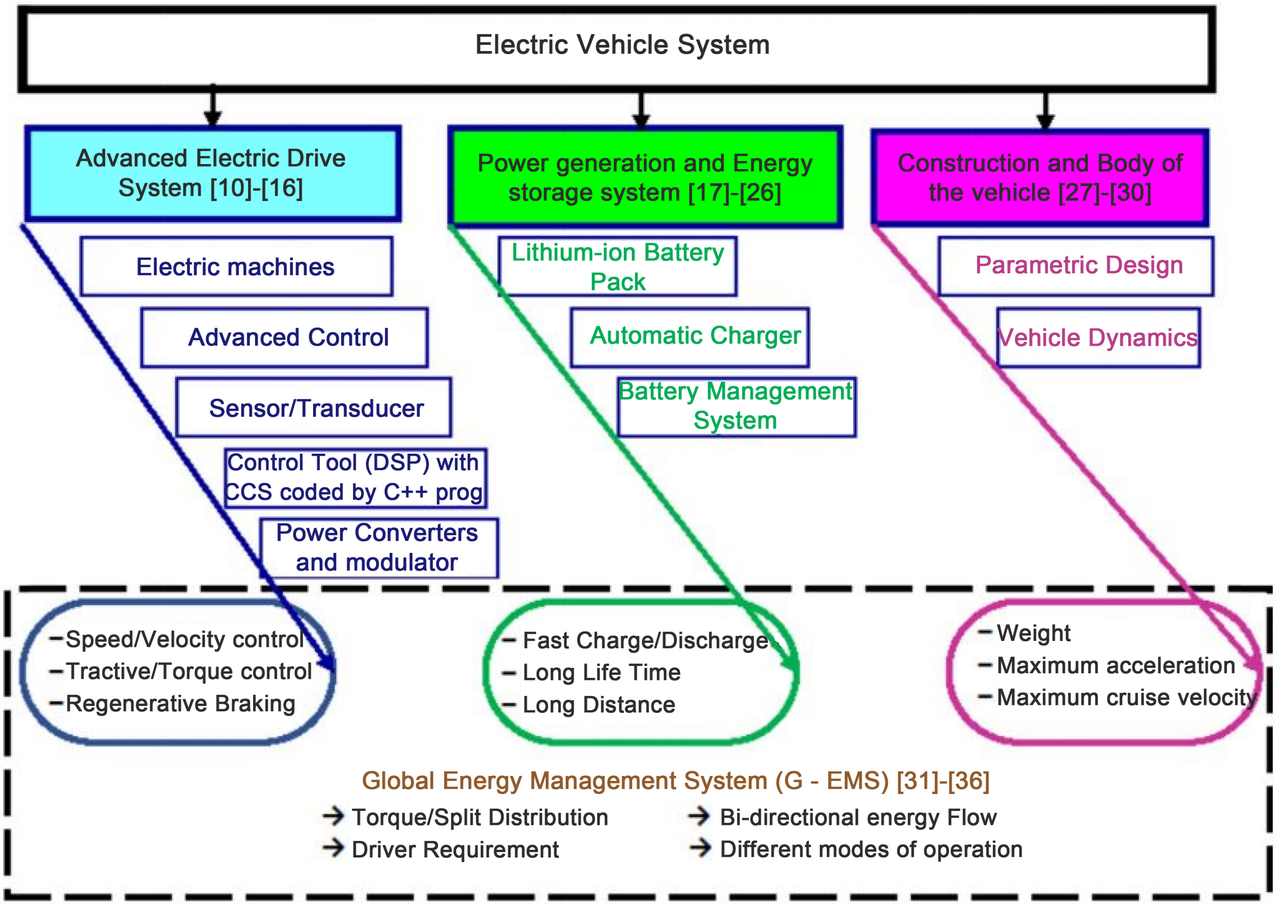

Figure 2. Research disciplines in electric vehicle technology.

2.1. Existing Technological Fundamentals and Potential Development Paths

Any electric propulsion system is built on a foundation of key components that allow the concept to operate. The energy storage unit (battery system), the electric machine, the power electronics, and a suitable charging device are the most critical components. In general, the energy storage system has a big influence on technical characteristics like efficiency and range. The type of rechargeable battery (e.g., lead-acid, nickel-metal hydride, lithium-ion [Li-ion] battery), capacitors, and hydrogen as an energy source with the fuel cell serving as an energy converter can all be used to identify energy storage devices. The gravimetric energy density (Wh/kg) and power density (W/kg) of the various battery options vary. Secondary batteries have a slightly lower energy capacity than other energy sources (such as hydrogen or gasoline). However, the electric drivetrain's higher performance compared to traditional combustion engines compensates for this drawback to some extent. Figure 3 depicts one potential power electronics topology and its relationship with the electric machine's energy storage device.

2.2. Parallel Hybrid or Power-Split Hybrid

The classic hybrid concept is a parallel hybrid, also known as a power-split

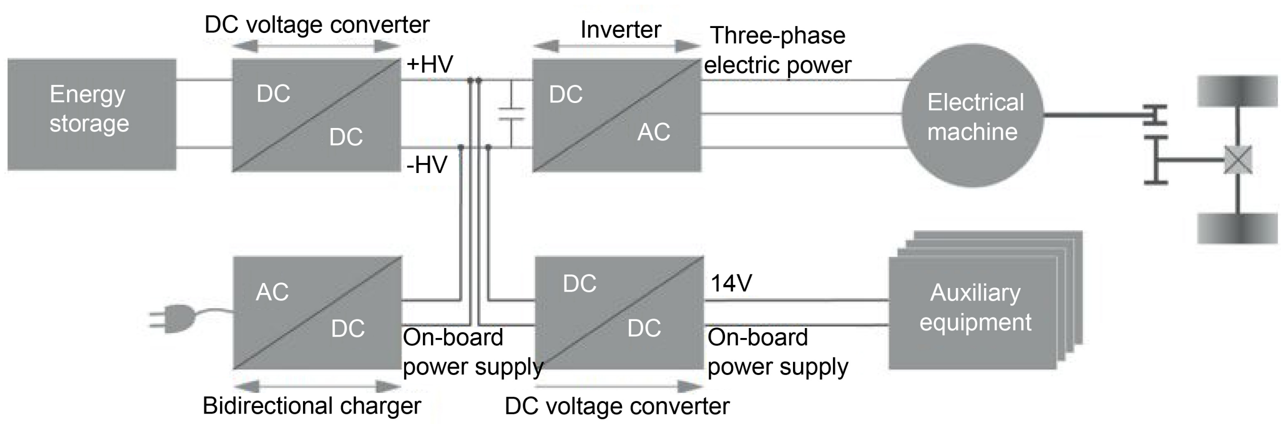

Figure 3. Electric drivetrain architecture.

hybrid. As seen in **Figure 4**, the electric motor serves as a backup for the combustion engine. A parallel hybrid or a power-split hybrid drive train are two options for the drive train architecture. In certain cases, pure electric propulsion over a short distance is feasible. The recuperation function recharges the battery. These hybrid vehicles may be categorized as mild or complete hybrids depending on the electric motor's degree of support. In mild hybrids, the electric power range usually ranges between 5 and 20 kW. Total hybrids now have an electric capacity ranging from 30 to 50 kW. The battery size normally varies from 1 to 2 kWh.

3. Characterization of HEV

Lukic *et al.* [25] [26] conducted research on the characteristics of a HEV.

where HF is defined as

$$HF = \frac{P_{EM}}{P_{EM} + PI_{CE}} \quad (1)$$

PEM is the peak power of the electric motor in Equation (1), while PICE is the peak power of the ICE.

These types can be divided into different groups:

- Micro-HEV (HF0.1): Micro-HEVs use the EM's limited power as a starter and alternator to provide a quick start-stop operation, enabling the ICE to propel the vehicle, allowing the ICE to be turned off when the vehicle is in stand mode. As a result, it reduces the vehicle's fuel consumption by 9.9%, particularly beneficial while driving in urban areas.
- Mild-HEV (HF0.25): Mild-HEVs have additional features such as using the EM to lift the ICE during acceleration and regenerative braking. On the other hand, the electric machine is not capable of moving the vehicle by itself [26]. It can save between 11 and 19 percent on fuel consumption.
- Power-assisted HEV (0.25 < HF < 0.5): Power-assisted HEVs will sustain ICE by providing powerful electric propulsion. The car can be transformed into a fully electric system or a zero-emissions vehicle (ZEV) for short distances.

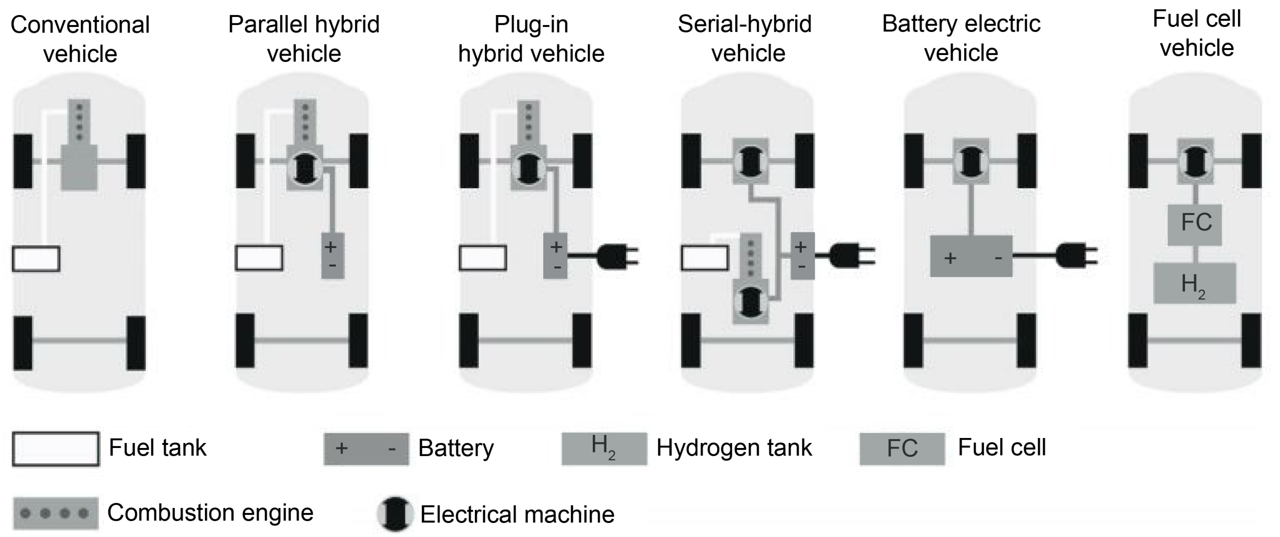

Figure 4. Electric propulsion system diversity vs. conventional propulsion.

The vehicle's propulsion can also be assured solely by the ICE. The fuel economy could be boosted by up to 50%.

- Plug-In HEV (HF > 0.5): A PHEV stores energy in a battery. A residential power grid is used to recharge the battery. An onboard generator and ICE are needed for these types of vehicles [27]-[32].
- Vehicles that do not use ICE, such as hybrid fuel cell vehicles, HFCVs, or battery electric vehicles, BEVs (HF = 1): BEVs or PHEVs, fall into this category. Since FC is a green technology part, HFCV is classified as an electric vehicle. A reformer on board the vehicle will remove stored hydrogen. The electrical machine will be powered by the electricity gained by the FC, which will usually be aided by a SC to boost its low power response.

The EV's structure is depicted in **Figure 5**, which consists of three main subsystems: electric propulsion, energy source, and auxiliary. The electronic controller, power converter, electric motor, mechanical transmission, and driving wheels make up the electric propulsion subsystem. The energy source, energy management unit, and energy refueling unit are all part of the energy source subsystem. The power steering unit, temperature control unit, and auxiliary power supply make up the auxiliary subsystem. The electronic controller provides proper control signals to turn on or off the power devices of the power converter, which acts to regulate power flow between the electric motor and the energy source, based on the brake and accelerator pedals' control inputs.

Longitudinal Dynamics of the Host Vehicle

HEV in **Figure 6** can be propelled by the engine and electric motor together or separately. Therefore, the torque demand Td at the wheels is calculated as

$$T_d = \left(T_{eng} + T_{em}\right) i_g i_O \eta_T sign\left(T_{em}\right) + T_{brk} \quad (2)$$

In Equation (2) T_{eng} and T_{em} are the torques of the engine and the motor,

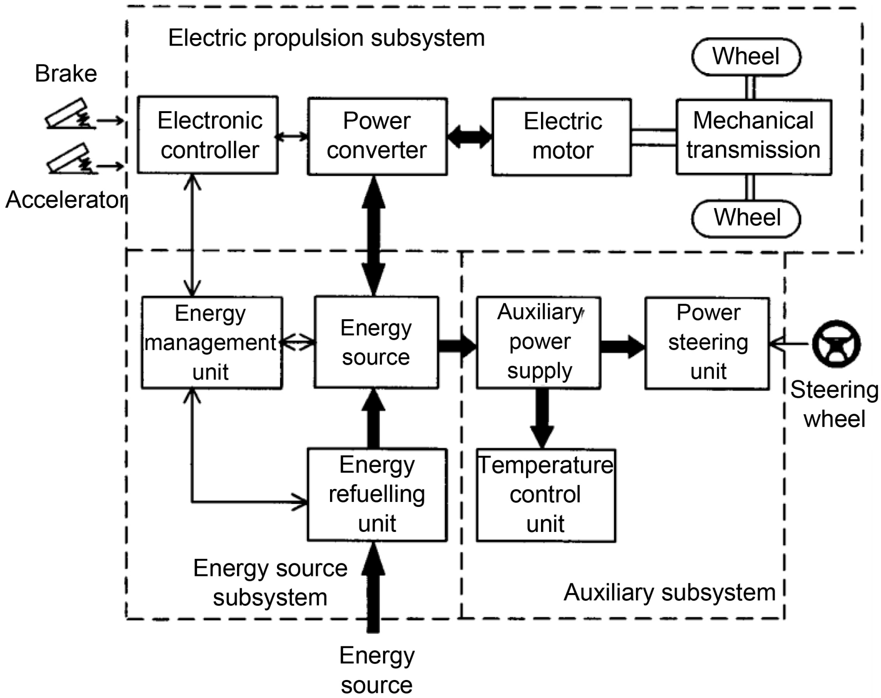

Figure 5. Electric vehicle composition.

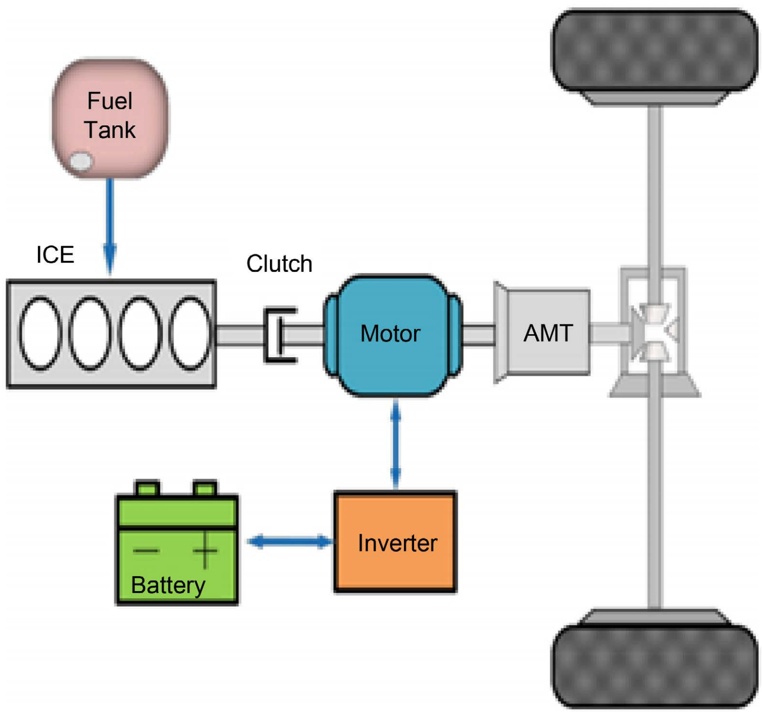

Figure 6. Powertrain configuration host vehicle.

respectively, i_g is the AMT ratio, i_0 is the final drive ratio, and η_T represents transmission efficiency, which is assumed to be a constant. The transmission gear ratio i_g is believed to be a function of simplicity, and T_{brk} is the braking torque, which is always negative.

4. Hybrid Fuel Cell

A series hybrid configuration is used in fuel cell vehicles. They are commonly equipped with a battery or supercapacitor to provide peak acceleration capacity while reducing the fuel cell's size and power constraints (and thus its cost). Electric, hybrid, and fuel cell vehicles state-of-the-art are reviewed in [28] [29], and topologies for each category's enabling technologies are addressed in [30].

4.1. Advanced Electrical Drives

Electrical drives transform electrical energy into mechanical energy in a regulated manner. An electrical machine, also known as an electro-mechanical energy converter, a power electronic converter, also known as an electrical-to-electrical converter, and a controller/communication unit make up an electrical drive. High-speed trains, elevators, escalators, electric ships, electric forklift trucks, and electric cars all use electrical drives as propulsion systems today. Torque control over a broad bandwidth is possible thanks to advanced control algorithms (mostly digitally implemented). As a result, precise motion control is possible. Drives in robots, pick-and-place machines, factory automation hardware, and so on are examples.

Figure 7 depicts the electrical drive's block diagram in which the electric motor is used to control electrical loads such as fans, pumps, trains, and so on. The speed and torque requirements of an electrical load are calculated. For the load drive, the motor that best fits the load's capabilities is chosen.

4.2. Control of Traction Motors

The most critical and distinguishing feature of a high dynamic performance traction drive is its rapid torque response. There are two operating regions in a well-controlled electric motor drive, constant torque and constant power. The typical torque/power-speed characteristic expected from traction motors for EVs and HEVs is depicted in **Figure 8**. The inverter current rating determines the maximum torque capability in the constant torque area. Due to inverter current and voltage limits, flux weakening or constant power area is used instead.

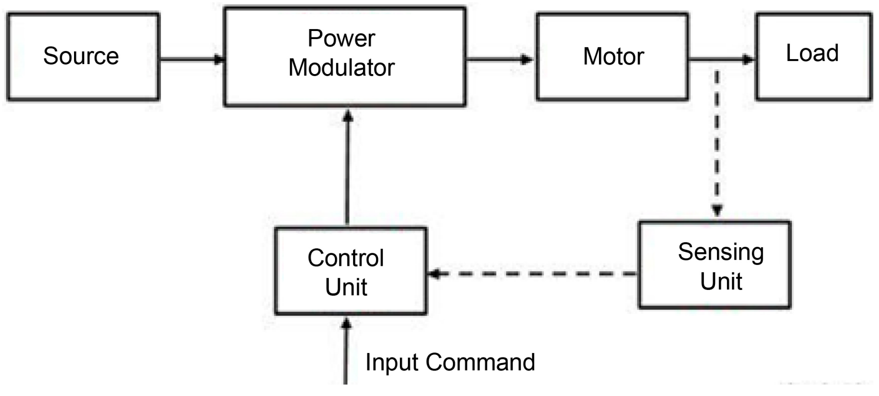

Figure 7. Block diagram of the electrical drive.

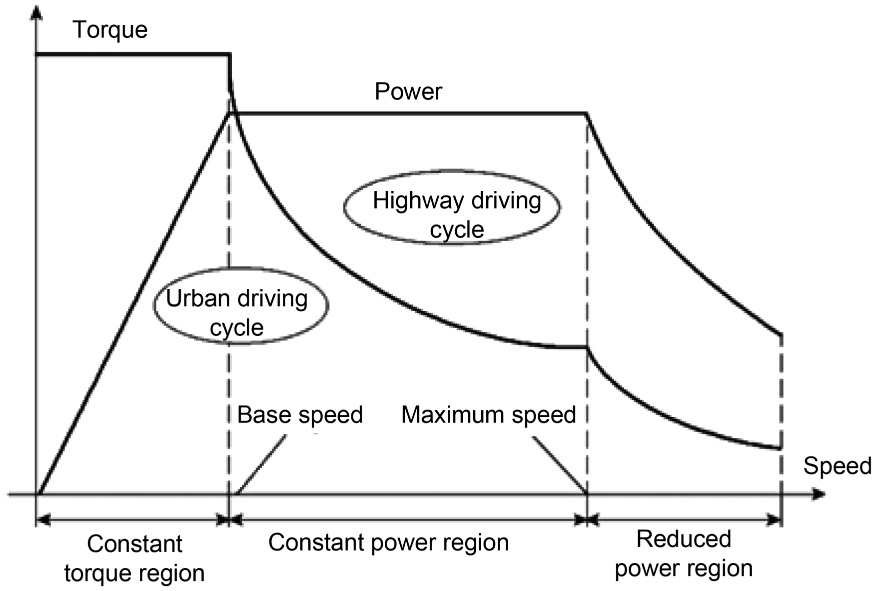

Figure 8. Typical speed-torque characteristics of EV & HEV from electric traction motor.

4.3. Advantages of a Hybrid Electric Vehicle

Here are some of the most significant benefits of owning a hybrid electric vehicle:

- Eco-Friendly: One of the most significant features of hybrid electric vehicles over gasoline-powered automobiles is that these run smoother and get higher gas mileage, making them more eco-friendly. A hybrid electric vehicle has two engines: a gasoline engine and an electric motor, which reduces fuel consumption and saves electricity.
- Economic Benefits: Many credits and incentives are ready to support hybrid electric vehicles becoming more competitive. Less money expended on petrol results in lower annual tax bills and exemption from congestion charges.
- Less Reliance on Fossil Fuels: Since hybrid electric vehicles are cleaner and use less fuel, they emit fewer pollutants and are less reliant on fossil fuels. It also assists in the lowering of oil prices on the domestic market.
- Regenerative Braking System: As you apply the brakes in a hybrid electric car, it helps to recharge the tank. An internal mechanism kicks in, storing the energy emitted and using it to charge the battery, minimizing the amount of time and the need to recharge the battery on a regular basis.
- Lightweight Materials: Hybrid electric vehicles are built of lighter materials, consuming less energy to work. The engine is also smaller in size and lighter, resulting in significant energy savings.
- Higher resale value: As the price of fuel continues to rise, more and more people are opting for hybrid electric vehicles. As a result, these green vehicles have begun to command and resale prices that are higher than average. So, if you're frustrated with your car, you can always sell it for a higher price to customers who are looking for it.

5. Conclusion

Environment protection and energy conservation have urged the development of EVs. As fossil fuel energy sources become scarcer and carbon emissions rise, technology must shift to systems that incorporate renewable energy sources as a design philosophy. Hybrid electric vehicles, among other innovations, are a hot topic with benefits such as lower fuel consumption, lower running costs, lower noise pollution, lower emissions, smaller engine capacity, and long operating life. With advancements in battery technology, control techniques, and government funding for car owners and manufacturers, hybrid electric vehicle research is expected to become more popular in the coming years. So far, this paper has concentrated on the classification, history, benefits and disadvantages, vehicle types, and energy usage of HEVs. We looked at various EV/HEV configurations, traction motor models for electric propulsion systems, and high-performance speed sensors with less motor control. All three major HEV configurations, series, parallel, and series-parallel have advantages and disadvantages from a device perspective. Still, the implementation is dependent on the necessary operational characteristics of the implemented configuration.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Ma, S.C., Fan, Y., Guo, J.F., Xu, J.H. and Zhu, J.N. (2019) Analysing Online Behaviour to Determine Chinese Consumers' Preferences for Electric Vehicles. *Journal of Cleaner Production*, **229**, 244-255. https://doi.org/10.1016/j.jclepro.2019.04.374

[2] Jahangir, H., Tayarani, H., Ahmadian, A., Golkar, M.A., Miret, J., Tayarani, M., *et al*. (2019) Charging Demand of Plug-In Electric Vehicles: Forecasting Travel Behavior Based on a Novel Rough Artificial Neural Network Approach. *Journal of Cleaner Production*, **229**, 1029-1044. https://doi.org/10.1016/j.jclepro.2019.04.345

[3] Aouzellag, H., Ghedamsi, K. and Aouzellag, D. (2015) Energy Management and Fault Tolerant Control Strategies for Fuel Cell/Ultra-Capacitor Hybrid Electric Vehicles to Enhance Autonomy, Efficiency and Life Time of the Fuel Cell System. *International Journal of Hydrogen Energy*, **40**, 7204-7213. https://doi.org/10.1016/j.ijhydene.2015.03.132

[4] Gopal, A.R., Park, W.Y., Witt, M. and Phadke, A. (2018) Hybrid- and Battery-Electric Vehicles Offer Low-Cost Climate Benefits in China. *Transportation Research Part D: Transport and Environment*, **62**, 362-371. https://doi.org/10.1016/j.trd.2018.03.014

[5] Ajanovic, A. and Haas, R. (2019) Economic and Environmental Prospects for Battery Electric- and Fuel Cell Vehicles: A Review. *Fuel Cells*, **19**, 515-529. https://doi.org/10.1002/fuce.201800171

[6] Ali, A. and Söffker, 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**, Article No. 476. https://doi.org/10.3390/en11030476

[7] Li, L., Zhou, L.Y., Yang, C., *et al.* (2017) A Novel Combinatorial Optimization Algorithm for Energy Management Strategy of Plug-In Hybrid Electric Vehicle. *Journal of the Franklin Institute*, **354**, 6588-6609. https://doi.org/10.1016/j.jfranklin.2017.08.020

[8] Wang, X., Li, L., He, K., *et al.* (2018) Dual-Loop Self-Learning Fuzzy Control for AMT Gear Engagement: Design and Experiment. *IEEE Transactions on Fuzzy Systems*, **26**, 1813-1822. https://doi.org/10.1109/TFUZZ.2017.2779102

[9] Wang, X.Y., Li, L. and Yang, C. (2016) Hierarchical Control of Dry Clutch for Engine Start Process in a Parallel Hybrid Electric Vehicle. *IEEE Transactions on Transportation Electrification*, **2**, 231-243. https://doi.org/10.1109/TTE.2016.2535316

[10] Yang, L.H., Wang, Y.J. and Zhu, C.M. (2016) Study on Fuzzy Energy Management Strategy of Parallel Hybrid Vehicle Based on Quantum PSO Algorithm. *International Journal of Multimedia and Ubiquitous Engineering*, **11**, 147-158. https://doi.org/10.14257/ijmue.2016.11.5.14

[11] Yang, C., Jiao, X.H., Li, L., *et al.* (2014) Electromechanical Coupling Driving Control for Single-Shaft Parallel Hybrid Powertrain. *Science China Technological Sciences*, **57**, 541-549. https://doi.org/10.1007/s11431-014-5458-8

[12] Trianni, A., Cagno, E. and Accordini, D. (2019) Energy Efficiency Measures in Electric Motors Systems: A Novel Classification Highlighting Specific Implications in Their Adoption. *Applied Energy*, **252**, Article ID: 113481. https://doi.org/10.1016/j.apenergy.2019.113481

[13] Lopez, I., Ibarra, E., Matallana, A. andreu, J. and Kortabarria, I. (2019) Next Generation Electric Drives for HEV/EV Propulsion Systems: Technology, Trends and Challenges. *Renewable and Sustainable Energy Reviews*, **114**, Article ID: 109336. https://doi.org/10.1016/j.rser.2019.109336

[14] Gao, Z., LaClair, T., Ou, S., Huff, S., Wu, G., Hao, P., *et al.* (2019) Evaluation of Electric Vehicle Component Performance over Eco-Driving Cycles. *Energy*, **172**, 823-839. https://doi.org/10.1016/j.energy.2019.02.017

[15] Sain, C., Banerjee, A. and Biswas, P.K. (2020) Modelling and Comparative Dynamic Analysis Due to Demagnetization of a Torque Controlled Permanent Magnet Synchronous Motor Drive for Energy-Efficient Electric Vehicle. *ISA Transactions*, **97**, 384-400.

[16] Sajadi-Alamdari, S.A., Voos, H. and Darouach, M. (2019) Nonlinear Model Predictive Control for Ecological Driver Assistance Systems in Electric Vehicles. *Robotics and Autonomous Systems*, **112**, 291-303. https://doi.org/10.1016/j.robot.2018.12.001

[17] Xiong, H., Zhang, M., Zhang, R., Zhu, X., Yang, L., Guo, X., *et al.* (2019) A New Synchronous Control Method for Dual Motor Electric Vehicle Based on Cognitive-Inspired and Intelligent Interaction. *Future Generation Computer Systems*, **94**, 536-548. https://doi.org/10.1016/j.future.2018.12.007

[18] Sequeira, M. and Alahakoon, S. (2019) Energy Efficient Variable Speed Drives Empowered with Torque Estimation. *Energy Procedia*, **160**, 194-201.

https://doi.org/10.1016/j.egypro.2019.02.136

[19] Wenig, J., Sodenkamp, M. and Staake, T. (2019) Battery versus Infrastructure: Trade-Offs between Battery Capacity and Charging Infrastructure for Plug-In Hybrid Electric Vehicles. *Applied Energy*, **255**, Article ID: 113787. https://doi.org/10.1016/j.apenergy.2019.113787

[20] Rechkemmer, S.K., Zang, X., Zhang, W. and Sawodny, O. (2019) Lifetime Optimized Charging Strategy of Li-Ion Cells Based on Daily Driving Cycle of Electric Two-Wheelers. *Applied Energy*, **251**, Article ID: 113415. https://doi.org/10.1016/j.apenergy.2019.113415

[21] Du, J., Liu, Y., Mo, X., Li, Y., Li, J., Wu, X., *et al.* (2019) Impact of High-Power Charging on the Durability and Safety of Lithium Batteries Used in Long-Range Battery Electric Vehicles. *Applied Energy*, **255**, Article ID: 113793. https://doi.org/10.1016/j.apenergy.2019.113793

[22] Jeong, S., Jang, Y.J., Kum, D. and Lee, M.S. (2019) Charging Automation for Electric Vehicles: Is a Smaller Battery Good for the Wireless Charging Electric Vehicles. *IEEE Transactions on Automation Science and Engineering*, **16**, 486-497. https://doi.org/10.1109/TASE.2018.2827954

[23] Wu, D., Radhakrishnan, N. and Huang, S. (2019) A Hierarchical Charging Control of Plug-In Electric Vehicles with Simple Flexibility Model. *Applied Energy*, **253**, Article ID: 113490. https://doi.org/10.1016/j.apenergy.2019.113490

[24] Kolhe, M., Adhikari, S.K. and Muneer, T. (2019) Parked Electric Car's Cabin Heat Management Using Photovoltaic Powered Ventilation System. *Applied Energy*, **233**, 403-411. https://doi.org/10.1016/j.apenergy.2018.10.012

[25] Lukic, S.M., Cao, J., Bansal, R.C., Rodriguez, F. and Emadi, A. (2008) Energy Storage Systems for Automotive Applications. *IEEE Transactions on Industrial Electronics*, **55**, 2258-2267. https://doi.org/10.1109/TIE.2008.918390

[26] Lukic, S.M., Mulhall, P. and Emadi, A. (2008) Energy Autonomous Solar/Battery Auto Rickshaw. *Journal of Asian Electric Vehicles*, **6**, 1135-1143. https://doi.org/10.4130/jaev.6.1135

[27] Lee, B.H., Shin, D.H., Song, H.S., Heo, H. and Kim, H.J. (2009) Development of an Advanced Hybrid Energy Storage System for Hybrid Electric Vehicles. *Journal of Power Electronics*, **9**, 51-60.

[28] Chan, C.C. (2018) Electric, Hybrid, and Fuel-Cell Vehicles: Architectures and Modeling. *IEEE Transactions on Vehicular Technology*, **59**, 589-598. https://doi.org/10.1109/TVT.2009.2033605

[29] Chan, C.C. (2017) The State of the Art of Electric, Hybrid, and Fuel Cell Vehicles. *Proceedings of the IEEE*, **95**, 704-718. https://doi.org/10.1109/JPROC.2007.892489

[30] Ehsani, M., Gao, Y. and Emadi, A. (2009) Modern Electric, Hybrid Electric, and Fuel Cell Vehicles. CRC Press, Boca Raton.

[31] Iqbal, M.Y., Wu, Z.F., Tie, W., Li, G.X., Ji, Z.Y. and Hu, G.C. (2021) A High-Efficiency Energy Harvesting by Using Hydraulic Electromagnetic Regenerative Shock Absorber. In: Feng, S. *Mechanisms and Machine Science*, International Conference on Maintenance Engineering, Huddersfield. 276-294.https://doi.org/10.1007/978-3-030-75793-9_28

[32] Iqbal, M.Y., Wu, Z., Xu, G. and Bukhari, S. (2019) Study of external characteristics of hydraulic electromagnetic regenerative shock absorber. *World Journal of Engineering and Technology*, **7**, 520-535. https://doi.org/10.4236/wjet.2019.73037