Implementation of various control strategies in hybrid energy storage systems for Electric vehicle applications

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***Abstract*: Electrical vehicles are very helpful in saving the environment. Hence, they are getting a lot of importance in the transportation system. The entire world is transforming towards the electricity-based transportation system. The main factor by which we can understand about the saving of energy is through the energy management process. The effective utilization of energy can be achieved by the energy management system.**

Many energy management methods are proposed in the literature, which depend on the design, control, economy, and demand for that particular energy management system. The energy management systems can be implemented either offline or in online mode. The performance of the energy management depends on the control strategy implemented in the system.

In this paper, the effective methods of energy management methods that are suitable for electrical vehicles are studies and implemented. All the implementations are carried out in a MATLAB environment. The results for effective energy management systems are presented.

1. Introduction

Hybrid electric vehicles consist of two different fuel options, usually one is the conventional IC engine, and the other is the battery or fuel cell or any other electrical-based storage system. The operation of the HEVs is effective if their power consumption is less. It is expected that the HEVs mostly they should operate with electrical energy rather than IC engine (conventional fuels like diesel and petrol). In this chapter, various energy systems are presented, which are in use extensively in electrical vehicles.

Personal transportation will be dominated by electric cars in the future (EV). When compared to today's conventional autos, which are solely powered by internal combustion engines, hybrid vehicles (HV) represent a significant step forward (EVs). However, the expensive cost of batteries is still a barrier to the widespread adoption of electric vehicles (EVs). Renewable energy sources may be used to extend the driving range of electric vehicles and reduce the need for batteries, according to some estimates. An electric vehicle (EV) is made up of three parts: an electric engine, a high-voltage battery, and an auxiliary battery. The range of solar-powered energy range extenders is substantially increased as a result of this (EREs). Following the current energy crisis and the worsening environmental situation, there is a growing global interest in sustainable energy sources.

Solar energy is a significant source of renewable energy. Solar energy is limitless, unbounded, and completely pure. Photovoltaic (PV) arrays are devices that convert solar energy into electrical current. However, solar photovoltaic (PV) systems suffer from two major drawbacks: the conversion efficiency of PV arrays is poor (9-16 percent), particularly under low irradiation conditions and the amount of electric power generated by solar photovoltaic arrays varies depending on the surrounding weather conditions.

The energy stored in the rechargeable battery of the Electric Vehicle is used to power the motor controller and other components. Depending on where the accelerator pedal is depressed, the motor controller regulates how much power is delivered to the electric drive motor (s). During operation, the electric drive motor(s) generates an electromotive force that causes the electric motor's shaft to rotate (s). This shaft is connected to the car's wheels and, depending on the way it spins in, it either propels the vehicle forward or backward. Recharging an electric vehicle is accomplished simply by connecting the vehicle's charge connector to a wall outlet that has been specially built for charging electric cars. The kind of battery, its capacity, and the voltage/current output of the charger all influence the amount of time it takes to charge a battery. Charging time for the vast majority of electric vehicles is no more than 6 hours.

It is the main goal of electric automobiles to decrease the number of hazardous gases emitted into the environment as a result of the combustion process that occurs in an internal combustion engine. A zero-emission car generates no emissions. Others who are opposed to the electric car sector claim that emissions produced during the process of generating electricity from fossil fuels have not led to a decrease in dangerous pollutants. While it is true that power plants emit pollutants, the government has enacted strict restrictions to limit the amount of pollution produced by power plants. EV owners may take advantage of the extra energy by charging their vehicles at night when demand is low and power plants are producing excess electricity. In turn, this has a positive impact on the efficiency of power plants.

1.1 HEV Architectures:

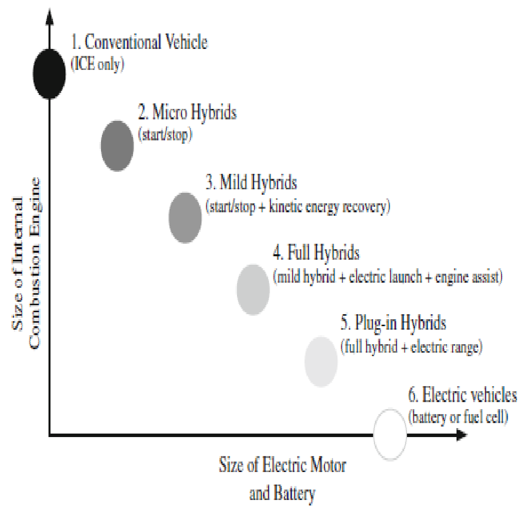


Fig. 1: Various electric vehicles

2. Literature Review

A lot of open literature is available related to energy management systems. The EMS for electrical vehicles is vital and is most important. The performance of the battery depends on the type of EMS implemented during the operation of the vehicle. Following are some of the major areas, where the work is available related to the EMS in hybrid electrical vehicles.

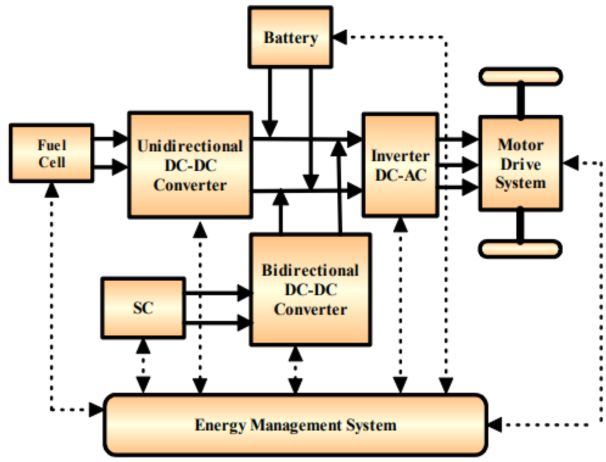


Figure 2: Schematic representation of EMS in EV.

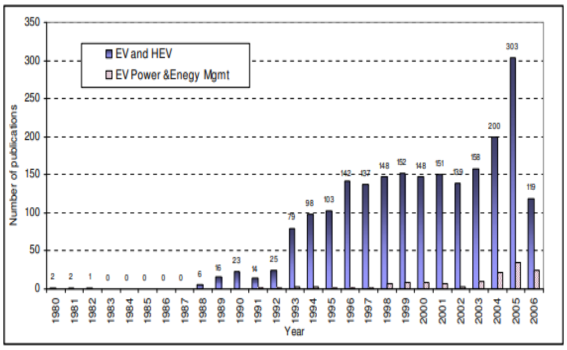


Figure 3: Number of publications in IEEE for EMS.

3. Control methods of Energy Storage Systems

The various methods that are employed in energy management systems are presented. The various methods include,

1. The off-line EMS methods.
2. The Online EMS methods.

3.1 Dynamic programming method:

Following are the advantages of this method.

- It is the benchmark method for
- EMS Achieves good results.

Drawbacks:

- Prior knowledge is required.
- Computational complexity.

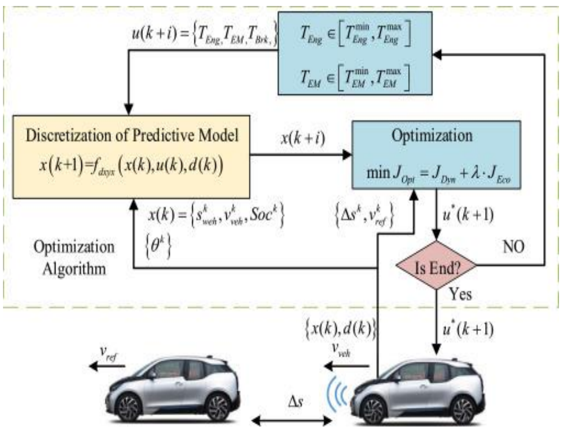


Figure 4.Dynamic programming method

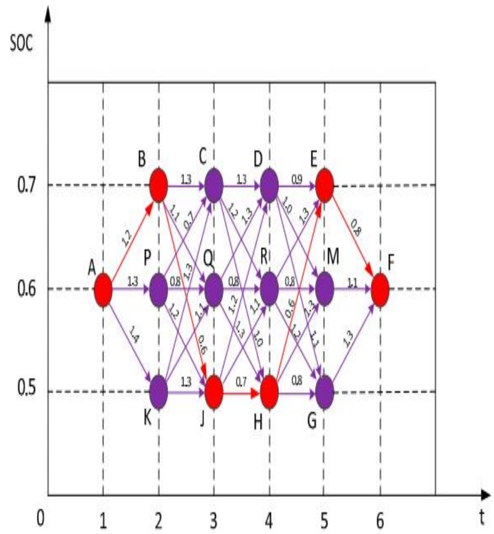


Figure 5: Dynamic programming principle

3.2 Stochastic Dynamic programming method:

- ➢ The adaptability of this method is good.
- ➢ It can achieve good fuel economy.
- ➢

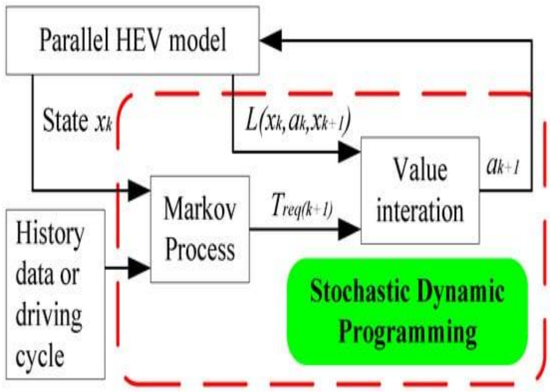


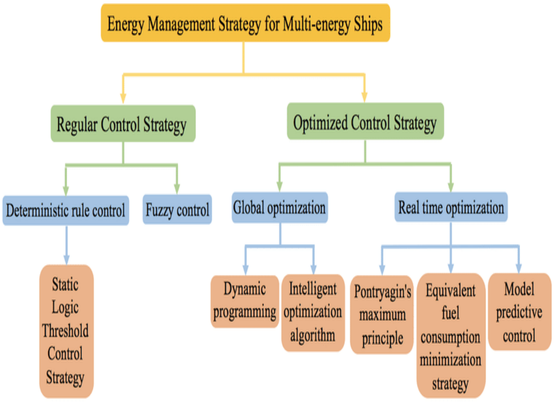
Figure 6: Stochastic dynamic programming

3.3 Deterministic rule-based EMS

In this method, engine performance is the vital criterion. All the parameters and the rules are defined by the engine performance factor. Following are the various deterministic methods

1. On/off EMS

Power followers Ems



The above list shows the various deterministic methods used in the design of the energy management system in electric vehicles

3.4 Battery state of charge

The figure below shows the energy management process in a hybrid electric vehicle. It computes the best choice between the fuel consumption and the state of charge of the battery.

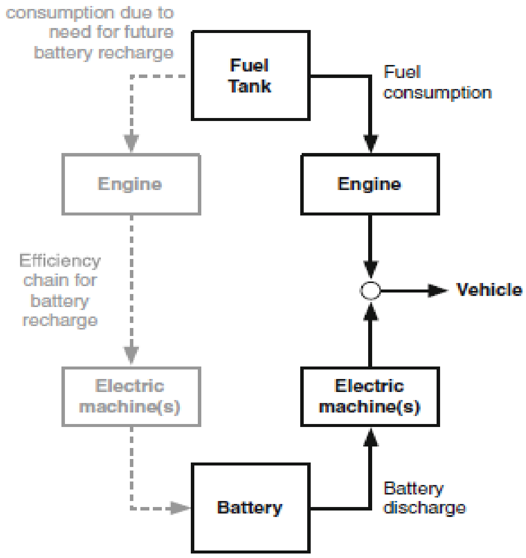


Figure 7: EMS process in the hybrid electric vehicle.

The expression for a state of charge is given by

$$p(SOC) = 1 - \left(\frac{SOC(t) - SOC_{target}}{(SOC_{max} - SOC_{min})/2} \right)^{a}.$$

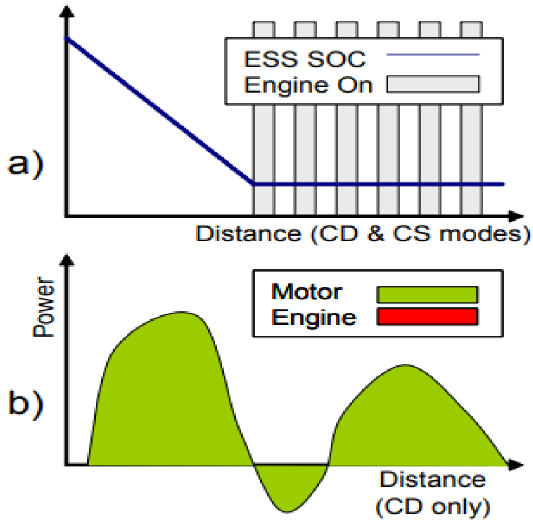


Figure 8: Battery state of charge (SOC)

4.Simulation Results

In this section, the energy management system for the hybrid electric vehicle is simulated using the nonlinear optimization method. Entire simulations are carried out in MATLAB software.

4.2 System Specifications:

Following are the system specifications under study.

- Battery Capacity (Ah)
  CAPbat=10000;
- Battery Voltage (V)
  Vbat=48;
- Initial State of Charge (SOC)
  SOCini=0.5;
- Minimum SOC
  SOCmin=0.2;
- Maximum SOC
  SOCmax=0.9;
- Battery Efficiency
  EFFbat=0.95;
- Battery self discharge
  SDbat=0.005;

By compiling the above program we obtain the following results. It consists of the following waveforms.

- SOC of the battery.
- Energy Flow.
- Energy capacity during charge and discharge.

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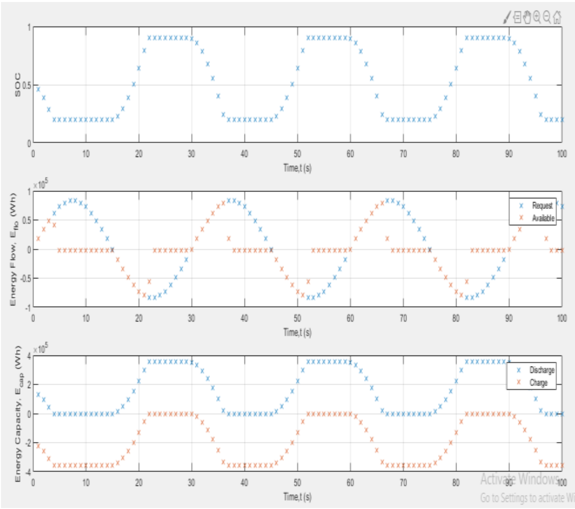

The energy is estimated in watt-hour. And the state of the charge is in per-unit value. From the simulation results, it is observed that the SOC of the battery is minimum if the energy available is the minimum. The SOC is maximum for the maximum power availability. The energy capacity during the charging and discharging also has shown which is in Watt-hours.

Conclusion

The energy management system (EMS) simulation is the major objective of the present work. EMS is the fundamental requirement of any electric propulsion system. Several methods are available to implement the EMS. But, very few methods give accurate results. Following are the important conclusions of the present work.

1. The energy management system in an electric vehicle is analyzed.
2. An optimization system is implemented to find the SOC of the battery.
3. The method implemented is accurately estimating the SOC for the given operating conditions.
4. Various control algorithms are also presented.

The analytical model of the energy management system is presented. The control parameters such as state of charge (SOC), energy flow are calculated using the optimization method. The dynamic programming method is employed in to find the SOC. The DP method gives accurate value of SOC than other OFF line methods.

Future Scope

The following aspects are left as the future scope of this project.

1. The cost of the battery is a vital factor, which depends on the SOC of the battery. Hence, the cost analysis needs to be performed for the battery system.
2. The parameters like total energy consumption, total emissions, and the size of the battery need to be addressed appropriately.

References

1. Zhang, F.Q.; Hu, X.S.; Langari, R.; Cao, D.P. Energy management strategies of connected his and PHEVs: Recent progress and outlook. Prog. Energy Combust. Sci. **2019**, 73, 235–256.

2. Onori, S.; Serrao, L.; Rizzoni, G. Hybrid Electric Vehicles: Energy Management Strategies; Springer: Berlin/Heidelberg, Germany, 2016.

3. Wang, Q.; You, S.; Li, L.; Yang, C. Survey on the energy management strategy for plug-in hybrid electric vehicles. J. Mech. Eng. **2017**, 53, 1–19.

4. Wirasingha, S.G.; Emadi, A. Classification and review of control strategies for plug-in hybrid electric vehicles. IEEE Trans. Veh. Technol. **2011**, 60, 111–122.

5. Salmasi, F.R. Control strategies for hybrid electric vehicles: Evolution, classification, comparison, and future trends. IEEE Trans. Veh. Technol. **2007**, 56, 2393–2404.

6. Karbaschian, M.; Sö_ker, D. Review and comparison of the power management approach for hybrid vehicles with a focus on hydraulic drives. Energies **2014**, 7, 3512–3536.

7. Tran, D.-D.; Vafaeipour, M.; Baghdadi, M.E.; Barrero, R.; Hegazy, O. Thorough state-of-the-art analysis of electric and hybrid vehicle powertrains: Topologies and integrated energy management strategies. Renew. Sustain. Energy Rev. **2019**, 119, 109596.

8. Miller, J.M. Propulsion Systems for Hybrid Vehicles; The Institution of Electrical Engineers: London, UK, 2004; Volume 45.

9. He, H.; Zhang, J.; Li, G. Model predictive control for energy management of a plug-in hybrid electric bus. Energy Procedia **2016**, 88, 901–907.

10. Donitz, C.; Vasile, I.; Onder, C.; Guzzella, L. Dynamic programming for hybrid pneumatic vehicles. In Proceedings of the 2009 American Control Conference, St. Louis, MO, USA, 10–12 June 2009; IEEE: New York, NY, USA, 2009; pp. 3956–3963.

11. Lin, C.C.; Peng, H.; Grizzle, J.W.; Kang, J.M. Power management strategy for a parallel hybrid electric truck. IEEE Trans. Control Syst. Technol. **2003**, 11, 839–849.

12. Patil, R.M.; Filipi, Z.; Fathy, H.K. Comparison of supervisory control strategies for series plug-in hybrid electric vehicle powertrains through dynamic programming. IEEE Trans. Control Syst. Technol. **2014**, 22, 502–509.

13. Murphey, Y.L.; Park, J.; Kiliaris, L.; Kuang, M.L.; Abul Masrur, M.; Phillips, A.M.; Wang, Q. Intelligent hybrid vehicle power control-part ii: Online intelligent energy management. IEEE Trans. Veh. Technol. **2013**, 62, 69–79.