HESS with Control Algorithms in Dual-Chemistry Battery Pack for Light Electric Vehicles

Kasturi Mahajan
Masters in Electric Vehicles
Department of Mechanical Engineering
MIT ADT University
Pune, Maharashtra, India
kasturim1999@gmail.com

Prof. Shashank Gawade
Department of Mechanical Engineering
MIT ADT University
Pune, Maharashtra, India
shashank.gawade@mituniversity.edu.in

***Abstract*— Electric vehicles with excellent sources of energy will proliferate in the near future. An overview of hybrid electric vehicles (HEVs) is covered in this review article, with a focus on battery cell technologies, topological HESS configurations, and control algorithms. The main objective is to improve the effectiveness and efficiency of the battery system under safe working conditions. A study found that some researchers have improved driving cycles, range, and vehicle efficiency using battery-UC HESS. The use of a second storage system has been found to increase the main storage system's lifespan (battery). Ultra-capacitors' quick charging and discharging capabilities made it feasible to store the regenerative braking capacity in the right way. The development of superior optimization techniques will lead to improved energy management within the HESS. Using a variety of modular hybrid battery managers, the HESS design links the different battery chemistries (HBMs). Power-mix algorithm for dual-chemistry HESS is one of this work's most important advances. These goals can be accomplished through a variety of means, some of which include the hybrid predictive power optimisation (PPO) control approach, the adaptable FLC plan of action, the grey wolf optimisation methodology, and the pontryagin's minimal principle.**

Keywords — ***HEV, HESS, Predictive Power Optimization (PPO), FLC, Energy storage, HBM, Grey Wolf Optimization, Pontryagin's Minimum Principle.***

I. INTRODUCTION

The problems associated with the energy crisis and environmental contamination have become much more severe in the twenty-first century [1]. Climate change and global warming are what pose the biggest danger to the environment. The use of fossil fuels as a source of energy has led to a rapid rise in greenhouse gases (GHG) and a rapid depletion of natural resources. The excessive use of fossil fuels has irrevocably harmed the ecosystem. The energy sector is one of the main drivers of the rise in greenhouse emissions. Due to greater environmental awareness and stricter emission laws, environmentally friendly electricity generation has become more essentialIt is absolutely necessary to make the switch to energy sources that are greener and more sustainable. [2].

The basis for electrifying cars is the development of energy storage technologies. The lithium-ion battery is significant energy storage devices right now [3]. An apparatus that transforms molecular energy into electrical energy is a battery. The creation of Lithium ion batteries, each with a distinct chemical composition, was motivated by various factors. LFP, NMC,LTO and others are a few of numerous Li-ion battery varieties used in the evs [4].

II. TYPES OF CONTROL ALGORITHMS

A. *Basic of hybrid energy storage system:*

While control procedures are being developed, a depiction of two distinct battery packs in the form of a schematic showing how they will be connected in parallel by way of a DC-DC converter. For example, if we examine any two distinct battery packs to be Li iron Phosphate and Li nickel manganese cobalt oxide, we can see that there are significant differences between the two., and In order to hybridise, it's necessary to find an acceptable compromise between all of the characteristics; for example, "LFP" and "NMC." [5].

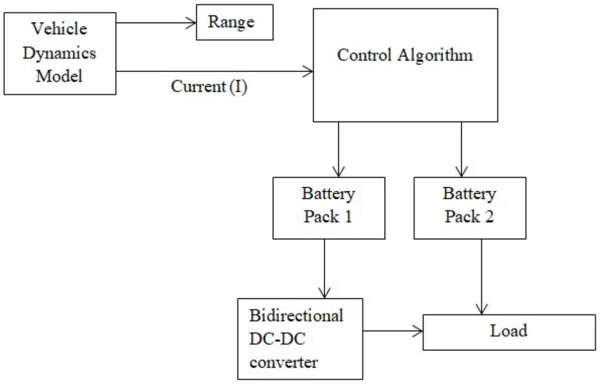


Fig 1.1 Schematic diagram of HESS

B. *Control strategies :*

Currently, strategies based on optimization have been researched to handle complex management objectives, such as lifetime and cost-effectiveness. These techniques are built on improving performance and reducing cost function [6].

III. ENERGY MANAGEMENT STRATEGIES

In the papers [7], numerous EMSs for FC-based hybrid energy systems have been described. These techniques can be broken down into four distinct categories: rule-based, control-based, filter-based, and optimization-based strategies respectively. [8].

A. *Pontryagin's minimum principle*

This regulating technique is the utmost fit for handling a vehicle's energy because of the EMS-base Pontryagin's minimal principle capabilities. It also gives the finest circumstances for promptly addressing issues, which makes it the best choice overall. This strategy aims to maximise the number of battery cycles while simultaneously minimising the amount of energy used. Control Utilising Adaptive and Fuzzy Logic.

Adaptive fuzzy energy management algorithms have been put into action in order to analyse the power separation that occurs between the Supercapacitor, the Fuel Cell, and the battery unit. As a result of the complexities of the hands-on controller issues, a fuzzy controller is required. [9-10].

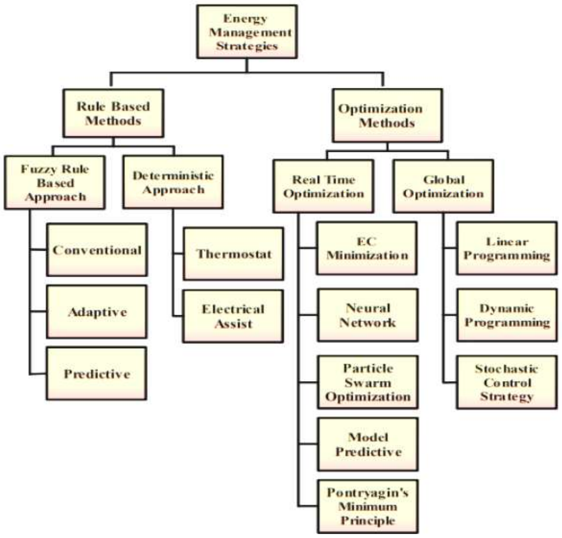


Fig. 2 Classification of EMS [9]

The evolution of the EMS is based on the consideration of these three factors.

(1) Operating cycle's energy requirement should always being met. Although its propulsion system and the operating environment may vary, electric vehicles must be prepared to function like conventional vehicles. As a consequence, it will always be crucial to show a pattern of operating circumstances in simulations and the real experiment.

Th

(2) Operating conditions have a considerable impact on the battery in terms of how long it will last, how efficiently it will perform, how healthy it will be overall,

(3) It is important to keep in mind that the primary source of power for the EV must come from the batteries. Because of the nature of batteries, the whole amount of power essential to energising the entirety of the drive cycle must originate from batteries; any more power must originate from either super-capacitors, fuel cells, or both. Batteries are the only acceptable source of power. [11-13].

B. Grey Wolf Optimization Technique

Based on Gray Wolf Optimizer, an energy management approach is created for a fuel cell and super-capacitor hybrid energy storage system. The algorithm resembles qualities that are similar to the behavior of the grey wolf, from which it derives its name.

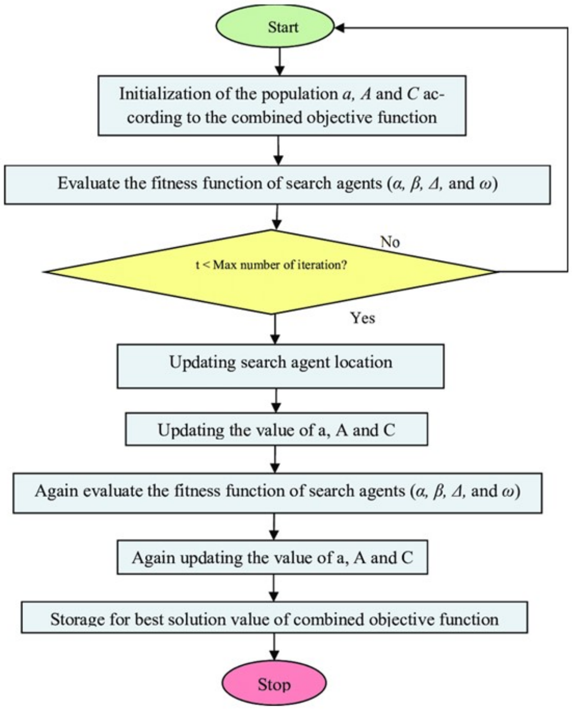


Fig. 3 Grey Wolf Optimization algorithm [12]

In this investigation, the Grey Wolf Optimizer algorithm was put through its paces by utilising a multi-sources, single-area power network that included hydro power plants, gas turbine power plants, and reheat thermal power plants, all of which were outfitted with mechanical hydraulic regulators. This network was used to test the algorithm's ability to optimise power distribution across the network. The research was carried out by utilising a power network that served only a single area. [14-17]

C. EMS based Particle Swarm Optimisation (PSO)

A stretegy using meta-heuristic population-based approach was chosen to tackle the problem. PSO, a well-known population-based optimization technique, was first presented by Kennedy and Eberhart. The steps are given below as:

Step 1: Initialization of variables like velocity, search region boundaries, acceleration coefficients, iterations, and swarm size. The placements of the particles are first established inside the searching region in a completely randomized fashion..

Step 2: The objective function's value has been determined at that particular time.

Step 3: The best position of the particle, referred to as pbest, and the best position in the world, referred to as gbest, are both determined in the third step.

Step 4: The speed and location of the swarm particle are reformed in the fourth step of the process.

Step 5: The algorithm is complete once Step 5 has been completed, when OF is minimal.

Step 6: It is decided what desirable characteristics the components should have.

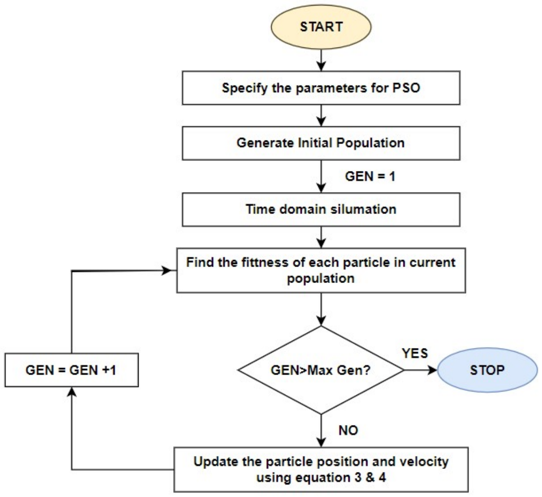


Fig.4. Flowchart of PSO Algorithm [13]

IV. THE ARCHITECTURE OF HESS

The reaction time of the slow unit, which is longer than one minute, needs to be synchronised with the reaction time of the fast energy storage unit, which has a response time of less than one minute to increase income (or decrease total price) from HESS. (reaction time less than one minute). An optimal control approach has been developed for this purpose.[18-22]

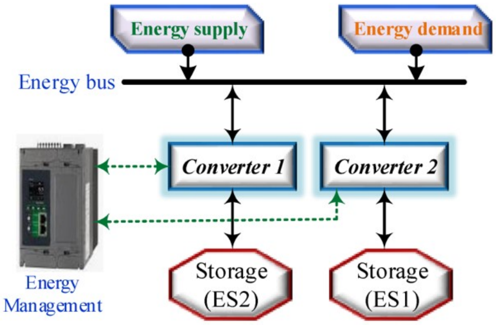


Fig. 5. The architecture of HESS [13].

A. Control strategy for battery UC HESS

To enable precise control of power flow in both battery and the super-capacitors, this architecture was selected. If the motor is only being powered by the batteries, losses can be minimized by connecting the batteries straight to the motor inverter.

Considering the low voltage at which supercapacitors discharge, they are not immediately connected in the arrangement. [23-22].

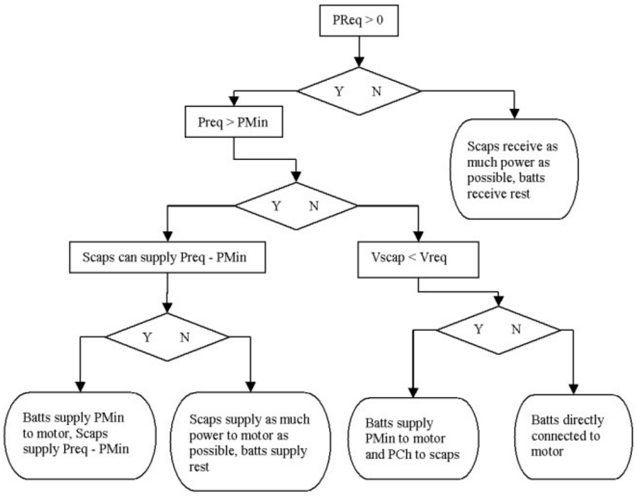


Fig.6. Flowchart of control strategy for a requested power PReq from the energy storage system [14]

B. dynamic programming in hybrid energy storage system

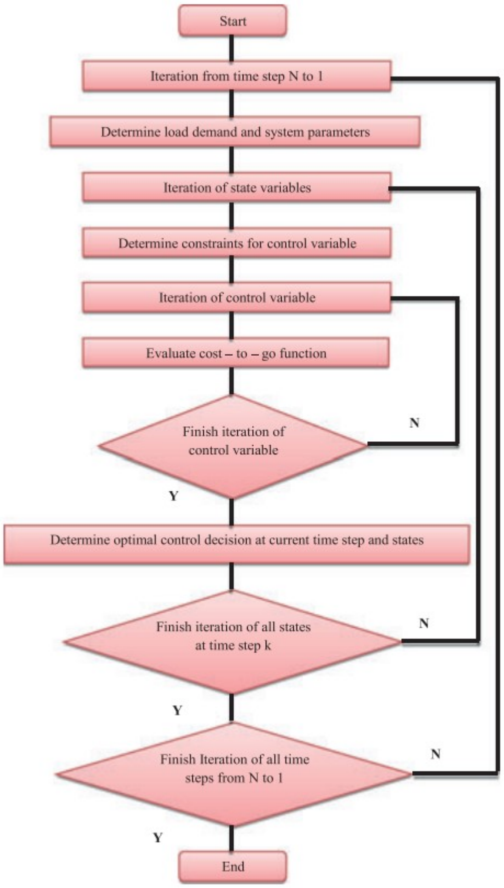
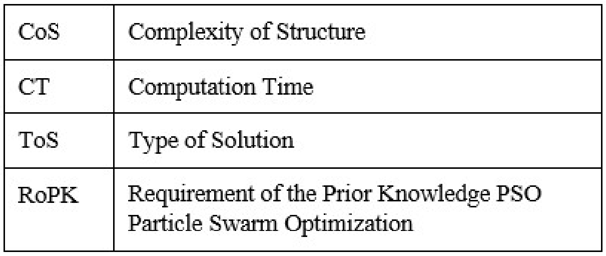


Fig. 7. Flowchart of dynamic programming [14].

TABLE I. EVALUATION OF DIFFERENT EMS METHODS

Methods	CoS	CT	ToS	RoPK
FL	×	Small	Global	Yes
PSO	×	Medium	Global	×
PMP	×	Small	Local	Yes
GWO	×	Medium	Global	×
DP	Yes	Medium	Global	Yes
MPC	×	Small	Global	×
NN	Yes	Small	Global	Yes

Here terms are described as follows:



CoS	Complexity of Structure
CT	Computation Time
ToS	Type of Solution
RoPK	Requirement of the Prior Knowledge PSO Particle Swarm Optimization

V. SUMMARY

This study educates us on a wide range of control strategies applicable to a variety of models, as well as their significance and possible future directions for research into control strategy. When common and well-known driving patterns are considered, an optimization technique has the potential to considerably increase the lifespan of the hybrid's power storage device. They aren't making any attempt to correct the sporadic working habits that they have been observing. Although fuzzy-based methods that are very effective for various drive cycles are available, optimal control approaches typically have a significant impact on better battery life. This is the case despite the fact that these alternatives are available. In addition to this, the GWO in the ESS that is integrated with the fuel cell helps to minimize the fluctuations in current and provides protection against the unstable state of charge that the battery may occasionally assume. Both of these benefits come about as a result of the combination of these two components.

REFERENCES

[1] Umang Selokar,"Modelling and Study of Thermal Effects on Battery Pack Using Phase Change Materials", South Dakota State University, 2019.

[2] Prathamesh Halagi "Characterization and Modeling of Lithium-ion Batteries for Grid Applications", University of Vaasa, 2021.

[3] Yin Jin et al., "Modeling and Simulation of Lithium-ion Battery Considering the Effect of Charge-Discharge State", Journal of Physics: Conference Series, Vol.1907, 2021, doi:10.1088/1742-6596/1907/1/012003.

[4] Abbas Fotouhi et al., "A Review on Electric Vehicle Battery Modeling: from Lithium-ion toward Lithium-Sulfur", Renewable and Sustainable Energy Reviews, Volume 56, April 2016, doi: 10.1016/j.rser.2015.12.009.

[5] Yuduo Huang et al,"Research on Fitting Strategy in HPPC Test for Li-ion battery", IEEE Sustainable Power and Energy Conference, 2019,

[6] Pagar, N. D., S. S. Gawde, and S. B. Sanap. "Online condition monitoring system for rotating machine elements using edge computing." Australian Journal of Mechanical Engineering (2023): 1-14.

[7] Praveena Krishna P. S. et al, "Energy Management Strategies for Hybrid Energy Storage System in Electric Vehicles: A Review", IEEE Transactions on Sustainable Energy (Volume: 9, Issue: 4, October 2018).

[8] K. Ettihir, L. Boulon, and K. Agbossou, "Optimization-based energy management strategy for a fuel cell/battery hybrid power system," Appl. Energy, vol. 163, pp. 142–153, 2016.

[9] X. Zhang, L. Liu, and Y. Dai, "Fuzzy state machine energy management strategy for hybrid electric UAVs with PV/Fuel cell/battery power system," Int. J. Aerosp. Eng., vol. 2018, 2018.

[10] N. Chettibi, A. Mellit, G. Sulligoi, and A. Massi Pavan, "Adaptive Neural Network-Based Control of a Hybrid AC/DC Microgrid," IEEE Trans. Smart Grid, vol. 9, no. 3, pp. 1667–1679, 2018.

[11] Pagar, N. D. "Influence of simultaneous optimisation to enhance the stress-based fatigue life of bellows joint." Australian Journal of Mechanical Engineering (2021): 1-16.

[12] N. Sulaiman, M. A. Hannan, A. Mohamed, P. J. Ker, E. H. Majlan, and W. R. Wan Daud, "Optimization of energy management system for fuel-cell hybrid electric vehicles: Issues and recommendations," Appl. Energy, vol. 228, no. May, pp. 2061–2079, 2018.

[13] H. Yin, S. Member, W. Zhou, S. Member, and M. Li, "An Adaptive Fuzzy Logic-Based Energy Management Strategy on Battery / Ultracapacitor Hybrid Electric Vehicles," IEEE Trans. Transp. Electrif., vol. 2, no. 3, pp. 300–311, 2016.

[14] Patle, B. K., et al. "Hybrid FA-GA Controller for Path Planning of Mobile Robot." 2022 International Conference on Intelligent Controller and Computing for Smart Power (ICICCSP). IEEE, 2022.

[15] Haldar, Arijit I., and Nitin D. Pagar. "Predictive control of zero moment point (ZMP) for terrain robot kinematics." Materials Today: Proceedings 80 (2023): 122-127.

[16] Darade, Santosh A., M. Akkalakshmi, and Dr Nitin Pagar. "SDN based load balancing technique in internet of vehicle using integrated whale optimization method." AIP Conference Proceedings. Vol. 2469. No. 1. AIP Publishing, 2022.

[17] https://www.researchgate.net/figure/Flowchart-of-GWO-algorithm-for-LFC-in-multi-source-single-area-power-network_fig4_346542200

[18] Ibrahem E. Atawi et al, "Recent Advances in Hybrid Energy Storage System Integrated Renewable Power Generation: Configuration, Control, Applications, and Future Directions" 30 December 2022, Issue Battery Energy Storage in Advanced Power Systems).

[19] R. Carter et al, "Strategies for control of a battery/ super-capacitor system in an electric vehicle", 2008 International Symposium on Power Electronics, Electrical Drives, Automation and Motion, 29 July 2008, IEEE ,PP 727-732.

[20] Sanap, Sudarshan B., and Nitin D. Pagar. "Structural Integrity Assessment of the Compensators Used in the Heat Exchangers Under Combined Angular Movement and Lateral Offset." ASME International Mechanical Engineering Congress and Exposition. Vol. 86717. American Society of Mechanical Engineers, 2022.

[21] Patil, Amit R., et al. "Experimental investigation on the effect of optimized dimethyl carbonate on CI engine performance & Emissions at various engine operating parameters using Taguchi method." AIP Conference Proceedings. Vol. 2469. No. 1. AIP Publishing, 2022.

[22] Pagar, Nitin D., and Amit R. Patil. "Life Augmentation of Turbine Exhaust System Compensators Through Integrated MADM Optimization Approach of Stress Based Fatigue Cycles." Gas Turbine India Conference. Vol. 85536. American Society of Mechanical Engineers, 2021.

[23] Pagar, N. D., and S. H. Gawande. "Parametric design analysis of meridional deflection stresses in metal expansion bellows using gray relational grade." Journal of the Brazilian Society of Mechanical Sciences and Engineering 42 (2020): 1-21.

[24] Gawande, S. H. "A combined numerical and experimental study on metal expansion bellows for STHE." Journal of the Brazilian Society of Mechanical Sciences and Engineering 40 (2018): 1-14.

[25] Pagar, Nitin D., and S. H. Gawande. "Dynamic Analysis of End Conditions for Shell Side Pipings of STHE." Gas Turbine India Conference. Vol. 83525. American Society of Mechanical Engineers, 2019.