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A Comprehensive Review on Control Solutions of Hybrid Energy Storage System (HESS) for Electric Vehicles

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Abstract:- In the near future, electric vehicles with superior energy sources will become more widespread. This review paper discusses an overview of hybrid electric vehicles (HEVs) with an emphasis on battery cell technologies, topological configurations of HESS, and its control techniques. The Energy Management Strategy (EMS) of HESS with a fuel cell (FC), a super-capacitor, and an ultra-capacitor uses in HEVs. The primary goal is to increase the battery system's efficiency and effective use under secure operating circumstances. According to a review, some researchers have used battery-UC HESS as a combination and demonstrated improvements in driving cycles, range, and vehicle efficiency. The multi-converter topology of the hybrid sources operates with high degree of flexibility along with reliability. It has been observed that use of an additional storage system can prolong the lifespan of the primary storage system (battery). The quick charging and the discharging abilities of ultra-capacitors made it possible to store the regenerative braking capacity in an appropriate fashion. Optimized energy management among the HESS will result from work on better optimization methods. The HESS design interfaces the various battery chemistries using a number of modular hybrid battery managers (HBMs). One of this work's major contributions is its power-mix algorithm for dual-chemistry HESS. There are a number of ways to accomplish these goals, including the hybrid predictive power optimization (PPO) control strategy, Adaptive FLC Strategy, Grey Wolf Optimization Technique, and the Pontryagin's Minimum Principle.

***Keywords**:- HESS, SESS, Predictive Power Optimization (PPO), Hybrid battery managers, Grey Wolf Optimization, Pontryagin's Minimum Principle.*

I. INTRODUCTION

There has been a sharp rise in the challenges related to the energy crisis and environmental pollution in the 21st century [1]. The greatest threat to the environment is caused by climate change and global warming. Fossil fuels are being used as a source of energy, which has caused greenhouse gases (GHG) to rapidly increase and natural resources to rapidly deplete. Overuse of fossil fuels has had a permanent negative influence on the environment. One of the leading contributors to the increase in greenhouse gases is the energy industry. The necessity for environmentally friendly power generation has increased as a result of environmental awareness and stringent emission laws. This has raised the prominence of the use of renewable energy sources across a range of applications. As a result, the ability of green energy sources to diminish global warming and climate change is recognized. It is imperative to transition to greener, more sustainable energy sources [2].

The creation of the energy storage devices is foundation of electrification of automobiles. One of the most important energy storage technologies currently in use is the lithium-ion battery [3]. A battery is a machine that converts chemical energy into electrical energy. Different criteria have led to development of Lithium ion batteries, each having a unique chemical make-up. Some of the numerous Lithium ion battery types used in the electric cars are lithium nickel-manganese-cobalt oxide (NMC), lithium iron phosphate (LFP), lithium manganese oxide(LMO), lithium cobalt oxide, etc [4].

II. TYPES OF CONTROL STRATEGIES

A. Introduction to HESS:

The below schematic diagram of two battery packs connected in parallel via DC-DC Converter in which control algorithms are getting implemented. For example if we consider two battery packs as Lithium iron Phosphate (LFP) and Lithium Nickel Manganese Cobalt Oxide (NMC) we have to balance all parameters for hybridization.

Along with various control strategies are designed to find out optimum results like Hybrid predictive power optimization (PPO) control approach, Pontryagin's Minimum Principle, Grey Wolf Optimization Technique, and Adaptive Fuzzy Logic Control Strategy ,Particle Swarm Optimization (PSO), Wavelet transform controller, PID (Proportional integral-derivative) controller, rule-based approach, Dynamic Programming algorithm, etc.[5].

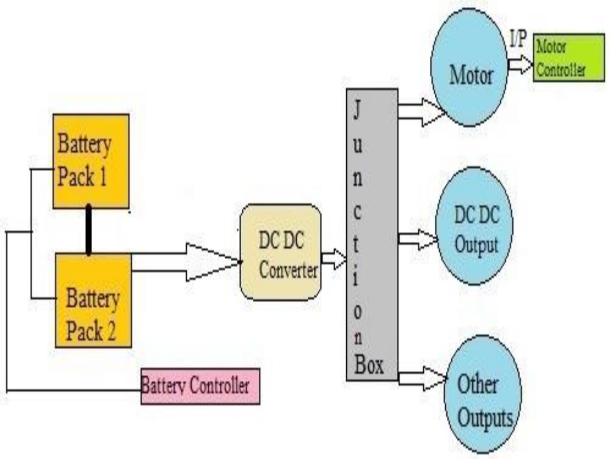

Fig 1: Rough line diagram of HESS

B. Types of Control Algorithm :

Recently, In order to address complex management goals, such as cost-effectiveness and lifetime, strategies based on optimization are researched. Such methods are based on the improvement of performance and the decrease of an instant cost function [6].

III. ENERGY MANAGEMENT STRATEGY

In the papers, a number of EMSs for FC-based hybrid energy systems have been documented [7]. These methods can be classified into four categorization: rule-based methods, control-based methods, filter-based methods, and optimization-based methods. Fuzzy logic (FL), neural networks, and state machinery constitute the majority of the rules' base (NN) [8].

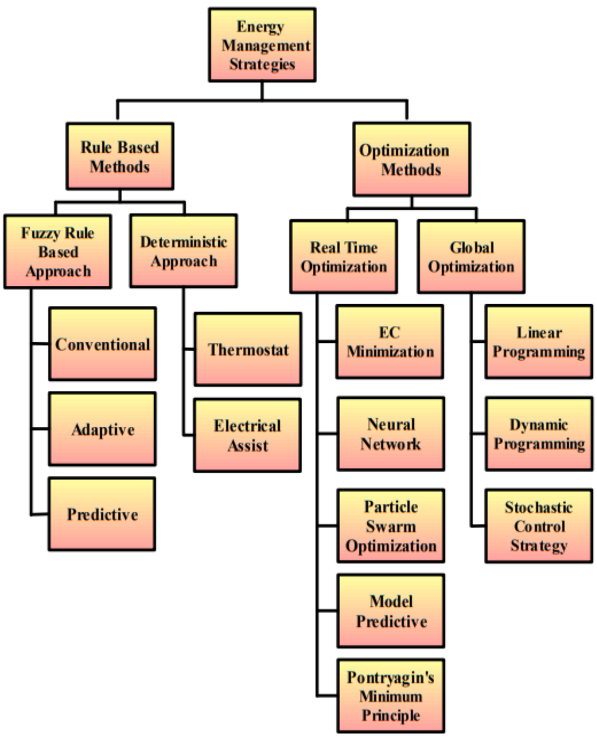

Fig. 2: Classification of EMS [9]

A. EMS based on Pontryagin's minimum principle

This controlling method provides the best conditions for swiftly resolving problems, and because to its EMS based Pontryagin's minimum principle capabilities, it is the most qualified individuals for the energy management of vehicle. This method aims to minimise electricity use while simultaneously maximising the battery's cycle life. The best solution will be developed for this energy management strategy if the drive cycle data for history specified in the distance.

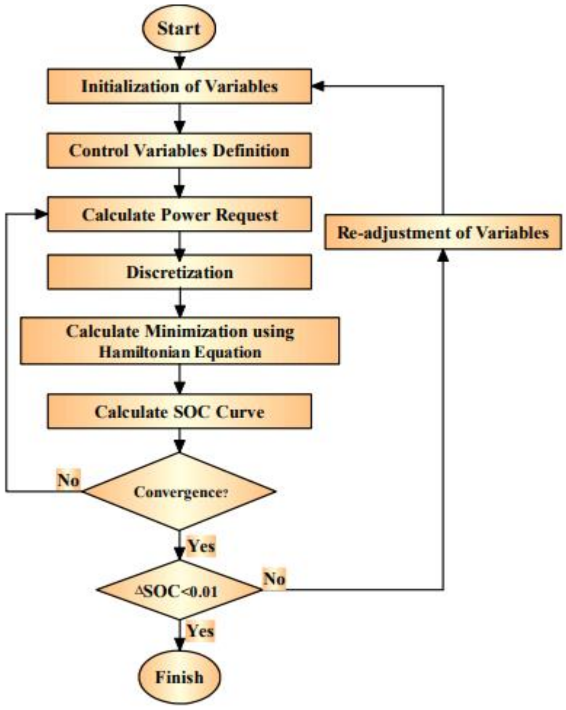

Fig. 3: Energy Management strategy based Pontryagin's minimum principle [10]

B. Energy Management Strategy based on Adaptive FLC

Adaptive fuzzy energy management strategy is implemented to test power separation among battery unit and Fuel Cell and Super-Capacitor. A fuzzy controller is required due to complex practical control issues.

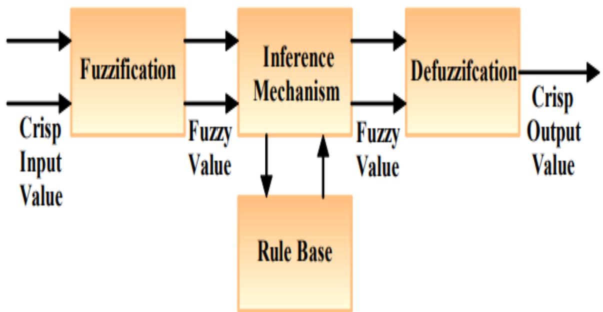

Fig. 4: AFEMS Controller [11]

Three main principles are considered for the progress of the Energy management strategy

- The energy needs of driving cycle should be continuously satisfied. Even if the propulsion system and environment in which it will be used may well be different, Ev`s has to be ready to operate like conventional vehicle. As a result, in simulations and

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actual experiments, it will always important to present pattern of the operating circumstances.

- Operating condition play a major role in determining the battery's lifespan, efficiency, and overall health, as well as its current dynamics and full current rating.
- It should be highlighted that the EV's primary energy source must be batteries. The energy needed to power the entire driving pattern should only come from the battery due to the properties of batteries, Super-Capacitors and/or Fuel Cell must be present as the sources of extra energy.

C. Energy management strategy based on the Grey Wolf Optimization Technique

Energy management strategy is designed for Hybrid energy storage system with Fuel Cell and Super-capacitor based on Gray Wolf Optimizer (GWO). The algorithm takes its name from chasing activity of grey wolf, and it simulates characteristics that are comparable to that behavior.

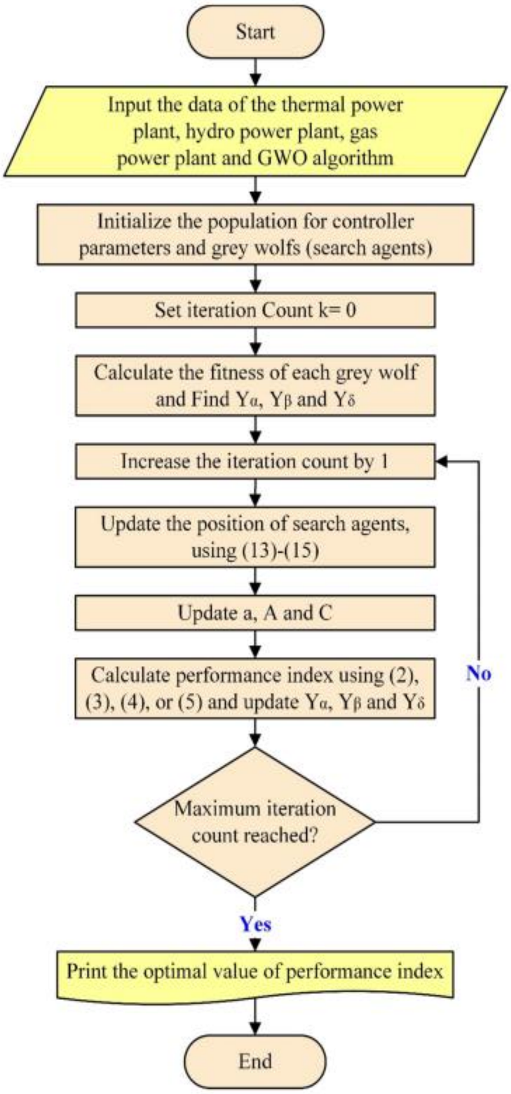

Fig. 5: Flowchart of the Grey Wolf Optimization algorithm for LFC in multi-source single area power network [12]

In this research survey, Grey Wolf Optimizer algorithm has been applied to a multi-source, single-area power network with reheat thermal power plant, gas turbine power plant, and hydro power plant with mechanical hydraulic governor.

D. Particle Swarm Optimization (PSO)

The algorithm selected to solve the issue is a meta-heuristic population-based approach. Kennedy and Eberhart introduced PSO, a well-known population-based optimization method, first.

- Step 1: Initialization of parameters such as swarm size, iterations, acceleration coefficients, inertia weight, search area boundaries, and velocity. Within the limits of the search area, the particle positions are initially set at random.
- Step 2: At the specific moment, the value of the objective function is determined.
- Step 3: Numbers of the particle's best position (pbest) and the world's best position (gbest) were obtained.
- Step 4: The swarm particle's position and speed are restructured.
- Step 5: The algorithm ends when the objective function is minimised and the maximum number of iterations has been achieved.
- Step 6: The elements' desirable values are identified.

IV. THE BASIC ARCHITECTURE OF HESS

In order to maximise revenue (or reduce total price) from HESS, an optimal control method has been designed in this study to sync the slow unit's response time, which is greater than a minute, and the rapid energy storage unit (having response time less than 1 minute).

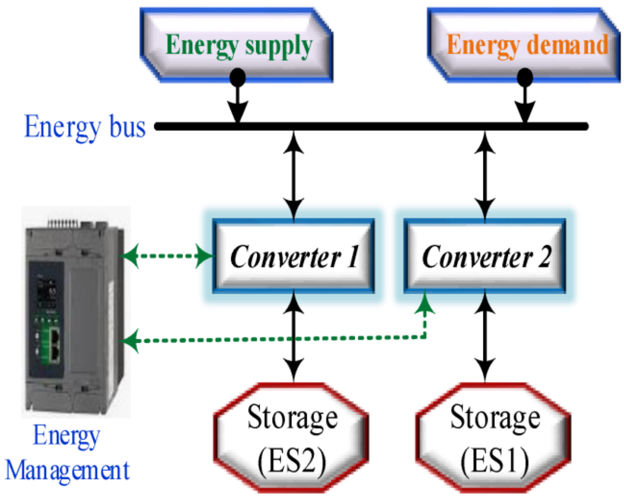

Fig. 6: The basic architecture of HESS [13].

A. Rule based energy management strategy

The control design variable is the electric machine's maximum power output while just operating on electricity. The electric machine's overall power and efficiency parameters are determined by its maximum power level.

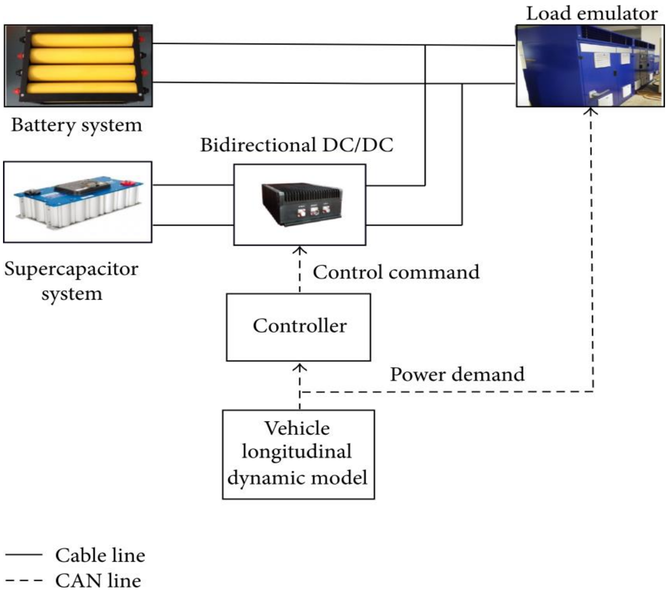

Fig. 7: Rule based energy management strategy [14]

B. Main issues and challenges of Hybrid energy storage system

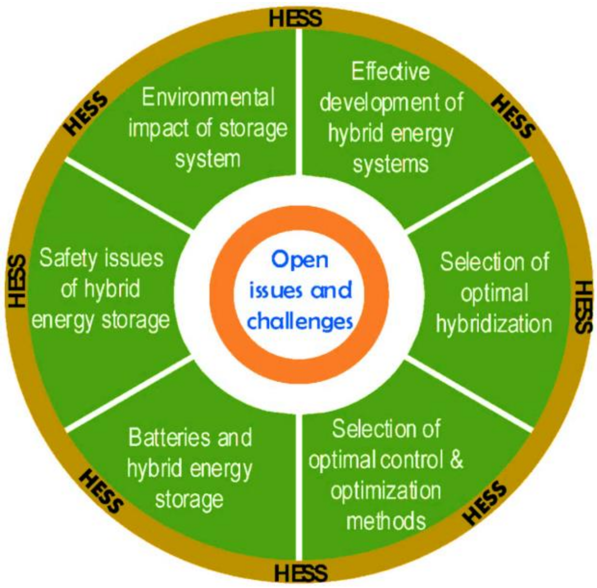

Fig. 8: Main issues and challenges of HESS [13].

Methods	CoS	CT	ToS	RoPK
FL	No	Small	Global	Yes
PSO	No	Medium	Global	No
PMP	No	Small	Local	Yes
GWO	No	Medium	Global	No
DP	Yes	Medium	Global	Yes
MPC	No	Small	Global	No
NN	Yes	Small	Global	Yes

Table 1: The evaluation of different EMS methods based on each parameter

Where,

CoS= Complexity of Structure
CT= Computation Time
ToS= Type of Solution

RoPK= Requirement of Prior Knowledge PSO Particle Swarm Optimization [20]

V. SUMMARY

In this study we come to know that various control algorithms for different models and their significance also future research directions towards control strategies. If the conventional, recognisable driving pattern is taken into account, optimization technique significantly extends life of the hybrid energy storage system. However, they do not resolve the inconsistent driving cycles. In general, improved battery life is significantly influenced by optimal control techniques, but very efficient fuzzy-based solutions are available for varying drive cycles. Additionally, GWO in ESS incorporating fuel cell reduces changes in currents and ensures against imbalance of the battery's SOC. The benefits of fuzzy-based control and optimization approaches are combined in the PMP technique, and RMS current of the battery in hybrid energy storage system is significantly reduced.

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