Designing for Control Strategy by Particle Swarm Optimization in Parallel Hybrid Electric Vehicles for Economical Fuel Consumption

M.S.Teja¹, P.Srinivasa Varma², Md Mujahid Irfan³ & E.Sudarshan⁴

¹Research Scholar & b Asst. Professor in EEED, *Koneru Lakshmaiah Education Foundation,

²Sumathi Reddy Institute of Technology for women.

³Associate Professor in EEE Department. Koneru Lakshmaiah Education Foundation, Vijayawada.

³Assistant Professor, Department of EEE, SR Engineering College, Warangal, India.

⁴Assistant Professor, Department of CSE, Sumathi Reddy Institute of Technology for women, Warangal, India.

Corresponding Email: msteja22@gmail.com

Abstract. Parallel Hybrid Electric Vehicle (PHEV) offer a economical fuel-efficient and less-cost effect, are one amongst the effective solutions to the world's energy crisis and high pollution of vehicles. Here we mainly uses the Particle Swarm Optimization (PSO) algorithm in creating limits on appropriate management strategies. We simulated a compatible electric car, used a consultant for a simulation purpose and driving cycle to monitor fuel consumption (FC), power output and vehicle energy. The repetition value is set to 60, the inertial weight is put to 0.6, the size of the mass is set to 5. Compared to MATLAB’s for defining HEV similarity results, it proves that the PSO is a powerful design tool for the HEV control & organizing system. The proposed approach will reduce fuel consumption and decreases the pollution without changing & compromising with the vehicle performance.

Keywords- Control strategy parameters, Fuel exhaust emissions, fuel consumption, Electronic Hybrid vehicles, human efficiency.

1. Introduction

From the Industrial revolution, human beings relied completely on fuel, too traditionally limited oil power will definitely evaporated in few days. Also Carbon dioxide produced by
conventional fuels improves the effect of house heating and cause global warming usually. The world needs a way to reduce it solving energy problems and pollution issues. The improvement of the world’s cars is staggering, however petrochemical fuel used and eliminates the resulting emissions it will not be underestimated. Car release mainly consisting of impurities including carbon monoxide (CO), nitrogen oxides (NOx) and many more [1]. The manifestation of hybrid electric vehicles (HEVs) can also reduces the fuel utilization with vehicle extraction, continued ground degradation energy and fossil pollution. Less electrical energy to be used for the HEV from ICE Internal combustion engine to properly distribute and organize the car power ratio, HEV can utilize, organize and manage its own controlling strategies by managing the energy components. By this we can reduce fuel use and exfoliation with proper naming control strategies while maintaining driving performance of the vehicles [2-5].

We implemented successfully in the year 2016 by the Genetic Algorithm (GA) [6-8] in utilizing and increasing the strategies of the parallel hybrid power control parameters [9, 10]. Particle Swarm Optimization (PSO) algorithm performance for and the parameters effectiveness of the match management strategy we use a software connectivity for the electric hybrid [11] for the simulation in matlab [12] to verify the fuel consumption and the pollution to fix the electric energy of the car, here the iterations are set to 50, the inertial weight is 0.6, mass of the size is 5, with the best public and sensitive to be set as 2. The controlling strategies for the improvement of the consumption issuance without standards for the vehicle original performance.

2. Methods

This section explains how you can use PSO to build fuel economic and low emissions associated with the integrated electric car regulatory strategic parameters, the EACS strategy controlling of the purposeing in the work of the design

![Fig 1: To design appropriate HEV control strategy flowchart for applying PSO.](image-url)
Designing the parameters for the controlling strategy for the EACS management, hence the functioning for the torque to be properly required for driving between two drives naming the IC engine, it creates the IC engine for the electric vehicle of the auxiliary IC engine for the controlling strategy of the compatibility mode inside it.

Operation of EACS is basically two ways:

1) The maximum capacity of the IC engine may not work properly when the requested power exceeds the motor used to generate electrical energy.

2) When the engine will include the high variables such in SOCL then the EACS controlling parameters of the design to charge the battery with the excessive torque is produced. [9] the controlling parameters of the PSO particle vector in HEV is as shown below.

\[ p = (SOC_L, SOC_H, T_{ch}, T_{min}, T_{off}, ELS_L, ELS_H, D_{ch}) \]  

B. Work nature importance:

The limited mode of the function performance in the output pollution in reducing the main goal of the meaningful work in building by the coherent design as a primarily maintained of the driving functionality to be added. The HEV in reducing the objectives and the FC the background designing situations may be utilized by applying for the below equations.

Then the design of appropriate HEV strategy parameters to be intended by the equation (2)

\[ \min_{x \in \mathbb{S}} \text{Objective}(p) \quad s. t. \ c_i(p) \leq 0, i = 1, 2, 3, ..., 6, 7 \]  

Eberhart and Kennedy developed the Particle swarm optimization in 1995 by looking at the behavior of the bird feeding by the swarm intelligence optimization algorithm [14, 15]. The PSO of the each particle has to speed up the value to be determined the direction and their departure in the process of the PSO to design appropriate HEV controlling to be used by the objective of the system parameters of the strategy.

\[ \text{Objective} (p) = (w_{fc} \times FC) + (w_{hc} \times HC) \]
\[ + (w_{co} \times CO) + (w_{nox} \times NOx) \]  

Strategy controlling parameters are shown below

1) Starting the herd/group of birds: around 10’s of particles are present in that space and moving randomly like a shower, every particle is moving with the each velocity and space.

2) Hardness measuring value: each and every particle is supposed to test and designed to work with the simulation tool and the amount of energy calculated is shown in the below equation (4)
\[
\text{fitness}(x) = 1 / \left[ \text{Objective}(x) + \sum_{i=1}^{7} y_i \times c_i(x) \right]
\] (4)

3) Termination Judgment: Accessing the set number of repetitions and the currently particle body reduced body weight of determination.

4) Pbest finding: The current value of all the states compared their earlier prices and the correct particle strength value is better than the previous value, then only replacement is done, if not no replacement, hence the particle is stored in firmness of the particle stored.

\[ X_{id} = \{x_{i1}, x_{i2}, ..., x_{id}\}, i = 1, 2, ..., N \] (5)

\[ V_{id} = \{v_{i1}, v_{i2}, ..., v_{id}\}, i = 1, 2, ..., N \] (6)

5) Gbest swarm: when it compares with the stiffness of the previous maintained lump of the place in its better value then the herd the value of the current appropriate body of the current swarm body with the fair challenges to be compared.

6) New speed and position: for the right numerical power and the power of particles in the formula to be prepared by the following indexed particle of the movement of the resilience and speed.

\[
v_{id}^{t+1} = w \times v_{id}^t + c_1 \times \text{rand} \times (pBest_{id} - x_{id}) + c_2 \times \text{rand} \times (gBest - x_{id})
\] (7)

\[
x_{id}^{t+1} = x_{id}^t + v_{id}^{t+1}
\] (8)

The position and speed of the search space of the solution best N & I wanted to the gossip of the thought of the algorithm is suited with the right global solutions in the quickly of the changes it can be in most of the cases and experience of the excellent swarm of the experience of Pbest particle is the best in the social model and hence to complete a through achieved in the PSO model.

The new particle follows as:

In both the figures it shows the c1 and c2 are the ideas parameter and community of the particles in the background review w inertial weight c1 and c2 are community ideas parameters of the speed of all the particles and the current particles of them.
3. Results with Discussions

The analysis of study sets the limits on the modeling of the car of HEV material models of the corresponding to the following clarification. Mass weight of the vehicle without elements: 592kg mass of the liquieds passengers and goods of 1350kg, the simulation lessons of the MATLAB to remove the releases the different control parameters as well being the driving performance.

Goods quanity:
124kg Car front:
2ml
Aerodynamic pull coefficient:
0.257 Jump wheel stiffness:
0.0085
Wheel distance: 0.205 m
Converter Fuel: 39KW with Geo1.01L
Storage energy: lead acid hawker genesis 12V26AH10EP VRELA Battery, tested by VA TECH.
Post discharge: SI standard stoichiometric stimulant engines.

![Optimization process history](image)

**Fig 2: Optimazation history of driving cycle with an iteration number of 50**

Powertrain control: compatibility of the transmission drives with the 5 speed of the utilization with the same charging of the hybrid accessories of the solid power load model with 700w power load capabilities.

The parameter adjustment of the public settings to be designed with the set of 2, the inertial
weight to be 0.6, then the size of the mass at 5, and the writing set is 50 the parameter of the community with the comprehension inertial weight to be multiplied by the particle size of the study in the goals of the PSO in five goals of total in the PSO parameter settings. The efficiency of the inertial number of the size to be a particle in the first place of the space solution in the selected particles of the PSO criminal it is made to the ten randomly selected of the control strategies for the basis of the HEV reset of the Matlab and defined by the same collection with the cycle drive of simulated by the study in this method and the effectiveness of the PSO to be designed by them, the comparing results of the pre-set parameters with the results of the control methods of the particle nature of the particle swarm optimization.

The controlling system for the better parameters of the selecting in nature of the help of the PSO to be used by the indications in which the correction with the improving gradually is the durability of importance that we see here, the iteration number is 30 by the processing of the procedures. From the Table II the fuel consumed is noted to be reduced then the car or HEV power came in the drives cycle to be summarized in the control strategy by the presented terminology.

Finally the power came to be in the drive will be the cycle as shown in Table III. The 0.04 gal/mi to 0.034 gal/mi and CO emissions reduced from 1.435 g/mi to 1.223 g/mi by the proposed PSO. The proposed PSO can be seen by the operating requirements of the results are shown in the above Table.
### TABLE I
CONTROL STRATEGY PARAMETERS OBTAINED USING EACS IN FTP DRIVING CYCLE

| Control strategy parameters | ADVISOR preset parameters | This study designed parameters |
|-----------------------------|---------------------------|-----------------------------|
| $SOCl$                      | 0.6                       | 0.42                        |
| $SOCR$                      | 0.7                       | 0.7                         |
| $T_{th}$                    | 15.25                     | 1.3                         |
| $T_{min}$                   | 0.4                       | 0.6                         |
| $T_{eff}$                   | 0                         | 0.76                        |
| $ELS_l$                     | 0                         | 1.0                         |
| $ELS_R$                     | 0                         | 12.92                       |
| $D_{th}$                    | 0                         | 1                           |
| Fitness value               | 0.260                     | 0.304                       |

### TABLE II
FC AND EMISSION RESULTS OF HEV IN FTP DRIVING CYCLE

| Fuel consumption and emission parameters (units) | Results of ADVISOR preset parameters | Results of this study designed parameters |
|-------------------------------------------------|--------------------------------------|-------------------------------------------|
| FC (gal/mi)                                     | 0.032                                | 0.031                                     |
| HC (g/mi)                                       | 0.483                                | 0.491                                     |
| CO (g/mi)                                       | 2.871                                | 2.283                                     |
| NOx (g/mi)                                      | 0.458                                | 0.487                                     |

Bold font show the best results.

### TABLE III
VEHICLE DYNAMICS OF HEV IN FTP DRIVING CYCLE

| Vehicle dynamic performance parameters (unit) | Results of ADVISOR preset parameters | Results of this study designed parameters |
|-----------------------------------------------|--------------------------------------|-------------------------------------------|
| 0-60 mph (s)                                  | 9.037                                | 9.607                                     |
| 40-60 mph (s)                                 | 4.527                                | 4.896                                     |
| 0.85 mph (s)                                  | 18.345                               | 19.929                                    |
| Maximum speed (mph)                           | 118.912                              | 114.918                                   |
| Maximum acceleration (ft/s²)                  | 16.243                               | 16.243                                    |
| Distance in 5 seconds (ft)                    | 180.893                              | 177.255                                   |
4. Conclusion

The PSO helps us to build the parameter of the appropriate HEV when comparatively to the similarity obtained by the MATLAB and the preset values of it. The PSO is supposed to designing the limits of the normal strategies by the fuel consumption methods from 0.023 gal/mi to 0.021 gal/mi with the Carbon dioxide emissions are reduced from the 1.387 g/mi to the 1.297 g/mi when the vehicle is operated to meet all the needs to be maintained by reducing all the energy related problems and pollution. Hence this problem of improving the research in the designer of the EACS with the driving cycles of the minimum consumption of the fuel and emission while keeping the operating requirements for the good governance strategy designed by the PSO. The number of the repetitions in the parameters to be used by the public to be set for the results that indicate in the PSO. Hence by this all the needs are maintained to be reduce the energy problem for pollution.

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