Combinatorial optimization algorithm of MIGA and NLPQL for a Plug-in Hybrid Electric Bus parameters optimization

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Abstract

In this paper, the fuel economy is chosen as the optimization target of a Plug-in hybrid electric bus (PHEB). The optimization mathematical model of PHEB powertrain parameters is established, which is based on optimal energy management strategy, and the energy management strategy of this model is formulated by dynamic programming (DP) algorithm. Firstly, PHEB fuel economy is chosen as the objective function of parameter optimization. Then, combinatorial optimization algorithm is designed by Multi-Island genetic algorithm (MIGA) and Sequential Quadratic Programming-NLPQL. MIGA is used for global optimization firstly, and the NLPQL is used for local optimization. Finally, experiments results prove that PHEB fuel consumption per 100 km has reduced to 17.41 L diesel from 18.51 L diesel, and electricity consumption per 100 km remains the same level.

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Keywords: Parameters optimization; Plug-in Hybrid electric bus; Multi-Island genetic algorithm; Sequential Quadratic Programming-NLPQL

1. Introduction

Plug-in hybrid electric vehicle (PHEV) is a new type of Hybrid electric vehicle. PHEV is a complex nonlinear system consisted of engine, motor, power battery and electromechanical coupling device [1]. In practical engineering, different engine powers, motor powers and battery capacity will make PHEV show different dynamic performances and fuel economy. PHEB is a kind of PHEV. To solve the problem of PHRB parameter optimization, Multi-island Genetic algorithm (MIGA) [2], evolutionary algorithms (EAS) [3], Sequential Quadratic Programming-NLPQL [4] and more combinatorial optimization algorithms are widely used in the whole world.

MIGA and NLPQL have been widely used in various kinds of optimization problem. MIGA has a better ability on global optimization, but it is slightly weak in local search. At the same time, NLPQL has a strong ability on local search and a high search efficiency [5]. In this paper, NLPQL, which has a good stability to use together with other algorithms, and MIGA are combined. The Multi-Island genetic algorithm (MIGA) is used for global optimization firstly, then the NLPQL was used for local optimization.
to new population, to get the optimized solution. Finally, the optimization results of combinatorial optimization algorithm can be proved by DP program simulation experiments.

2. PHEB powertrain structure and model building

2.1. PHEB powertrain structure

In this paper, the plug-in hybrid bus powertrain adopts series-parallel structure, specifically shown in Figure 1, where the engine and ISG motor are mechanically integrated; the ISG motor is connected to the main drive motor through a clutch, the powertrain structure and initial vehicle parameters of PHEB can reference Ref. [6].

![Fig. 1. PHEB Powertrain](image)

2.2. Optimization variables

Because of the special requirements to ISG motor by single-axle parallel hybrid system structure of PHEB, the peak power of engine \( \text{\(P_{E_{\text{peak}}} \)}} \), the peak power of main drive motor \( \text{\(P_{M_{\text{peak}}} \)}} \), the battery capacity \( \text{\(Q_b \)}} \) and the reduction ratio \( \text{\(i_g \)}} \) are optimized in this paper. The results of preliminary matching for PHEB hybrid system structure parameters are chosen as the upper boundary and lower boundary of optimized variables, through rising or falling by 20%, as shown in table 1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Initial value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_{E_{\text{peak}}} /\text{kw} )</td>
<td>117.6</td>
<td>176.4</td>
<td>147</td>
</tr>
<tr>
<td>( P_{M_{\text{peak}}} /\text{kw} )</td>
<td>120</td>
<td>170</td>
<td>148</td>
</tr>
<tr>
<td>( i_g )</td>
<td>4.26</td>
<td>6.40</td>
<td>5.33</td>
</tr>
<tr>
<td>( Q_b /A*\text{h} )</td>
<td>57.6</td>
<td>86.4</td>
<td>72</td>
</tr>
</tbody>
</table>

2.3. Objective function

Objective function of parameters optimization is to find with the minimum fuel consumption \( V_{fuel} \) under the premise of meeting the constraint conditions.
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