



# Research on Optimized Working Cycle Algorithm for Hybrid Rolling Stock

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# Self Introduction

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## Education

2010-2013: Harbin University of Science and Technology,  
**China**  
PHD/Mechanical Engineering

2008-2010: Harbin University of Science and Technology,  
**China**  
Master/Mechatronic Engineering

## Work Experience

2019 – today: **CRRC ZELC Verkehrstechnik GmbH**  
Head of R&D Center

2013 – today: **CRRC Zhuzhou Locomotive Ltd.,**  
Department Manager

# [Outlines]



- I. Why hybrid
- II. Hybrid topology
- III. Working cycle optimized algorithm
- IV. Simulation

# enviroment

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Rail accounts for 8% of global passenger travel and about 7% of freight activity, but only 2% of transport energy use.

Compare to road transport and aviation, rail transportation is much more efficient.

However, we still have space to reduce emmission and energy consumption.



# electrification

## Proportion of electrified lines in the state railway network

in selected European countries 2018



Almost 30% rail line is not electrified in Austria and 40% in Germany.

# Challenge

## diesel rolling stock:

- Greenhouse gas emission is high.
- Big noise and air pollution, especially in tunnel.

## Electrification cost:

- over 200 million euro per kilometers

## EU policy :

no diesel locomotive will be used in 2050

*So, what is the solution now?*

**NEW ENERGY HYBRID** (super capacitor, battery, fuel cell, etc.)



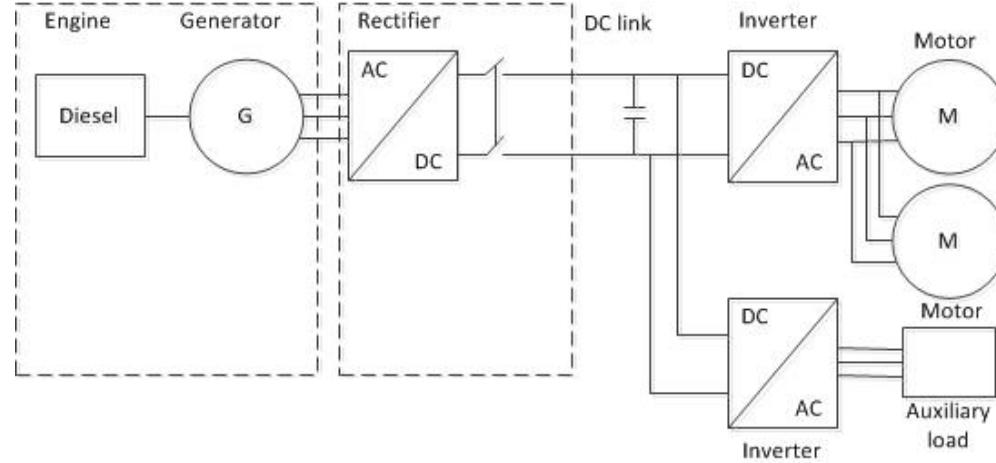
# [Outlines]



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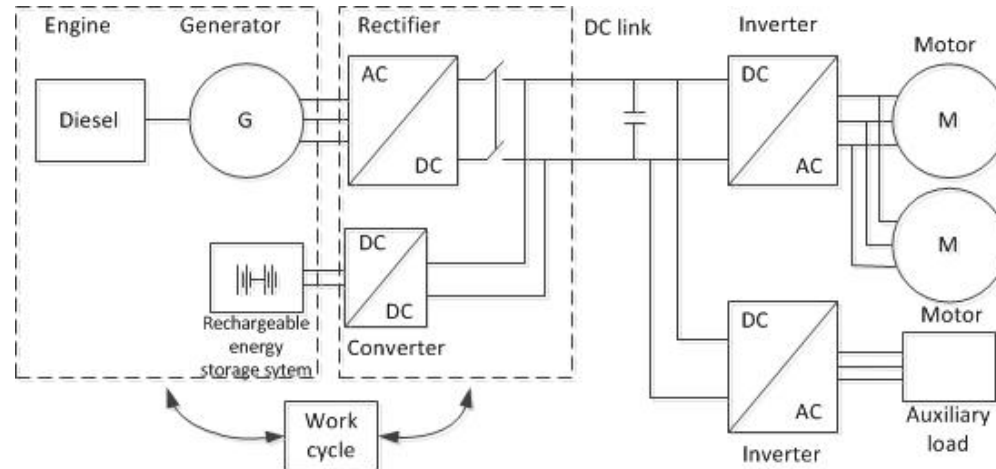
# What is hybrid

diesel rolling stock  
topology



hyrid rolling stock  
topology

use an onboard rechargeable  
energy storage system  
placed between the power  
source and traction  
transmission system



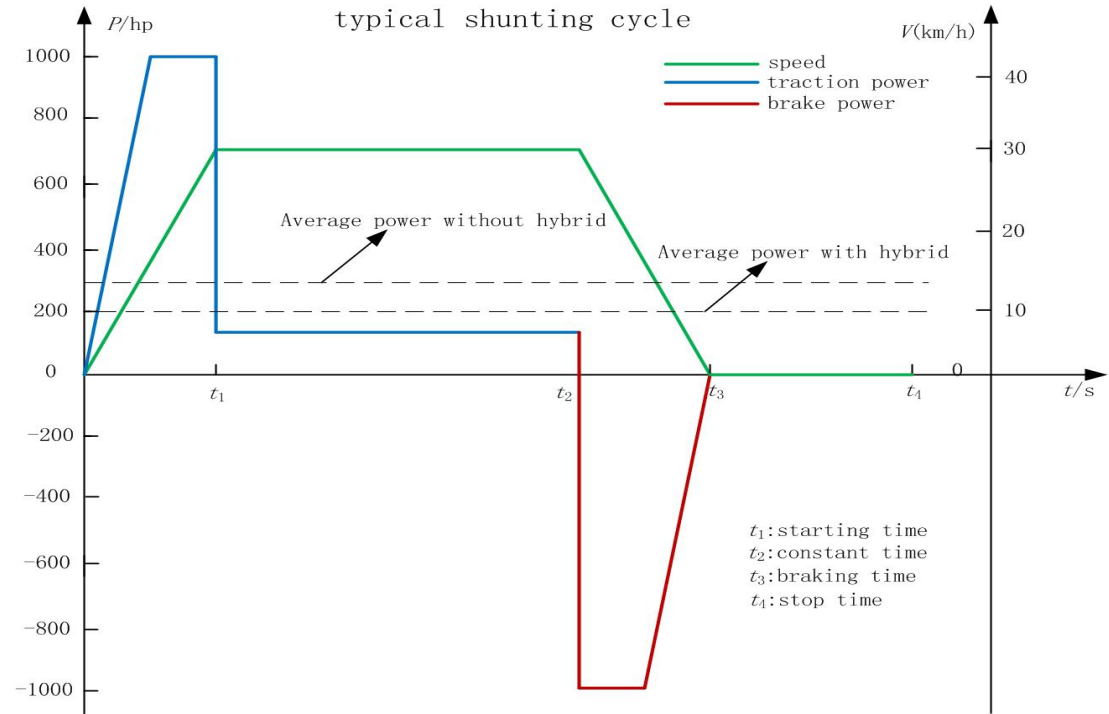


# Advantages

an example shunting loco with diesel engine and supcapacitor

lower average power:  
means lower emission  
and lower energy  
consumption

diesel engine VS  
supcapacitor: supcapacitor  
means lower noise and  
vibration



# Question

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question: how to realize the advantages aforementioned.

when diesel engine should put into use?

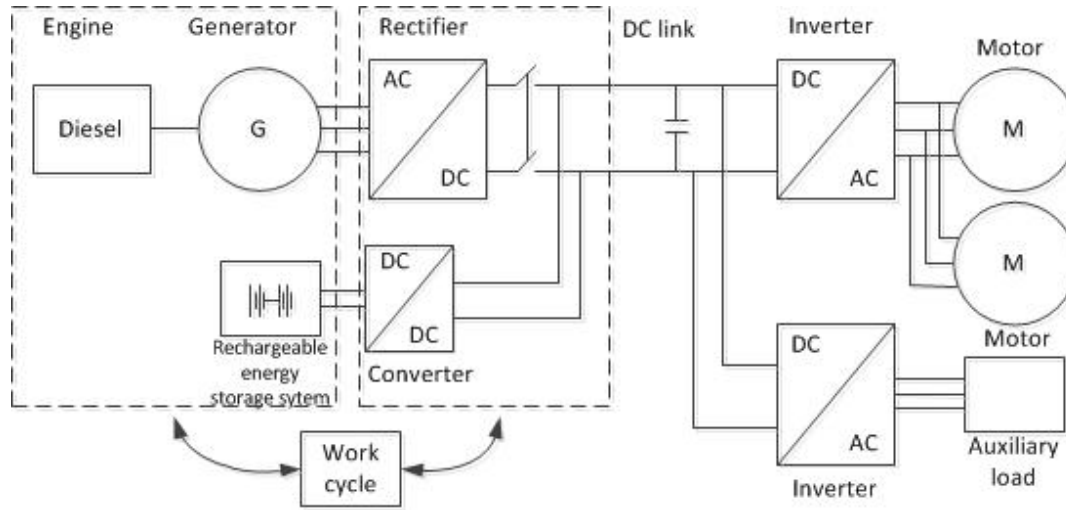
When rechargeable energy storage system should put into use?

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# Topology



**energy source:**

diesel engine+battery

**work cycle control:**

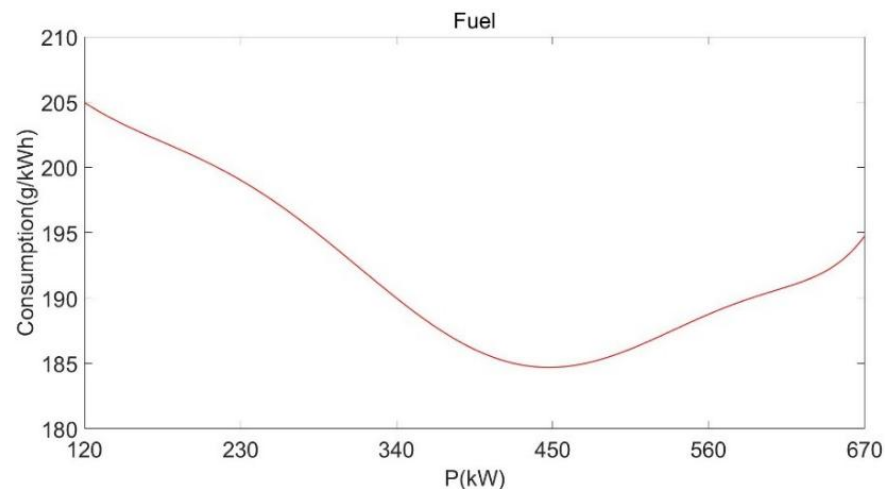
By controlling the AC/DC rectifier and DC/DC converter, we can control the work cycle of diesel engine and battery



# Basic requirements

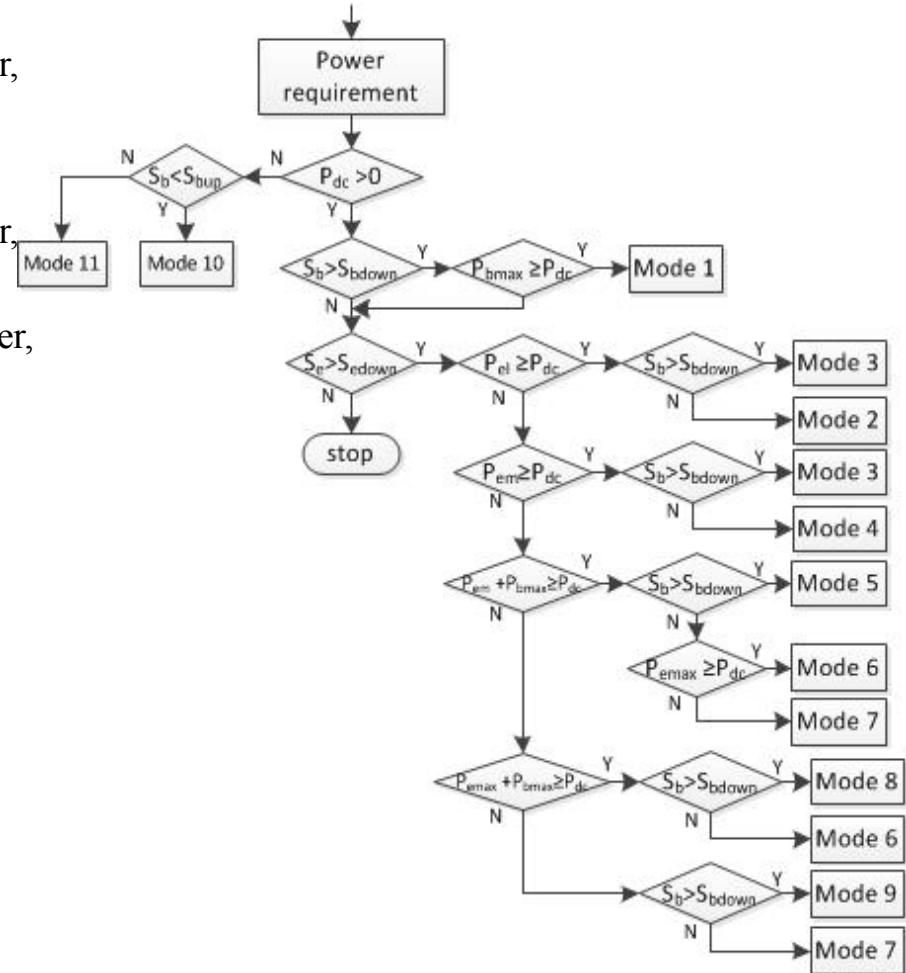
## basic requirements:

- (1) The first option of the energy used to support DC link is battery system, while diesel engine system is the second choice.
- (2) The regenerative brake energy will be used to charge battery system firstly, and the redundant will be dissipated by brake resistor.
- (3) Diesel engine system should work at optimal fuel consumption area as much as possible.



# Algorithm

- Mode 1, only battery output power
- Mode 2, diesel engine work in optimal area to output power, while battery is charged in high-power
- Mode 3, diesel engine output.
- Mode 4, diesel engine work in optimal area to output power, while battery is charged in low-power
- Mode 5, diesel engine work in optimal point to output power, while battery supplies the rest needed power.
- Mode 6, diesel engine work in maximum power to output power, while battery is charged in low-power
- Mode 7, diesel engine work in maximum power to output power
- Mode 8, diesel engine work in maximum power to output power, while diesel engine supplies the rest needed power.
- Mode 9, battery and diesel engine all work in maximum power
- Mode 10, battery is charged by regenerative brake power
- Mode 11, regenerative brake power dissipated by brake resistor



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# Rolling stock parameters

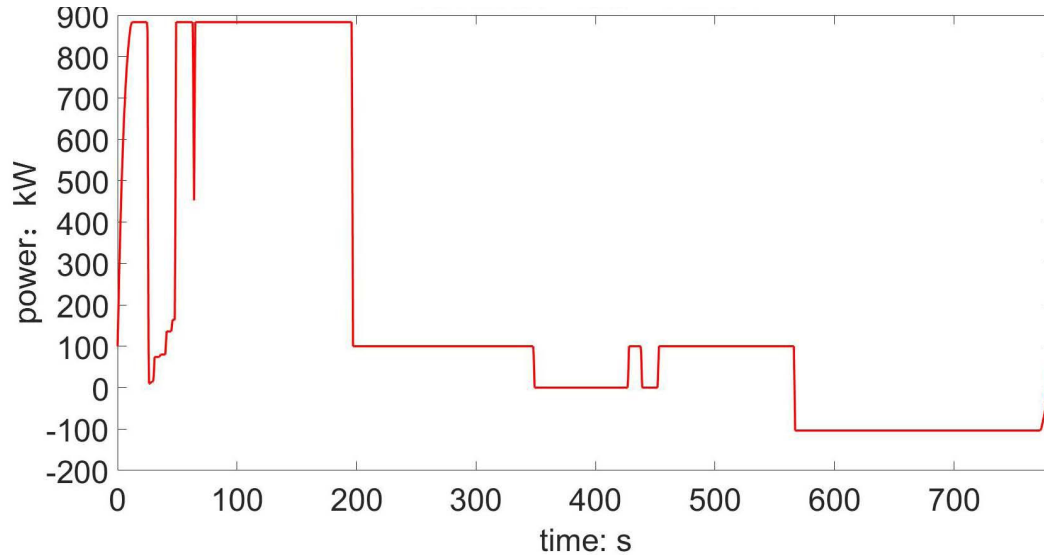
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number	parameters	value
1	locomotive weight	64t
2	axle load	16t
3	axle arrangement	B <sub>0</sub> -B <sub>0</sub>
4	motor rate power	4*670kW
5	diesel engine max power	670kW
6	battery max power	250kW
7	locomotive max speed	100km/h





# Required power curve



assumption: the required power curve used in this paper to simulate is shown in leftside.

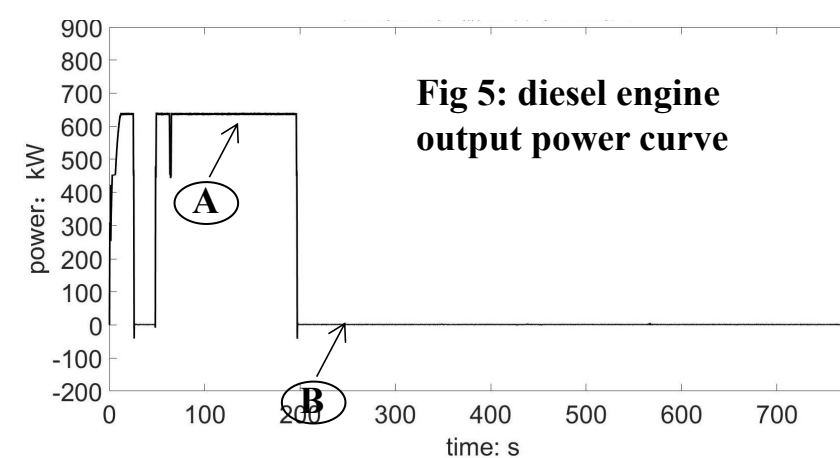
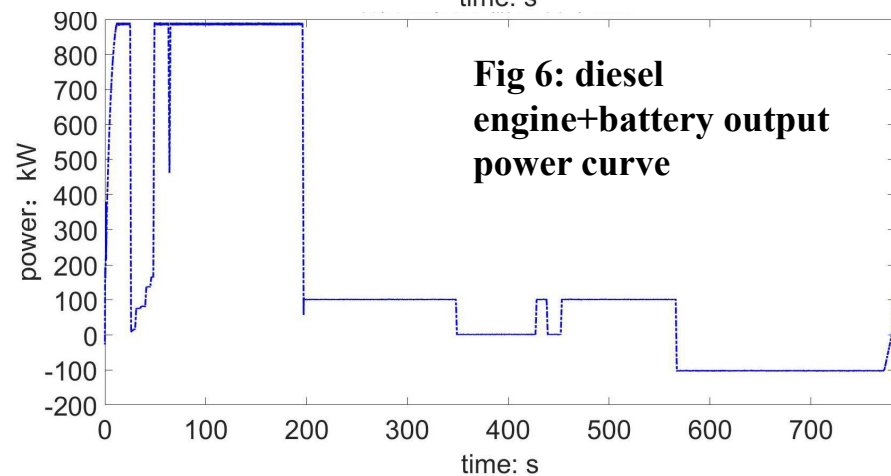
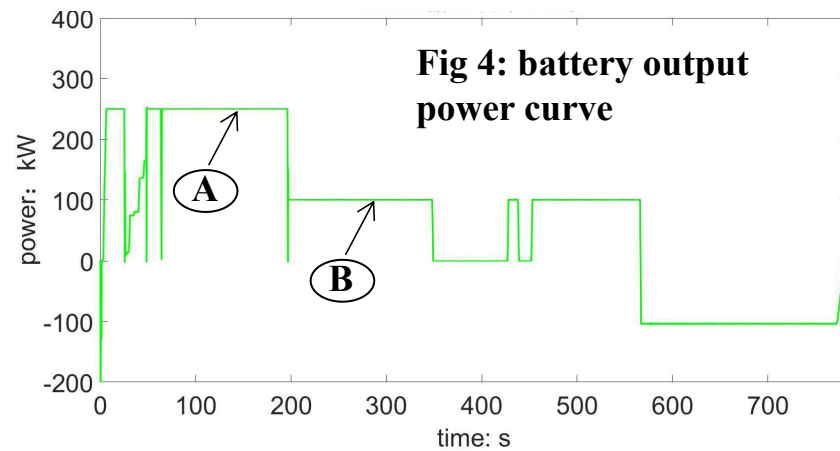
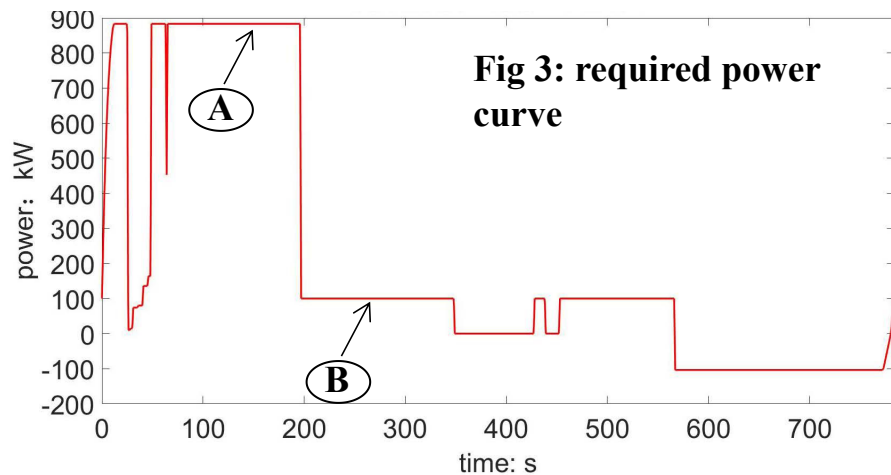
max required power: 890kW

max output power(battery)  
:250kW

max output power(diesel engine)  
:670kW

optimum fuel consumption point(diesel engine)  
:450kW

# Simulation results



# Summary

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By comparing Fig. 3, Fig. 4 and Fig. 5, we can see that when the required power of vehicle exceed battery's maximum output power and the rest energy in battery is more than its lowest limit, battery will output its maximum power and diesel engine will supply the rest needed power. **(area A)**

When the required power of vehicle is less than battery's maximum output power and the rest energy in battery is more than its lowest limit, battery will supply power to DC link separately. **(area B)**

In a word, the algorithm's simulation output power curve can follow the vehicle's power requirement curve exactly.



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