MODELLING OF BRAKING SYSTEM ON SERIES HYBRID ELECTRIC VEHICLE APPLICATION

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DECLARATION

I declare that this project report entitled "Modelling of Braking System on Series Hybrid Electric Vehicle Application" is the result of my own work except as cited in the references

Signature : .....

Name : Muhamad Firdaus Bin Mohd Yussof

Date : .....

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive).

Signature :. .....

Name of Supervisor : Dr. Adzni Bin Md. Saad

Date : .....

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DEDICATION

This report is dedicated to my beloved mother, family and my friends who have been supported and encourage me during my studies.

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ABSTRACT

Nowadays, the vehicle fuel price especially gasoline and diesel have been increased significantly. This increased make driver and consumer more interested toward conventional vehicle that can reduce the fuel consumption and hybrid electric vehicle which have low fuel consumption. The objectives of this study are to develop mathematical model of braking system for series hybrid electric vehicle application. The simulation is run toward the regenerative braking model to get the vehicle performance. Then, this study is to investigate the braking system behaviour on the vehicle performance. In this project, the investigation only based on the mathematical model simulation without any experimental work involved. At the beginning of the project, find the suitable sample of the braking parameter from various resources to use in the simulation of the project. From the simulation, the result of the vehicle performance such as the battery SOC, vehicle speed and the fuel consumption will be discussed. The vehicle weight is being change to investigate it influence toward the vehicle performance. When the weight of the vehicle increase, the fuel consumption of the vehicle will decrease because of the speed of the vehicle also decrease.

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ABSTRAK

Pada masa kini, harga bahan api kenderaan terutamanya petrol dan diesel telah meningkat dengan ketara. Peningkatan ini membuatkan pemandu dan pengguna lebih berminat ke arah kenderaan konvensional yang boleh mengurangkan penggunaan bahan api dan kenderaan electrik hibrid yang mempunyai penggunaan bahan api yang rendah. Objektif kajian ini adalah untuk membangunkan model matematik sistem brek untuk kenderaan elektrik hybrid sesiri. Simulasi dijalankan terhadap model brek regeneratif untuk mendapatkan prestasi kenderaan. Kemudian, kajian ini adalah untuk menyiasat perubahan sistem brek terhadap prestasi kenderaan. Dalam projek ini, siasatan hanya berdasarkan simulasi model matematik tanpa melibatkan sebarang kerja eksperimen. Pada permulaan projek, sampel yang sesuai untuk parameter brek dari pelbagai sumber dicari untuk digunakan dalam simulasi projek. Hasil dari simulasi, prestasi kenderaan seperti SOC bateri, kelajuan kenderaan dan penggunaan bahan api akan dibincangkan. Perubahan berat kenderaan dilakukan untuk menyiasat kesannya terhadap prestasi kenderaan. Apabila berat kenderaan meningkat, penggunaan bahan bakar kenderaan akan berkurangan kerana kelajuan kenderaan juga berkurangan.

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LIST OF ABBREVATIONS

HEV	Hybrid Electric Vehicle
HV	Hybrid Vehicle
EV	Electric Vehicle
BEV	Battery Electric Vehicle
ICE	Internal Combustion Engine
RBS	Regenerative Braking System
ESS	Energy Storage System
SOC	State-Of-Charge

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CHAPTER 1

INTRODUCTION

1.1 Background of study

1.1.1 Hybrid electric vehicle (HEV)

Improving fuel efficiency and reducing emission produce by vehicles have been important task to the automobile industry in this crucial time being because of the awareness to the global crude oil supply and the greenhouse effect which can harm people. Hybrid vehicle (HV) development is one of the solution that have been carried out to solve the problem which can reduce emission while having much better fuel consumption vehicles(J. Liu & Peng, 2007). Hybrid vehicle (HV) technology is the vehicle that have two or more power sources.

Hybrid electric vehicles use combination of two power source which are internal combustion engine and the electric motor. There are three types of drivetrain for hybrid electric vehicle which are parallel hybrid, series hybrid and power-split hybrid.

a) Parallel hybrid

For this type of system, the internal combustion engine (ICE) and the electrical motor both are connected to the mechanical transmission(Dao, Seaman, & McPhee, 2010). This two power sources can be simultaneously give the power to drive or move the vehicle by using conventional transmission. Parallel hybrid contains complex control system which lead to high maintenance cost and it also have high probability to breakdown if the settings of the control system is not carefully manage.

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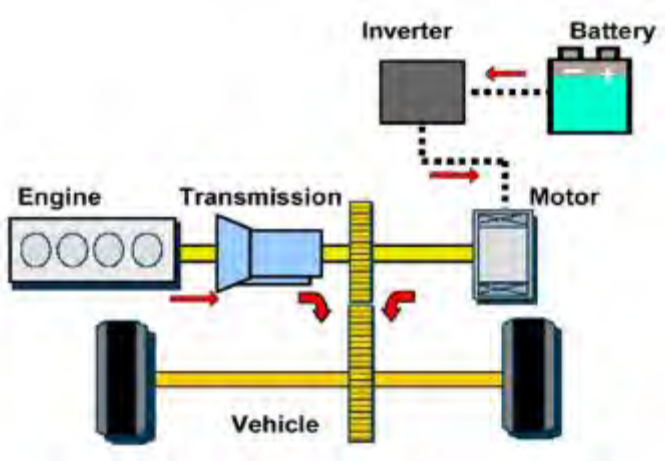

Figure 1.1: Parallel hybrid electric vehicle model

b) Series hybrid

All the components such as ICE engine, electric motor, and battery are in series for this type of drivetrain. The drivetrain is only driven by the electric motor while the ICE engine just acts as generator to recharge the battery that need to supply electric power to the electric motor when required [2]. All the needed power to move the vehicle should go through the generator and electric motor lead to higher traction drive system required for the series hybrid electric vehicle and still it gives many advantages such as better fuel consumption, can operate in longer time, and the ICE engine can operate in its most efficient range even while the vehicle changes speed. This type of drivetrain is the most suitable during stop and go situation in city driving.

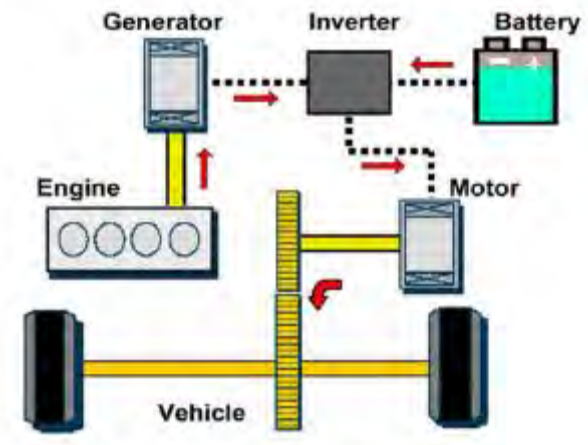

Figure 1.2: Series hybrid electric vehicle model

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c) Power-split hybrid

Power-split hybrid configuration is a combination of the two previous transmission which are series hybrid and parallel hybrid transmission(Dao et al., 2010). This combination hybrid system has a power split planetary gear system was created to achieved both advantages from series and parallel hybrid transmission while keep away from their disadvantages(J. L. J. Liu & Peng, 2006).

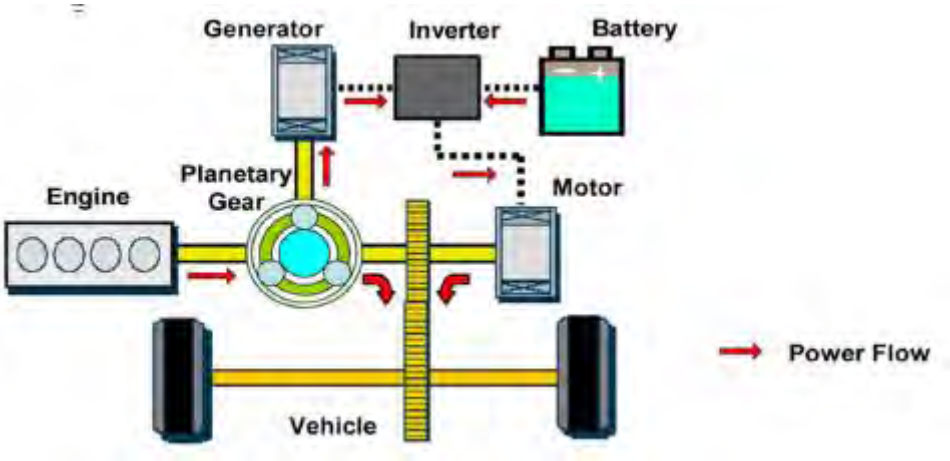

Figure 1.3: Power split hybrid electric vehicle model

1.1.2 Braking system

Braking system is a mechanism use to reduce speed of a vehicle or stop it from moving by pressing a pedal when a vehicle in a moving state(Gupta, Kumar, & Deb, 2014). The type of brakes use in automobiles are disc and drum brakes with various of braking system are used to transmit force from pedal to brakes on wheels(Puttewar, Kakde, & Fidvi, 2014). There are many types of braking system used for vehicle such as:

a. Hydraulic braking system

Hydraulic braking system is a mechanical braking system that use fluid as a medium to transfer from the pedal to the brake pad(Deshpande, 2015). According to the Pascal's law, uniform braking can be applied for each wheels because when a pressured is applied on a fluid, it will distribute equally in all directions(Deshpande, 2015).

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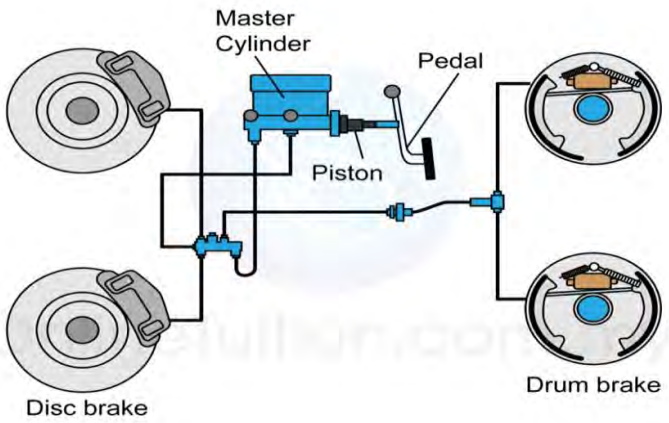

Figure 1.4: Diagram for the hydraulic braking system

b. Pneumatic braking system

Pneumatic braking system is using compressed air to transmit the force to the brake pad to stop the vehicle. This type of braking system usually used in heavy vehicle. Pneumatic brake shows longer delay time because of the air pressured response are much slower than hydraulic brake(He, Wang, Zhang, Wu, & Chen, 2011).

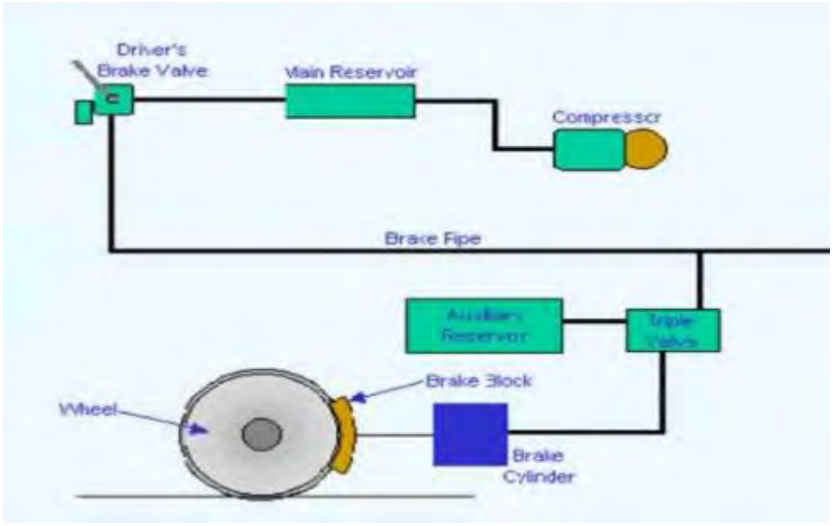

Figure 1.5: Block diagram for the pneumatic braking system

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c. Vacuum braking system

In mid 1860s, a vacuum braking system is installed on train. This type of braking system crate vacuum in brake pipe by using vacuum pump. This vacuum braking system is act as vacuum-assisted hydraulic braking system in most of the light weight vehicle which the vacuum in pipe is creating by the engine of the vehicle. The driver's effort needed to push the pedal can be reducing by creating the vacuum in the brake pipe(Journal et al., 2015).

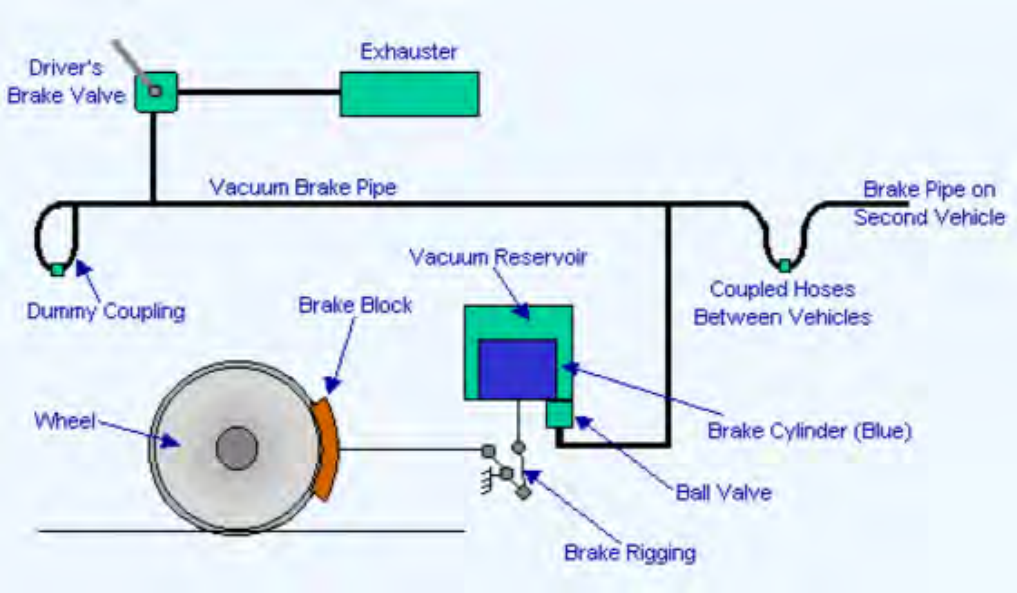

Figure 1.6: Block diagram of basic vacuum brake equipment

While braking a vehicle, the kinetic energy of the vehicle will lose to surrounding as heat energy(N.R.Hema Kumar, 2009). The regenerative braking system was developed to act as energy recovery of a vehicle that slow down by converting it kinetic energy into another form that can be stored and be used when needed(Engineering, P, & Ujjain, 2013).

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1.2 Problem statement

In nowadays worldwide, there are too many vehicles that are using fuel with less efficient which have release more emission to the surrounding that will cause air pollution. Fossil fuel is an unrenewable resource that will be depleted in the future. Vehicles with high efficiency fuel usage are more favourable to be used among the people in order to reduce the use of the fossil fuel.

Besides that, every vehicle waste some generated power as heat energy while braking to slow down or stop the vehicle from moving. Almost 30% of the vehicle generated power are wasted and dissipated into the air as heat that created when friction occur between brake pad and disc on the wheels(Gupta et al., 2014). This heat lost can be converted back and stored as electrical energy which can be reused to move the vehicle. This system of braking known as regenerative braking system and it is a technology that increase the fuel efficiency of a vehicle which can reduce dependency toward the fossil fuel.

1.3 Objectives

There are two main objectives for this project which are:

i. To develop mathematical simulation model of braking system for series hybrid electric vehicle (HEV) application.

ii. To investigate the effects of braking system behaviours on vehicle performance.

1.4 Scope of project

The main purpose of this study is only limited to investigate the braking system performance based on mathematical model simulation without any experimental work involved. This project will be focus on regenerative braking system which is work in series transmission type of the hybrid electrical vehicle (HEV). This project also to study about the influence of changing braking system parameters on vehicle performance.

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1.5 General methodology

1.5.1 Research work

Do some research from different medium such as journals, books, internet and others to get as much as possible the information about the hybrid electric vehicle and braking system. All this information will be useful to fulfil the objectives of this project. Beside that it also can be helpful when to develop the mathematical simulation model of braking system.

1.5.2 Generate the mathematical model

Use all information that was gathered from the research work to generate a suitable mathematical model of the regenerative braking system on series hybrid electric vehicle (HEV) application.

1.5.3 MATLAB Simulink

Building the mathematical model of the regenerative braking system in series hybrid electric vehicle (HEV) by using the MATLAB Simulink software and run the simulation. All the result from the simulation will be recorded and do necessary analysis for those data.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Regenerative braking system technology used to recover energy that lost during vehicles deceleration or stopping while in motion. Hybrid electric vehicle (HEV) currently in use have some means of regenerative braking system to recover energy. Beside the regenerative braking system, the vehicle also still using the conventional braking system (mechanical braking system). This chapter provides an overview of research done so far in the field of the regenerative braking system. The regenerative braking system considered in this study is for series hybrid electric vehicle. The focus of this literature review was to determine what research has been done so far on regenerative braking system. In addition, several vital topics related to regenerative braking are highlighted.

2.2 Series hybrid electric vehicle overview

In series hybrids, the mechanical output from the internal combustion engine is used to drive a generator which produces electrical power that can be stored in the battery or used to directly power an electric motor that will drive the wheels. There is no direct mechanical connection between the engine and the driven wheels. Series hybrid tend to be used in high power system such as large trucks or locomotives but can also be used for lower power passenger vehicles(Hodkinson & Fenton, n.d.). There are many advantages made possible by the series hybrid vehicle such as it is possible to run the internal combustion engine at its most efficient operating point and share its electrical output between charging the battery and driving the electric motor. Emissions can be greatly reduced and the most electrical power can be generated per volume of fuel when the engine at its most operating point. Less complex configuration also causes it easier to implement into a vehicle which makes this method more cost.

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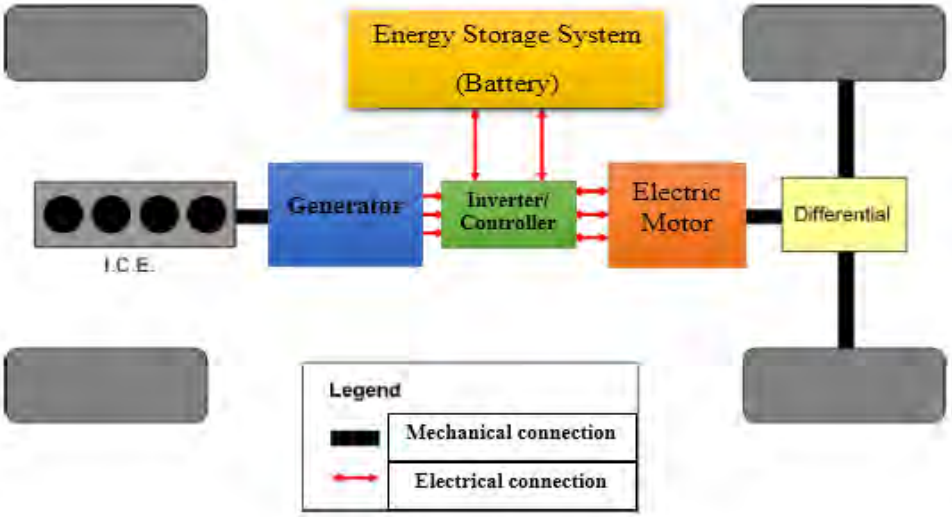

Figure 2.1: Series hybrid configuration

2.3 Regenerative Braking System (RBS)

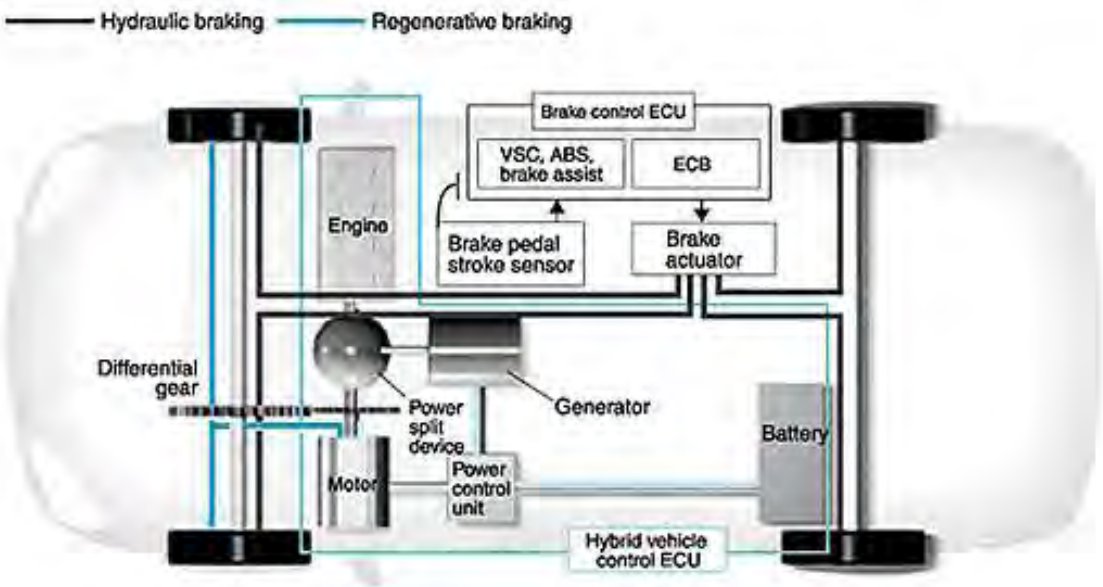

Figure 2.2: Regenerative braking system

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Kinetic energy that always loss to surrounding during braking or deceleration of vehicle could be restored to a battery by using regenerative braking system. Regenerative braking system is an important technology that could drive to zero emission which can reduce pollution to environment and reduce the dependency to the fossil fuel which become the source for the conventional vehicle to move. Conservation of energy have state that energy cannot be created or destroyed but it can be change into different type such as kinetic energy, heat energy, electric energy and others. Regenerative braking system in the hybrid electric vehicle and electric vehicle allows them to use the motor as a generator when the brakes were applied, the kinetic energy during braking will be keep up as electricity in the energy storage system which is a battery or ultracapacitor. This technology is an effective approach to extend the driving range for the hybrid electric vehicle and electric vehicle which can save from 8% to 25% of the total energy used by the vehicle depending on the driving cycle and how it was driven(Bai, Li, & Cao, n.d.).

2.3.1 Regenerative braking system work

When the driver steps on the brake pedal, this type of braking system will put this hybrid electric vehicle's electric motor into reverse mode that cause it to run backwards, thus slowing the vehicle wheels. While running backwards, the electric motor will also act as generator which generated electricity that will be restored into the vehicle's battery. This technique commonly uses in modern electric and hybrid vehicles to extend the range of battery pack.

2.3.2 Methods of regenerative braking

There are two basic method of regenerative braking method that usually used today. These methods are parallel regenerative braking and series regenerative braking. Each of this regenerative braking method have its own advantages and disadvantages.

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