Faculty of Electrical and Electronic Engineering Technology

ENERGY STORAGE SYSTEM OF REGENERATIVE BRAKING IN URBAN RAILWAY BASED ON SUPERCAPACITOR

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DEDICATION

To my beloved parent is Usin bin Amboi and Aliza binti Kadir, the one who support me to get through everything during my studies here. To the most caring Academic Advisor, En Adam Bin Samsudin. To my beloved and the best supervisor, En Adlan bin Ali.

ABSTRACT

A railway electrification system has been used long time ago because of the high power to the weight ratio advantage compare to the diesel and steam systems. The electrification systems generate an electrical power and supplies electrical energy to railway trains and multiple units which is enables for faster expedition and higher tractive power. Using electrification systems it can reduce cost of maintenance especially on the traction units and give a better result in enviroment effect for overall system compare to the othersystems. By using 25 KV AC supply from overhead lines and 750 V that using a third rail system.Supercapacitor (SC) is an energy storage technology that is rapidly developing and being implemented in various industrial applications. This system consists of double-layer supercapacitor, along with the required conditioning choppers and auxiliary devices, necessary to capture and store a transit vehicle's kinetic energy that would otherwise be lost during braking. In Malaysia, train that using supercapacitor as energy storage for storing braking energy for reuse during acceleration is KTM Class 61 (Keretapi Tanah Melayu) but powered by on board diesel multiple unit or DMU. This project propose focus on modeling and analyze the energy storage inelectrification train using supercapacitor. Supercapacitor is a common component which is used in electric vehicle or electrification train system. It has higher power density to store energy. It has higher power to discharge process are studied and investigated. This project focus on stored and recycled wasted energy by using Energy Storage System (ESS). 30 V lead acid battery, 16 V supercapacitor module are connected and tested in MATLAB simulations. The results of supercapacitor's behaviour and battery's behaviour respectively. In the simulation model, current, voltage and power are investigated and studied.

ABSTRAK

Sistem elektrifikasi keretapi telah lama digunakan kerana kelebihan nisbah kuasa hingga berat berbanding sistem diesel dan wap. Sistem elektrifikasi menghasilkan tenaga elektrik dan membekalkan tenaga elektrik ke kereta api keretapi dan beberapa unit yang membolehkan ekspedisi lebih cepat dan daya tarikan yang lebih tinggi. Dengan menggunakan sistem elektrifikasi, ia dapat mengurangkan kos penyelenggaraan terutama pada unit daya tarikan dan memberikan hasil yang lebih baik dalam kesan persekitaran untuk keseluruhan sistem dibandingkan dengan sistem lain. Dengan menggunakan bekalan 25 KV AC dari saluran overhead dan 750 V yang menggunakan sistem rel ketiga. Supercapacitor (SC) adalah teknologi penyimpanan tenaga yang berkembang pesat dan dilaksanakan dalam pelbagai aplikasi industri. Sistem ini terdiri daripada supercapacitor dua lapis, bersama dengan mesin pencincang dan alat bantu yang diperlukan, yang diperlukan untuk menangkap dan menyimpan tenaga kinetik kenderaan transit yang mungkin akan hilang semasa pengereman. Di Malaysia, kereta api yang menggunakan supercapacitor sebagai simpanan tenaga untuk menyimpan tenaga brek untuk digunakan semula semasa pecutan adalah KTM Class 61 (Kereta Tanah Melayu) tetapi digerakkan oleh unit diesel atau DMU. Penyelidikan ini mencadangkan fokus pada pemodelan dan menganalisis penyimpanan tenaga dalam kereta elektrik menggunakan supercapacitor. Supercapacitor adalah komponen biasa yang digunakan dalam kenderaan elektrik atau sistem kereta api elektrifikasi. Ia mempunyai ketumpatan kuasa yang lebih tinggi untuk menyimpan tenaga. Ia mempunyai kuasa yang lebih tinggi untuk proses pelepasan dikaji dan disiasat. Projek ini memberi tumpuan kepada tenaga terbuang yang disimpan dan dikitar semula dengan menggunakan Sistem Penyimpanan Tenaga (ESS). Bateri asid plumbum 30 V, modul superkapasitor 16 V disambungkan dan diuji dalam simulasi MATLAB. Keputusan tingkah laku supercapacitor dan tingkah laku bateri masing-masing. Dalam model simulasi, arus, voltan dan kuasa disiasat dan dikaji.

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C = Capacitance of the capacitor

A = The area of overlap of the plates of the capacitor

Er = Dielectric constant of the material between the plates

EO = Electric constant

d = Separation of the plates

d = Separation of the plates

E = Electrical Source

L = Inductor

VD = Voltage Divider

LIST OF ABBREVIATIONS

CO_2 = Carbon Dioxide

SC = Supercapacitor

SESS = Supercapacitor Energy Storage System

EDLC = Electrical Double-Layer Capacitor

Supercapacitor
ESR = Chemistry And Cell Design.

SOE = State Of Energy

OESS = On-Board Energy Storage System

MTA = Metropolitan Transportation Authority

IGBT = Insulated Gate Bipolar Transistor

FESS = Flywheel Energy Storage System

PV = Photovoltaic

RERs = Renewable Energy Resources

CmB/CmSC = Capacity Of Batteries And Supercapacitors

MPC = Model Predictive Control

OESDs = Onboard Energy Storage Devices

PWM = Pulse Width Modulation

SOC = State of Charge

PID = Proportional + Integral controller

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CHAPTER 1

INTRODUCTION

This chapter introduces the project with its background project, problem statement, project objectives, work scope project in order to provide a sense of purpose and reasons to proceed with this project.

1.1 Background

Nowdays, with the growing renewable sustainable energy, the demand of electrical transportation system is increasing because of these systems prevent enviromental pollution also reduction of energy consumption and CO_2 emissions and electricity is cheap compared to fossil fuels. When the train stops it produced high voltage motors also high amount of braking energy is produced. When a trains is operated in powering mode, it will consume power from wayside power substations or onboard-power supply[1].

Futhermore when a train is operated in braking mode, it can efficientlyrecycle braking power as regenerative power which can be fed back into catenary, used by train itself or stored in energy storage. By integrating optimization of train operation and applications of power electronics technology, power management cannot only providebalance of demand and supply but also improvement of energy-saving operation. In urban railway operations, energy-saving operation can be achieved by reducing energy consumption and increasing regenerative energy usage. To reduce energy consumption of a train, various approches for design of energy-saving driving strategy have been proposed by many projectes[1][2].

Supercapacitor (SC) is an energy storage technology that is rapidly developing, and being implemented in various industrial applications. Some electric rail transportation systems use supercapacitors for voltage enchancement and recuperation of regenerative braking energy. In dc electric rail systems when a train accelerates, it absorbs a large amount of power from the dc line to create the required torque and power needed for maintaining the desired speed. Therefore, due to the significant amount of power and current being drawn from the dc voltage during acceleration, an under- voltage condition may occur. If the dc voltage drops below pre-specified limits for a certain time, protection devices react[1][2].

Another concern in electric rail systems is recuperation of regenerative

braking energy. Regenerated braking energy is produced by dropping down the train to the lower speed but at the same time it still need a friction brake to make sure the coach in completely stop and as a back-up system while regenerative brake malfunction and this energy can be fed back to the DC line voltage.

Thus, in this project will be focus on supercapacitor energy storage system (SESS) used in regenerative braking for railway electrification system.

1.2 Problem Statement

During regenerative train braking the kinetic energy of the train is converted to electricity that can be used or transfer to another system when needed. Thisis compare to the other conventional brake which is the kinetic energy converted to heatand wasted to the environment. As an urban rail transit this railway system needs frequent start-up and braking. Traction power supply substation cannot absorb energy in reverse direction, the excess energy generated during regenerative braking cannot be reused, resulting in energy waste.[3][5]

Thus, in order to solve this problem, this project will studies the regenerative braking energy absorption based on supercapacitor, and stores the excess energy genereted during regenerative braking into the supercapacitor energy storage system and the energy in the supercapacitor energy storage system is released when the train start to accelerate, so there is no energy wasted and so that the regenerative braking energy is full utilized.

1.3 Objective

The main objective of this project which is Energy Storage using supercapacitorin regenerative braking for railway electrification system is deeply concentrated on aspectas listed below :

i. To develop the effective energy management for reduction of energywaste and consumption on urban railway.

ii. To investigate and study the behaviour and characteristics of supercapacitors.

iii. To design the simulation modelling of a Energy Storage System using Supercapacitors.

1.4 Scope Of Project

The scope of this project are as follows :

i. Studies and focused on the operation of supercapacitor energy storage system (SESS). Stores the excess energy generated during regenerative braking into the supercapacitor energy storage system.

ii. Review of the various aspects related in reduce energy consumption of a train by using supercapacitor energy storage system (SESS).

iii. Investigation the status of charging and discharging condition of supercapacitor modeled. 30 V lead acid battery and 16 V supercapacitor module are connected and tested in MATLAB simulations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The urban population has steadily increased as the world's urbanisation accelerates. Urban traffic is rapidly increasing as a result of the rising number of floaters and road vehicles. Aside from that, as the demand for renewable energy grows, the demand for electric transportation systems grows as well, because these systems reduce emissions and electricity is less expensive than fossil fuels. The transportation sector plays a critical role in reducing CO2 emissions, and as demand rises in response to an increasing global population, significant changes in terms of electrification will be needed. Since appropriate energy storage solutions are now available, it is now possible to use electrified systems more effectively. Electric rail transit networks are constantly improving in order to provide quick and dependable service to their growing number of customers. The recovery of regenerative braking energy is a major challenge for electric rail transit systems[1].

2.2 Electrification railway system

Because of the high power to weight ratio advantage over diesel and steam systems, a railway electrification system has been used for a long time. The electrification systems produce electrical energy and supply it to railway locomotives or multiple units, allowing for faster expedition and higher tractive power on hilly gradients. Furthermore, using electrification systems can reduce maintenance costs, especially for traction units, as well as provide a better overall environmental impact than other systems. The biggest drawback of electrification schemes, however, is the capital expense of the electrification equipment[1].

There are two main systems currently used which is 25 kV AC that using overhead lines and 750 V DC that using a third rail system. However, there are many developments has been done which is most recently of the systems are converted from AC supply to the DC supply because of the train power capability is limited for DC systems. In the early development, a low DC voltage has been used in the electric system which the motor was directly fed from the traction supply. The lower voltage normally using a third rail supply systems and the voltage that above 1 kV are using overhead systems. After several years, the rectifier has been used to convert the AC voltage to the DC voltage and supply to the traction systems[2][7].

2.3 Regenerative Braking System

The most important mission of railway vehicle braking systems is to perform their functions without compromising reliability principles. In this sense, braking systems convert all or part of a moving vehicle's kinetic energy into other forms of energy in order to reduce speed. If necessary, the braking systems bring the vehicle toa stop. It also aids in preventing forces caused by weight on gradients in order to maintain the vehicle's constant speed and to maintain the vehicle's condition on an inclined track with environmental influences such as wind and rainfall. The brake capacity of a train or railway vehicle is an important feature that states the general design and practical capability to decelerate the vehicle from its maximum operating speed with the greatest braking force occurring during an emergency brake. Some of themost important factors influencing braking capacity are train weight and speed, brake type, functional and design characteristics of the brake equipment, braking characteristic, and thermal events.

A regenerative braking system is one of the mechanisms that use an energy recovery concept that has been used in train systems to slow down the coach while also converting the kinetic energy that can be used or transferred to another system when needed. Traditional vehicle braking systems convert kinetic energy to heat through friction, wasting a significant amount of energy potential. This kinetic energy is reclaimedand stored in a reusable manner by regenerative braking systems. To capture and apply this available form of power, more and more modern electric drive vehicles, including locomotives, feature regenerative braking systems.[4][6]

This is in compare to the other conventional brake, which converts kinetic energy to heat and wastes it to the environment. The advantage of the regenerative braking system in the train system is its ability to convert kinetic energy into electromagnetic energy. Motors and generators can be used interchangeably because they operate on the same principle. The electrical energy generated by braking can be dissipated through a resistive network (dynamic) or stored (regenerative), and the First Law of Thermodynamics states that the vehicle will slow down as this process takes place. When applied to rail vehicles and systems, regenerative braking provides two