Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 138 (2017) 93–98

Energy Procedia

www.elsevier.com/locate/procedia

2017 International Conference on Alternative Energy in Developing Countries and Emerging Economies 2017 AEDCEE, 25-26 May 2017, Bangkok, Thailand

A Demonstration Project for Installation of Battery Energy Storage System in Mass Rapid Transit

Tosaphol Ratniyomchai, Thanatchai Kulworawanichpong*

[a]School of Electrical Engineering, Suranaree University of Technology, 111 Suranaree Avenue, Muang, Nakhon Ratchasima, 30000, Thailand

Abstract

This paper presents an application of the stationary Li-ion battery on behalf of battery energy storage system (BESS) in the mass rapid transit system. The DC electrified railways have often-frequent stop during their journey that mean the regenerative braking energy from the train braking is likely to regenerate back to the DC electrified network. This energy could potentially support the auxiliary loads onboard and the adjacent trains simultaneously; however, the electrical braking resistance onboard would dissipate some of the surplus energy. The surplus energy could be absolutely recovered and stored in the stationary BESS and then this potential energy is efficiently supplied to support that own train's for acceleration or other adjacent trains simultaneously. The modified Bangkok Transit System (BTS)-Sky Train Sukhumvit Line in Thailand (from Mochit – Bearing stations) is employed for the demonstration with the multi-train simulator (MTS). This system has the service distance of 21.60-km with 22 passenger stations and 8 traction substations. The electrified operation system is 750-V DC rectifier substations to supply the electric power through the 3rd rail. Results show that the energy saving of the BTS system with the stationary BESS and with regenerative braking energy is achieved by 13 times of the system with BESS and without regenerative braking energy.

Peer-review under responsibility of the scientific committee of the 2017 International Conference on Alternative Energy in Developing Countries and Emerging Economies.

Keywords: Battery energy storage system; Li-ion battery; regenerative braking energy; mass rapid transit; energy saving

1. Introduction

The transportation by the electrified railways both AC high speed and intercity trains) and DC (mass rapid transit, metro and light rail vehicles) systems are one of the best ground transportation in terms of quantity, quality safety,

* Corresponding author. Tel.: +66- 88-583-7207; fax: +66-44-224601.
E-mail address: thanatch@sut.ac.th

1876-6102
Peer-review under responsibility of the scientific committee of the 2017 International Conference on Alternative Energy in Developing Countries and Emerging Economies.
10.1016/j.egypro.2017.10.065

energy saving, less time, environmental friendly for both goods and passenger services. Even the electrified railways is less consume energy than other fuel engines in comparison with the same capacity of the load, they still need to do the research and development to enhance the performance the train services. Considering the DC electrified railway systems as the mass rapid transit, there are many researches to improve the efficiency of the DC power network by reusing the energy from the train braking [1]. This braking energy regenerates from the traction motor that acts like the generator during the train braking. Usually, the regenerative braking energy is used to support the auxiliary load onboard and the adjacent train travelling at the same time. In general, the traction substation of the DC electrified mainly consists of the rectifier transformer that is non-bidirectional in power, therefore, the surplus energy from the regenerative braking energy has to dissipate by the electric resistance onboard. At present, there are many studies on the applications of energy storage devices such as batteries, flywheel, electrochemical double-layer capacitor (EDLC) and hybrid energy storage to store the regenerative braking energy [2]. Those energy storages are one of the solutions for using in the mass rapid transit due to the frequent stops and short track. There are two types of the energy storage installations in the DC electrified railways; (1) onboard application is a temporary accumulation the regenerative braking energy and then regenerated the stored energy to support the own train motoring [3-6], and (2) wayside or stationary application is also a temporary accumulation the regenerative braking energy and then regenerated the stored energy to support the adjacent trains motoring [7-9].

Considering the applications of batteries as a Lithium-ion (Li-ion) battery in the DC electrified railways, Li-ion battery is a new energy storage comparing with the conventional batteries. The characteristic of Li-ion battery is high energy density, high efficiency, long-lift time, light-weight and fast in charge and discharge ability [10]. Li-ion battery is the most favorite battery technology for the portable electric devices, especially in automotive market and electrified railway applications. An energy saving and voltage compensation in the DC electrified railway system are achieved by the application of the stationary Li-ion battery [11]. In addition, the catenary-free operation is also capable by the energy support of the onboard Li-ion battery [12].

In this paper, the stationary BESS based on the Li-ion battery is implemented in the mass rapid transit in the BTS-Sky Train, Sukhumvit Line, Bangkok, Thailand. The train movement model, BESS model, simulation results and conclusion, consecutively conducts the paper.

2. Train movement model

The characteristic of the electrified railways movement is obtained from a standard operation curve as shown in Fig. 1., including train motoring mode, cruising mode, coasting mode and braking mode. The speed of the train is limited at the maximum speed and constant at this speed during the cruising mode. The Newton's second laws of motion is applied for calculating the characteristic of the train movement taken into account, for example, the gradients, friction force, speed limitation, and train operation modes [13]. The absolute force F applies to accelerate the train expressed in (1), where M_{eff} is the effective mass of the train and α is acceleration rated of the train. With the train motion simulation, an appropriated step time is considered with the various train operation modes during the travelling between two adjacent platforms. However, the train operation modes are based on the consecutive modes in Fig. 1, and controlled by the train speed control strategy, for example, P-controller and hysteresis control [14].

$$\begin{aligned}
F &= F_T - F_R - F_G = M_{eff}\,\alpha \\
F_G &= M_{eff}\, g \sin\theta \\
F_R &= A + B\cdot v + C\cdot v^2 \\
M_{eff} &= M_t(1 + \lambda_w) + M_l = M_t(1 + \lambda_{eff})
\end{aligned} \tag{1}$$

where F_T is the tractive effort (N); F_R is the train resistance force including friction force (kN); F_G is the gradient force (N); v is the train speed (km/h); M_t is the tare mass of the train (kg); M_l is the passenger and freight load (kg); λ_w is the rotary allowance; λ_{eff} is the effective mass factor; A (kN), B (kNh/km), and C (kNh^2/km^2) are the Davis's coefficients; g is the gravity of earth, 9.81 m/s^2.