Assessment on Potential Energy Storage Technologies for Urban Rail Transportation Systems

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ABSTRACT: Energy storage has been used to capture energy for many purposes. This technology always moves towards the future for new improvement. These technologies have grown for better quality and more advantages. There are a lot of energy storage types with different specifications and functions. Mainly, this technology exists due to capture renewable energy as it is uncontrolled. Energy generated can be high or low depends on the condition. Hence, energy storage helps to store the generated energy for later use. This research paper focuses on the supercapacitor as energy storage for urban rail transportation systems. The supercapacitor is one of the latest technologies available. This energy storage selected as it has better characteristics over other technologies such as high-density power, fast charging/discharging, long life span, and many more. The purpose of this energy storage in the urban rail transportation systems is to capture regenerative braking energy to prevent energy-wasting when not able to reuse. This research will study the appropriate sizing of supercapacitor energy storage for the Kelana Jaya line. The circuit modelling simulation is performed by using PLECS software for data and analysis purposes. Several types of sizing will be analyzed to determine the most suitable one.

Keywords: *Regenerative energy; Supercapacitor; urban rail transportation*

1. INTRODUCTION

Suggested methods to optimize the recovery of regenerative braking energy are the train frequency optimization, Energy Storage Systems (ESS), and reversible substation. For train frequency optimization, which required the coordination of different train operations. This method needs to make sure when one train braking, another train will be available to consume generated energy. For ESS, the generated energy is stored when charging, storage technologies available include a SuperCapacitor (SC), battery, and flywheel, then discharged to the third and fourth rail when required. ESS configuration can be set as Onboard ESS or Wayside ESS. Lastly, a reversible substation provides a way for power to flow and to recycle the power.

1.1 Braking Systems

There are three types of braking systems commonly used in urban rail systems, which include mechanical, electromechanical, and electrodynamic braking. Mechanical braking nowadays used axle-mounted disc brakes, the process of the braking trigger when compressed oil applied to clamp brake lining with the disc. Both brake lining and disc rub against each other to slow down the rolling stock. Axle-mounted disc suggested using lighter material that is widely used in the urban rail industry as they have good heat resistance properties. To avoid wheel sliding when braking, it needs electromechanical braking. This braking operates by using batteries to produce a magnetic field that can generate eddy currents at the top of rails, an opposite direction with rolling stock movement force created. Electrodynamic braking also called regenerative braking or motor braking. This braking generated electricity and able to accelerate others rolling stock available, when there is no available rolling stock nearby it will dissipate as heat by the resistor bank. The method of braking is to reverse the motor torque to slow down the rolling stock.

1.2 Supercapacitor

A general term for electrochemical capacitor is SC, that can be categorized into three types which are electrostatic double-layer capacitors (EDLC), pseudo capacitors, and hybrid capacitors. To store energy in SC, two methodss used are faradic and non-faradic. For the faradic method, the electric charges are moved between electrodes and electrolyte. Pseudo capacitors use faradic method, EDLC use non-faradic method while Hybrid capacitors use both methods to store energy. Besides that, no chemical reaction required for storing energy for the non-faradic method.

2. METHODOLOGY

The first objective is to determine the ESS configuration. Secondly, is to design ESS modelling. The final objective is to evaluate ESS sizing.

2.1 SC Model and Equation

For the SC model, there are two types of circuit model that can be designed, which are simplified equivalent circuit and multi-branch equivalent circuit. The circuit consists of resistors and capacitors combination to make it behave as an SC. Since the SC has low rated voltage, it needs to be combined in the combination of series and parallel.

The equation for SC includes the stored energy (Wh) (1), pulse current for 1 second from rated voltage to half (A) (2), and peak power (W) (3). All equations are shown below.

$$Wh = \frac{0.5 \times C \times V^2}{3600} \quad (1)$$

$$A = \frac{0.5 \times V \times C}{1 + ESR \times C} \quad (2)$$

$$W = \frac{V^2}{4 \times ESR} \quad (3)$$

3. RESULTS AND DISCUSSION

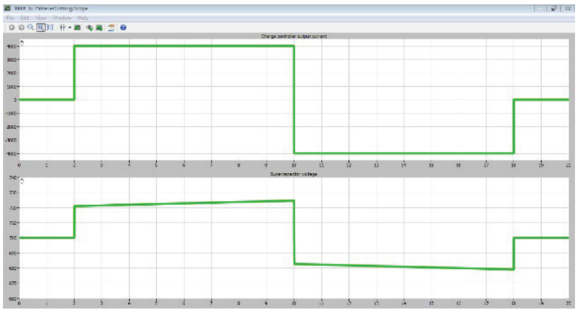

Figure 3 Small size ESS modelling (1.45kWh) output

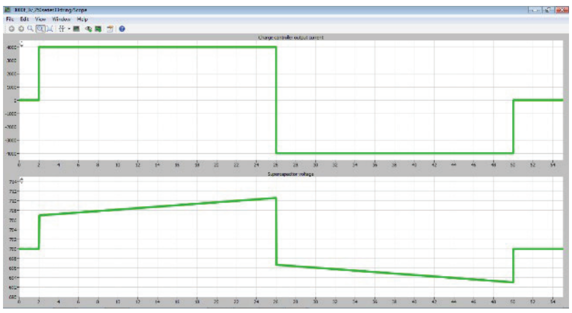

Figure 4 Medium size ESS modelling (3.99kWh) output

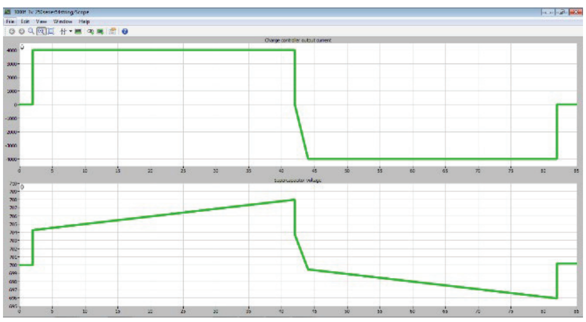

Figure 5 Large size ESS modelling (6.53kWh) output

Table 1 ESS modelling overview

Size	Small	Medium	Large
Capacitance	144F	396F	648F
Configuration	250 series 12 string	250 series 33 string	250 series 54 string
Total of SC used	3000	8250	13500
Charge/discharge time	8s/8s	24s/24s	40s/40s
Total usable power	1.45kWh	3.99kWh	6.53kWh
Pulse current	31.93kA	87.92kA	143.78kA
Peak power	29.3MW	80.82MW	132.04MW

4. CONCLUSION

In conclusion, small size ESS modelling is the most suitable for the Kelana Jaya Line. The reason because of the cost for ESS installation. The price for single-cell SC for 3000F, 3V is about RM 315.36. To build the entire ESS need a lot of costs to be considered. Hence, small size ESS modelling is the most cost-effective compare with medium and large sizes.

Furthermore, ESS can be installed at several numbers of Traction Power Substation (TPSS) to cover urban rail transportation system and avoid power losses when they consume power from ESS at each station. It will be more efficient to install several small size ESS rather than to install a few medium and large ESS due to the distance of each station and TPSS. The size is not necessarily significant, because it will be waste if the ESS cannot be fully charged when rolling stock operates outside the peak hour. Finally, small-size ESS can charge/discharge in a short time, and it will be convenient for rolling stock to charge the ESS when braking and consume when accelerating.

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