Modelling and Design of a Current Controller for Light Rail Regenerative Inverter System

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***Abstract*—Three phase voltage source inverter has been proposed to transfer the braking energy of a light rail vehicle back to the utility grid. This solution saves cost in purchasing large number of energy storage modules. However, it raises some concerns on power grid integrity, such as harmonics distortion. Therefore passive filters are normally added to mitigate the harmonics. This paper proposes a grid current controller to minimize the needs of ac filters. The proposed PI controller is stable and shows good dynamic response with the settling time measured at 3.49 ms. In addition, sinusoidal grid currents are produced successfully. The total harmonics distortion index for the grid current is measured at 2.61%.**

***Keywords*— Railway, dc electrification, voltage source inverter, current control, PI controller**

I. Introduction

An electric railway system is ideal to solve traffic congestion and environmental pollution issues in crowded cities. Light rail transits and metros are commonly chosen as urban rail vehicles [1]. In order to accelerate a train from stand still, a set of ac-dc conversion system is configured in a traction power substation. Subsequently, to stop a train, regenerative braking technology is strongly recommended.

The simplest way to utilize the regenerative braking energy is to schedule a departing train near to the braking train. Thus the harvested braking energy can be utilized to accelerate the departure train. An optimum headway time of about 2 minutes has been proposed [2]. This proposed time interval is more practical to be implemented during peak hours. However, during off-peak hours where long interval of departure time is planned, self-protection scheme will be activated to dissipate the braking energy as heat.

In order to proper manage the braking energy, on-board energy storage [3], [4], and wayside energy storage systems, [5], [6] had been actively investigated. A wayside energy storage concept is illustrated in Fig. 1 (a). Energy storage modules such as ultra-capacitors, and batteries will be charged via dc-dc converter when the braking energy is generated [7]. This method does not introduce any negative effect to the utility grid. Unfortunately the size, weight and life cycle of the energy storage modules are documented as main disadvantages in long run [8].

An alternative way to store the braking energy without costly batteries is directly transfer this energy back to the utility grid [9], [10]. Fig. 1 (b) shows an example of the regenerative power conversion system which employs a dc-ac power converter as a recuperating converter. However, highly distorted ac waveforms (voltages and currents) becomes major concerns in this design. Therefore ac filters are implemented to purify the distortion based on industrial standard [11].

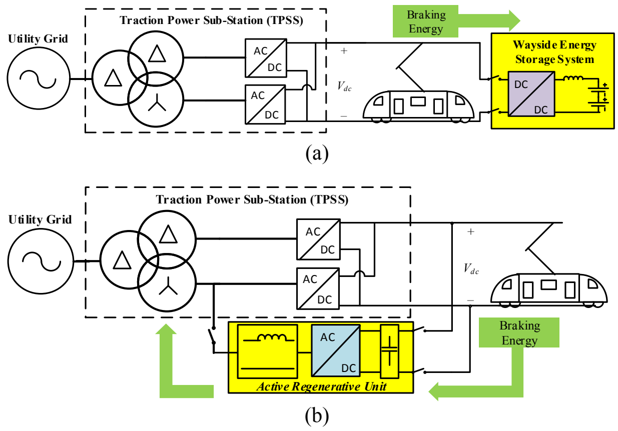

Fig. 1: Regenerative braking energy recovering solutions in railway traction (a) Wayside Energy Storage System (WESS), (b) Active Regenerative Unit [9].

This paper focuses on modelling of a regenerative inverter system followed by designing and tuning a current controller for the respective system. The aim of this study is to minimize the ac filters size in purifying the grid current. A classic pulse-width-modulated voltage source inverter is employed as the regenerative converter. The current controller is expected to produce good quality grid currents. The controller designed is then verified in MATLAB/Simulink environment. All simulation results are presented with full analysis.

II. Regenerative Inverter System

A classic three phase two-level voltage source converter as shown in Fig. 2 is configured between a regenerative energy source and the utility grid. This converter employs power switches such as IGBTs to allow bi-directional power flows. Although this converter can be used in both rectification and inverting modes, this paper focuses to design a current controller when the converter acts in inverting mode.

The dc link terminal (regenerative energy source supply) is defined as input terminal in this paper. The dc power is converted to ac by switching on and off the six power switches in respective order. As a result, alternating voltage and current waveforms are produced at the ac terminal of power inverter. However, the produced waveforms contain a lot of sideband signals. This paper aims to introduce current controller to mitigate current harmonics instead of using ac line filters. The following sub-sections will present the modelling of the regenerative inverter system with the control and modulation techniques used to operate the power inverter.

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