Studies in Materials Science and Mechanical Engineering

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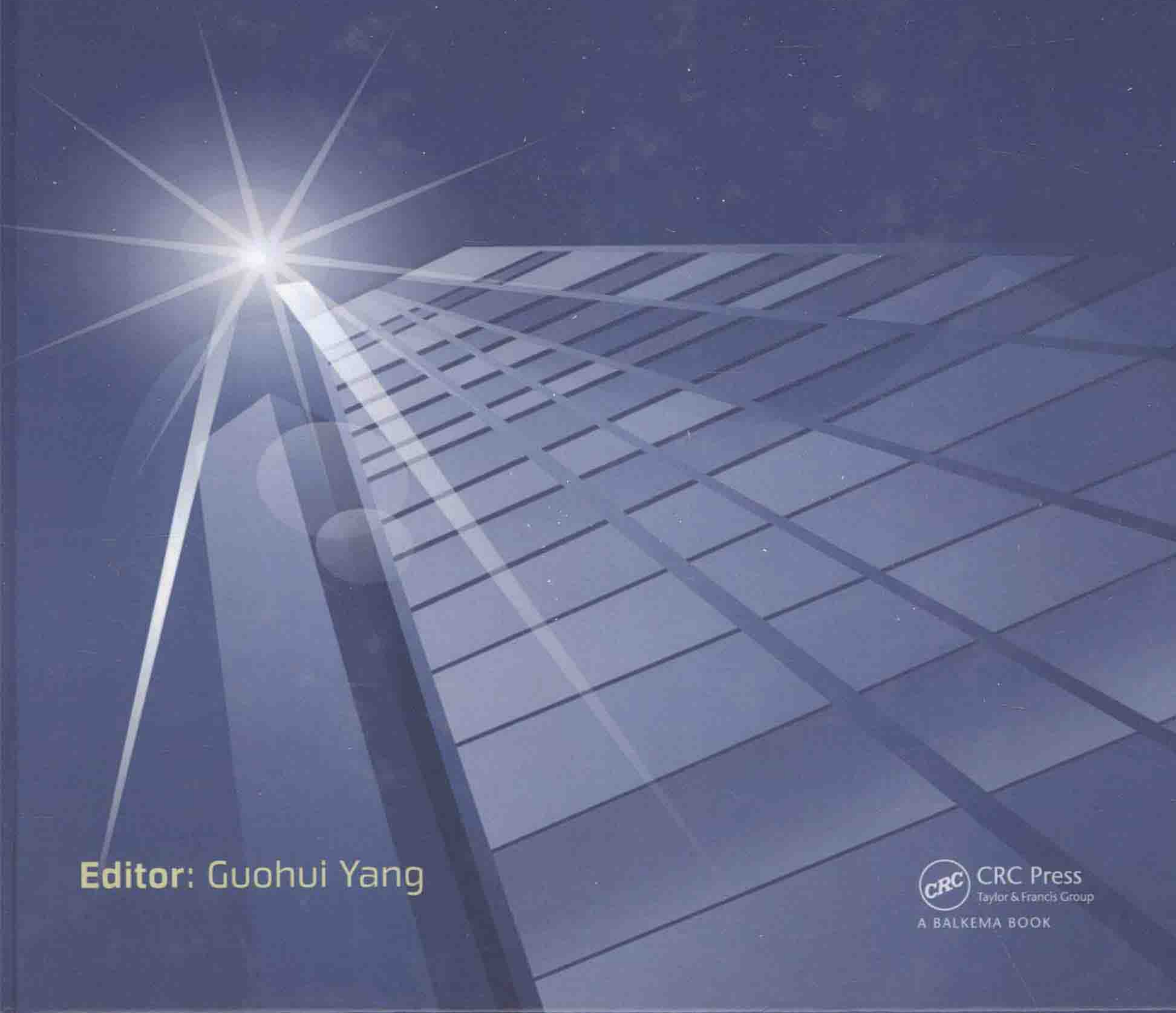
Advances in Future Manufacturing Engineering



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Editor

Guohui Yang

International Materials Science Society, Hong Kong, Kowloon, Hong Kong

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Preface

The 2014 IMSS International Conference on Future Manufacturing Engineering (ICFME 2014) was held on December 10–11, 2014, Hong Kong.

This conference gathered academics, industry managers and experts, manufacturing engineers, university students and others interested or proficient in the field of manufacturing engineering to discuss the state of the art in the field. During this conference progresses, problems and developments in manufacturing engineering was discussed. The conference is expected to play a role in the development of future manufacturing engineering.

Manufacturing engineering is a discipline of engineering dealing with different manufacturing practices and includes research, design and development of systems, processes, machines, tools and equipments. The manufacturing engineer's primary focus is to turn raw materials into a new or updated product in the most economic, efficient and effective way possible. This field also deals with the integration of different facilities and systems for producing quality products (with optimal expenditure) by applying the principles of physics and the results of manufacturing systems studies, such as Design and Manufacturing, Materials Science and Materials Processing Technology, Computer-aid Manufacturing, Mechanics.

Manufacturing engineers develop and create physical artifacts, production processes, and technology. It is a very broad area which includes the design and development of products. The manufacturing engineering discipline has very strong overlap with mechanical engineering, industrial engineering, production engineering, electrical engineering, electronic engineering, computer science, materials management, and operations management. Manufacturing engineers' success or failure directly impacts the advancement of technology and the spread of innovation.

We have received good-quality and enthusiastic responses from people in different countries and different industries. They have submitted many great papers and ideas related to this conference. Here we extend our sincere thanks to all of the people who have responded actively and spent days to write and edit the conference papers.

Also we'd like to give the keynote speakers our appreciation for their great contribution to this conference. We thank all the delegates who attended the conference here for their sharing of suggestions, opinions and ideas in the field of future manufacturing engineering. Sincere thanks go to the sponsors and organizers of this conference who have offered us a good chance to gather, discussing and sharing information and ideas in manufacturing engineering. Last but not least we would like to express our sincere appreciation to all staff and volunteers who worked so hard to make this conference a success.

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Autotransformer-fed railway power supply model using MATLAB/SIMULINK

Supachai Kaewpoung, Chaiyut Sumpavakup & Thanatchai Kulworawanichpong
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ABSTRACT: This paper presents autotransformer-fed railway power supply model by using MATLAB/SIMULINK. The purpose of this study is to characterize voltage profiles and current of trains running. The system model created in this study consists of 4 main components: i) overhead contact wire and running rails ii) traction power supply substation iii) autotransformer and iv) rolling stock. The test systems used herein are 25-kV, 50-Hz double- and single-track AC railway systems with autotransformer feeding configuration to analyze voltage profiles and current of trains running, respectively. The substation spacing distance is 30 km and autotransformers are installed at every 10-km spacing. As a result, the proposed SIMULINK model can be used to analyze the voltage profiles and current of the autotransformer-fed railway power supply system, effectively.

Keywords: Autotransformer; Voltage profile; Traction power substation; MATLAB/SIMULINK

1 INTRODUCTION

The high-speed rail is one of the facilities of transportation. Continually being developed to become an important aspect of modern railways. At present, the power supply to the train tracks to an AC power supply which can afford long distances. In the past, the DC power supply at 1.5 kV to 3 kV in 1900 and 1930 were used as a control. However, there is some difficulty in turning the motors to drive [1,2] high-speed trains operating at some higher speed than the speed of typical trains in services. Typically, high-speed rail in various forms are usually powered by electric power source through wires above locomotives. To analyze power loading of train running needs power network solving algorithms that are conventionally complicated and tedious for computer programming. It would be simpler if some graphic-based programming, like MATLAB/SIMUINK, is exploited. In the past, MATLAB/SIMUINK has been applied to various research fields as a potential tool for analysis, simulation and design. However, the use of MATLAB/SIMULINK in railways is very few. Traction power supply systems [3], especially for long-distance and high-speed trains, are focused. Autotransformer feeding configuration [4] of the traction power supply system is chosen in order to performing the analysis of voltage and current in the system.

This paper presents a model of AC railway systems equipped with autotransformers by using MATLAB/SIMUINK to analyze the voltage profile of a tested high-speed rail transit section. Comparison between three train models, which are a constant power model (S-model), a constant impedance model (Z-model) and a constant current (I-model) is engaged. Description of AC railway power supply system is summarized in Section 2. Section 3 presents circuitry models for autotransformer feeding configuration by using MATLAB/SIMUINK. Tests and their results are shown in Section 4. The last section is a conclusion remark.

2 AC RAILWAY POWER FEEDING SYSTEM

AC electric power supply is configured to supply a wide range of different industries. The standard AC railway power supply system is preferred a single-phase power feeding system. In this single-phase feeding scheme, AC power supply is connected directly to the high voltage three-phase power through traction substation transformers to convert three-phase high-voltage electric power into single-phase 25-kV electric power. In Great Britain, the standard HV/MV interfacing power systems are typically 132/25 kV, 275/25 kV or 400/25 kV [5]. The HV-side of the traction substation transformer is connected to the utility's three-phase busbars while the LV-side busbar of the

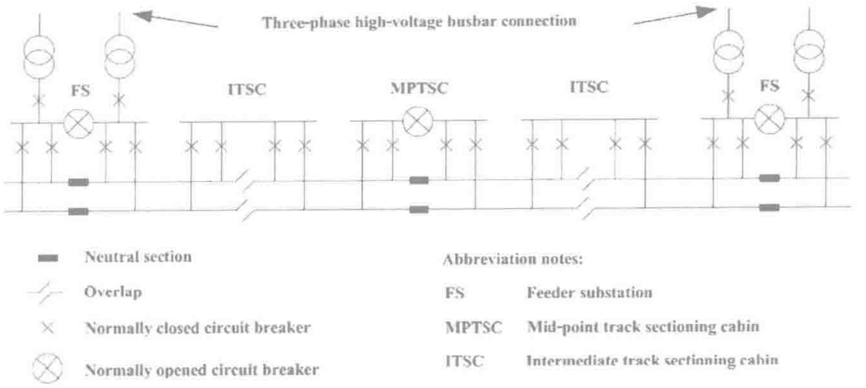

Figure 1. Typical AC railway power supply system.

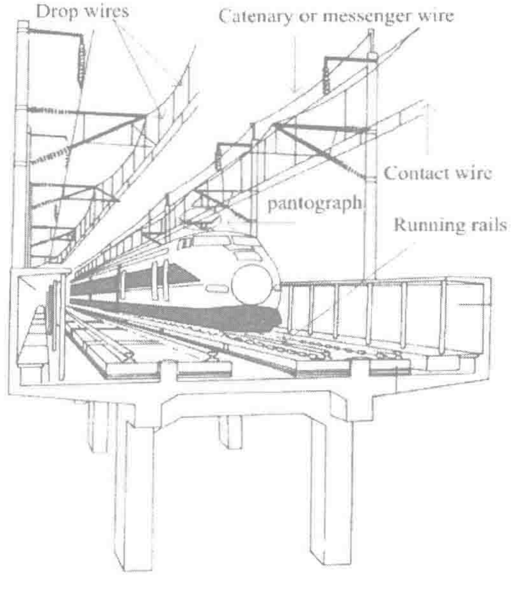

Figure 2. Structure of overhead railway power feeding system.

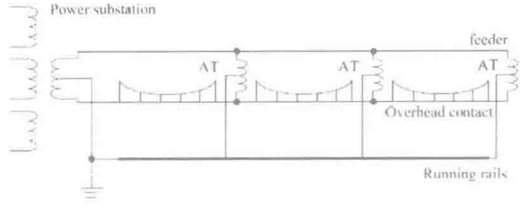

Figure 3. AT-fed railway power supply system.

transformer is connected to a single-phase railway power feeding system [6] as shown in Fig. 1. The single-phase AC railway power feeding system is designed to energize electric trains. There is track-side switchgear at the middle way between two adjacent substations called MPTSC. Sometimes, it is also installed ITSC to help isolating a temporary or permanent faults in line sections. The ITSC is normally located between the substation and the MPTSC.

Structure of the AC railway power feeding system consists of overhead feeding conductors, normally called contact wire and catenary (catenary is commonly known in the United Kingdom and Canada while messenger wire is commonly used in the United States or other European countries) [7]. The catenary or messenger wire is used in order to fix the contact wire at the minimum swing. Any running train is drawn its required power from the contact wire through the sliding contact made from graphite mounted on the roof of the power-train car, called a pantograph. All details just mentioned are shown in Fig. 2.

3 MATLAB/SIMULINK MODEL OF AT-FED RAILWAY SYSTEMS

Autotransformer or AT-fed railway power systems can be described by Fig. 3. It illustrates power-feeding arrangement with 1) contact wire, 2) running rails and 3) feeder. The feeder is used for current returning purpose. It is sometimes called negative feeder. The autotransformer is installed at every one-third of the feeding length. Some might be known that current flowing into contact wire, running rails and feeder is simply computed. The current distribution in the feeding sections can be summarized as shown in Fig. 4.

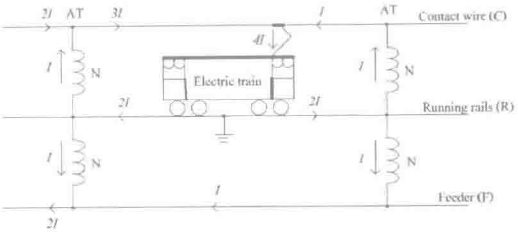

Figure 4. Current distribution in AT-fed railway system.

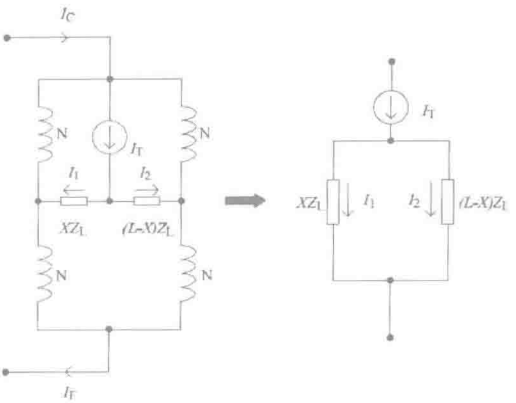

Figure 5. Current divider model for AT feeding section.

Assume that a train consuming current I_T is running between two adjacent autotransformers. By dividing the current flow into two current parts I_1 and I_2 as shown in Fig. 5 where Z_L is impedance per length of the feeder line. The section length between two autotransformer is L. As can be seen, the current flow is depended on the train's position X, while it is shown in Fig. 5.

To model AT-fed railway power feeding system needs separate circuit for each power system component. In this paper, four major components of the AT-fed railway power system are introduced such that 1) traction power substation, 2) autotransformer, 3) overhead power line system and 4) train. Their MATLAB/SIMULINK models can be presented as shown in Fig. 6.

4 SIMULATION AND RESULTS

In this paper, two test systems are conducted. The first test system is a high-speed 25-kV, 50-Hz, double-track, AT-fed railway power system. The second test system is just a single-track AT-fed railway system. Simulation is carried out by using MATLAB/SIMULINK program with personal computer (Intel Core i3 2.26 GHz, 2 GB RAM). AC power supply substations have a distance of 60-km between two adjacent substations. This means that the feeding length of

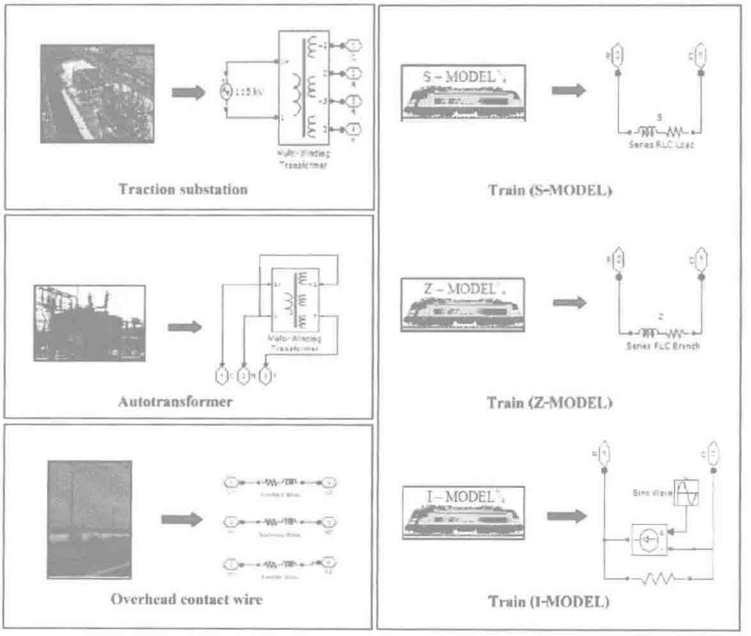

Figure 6. MATLAB/SIMULINK model of railway system components.

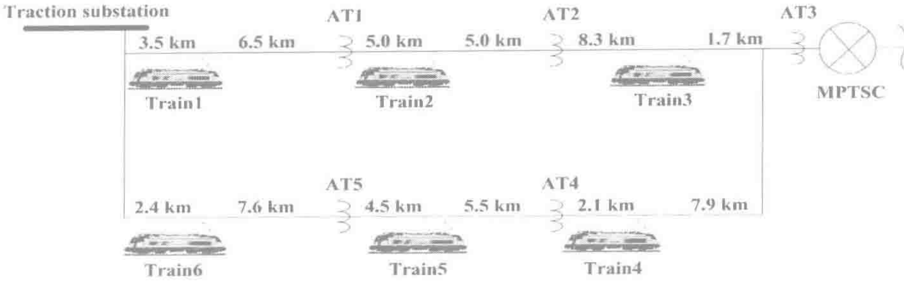

Figure 7. Test system 1.

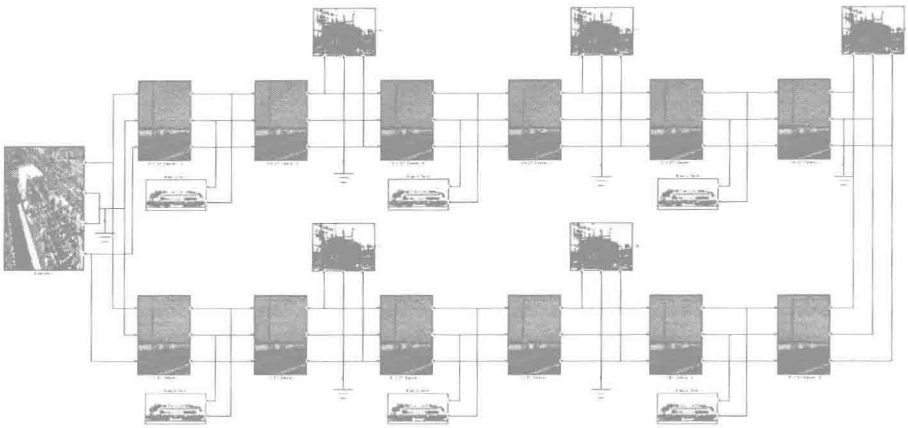

Figure 8. MATLAB/SIMULINK model of test system 1.

the test system is 30 km. Autotransformers are installed at every 10-km apart from each other. The first test system situates 6 trains running on the track, 3 trains on the up-track and 3 trains on the down-track as shown in Fig. 7. Its MATLAB/SIMULINK model can be presented in Fig. 8 to study the voltage profile and current distribution of the AT-fed railway system. This test can be detailed by using three train models (S-model, and Z-model).

Table 1 presents train model data for test system 1. It is assumed that all trains are running at 0.98 lagging power factor. Table 2 describes the voltage result at the substation and autotransformers.

The second test is a single-track system as shown in Fig. 9. Its MAT/SIMULINK model is shown in Fig. 10. It is used to prove the current distribution in the AT-fed power system as shown in Fig. 4. The test is assumed that there is only one train running in the system. The test cases are the running train located at feeding section 1 between 1) traction substation and AT1, 2) AT1 and AT2 and 3) AT2 and AT3 (MPTSC).

Table 1. Train model data for test system 1.

Positions of train (km)		S (MVA)	Z (Ω)	P.F (lagging)
Up-track	3.5	3.2066	191.02 + j38.75	0.98
	15.0	0.3236	1892.75 + j384.39	
	28.3	0.2205	2777.75 + j564.13	
Down-track	7.9	3.7015	164.47 + j33.61	
	15.5	0.3236	1892.75 + j384.39	
	27.6	3.5749	171.33 + j34.79	

Table 2. Results of test system 1.

	Voltage (kV)			
Positions	S-model	Vdrop (%)	Z-model	Vdrop (%)
Substation	25.00	0	25.00	0
AT1	24.80	0.80	24.80	0.80
AT2	24.69	1.24	24.70	1.20
AT3	24.60	1.60	24.60	1.60
AT4	24.56	1.76	24.57	1.72
AT5	24.75	1.00	24.75	1.00