UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ASSESSMENT ON RAPID POWER FACTOR COMPENSATION FOR HIGH SPEED RAIL TOWARDS POWER SYSTEM STABILITY USING POWERWORLD SOFTWARE

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology (Power Industry) with Honours.

By

AUNI NAJIHAH BINTI MOHAMED GHAZALI

B071710646

970425065078

FACULTY OF ELECTRICAL AND ELECTRONIC ENGINEERING TECHNOLOGY

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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....

Auni Najihah binti Mohamed Ghazali

Alamat Tetap:

Lot 3610, Jalan Mergastua 28000 Tenerkiih

Pahang

Disahkan oleh penyelia:

....

ADLAN BIN ALI
LECTURER
DEPARTMENT OF ELECTRICAL ENGINEERING TECHNOLOGY,
FACULTY OF ENGINEERING TECHNOLOGY,
UNIVERSITY TECHNICAL MALAYSIA MALACCA (UTeM)
Tel: +6019-3101900 email:adlan@utem.edu.my
Office: +606-234 6950

EN ADLAN BIN ALI

Cop Rasmi Penyelia

Tarikh: 23/3/2021

Tarikh: 6th April 2021

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I hereby, declared this report entitled Assessment on RAPID POWER FACTOR COMPENSATION FOR HIGH SPEED RAIL TOWARDS POWER SYSTEM STABILITY USING POWERWORLD SOFTWARE is the results of my own research except as cited in references.

Signature: ……………………………………………

Author : Auni Najihah binti Mohamed Ghazali

Date: 23 March 2020

APPROVAL

This report is submitted to the Faculty of Electrical and Electronic Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Power Industry) with Honours. The member of the supervisory is as follow:

Signature: ……………………………………………………………

Supervisor : ADLAN BIN ALI
LECTURER
DEPARTMENT OF ELECTRICAL ENGINEERING TECHNOLOGY,
FACULTY OF ENGINEERING TECHNOLOGY,
UNIVERSITY TECHNICAL MALAYSIA MALACCA (UTeM)
Tel: +6019-3101900 email:adlan@utem.edu.my
Office: +606-234 6950

ABSTRAK

Dalam elektrifikasi kereta api 25 kV AC dengan sistem bekalan 50 Hz rangkaian hubungan pada dasarnya mempunyai sistem ketidakseimbangan yang disebabkan oleh faktor kuasa. Keadaan faktor kuasa yang buruk boleh membahayakan utiliti elektrik. Gambaran keseluruhan kereta api berkelajuan tinggi dan isu-isu yang terlibat telah dikemukakan dalam laporan ini. Beberapa penyelesaian mitigasi faktor kuasa telah dijelaskan dalam laporan untuk mengurangkan komplikasi faktor kuasa. Laporan ini menganalisis dan menilai penyelesaian, secara teori dan praktikal dengan simulasi PowerWorld untuk mendekati penyelesaian faktor kuasa. Tujuan utama laporan ini adalah untuk mencari teknik pampasan faktor kuasa yang paling cekap dan sesuai.

ABSTRACT

In railway electrification of 25 kV AC with 50 Hz supply system of a contact network has essentially an unbalance system that cause by the power factor. The bad state of the power factor could harm the electrical utilities. An overview of high speed rail and the issues involved have presented in this report. Few solutions of mitigation the power factor has been describe in the report to reduce the power factor complications. This report analyses and evaluates the solution, theoretically and practically with simulation of PowerWorld in order to approach the power factor solutions. The main purpose of this report is to find the most efficient and suitable technique of power factor compensation.

DEDICATION

This project is wholehearted dedicated to my parents, family and Encik Adlan bin Ali. They have never give up on me whenever I demotivate while in progress of completion the report.

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LIST OF ABBREVIATIONS

AC	**Alternative Current**
APC	**Active Power Factor**
ARPQC	**Principal Component Analysis**
ATP	**Automatic Train Protection**
CR	**Controlled Reactor**
DC	**Direct Current**
ESS	**Electrical Substation**
ETMP	**Electromagnetic Transient Program**
FC	**Fixed Capacitor**
G	**Ground Feeder**
HSR	**High Speed Rail**
HST	**High Speed Train**
HV/HC	**High Voltage, High Capacity**
IR	**Industrial Revolution**
N	**Normal Feeder**
NTG	**National Transmission Grid**
OCS	**Overhead Catenary System**
P	**Positive Feeder**
PCC	**Point of Common Coupling**
PF	**Power Factor**
PFC	**Power Factor Correction**

PQ	**Power Quality**
SCC	**Steinmetz Compensation Circuit**
SVC	**Static Var Compensation**
TCF	**Thyristor Controlled**
TPSS	**Traction Power Supply System**
TSC	**Thyristor Switched Capacitor**

CHAPTER 1

INTRODUCTION

1.1 Introduction

As the world of technology advancing, the fourth in the line of industrial revolution (IR 4.0) are making disruptive technologies change the system on how we live and work. This phenomenon is solely focus on automation, real - time data, machine learning, and interconnectivity. One of the most vital phenomena of the industrial revolution 4.0 are the development of railway industry. Railway industry has become one of the major components of the transportation sector and it is intimately linked to the economy's growth.

Railway industry are basically about transferring passengers and goods on wheeled vehicles that are running on rails that located on tracks. It is one of the mode of transportation that has four important subsets; which are rolling stocks, tractions, signaling and communications, and electrifications. Rolling stock are the railway vehicles while track and network is a permanent infrastructure that facilitate the train to move. Nevertheless, signaling and communication is a structure that used to control railway traffic while keeping a safe distance between trains and electrifications is a system that supplies electric power to railway trains without on board prime mover.

There are more than five types of train that have been introduced, such as urban rail transit, high speed rail, commuter rail, light railway and many more. With the adaption and modification of the railway industry, we can gain a lot of benefits by becoming more flexible and increment of innovation can occur.

1.2 Background of Project

For this project with the reference to railway industry, we are merely pay particular attention to electrifications of high – speed railway. Generally, electrifications are defined as the transformation of a machine or a system for the use of electrical power. Whereas, high – speed rail is a type of rail transport that travels significantly at least 250 km/h or more.

This electric locomotive runs on the electric traction system which can either be alternate current (AC) or direct current (DC). On the AC system, traction system normally uses 25 kV AC. While on DC system, the power is 750V or 1500 V DC traction system. The supply of electrical power to move the trains with a nearly continuous conductor, that are located along the track, are designed into two forms; an overhead line and third rail. An overhead line is dangle from poles along the track or from structure, whereas third rail are mounted at track level. However, for high – speed rail application, a high voltage AC system is much more efficient. Thus, the best transmission of power for high speed train are through overhead wires.

An overhead equipment (OHE) will distribute the power through a pantograph that in contact with AC overhead contact wire that will feed to the electric locomotive. In order to get the determined voltage and frequency levels, the power is required to convert by employing rectifiers, inverters, transformer, and cyclo – converter, depends on the category of traction system and type of motors that is used for the train movement.

1.3 Problem Statements

The synchronous proliferation of the railway industry and new high – speed train in the industry, a remarkable distortions of network voltage and current in TPSS and connected power system has become the main issue. Power quality (PQ) complication can occur on the power line considering that they are directly connected to the transmission grid for high voltage. This problem would make calculation and evaluation on non – linear and dynamic natures of modern trains difficult. A contribution to an excess of reactive power consumption and distortion of an input voltage and current in electric trains could have arisen. The uneven distribution of load on different feeders are required to be considered. The grid – side quality of the power is degraded together by the factor in poor and severe unbalance power factor (PF).

These issues have been reported frequently under those circumstances of their utility power system and adverse effects on both traction electrical devices. Over and above that, the control system, rail signaling and communication, and upstream power system of a HSR also gave a remarkable affect to the PF problem.

Taking this issues into consideration, it is a mandatory to improve the PF to ensure to have reliability and stability of the utility power system for HSR. Low power factor also causes huge additional energy penalty.

1.4 Scopes of Project

This project mainly focuses on compensating the power factor for high speed electric railway. The aim of this projects is to find the best solution to counter the power factor problems on high speed railways toward sustainability of railway electrification system that supply electric power to railway train.

1.5 Objectives

1. To identify suitable method of power factor compensation for high speed rail application
2. To analyse methods of power factor compensation for high speed rail application using suitable simulation software
3. To evaluate the most effective methods of power factor compensation for high speed rail application

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter is about the literature review as a reference that helps my project based on reading of journal or conference paper which that from there will get some knowledge and idea for my project. The journal will go through read from 5 years past. It will come out with the results and summarize of each of the paper.

2.1 High Speed Railway

High speed railways is a complex system that combine the state of the art in the many different fields not just engineering but many other related departments. This includes the infrastructure, stations, rolling stocks, operations, maintenance strategy and corresponding facilities, financing, management and marketing. The principle of all high speed rail systems worldwide is similar but they have a slight different system for every HSR in each country. Every high speed rail depends on how the interactions of their components are designed. In terms of cost and performance, the HSR system also can be differ from one country to another. This all rely on the operation criteria, cost management and their commercial approach.

High speed railway technology is getting more relevant in many countries around the world because of its benefits, such as high energy efficiency, economic performance and environmental protection. (Jiaxin Yuan et.al 2018)

Thunwa B & Komsan H. (2018) also claimed that HSR is a significance transport infrastructure development. It would make people's journey easier and more convenient, as well as enhancing social growth and advancement around the railway station, enabling the country to develop financially and prosper.

2.2 AC Railway Electrifications

High speed rail system are characterized primarily by the high power that supplies the trains that run on those power lines. To meet the necessity requirement with minimal resistive losses, an appropriate high supply voltage is required which involves the given power, a low current value and implies the use of alternating single phases.

However, as the technology of railway advancing, a study and development of 2 x 25kV system has been improved which allows transmission of power at 50kV which using a three – phase voltage system; contact line, track and feeder. High speed lines' power supply system are categorized by high specific power which implies the need to connect to very powerful high voltage network. However, this can cause extremely high cost, not only for the entire high voltage substation segment, but also specifically for the power lines. It significantly affects the overall cost of the equipment. Thus, the deployment need to be reduce. For this scenario, the choice of an industrial frequency 2 x 25 kV system has the advantage of connecting the substations directly to the general three – phase network which only requires a simple transformation.

In the earliest industrial electrification, the power is more stable compare to the single – phase power that are merely high. In order to solve the unbalance power, we have to reduce the equivalent single phase load of the network in the three phase by using the same typology transformer, the 2 x 25kV module. Single phase transformer is directly linked to the three phase line with corresponding sub- station rotation of the lines.

On the other hand, by considering the electrical substation (ESS) that are linked to a three different phases of grids, this also involves the division of the traction line into separate phase voltage angles that supplied sectors. Thus, those sectors need to be isolated and segregated to neutral area. Nevertheless, traction load distribution has to be improved on the three phase of the primary line. The transformer connections are formed following the 'order 3' sequence of the voltage, by obtaining ΔU at every neutral zone that is also equal to $\Delta U = \sqrt{3}\, U$ as shown in Figure 1.

On the other hand, Keng – Weng Lau et.al (2016) purposed that in today's world, the 50 Hz, 25 kV AC electrified equipment is widely used in high- speed long distance railways. The power in the three – phase grid is converted into two single phase outputs in traditional traction power supply which is the substation and the locomotive supply, as shown in Figure 2.

They also describe that neutral sections (NSs) that is without power supply are crucial to avoid risk of mixing of phases since the two single phase power is a different phase. The locomotives are tending to lose power and velocity, where the traditional ac power architecture are not suitable for HSR. Taking this into the account, a new system is proposed where the locomotive loads are connected across one single phase out of substation transformer only where another phase unloaded not included as seen in Figure