MULTI-STAGE POWER CONVERSION USING MATRIX CONVERTER FOR SOLID STATE TRANSFORMER TECHNOLOGY

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DEDICATION

This project report is dedicated to my parent, Mr Mohd Noor and Mrs Che Norlia, who are supporting me to continue my study. It is also dedicated to my supportive wife and child, Norhijroton Ramlan, Muhammad Faizzuddin, Ahmad Khairul Ikhwan, Nur Alya Maisarah and Adam Muiz, which is not give-up and always supporting me to finish this study. Not forget to all my friends, classmate, colleague, relatives, and lecturers, thanks and appreciate for the support, encouragement and understandings.

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ABSTRACT

The traditional power transformer typically operated at low frequency with the bulky size either working with step-down voltage or step-up voltage in power system. Aiming to reduce the size of this transformer structure, the solid-state transformer (SST) is suggested. In brief, SST is an ac-to-ac power electronics circuits that operate in high switching frequency offering higher efficiency. Implementation of the smart-grid concept can be made faster than expected with the introduction of SST technology. To-date, there are plenty of power converters that incessant proposed to be used on SST technology. The benefit in term of the structure will give the smaller size and less weight if compare with magnetic transformer. On the other hand, it will impact the cost of equipment and transportation during the installation process. This project will review one of the multi-stage power converters for SST technology of three-phase power system introduced in term of important indices by using a matrix converter. The aims of this project to simulate and analyses the performance of a matrix converter as the ac-ac converter in SST technology.

ABSTRAK

Pengubah kuasa lazim kebiasaannya beroperasi pada frekeunsi yang rendah dan bersaiz besar sama ada dalam bentuk voltan langkah turun atau pun voltan langkah naik dalam system kuasa. Dalam mensasarkan pengecilan saiz pengubah kuasa, pendekatan pengubah keadaan pepejal atau dikenali sebagai SST adalah amat disarankan. Secara ringkasnya, pertukaran arus ulangalik kepada arus ulang alik dalam litar kuasa elektronik beroperasi dalam suis frekuensi yang tinggi serta memberikan kecekapan yang tinggi. Dengan pengenalan teknologi SST, perlaksanaan konsep grid pintar dapat dilaksanakan dengan lebih pantas daripada apa yang dijangkakan. Sehingga kini, terdapat banyak penukar kuasa sentiasa terus-menerus diusulkan pada penggunaan teknologi SST. Manfaat dari segi struktur, dapat dilihat dari aspek saiz yang lebih kecil dan kurang berat jika dibandingkan dengan pengubah magnet biasa. Antara lain, ianya akan memberi kesan kepada kos peralatan dan pengangkutan semasa proses pemasangan dilaksanakan. Projek ini akan mengkaji semula salah satu penukar kuasa pelbagai peringkat untuk teknologi SST sistem kuasa tiga fasa yang diperkenalkan dari segi indeks penting dengan menggunakan penukar matriks. Matlamat projek ini adalah untuk mensimulasikan dan menganalisis prestasi penukar matriks sebagai penukar au-au dalam teknologi SST.

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LIST OF ABBREVIATIONS

HF	-	High Frequency
LF	-	Low Frequency
SST	-	Solid-State Transformer
AC	-	Alternating Current
HFT	-	High-Frequency Transformer
LFT	-	Low-Frequency Transformer
IGBT	-	Insulated-Gate Bipolar Transistor
FYP1	-	Final Year Project 1
FYP2	-	Final Year Project 2
PWM	-	Pulse Width Modulation
SPWM	-	Sine Pulse Width Modulation
SVM	-	Space Vector Modulation
TPMC	-	Three-Phase Matrix Converter
SPMC	-	Single-Phase Matrix Converter
THD_v	-	Total Harmonic Distortion (voltage)
THD_i	-	Total Harmonic Distortion (current)
FFT	-	Fast Fourier Transform
RMS	-	Root Mean Square

LIST OF SYMBOLS

S_{SST}	-	SST rated power
f_{HFT}	-	Frequency Transformer
V_{ip}	-	SST input line-to-phase voltage
V_{op}	-	Output phase-to-ground voltage
f_i	-	Frequency input
f_o	-	Frequency output
n	-	HFT turns ratio
L_i	-	Input filter inductance
C_i	-	Input filter capacitance
r_p	-	Input filter damping resistor
L_o	-	Output filter inductance
C_o	-	Output filter capacitance
C_{HF}	-	High-Frequency capacitance
µF	-	Micro farad
Ω	-	Ohm
Hz	-	Herzt
V	-	Voltage
Amp	-	Ampere
VA	-	Voltage-Ampere
Vi	-	Voltage Input
Vo	-	Voltage Output

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In the power system, the conventional transformer is the main part to convert AC power source either to step-down or step-up either in transmission and distribution. Nevertheless, the size of this transformer is too bulky and heavy. The low efficiency due to high power losses in the form of the hysteresis losses is one of the disadvantages of this low-frequency transformer.

To overcome this weakness solid-state transformer (SST) operated with high frequency is suggested to replace. The HF transformer would reduce the volume and provides galvanic AC-AC conversion(Maharjan *et al.*, 2017). On the other hand, the advantages of this SST technology provided low hysteresis loss and able to reduce the eddy current loss by laminated the core(Sandeep, Shinde and Dake, 2017).

The penetration of renewable energy connected to the smart-grid cause to the high demand application of power electronics offers the space of solid-state transformer technology developing faster as expected. The combination of power converters with HF transformer is needed to make the SST technology working successfully.

The direct converter is also called as matrix converter which is part of the converter can be applied into the SST Technology to perform good AC waveform. A matrix converter consists of bi-directional switches that convert power conversion which has operated rectification and inversion to convert AC-AC. The equivalent circuit matrix converter (indirect matrix converter) shown in Figure 1.1 and the circuit matrix converter (direct converter) shown in Figure 1.2.

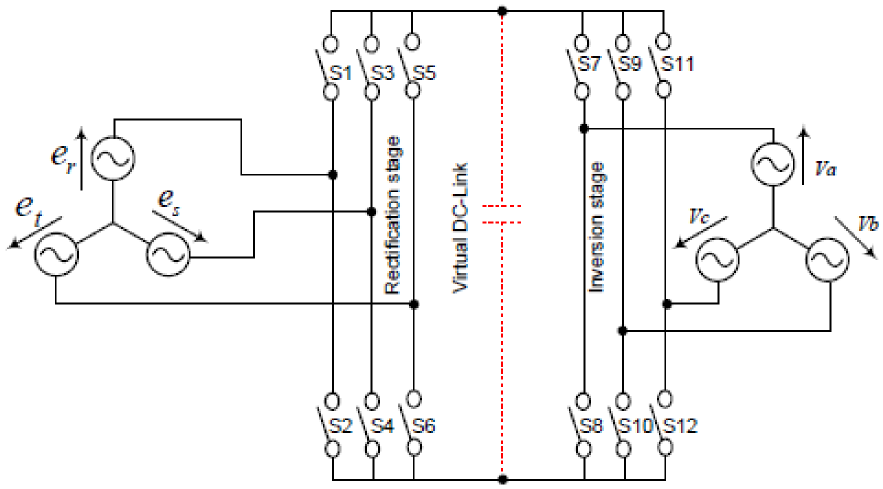

Figure 1.1: Equivalent circuit matrix converter (indirect matrix converter)(Hassan, Sayed and Mohamed, 2017)

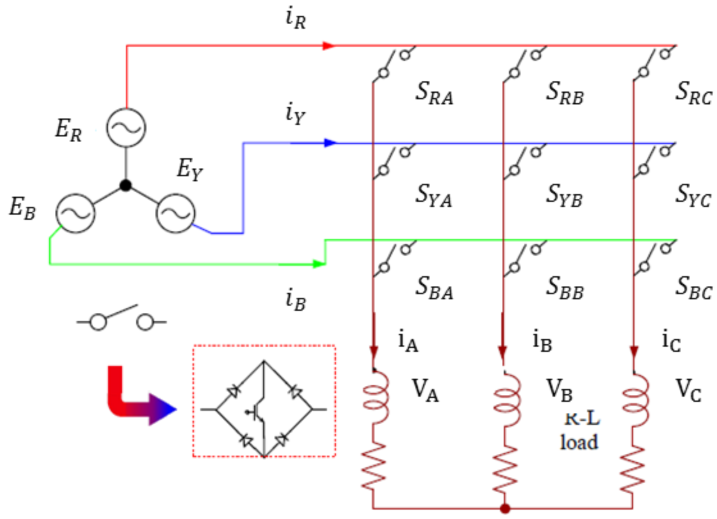

Figure 1.2: Circuit matrix converter(Maharjan *et al.*, 2017)(Kumar, Vyjayanthi, Sreenivasulu, 2016)(Hassan, Sayed and Mohamed, 2017)(Ahuja, Kumar and Agarwal, 2013)(Erdem, Tatar and Sunter, 2005)(Djahbar, Benziane and Zegaoui, 2014)

1.2 Problem Statement

The conventional transformer either step-up or step-down transformer shown in Figure 1.3 from the AC source to the AC load or grid system, the size is bulky and heavy. The expensive of cost not only due to the material, but the transportation cost to bring this conventional transformer to the site also need to reconsider(Hassan, Sayed and Mohamed, 2017; Krishnamoorthy, Enjeti and Sandoval, 2017; Wang, Lei and Liu, 2017).

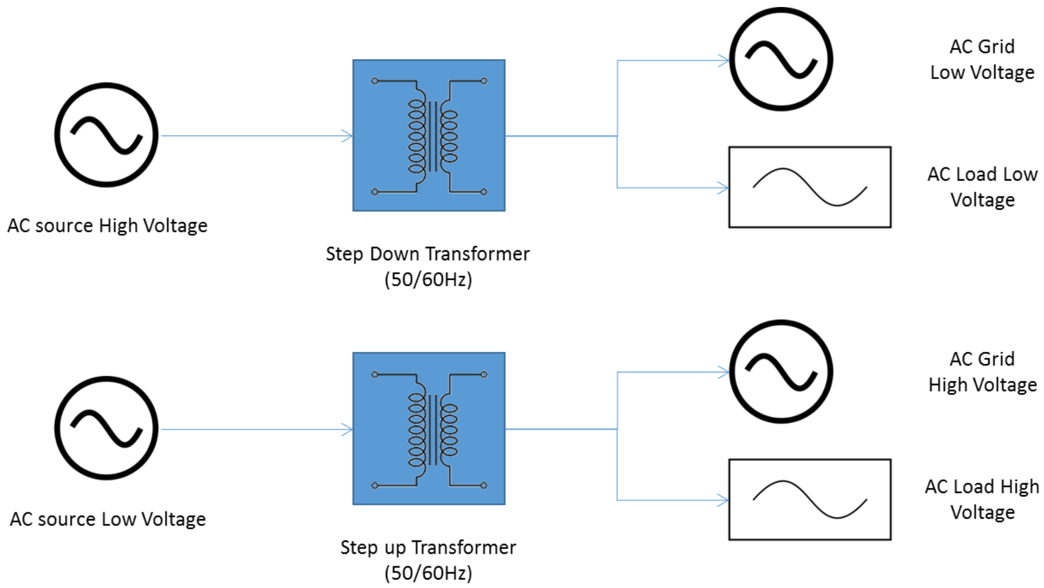

Figure 1.3: Step-up and step-down transformer concept connected from the source to the load or grid

The traditional LF transformer is operating with high losses due to overheating at core and coil whereby produce hysteresis and eddy current finally will be effected to the lower efficiency(Hassan, Sayed and Mohamed, 2017).

1.3 Objectives of Project

The main objectives of this project are:

1. To design multilevel power converters for SST technology of three-phase power system introduced in term of important indices by using matrix converter
2. To simulate and analyses the performance of a matrix converter as the ac-ac converter in SST technology.

1.4 Scope of Project

This project will be focused on matrix converter AC-AC by as the solid-state transformer. The Matlab/Simulink software will be applied to simulate and analyze the results for the three-phase and single-phase matrix converter which is connected to the primary and secondary HF transformer.

1.5 Report Outline

Six chapters involved in this project. Chapter 1 is consists of the introduction of the project that describes the project in general. The subtopic for the problem statement will be discussed based on specific problems that related to this project. In the objectives, will be explained the purpose and agenda to achieve this project. Chapter 2 elaborate literature review that linked to this project. The explanation is based on information which has gathered from the journal, thesis, the internet, reference books and relevant article. Chapter 3 contains the research methodology that explains in detail the overall project flow of multi-stage power conversion using matrix converter for Solid State Transformer technology. Chapter 4 describes the results and analysis and in Chapter 5 contains the conclusion and recommendation of the project. Finally, Chapter 6 will discuss more on project management.

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