

EXAMINE THE IMPACT OF PARALLELING TWO 132/22KV
TRANSFORMERS THAT HAVE A DIVERSE TOPOLOGY CONSIDERING
POTENTIAL FAULT EVENT FOR UTM HIGH VOLTAGE NETWORK

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DEDICATION

This research specially dedicated to both my beloved mother, father, husband, sons and daughter for their support and encouragement, and also to my supervisor Dr Syed Norazizul bin Syed Nasir and all my friends.

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ABSTRACT

Transformer is a magnetically coupled circuit, whose operation is governed by Faraday's Law of electromagnetic induction. Transformers are also used in AC voltage transfer from one level to another. A step-up transformer raises the voltage from primary to secondary level, while a step-down transformer decreases the secondary to lower voltage. Transformers play a significant role in the power utility as it is the core of the high voltage transmission system. Transformer must always operate without fail and if one transformer fails due to fault, another transformer must take action to supply uninterrupted power (n-1 source) to consumer. To ensure n-1 criteria is met, transformers at transmission level are connected in parallel. To connect transformers in parallel, certain conditions need to be met and the conditions will be discussed in Chapter 1. This study will focus on one of the parallel criteria which is transformer's topology or as known as vector group. Currently, Universiti Teknologi Malaysia (UTM) high voltage network are installed with two 30MVA 132/22kV transformers of same vector group which is YNd1. It should be no restriction to parallel these two transformers since they have same vector group. To examine the effect of paralleling two transformers of diverse topology, two transformers of different vector will be paralleled using MATLAB Simulink software. This network will then be simulated with potential fault event which in this case, will restrict to only short-circuit fault. This study will extend to analysing the network with the absence of earthing transformer that is connected at secondary side of 132/22kV transformer. Literature studies have also been conducted on the previous parallel transformer scenarios. The results of the simulation will be analysed in order to find out the effect of paralleling transformers with diverse topology. If the result is satisfactory and within limit, it can be applied in electricity industry.

ABSTRAK

Alatubah merupakan litar berpasangan magnet, yang operasinya adalah berpandukan kepada aruhan elektromagnetik '*Faraday's Law*'. Alatubah biasanya digunakan untuk menukar voltan AC dari satu tahap ke tahap yang lain. Alatubah menaik meningkatkan voltan dari sisi primer ke tahap voltan yang lebih tinggi di sisi sekunder, sementara alatubah menurun mengurangkan sekunder ke tahap voltan yang lebih rendah. Alatubah memainkan peranan penting dalam sistem kuasa. Ia adalah komponen tulang belakang sistem penghantaran kuasa voltan tinggi. Alatubah mestilah beroperasi tanpa gagal dan jika salah satu alatubah mengalami kerosakan, alatubah lain mestilah mengambil alih untuk membekalkan kuasa elektrik tanpa gangguan (sumber n-1) kepada pengguna. Alatubah penghantaran biasanya disambungkan secara selari untuk memastikan kriteria n-1 dipenuhi. Keadaan penyambungan transformer secara selari akan dibincangkan dalam Bab 1. Kajian ini akan melihat dengan lebih mendalam kepada salah satu kriteria selari iaitu topologi alatubah atau lebih dikenali sebagai kumpulan vektor. Pada ketika ini, Voltan Tinggi Universiti Teknologi Malaysia (UTM) dilengkapi dengan dua alatubah 30MVA 132/22kV kumpulan vektor yang sama iaitu YNd1. Seharusnya tidak ada batasan untuk kedua-dua alatubah ini disambung secara selari kerana mereka mempunyai kumpulan vektor yang sama. Untuk mengkaji kesan sambungan secara selari bagi dua alatubah dari topologi yang pelbagai, dua alatubah dari kumpulan vektor yang berbeza akan disambung secara selari dengan menggunakan perisian '*MATLAB Simulink*'. Litar ini kemudiannya akan disimulasikan dengan arus kerosakan yang mana dalam kes ini, hanya akan terhad kepada kerosakan litar pintas. Kajian ini juga akan menganalisa litar dengan ketiadaan alatubah pembumian yang disambungkan di sisi sekunder alatubah 132/22kV. Kajian literatur juga telah dibuat ke atas pelbagai kajian sebelum ini yang pernah dibuat penyambungan alatubah dalam keadaan selari. Hasil simulasi akan dianalisis untuk mengetahui kesan penyambungan alatubah dalam keadaan selari dengan topologi yang pelbagai. Sekiranya hasil memuaskan dan masih dalam limit yang dibenarkan, ia kemungkinan dapat diterapkan dalam industri elektrik.

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LIST OF ABBREVIATIONS

TNB	-	Tenaga Nasional Berhad
T1	-	Transformer 1
T2	-	Transformer 2
PMU	-	Pencawang Masuk Utama
PPU	-	Pencawang Pembahagian Utama
HV	-	High Voltage
LV	-	Low Voltage
NER	-	Neutral Earth Resistance
SLG	-	Single Line to Ground
THD	-	Total Harmonic Distortion
MRT2	-	Mass Rapid Transit 2
DL	-	Double Line
DLG	-	Double Line to Ground
TL	-	Three Line
OLTC	-	On-Load Tap Changer

LIST OF SYMBOLS

MVA	-	Mega Volt-Ampere
kV	-	kilo-Volt
kA	-	Transformer 2
V	-	Volt
A	-	Ampere
Ω	-	Ohm
%	-	Percentage

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Transformer is one of the main equipment in TNB distribution system which can be categorised into power transformer and distribution transformer. Power transformer (7.5 MVA and above) is mainly used in PMU and PPU whilst distribution transformer (1000 kVA and below) is usually utilised in substation [1]. In the field of power utilities, the n-1 contingency power supply system is planned so that during fault event, the other transformer can automatically supply to the affected loads. According to IEEE Standard C57.152TM-2015, two or more transformers connected to common load buses should be taken into account in parallel. These common buses can be connected to all kinds of loads, as well as to capacitor banks, shunt reactors and power sources. The transformer primary windings can be linked to common buses or buses with electricity from different lines [2]. The operating of power transformers in parallel is a common occurrence. The objective is to minimize reactive current circulation between transformers caused by mismatches in their electrical characteristics. Numerous control systems have been developed over the years to optimize the functioning of paralleled transformers equipped with on-load tap changer (OLTC) [3]. The operation of parallel transformers contributes to improved system reliability and performance; hence it increases transformers' short circuit current.

Transformer operates in parallel when load is increased and capability exceeds. In order to provide increased load, an additional transformer may be connected to the existing transformer in parallel. When bigger capacity of transformer is not available, two or more smaller transformers are put in parallel to replace bigger capacity of transformer to meet load requirement. Parallel transformer can also secure the security of supply especially when a fault occurs in one transformer, the other transformer can supply and backup to the affected loads while the faulty transformer can be taken out

for service [4]. The connections of transformer when connected in parallel is shown in Figure 1.1:

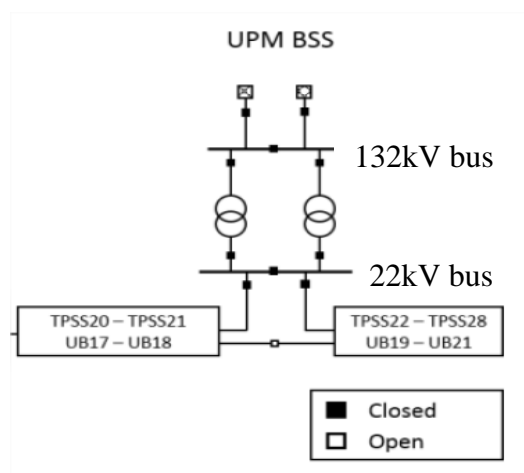


Figure 1.1 Example of parallel connection of transformers

Both transformers are interconnected in bus tie configuration. Low voltage side transformer's busbar is connected between each other by bus tie. To parallel two transformers, bus tie circuit breaker is in close position. While to non-parallel transformers, bus tie circuit breaker is switched to open position. These two transformers (T1 and T2) are isolated from each other during non-parallel operation. In case of any breakdown or planned outage one of the transformers, bus section circuit breaker at LV side is closed in order to supply uninterrupted power supply to consumer. The breakdown transformer can be taken out for maintenance without interrupting supply. The IEEE Standard describes general needs for the parallel transformers. Transformers can be made parallel when transformer ratios of the reactance to the equivalent resistance of the secondary windings, relative impedances of transformers, phase sequence and phase shift are the same [2].

Obviously, it is virtually impossible to meet the requirements described under actual operation conditions because of potential difference in transformer characteristics and electrical network configuration. It is nearly impossible to fulfil the described requirements in actual operating conditions as a result of possible differences in electrical network transformer characteristics and configuration. The problem of transformers running parallel is of particular practical concern especially

when power supply of transformer primary windings from different power lines and difference of relative impedances of parallel transformers under change of transformer ratios [2].

In this case, parallel transformers should meet the voltage control requirements of the load buses as a result of inappropriate transformer ratios. The circulating current should be minimized. These conditions should also be provided irrespective of changes in the power system configuration [5]. Many studies focus on the problem and control of paralleled power transformers. However, not any evidence on the impact on the parallel transformers of the power supply system configuration and the load connection layout [5-9].

1.2 Problem Statement

Normally in any utilities practice, transformers will only be paralleled when they met the requirements for paralleling. The requirements are MVA rating, tap changer and vector group should be the same. Also, to parallel transformers, make sure that loading for each transformer is less than 50% of full capacity.

Utility companies would not permit transformers to be paralleled when these requirements are not met. This is because if the transformers do not meet the conditions of paralleling transformers, then large circulating currents would flow between two transformers which are dangerous and unnecessary. This circulating current will keep circulating between transformers and does not contribute to load current. This circulating current can overheat the transformer and reduces the lifespan of the transformers [10]. In this study, we will examine the effect when transformers with diverse topology are paralleled together. This study can be implemented to real situation if the result comes out satisfactory.

1.3 Objectives

The main objectives of this study are:

- (a) To evaluate utility's current practice in paralleling transformers.
- (b) To analyse the output voltage and current using MATLAB Simulink by paralleling transformers of different topologies with earthing transformer and without earthing transformer during fault event by considering 4 types of short circuit fault (single line to ground fault, double line fault, double line to ground fault and three-line fault).
- (c) To validate the advantage and disadvantage of paralleling transformers with same and different topology.

1.4 Scope

The scopes of work considered in this research are summarized as follows:

- (a) This research will only focus on Universiti Teknologi Malaysia (UTM) High Voltage Network that comprises of two 30MVA 132/22kV transformers of vector group YNd1.
- (b) There are 3 topologies to be focused in this study which are:
 - i. Two (2) 30MVA 132/22kV transformers of vector group YNd1. The primary winding of the transformer is connected in Wye/Star while secondary winding is connected in Delta connection.
 - ii. Two (2) 30MVA 132/22kV transformers of vector group Dd1. The primary winding of the transformer is connected in Delta while secondary winding is also connected in Delta connection.

- iii. Two (2) 30MVA 132/22kV transformers of vector group YNd1 and Dd1.
- (c) The fault event that will be simulated for this study is only on short-circuit fault comprises of single phase to ground, phase to phase, phase to phase to ground and three phase faults.
- (d) 22/0.415kV Zig-zag earthing transformer at low voltage side. This transformer is installed at the low voltage (secondary) side of power transformer.

1.5 Thesis Outline

Chapter 1 explains the general background of transformer, parallel operation of transformers and types of fault. Other than that, project objectives and project scopes are also being emphasized in this chapter.

Chapter 2 focuses on the literature review related to the paralleling transformers with diverse topology. It will cover on the past studies on the paralleling method together with the benefits and drawbacks. Other than that, these studies will be highlighted in detail and being compared with other studies.

Chapter 3 discusses the methodology of the project and the proposed framework using MATLAB Simulink.

Chapter 4 highlights on the results of simulation by using MATLAB Simulink software for all topologies as mentioned in scope. The simulation will focus on paralleling transformers with same topologies and different topologies

Chapter 5 reviews the conclusion of paralleling transformers using MATLAB Simulink. This chapter will also discuss recommend for future works.

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