# Faculty of Electrical and Electronic Engineering Technology



# INVESTIGATION OF FAULTY CAPACITOR IN SYMMETRICAL SHUNT CAPACITOR BANK VIA UNBALANCED CURRENT

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**Bachelor of Electrical Engineering Technology (Industrial Power) with Honours**

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# INVESTIGATION OF FAULTY CAPACITOR IN SYMMETRICAL SHUNT CAPACITOR BANK VIA UNBALANCED CURRENT

**MUHAMMAD AMIRUL SYAFIQ BIN AZLI**

**A project report submitted**
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I declare that this project report entitled "Investigation Of Faulty Capacitor In Symmetrical Shunt Capacitor Bank Via Unbalanced Current" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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## DEDICATION

MY BELOVED FAMILY,

Mr. Azli bin Hamid and Mrs. Sazlina binti Mokhtar

For their unwavering moral support and encouragement through my time at University Teknikal Malaysia Melaka.

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# ABSTRACT

Shunt capacitor banks (SCB) are situated closer to the main substation to compensate for capacitive reactivation of electricity. A higher power factor is achieved, power losses are minimized, and a higher voltage profile is achieved. With this contemporary technology and the rising use of electrical equipment with motors nowadays, the power factor at the transmission site will constantly be in a trailing condition, and this must be corrected to ensure that the electricity's utilization efficiency is always close to the ideal power factor. However, the increased use of capacitor banks has resulted in an increase in the number of capacitor bank failures at the transmission site. As a result, observing the current output from the capacitor bank is the quickest and most straightforward means of identifying a failing capacitor bank. An innovative approach for identifying the failed phase and section in capacitor banks are presented in this study paper. The approach is based on the unbalance current approach.

# *ABSTRAK*

Bank kapasitor shunt (SCB) kebiasaanya terletak berdekatan dengan pencawang utama untuk mengawal kapasiti kuasa eletrik. Perkara ini termasuk dari segi untuk mengawal faktor kuasa, mengurangkan kehilangan kuasa, dan meningkatkan profil voltan dalam setiap sistem tapak talian penghantaran eletrik. Dengan peningkatan penggunaan pelbagai peralatan moden yang kebanyakanya beroperasi dengan motor, faktor kuasa di tapak talian penghantaran akan selalu berada dalam keadaan yang tertinggal, perkara ini perlu diperbaiki supaya dapat memastikan kecekapan penggunaan elektrik akan selalu berada pada kedudukan faktor kuasa yang paling optimum. Tetapi peningkatan penggunaan bank kapasitor yang melebihi had kini juga telah meningkatkan kegagalan di kebanyakan bank kapasitor di lokasi tapak talian penghantaran eletrik. Oleh itu, kaedah yang cepat dan berkesan untuk mengesan bank kapasitor yang mengalami kerosakan ialah dengan memerhatikan keluaran arus eletrik dari setiap bank kapasitor. Maka, kertas kerja ini menyajikan kaedah baru untuk mengenal pasti fasa dan bahagian yang mengalami kerosakan di bank kapasitor dengan menggunakan kaedah arus eletrik yang tidak seimbang.

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| | | |
|---|---|---|
| $S$ | - | Apparent Power |
| P | - | Real Power |
| Q | - | Reactive Power |
| $\Omega$ | - | Ohm |
| Xc | - | Capacitor Impedance |
| $\mu$ | - | Micro |
| k | - | Kilo |

## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| *V* | - | Voltage |
| *I* | - | Current |
| *CBs* | - | Capacitor Banks |
| *SCBs* | - | Shunt Capacitor Banks |
| *C* | - | Capacitor |
| *CT* | - | Current Transformer |
| *PS CAD* | - | Power System Computer Aided Design |
| *MATLAB* | - | Matrix Laboratory |
| *f* | - | Frequency |
| *T* | - | Transformer |
| *TMAS* | - | Telok Mas Substation |
| *MMAU* | - | Merlimau Substation |
| *UPSR* | - | Ujong Pasir Substation |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

A distribution system can supply electricity to various types of loads that require electricity to run, such as residential, manufacturing, domestic, and commercial, with demand levels fluctuating during the day. The system's operating state varies depending on whether it is heavily or lightly loaded. Reconfigurable distribution systems can adjust to both regular and abnormal distribution structure conditions based on different load and changes in distribution system and generation. This is a reconfiguration optimization strategy that adjusts the open or closed status of distribution system switches to link all feeders with the goal of increasing grid performance. Network reconfiguration advantages include boosting voltage profile and power factor, increasing power system reliability, lowering power loss, and flattening peak demand. Therefore, reconfiguration of energy networks, which account for most power grid failures and outages, is becoming more frequent.



Capacitor banks are classified into two categories. Banks of series capacitors and banks of shunt capacitors. All these configurations are based on the interaction mechanism of the device. SCBs improve voltage profile and power factor while decreasing line current and losses. Although series CBs improve the system's voltage profile, since they are connected in series, they have no power over the current flow [5]. Furthermore, the voltage of the capacitor bank rises to 15 times its rated voltage. Consequently, series CBs are used in only a few high-voltage devices. A SCB is a power-system instrument that increases voltage profile, power factor adjustment, and/or reduces power loss [2]. SCBs can only be used if the security and control configuration have the required information and equipment. Engineers will face difficulties when installing the SCB, such as deciding the best place for SCBs in a device to provide the required reactive capacity while being cost efficient and easy to manage. In terms of security engineering, the protection must ensure that all faults, both internal and external to the SCB, do not disrupt the operation, and it must be transient-resistant, fast, sensitive, and dependable.

Shunt capacitor banks (SCB) are located closer to the main substation for capacitive reactive power compensation. This increases the power factor, reduces I2R power losses, and boosts the voltage profile. SCB cuts power losses all the way down to the coupling point, so it should be installed as close to the load as possible to get the most gain. With the availability of pole-mounted hardware, such as SCB, the trend has changed. Capacitor banks are also built on main distribution lines as well. The capacitor system is the most important pillar in the construction of a SCB. Within a steel cage, the capacitor units will be connected in paralleled series to form a single-phase capacitor bank [4]. The series combination reduces the dielectric cost, while the parallel combination increases the SCB's overall capacitance. As a rule of thumb, enough parallel units must be attached so that the separation of one capacitor unit in a device does not result in a voltage unbalance of more than 110 percent of the group's rating voltage on the current capacitors [1].

SCB security would be largely reliant on SCB and power device safety systems. SCB monitoring measures have been put to save the SCB from being unreliable. In the event of a malfunction, the protection scheme's first step is to isolate the device or element within the SCB so that the whole SCB unit is not affected. If the malfunction worsens, the protection scheme disconnects the SCB from service, possibly resulting in a disastrous breakdown, and even sounds a warning to indicate an unbalance within the SCB. All of this, though, is only possible if we can locate the fault and its direction precisely. The fault analysis contains all important information about the SCB during fault analysis. This paper describes how to use a mathematical method to calculate the different parameters of a faulty capacitor bank. The study also includes the SCB fault analysis during fault operation. The final part of the paper would explain the flawed method by studying the unbalance presented with MATLAB and PS CAD applications.

## 1.2 Problem Statement

Before investigating the problem, the distribution system at transmission site always had been having problem with the automatically shunt capacitor bank failure for sometime. This failure can happen because various types of loads that require electricity to run, such as residential, manufacturing, domestic, and commercial, with demand levels fluctuating during the day. So power factor for each one of phase in transmission system will always not consistance and frequently change the power factor and can make some capacitor bank cannot hold this problem. Since the bank is not tested on a regular basis, the issue was not discovered right away. Firstly, the problem will be discovered when the operator of transmission site will found the power factor will not at optimum range. Continous onsite surveillance maybe will have found the problem earlier and start to find the issue. The obvious first step was to patch the blown fuses at shunt capacitor bank that had been found. Later, it was discovered that some capacitor cells already broken, and these were replaced as well. When the issues continued, a thorough investigation was carried out. This will increase the cost for maintenance and make energy provider such as TNB need to cut off power distribution and make some area do not have electric supply.



When one of the three phases at transmission site is not balanced, some fuses at capacitor bank maybe had exploded and some capacitor cells had failed at the time of the measurements. Variable phases 1 and 3 had burst fuses, and one of the three 16.7-kvar (three-phase) cells in phase 3 had failed, so phase 3 was only supplying 33.3 kvar instead of the nominal 50 kvar. During the measurements, no apparent cause was discovered. Either the issue was caused by accumulated effects over time, or it was a one-time issue that did not arise during the measurements. The lack of failures during the measurements necessitated further investigation to determine the source of the problem. It would have been easier to match cause and effect right away if errors had occurred during the measurements. And to easily detect this problem, using a unbalance current meassurement to find at what phase has a problem and initial act can be done as fast as possible to avoid futher problem [3].

## 1.3 Project Objective

The objectives of this project are as follows:

a) To investigate and analyze capacitor failure in a symmetrical shunt capacitor bank by looking at the pattern or effect of unbalanced current in the shunt capacitor bank at transmission site.

b) To develop a system that can easily detect the source of shunt capacitor bank failure in industry so the initial protection measure can be done as soon as possible.

c) To evaluate the performance of shunt capacitor bank to improve the power factor at transmission site.

## 1.4 Scope Of Project

This research would include a variety of topics, including the use of tools such as MATLAB and PS CAD to build and operate a three-phase distribution system with a shunt capacitor bank to achieve an optimal power factor of one or less than one but still at optimum factor. This project would also investigate each phase that is always used in the manufacturing field and ensure that each phase is in balance current. If one of the phases is out of balance, this analysis would look at how to verify the failure of a shunt capacitor bank using the unbalance current method. This method will be used because it is the simplest and best way to determine if the capacitor bank has failed.

## 1.5 Thesis Outline

Introduction is the first chapter in this bachelor's degree project. It will explain the project's objectives, the problem statement, and the purpose of the project. The literature review will then be presented in Chapter 2. This chapter then will review some related articles from journals and previous research paper in order to get a deeper understanding of how current projects are developed and to spot differences and correlations in previous relevant research. In Chapter 3, the project's system and methodology for the guide, equipment and software will be explained in much more detail. Finally, the last chapter will explain the conclusions that will be presented to see how far the project has progressed.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

A literature review is an examination of previous journals and research papers on investigation of faulty capacitor in symmetrical shunt capacitor bank. To ensure the success of this project, this chapter will be used in the future as a reference to assist with challenges encountered during project execution.

## 2.2 The Capacitor Unit

A shunt capacitor bank is constructed around the capacitor unit as seen in Figure 2.2(a), and this equipment is always used by energy providers such as TNB to maintain the optimal power factor, so ensuring that the end user receives the optimal and best possible electricity. The capacitor system is made up of individual capacitor elements that are grouped together in parallel linked groups within a stainless-steel enclosure. A resistor is used in the internal discharging system, which reduces the unit's residual voltage in 5 minutes to 50V or less or less depending on the model. Voltage ratings of capacitor systems range from 240 V to 25 kV, and their sizes range from 2.5 kVar to an average of 1000 kVar [6]. Capacitor systems are available in a variety of sizes and voltage ratings.