INSULATION MONITORING DEVICE

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I declare that this report entitle “Insulation Monitoring Device” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

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To my beloved mother and father

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ABSTRACT

In the history of surgical procedure, patients have the possibility to bare the side effect of the electrical shock. This electric shock is caused theoretically by electromedical equipment within the medical room surrounding. A primary concern of this electric shock is when there is a micro-shock that passed through the patient while having medical operation and can harm the patient. However, a problem rises when the detection of the leakage current is not accurate. The objective of this project is to design and develop an insulation-monitoring device for detecting the leakage of current in IT electrical network system. The second objective of this project is to test the performance of proposed system in terms of accuracy and precision. For the methodology, the proposed system will be using Arduino UNO and voltage divider theory. Data for this study will be collected using two methods which are from simulation setup and experimental setup. For simulation setup, software Proteus Release 8.0 is used. By employing experimental setup, a circuit contains a decade resistor and a socket for the 100-W lamp to replicate the medical room situation is built. From the experimental setup, the accuracy, precision and sensitivity can be obtained. The finding of the experiment is that the insulation – monitoring device able to detect the leakage of current even though there are error on current measurement from the electrical network system. The average percentage error for accuracy is at 15.683% and the average percentage error for the precision is at 14.59%. On top of that, the sensitivity of the IMD detection is at 37.74%. Thus, for recommendation to increase the reliability of the device, more powerful microprocessor need to be implemented to reduce the error.

ABSTRAK

Dalam sejarah prosedur pembedahan, pesakit mempunyai kemungkinan untuk menghasilkan kesan sampingan daripada kejutan elektrik. Secara teorinya, kejutan elektrik ini disebabkan oleh peralatan electromedikal di dalam bilik perubatan. Tumpuan utama kesan kejutan elektrik ini adalah apabila adanya kejutan-mikro yang melepasi pesakit semasa operasi perubatan berlangsung; pesakit terdedah kepada serangan jantung dan boleh membahayakan nyawa pesakit. Walaubagaimanapun,pengesanan kebocoran arus elektrik tidak tepat. Objektif utama projek ini ialah untuk mereka dan membina sebuah alat pemantauan penebat untuk mengesan kebocoran arus pada sistem elektrikal IT. Objektif kedua ialah untuk mengkaji keupayaan sistem dalam erti kata ketepatan dan kebolehulangan. Untuk metodologi,sistem cadangan akan menggunakan Arduino Uno dan teori pembahagi voltan. Data untuk kajian ini dikumpulkan dengan menggunakan dua kaedah iaitu dari persediaan simulasi dan persediaan eksperimen. Untuk penggunaan simulasi , perisian Proteus Versi 8.0 akan digunakan. Bagi persediaan eksperimen , litar yang mengandungi perintang dekad , dan soket untuk lampu 100 -W untuk meniru keadaan bilik perubatan akan dibina. Metodologi ini memberi peluang untuk mendapatkan data untuk ketepatan, kebolehulangan dan sensitiviti. Penemuan dalam ujikaji ini menunjukkan alat pemantauan penebat mampu mengesan kebocoran arus elektrik tetapi terdapat ralat dalam mengesan kebocoran arus di dalam rangkaian sistem elektrikal .Purata peratusan bagi ralat ketepatan ialah 15.683% dan purata peratusan bagi ralat kebolehulangan ialah 14.59%. Selain daripada itu,kepekaan untuk pengesanan IMD hanya pada 37.74%.Oleh yang demikian, sebagai cadangan untuk meningkatkan keupayaan alat ini, mikropemprosesan yang lebih berkuasa harus digunakan bagi mengurangkan ralat

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LIST OF ABBREVIATIONS

IT	-	Insulated-terra
IMD	-	Insulation monitoring device
PIM	-	Permanent insulation monitors
N	-	Neutral
PE	-	Protection earth
EME	-	Electromedical equipment

LIST OF SYMBOLS

I_d	-	Fault current flowing on earth connection resistance of the frame.
C1	-	Earth impedance capacitive component for phase 1.
C2	-	Earth impedance capacitive component for phase 2.
C3	-	Earth impedance capacitive component for phase 3.
Z_N	-	Additional impedance connected between neutral point and earth in IT system.
R_B	-	Resistance of natural earth connection
U_D	-	Contact voltage between frame and earth
G	-	Low frequency generator

CHAPTER 1

INTRODUCTION

This chapter will discuss about the project background, motivation, problem statement, project objective and scope of work for the insulation-monitoring device.

1.1 Motivation

Over the past century, deaths from electric shock have been reported in the operation room are caused by three possible mechanism of death [1]. The three possible threats are ventricular fibrillation, respiratory arrest, and asphyxia which happen when there is a long run of shock passed across the patient chest [2][12][15]. By avoiding these three possible mechanisms of death caused by electric shock, operation room safety can be increased. One way to increase the safety of operation room is by using IT system that equipped with insulation monitoring device. This device can provide extra safety to medical environment by alerting the operator if there is a leakage of current, which can lead to electric shock.

A much debated question is whether the insulation-monitoring device able to detect leakage of current in the medical environment in term of accuracy and sensitivity. Others researcher trying to get the value of the leakage current using different method such as differential current between two points [1], technique of the balanced voltmeter [3], direct current (DC) current injection method [3] and many more. Based on the method that being mention before, there are pros and cons for each method in term of accuracy and sensitivity of the detection.

Furthermore, the insulation-monitoring device is meant to help the medical sector by reducing the patient risk towards the electric shock especially in an operation room. From the Malaysian Electrical Installations of Building 2009 standard [16], the medical IT system should be set up with an insulation-monitoring device. Previously from International Electrical Installation of Building for Medical Environment 2002 [13], the usage of insulation-monitoring device should helps the IT system to perfectly detect leakage of current in medical environment. Malaysian government should obligate every hospital and medical clinic to install the insulation-monitoring system in IT system electrical network. Thus, the importance of the device have been studied and researched since 2002 to solve the micro-shock problem especially in an operation room. So, the insulation-monitoring device has the best way to overcome the leakage of current especially in medical environment.

1.2 Project Background

One of the most important events in 1740s was the discovery of Leyden jar’s [2], which is the original form of the capacitor and the beginning of electrical era. Investigating electricity is a continuing concern after electric battery invented by Volta, the invention of generators using the study of electromagnetism and the usage of these generators in every major industry in the world. Recently, researchers have shown an increased interest in two types of electrical shock; direct contact to an exposed live conductor and indirect contact. In this report, we will investigate the indirect contact, which happens when leakage of current occurred. Previous studies have reported about death cause by electrical shock during the surgery [2]. Due to these accidents, researchers want to minimize the problems by suggesting their proposals to prevent the leakage of current. IT system in figure 1.1 has the ability to prevent the leakage of current and any power interruption during a surgery. The system in Figure 1.1 namely Insulated and Terra system principles are naturally earthed by the high impedance up to 1500Ω. The neutral port of transformer is not earthed but it is actually unearthed by the capacities of network cables. The system is designed to preclude an electric spark that is not dangerous to human, especially the patient during surgery. To increase the safety for the usage of the system, an isolation transformer will be introduced together with the insulation-monitoring device. The insulation-monitoring device will trigger the alarm and gives the signal if there is leakage of current within the electrical lines. The IT system must be equipped with the insulation monitoring device in order to comply with the Malaysian standard for medical room, IEC 61557-8. Thus, developing an insulation-monitoring device will surely help the medical sector to prevent any electric shock especially in the operation room.

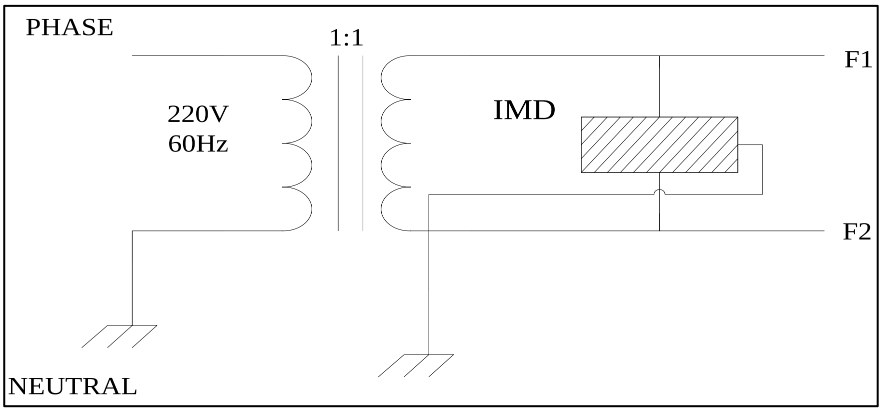

Figure 1.1: The IT (Insulated –Terra) system

1.3 Problem statement

Electric shock is a classic problem in medical sector. In order to solve this problem, researchers are working on to design an earthing system that can prevent electric shock in the operation room. The researchers introduced various standardized earthing systems, which given the international standard for medical room (IEC 60364). IT system is one of the systems that meet the international and Malaysian standard. Figure 1.2 shows that the IT system with no presence of IMD, which can risk the patient if the electro medical equipment having an insulation failure. From figure 1.2, resistance of patient is at 51kΩ, which is not a safe condition for a patient. Micro-shock will be produced when the current induced threshold is at or below 51k and can cause death.

Insulation monitoring device is a device used to detect leakage of current at medical environment, military sector, server room and many more. This device can alert and gives alarm to the users whenever there is a leakage of current across the electrical line. However, the problem came when the detection of the leakage of current is not accurate. According to IEC 61557-8 standard, an insulation-monitoring device should be able to detect the current induced threshold of below or equal to 51kΩ. Failure to detect the leakage of current can lead the patient to experience the micro-shock. Furthermore, method of detecting leakage of current must be suitable for an insulation-monitoring device as accuracy is the most important factor to detect leakage of current.

Moreover, the most important criteria for the device are the precision of the current measurement. The sensitivity of the device is depending on the resolution of the analog-to-digital convertor (ADC) of the microprocessor. The selection of the circuit to increase the precision also need to be determined as the threshold resistance for the electrical line will be at 51kΩ. The detection of the threshold for the device must be sensitive and precise enough to detect the changes of current every one second. Thus, for solving the problem, the insulation monitoring device design must follow the international electrical standard. On top of that, suitable earthing system and the technique to detect the leakage of current must not be taken lightly as both criteria are the most important part in increasing the accuracy and precision of the device.

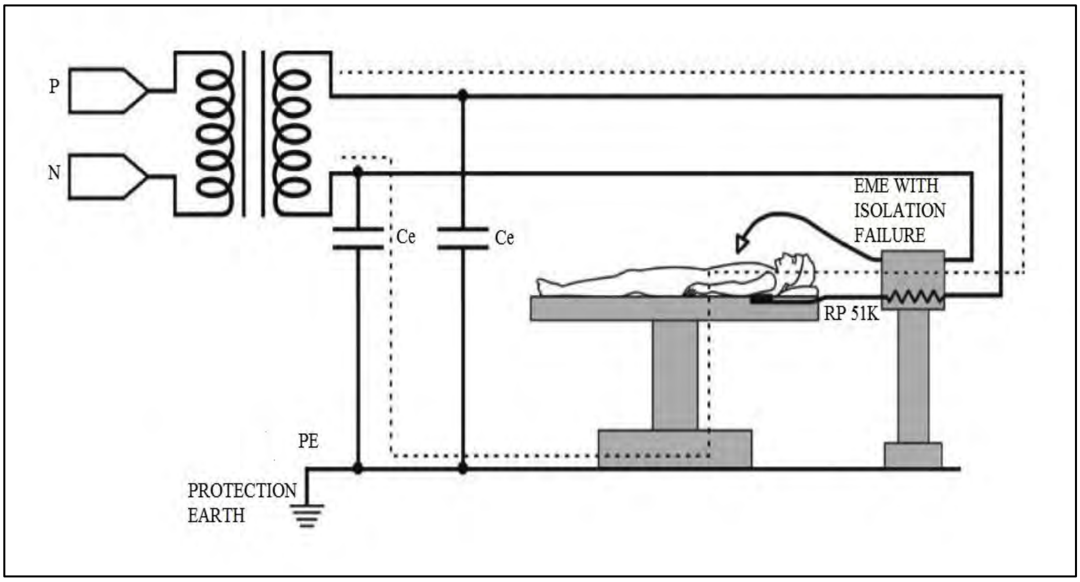

Figure 1.2: IT System used with no presence of IMD [1]

1.4 Objectives

The objectives of this project are

1. To design and develop an insulation-monitoring device for detecting the leakage current in IT electrical network system.
2. To test the performance of the proposed system in terms of accuracy and precision.

1.5 Scope of Work

1. This project is developed currently to be used in single phase power supply
2. Supply voltage is $200V_{AC}$ with current rating 31.5 kA.
3. This device detects the current leakage in single-phase power supply only.
4. To prove the accuracy and precision of the device, several experiments in the lab are performed.
5. Simulation using Proteus 8.0 software will be used to analyze the hardware functionality and experimental set up.
6. The design and development of the hardware are based on Malaysian Electrical Building Installation 2009.

1.6 Project Development Workflow

For the development of the insulation-monitoring device, the stages of the workflow can be seen in figure 1.3. First of all, the most important aspect to develop an insulation monitoring device is to collect all the information related to the device from any source such as IEEE journal, internet, reference book and many more. Then, after gathering the information from various sources, the simulation design must be acquired in order to propose the best research methodology for testing purpose. After that, the drawing of the desired design of circuit will be tested and verified the performance in terms of accuracy. If the performance of the design of the circuit is not proven, the circuit drawing will be repeated until the circuit can work perfectly. After the circuit has been verified, the hardware development will be started. Later on, after the hardware development, the analysis and data collection can be done. Data analysis and collection will be focused on accuracy and precision of the hardware.

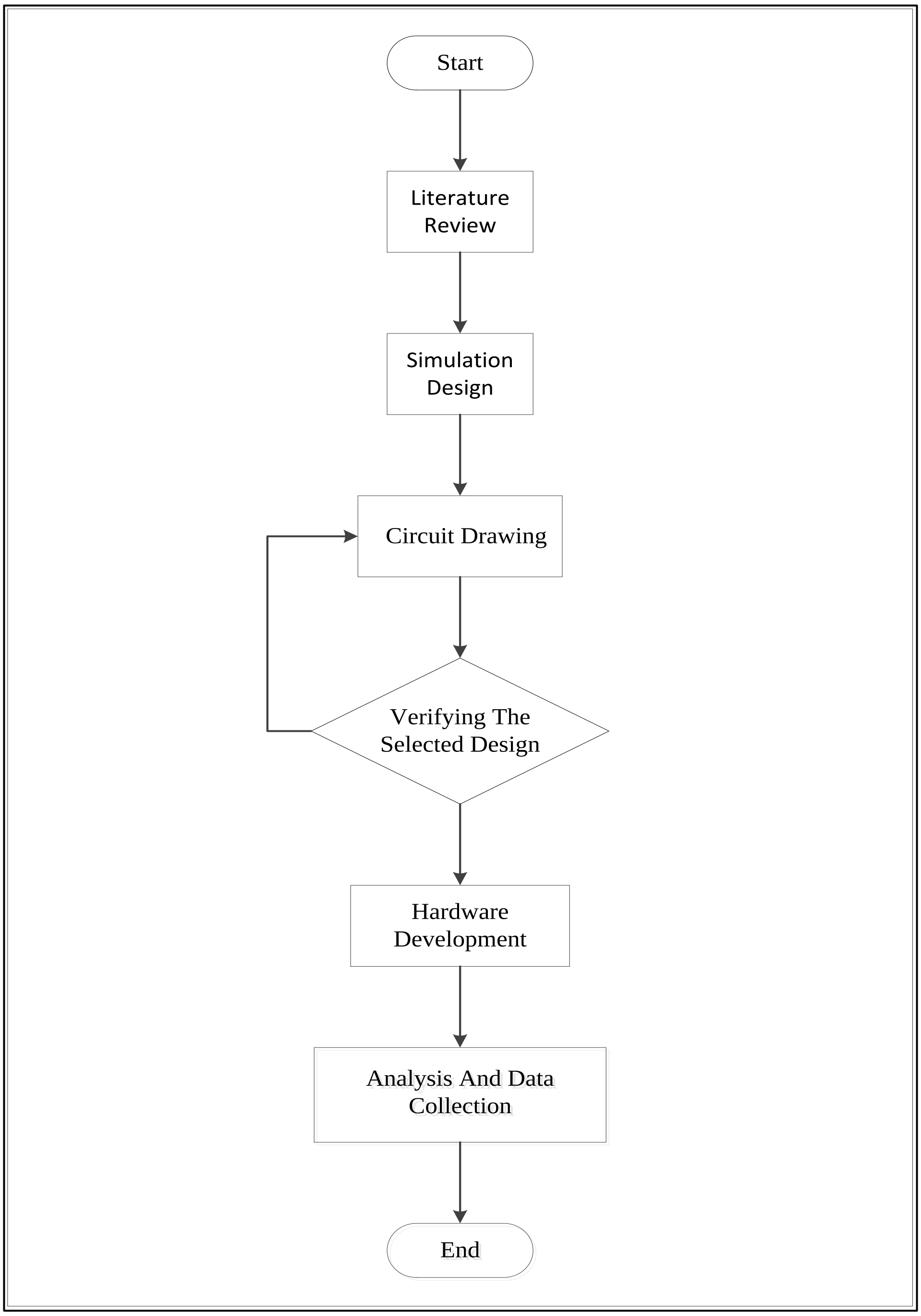

Figure 1.3: Project development workflow

CHAPTER 2

LITERATURE REVIEW

For this chapter, the collections of information that related to the system development of the insulation monitoring device has been search, evaluate and analysis. Any backgrounds, problems and solution regarding the development of the device will be covered in this chapter.

2.1 Introduction

As for analysis of information, there are two criteria that going to be studied in the literature review. The most important criterias are the accuracy of the detection of leakage current and the most suitable earthing system to be used with the insulation-monitoring device. Both criteria have been studied thoroughly to develop the most efficient insulation-monitoring device with the highest accuracy. Besides that, calculating fault current and contact voltage are also important criteria that going to be studied in this literature review. From figure 2.1, we can see the general block diagram of the insulation-monitoring device. Generally, the insulation-monitoring device works when there is a leakage of current, which will be detected by a current sensor. After the input of leakage current has been received, the microcontroller will process the input from analog data to digital data and finally will bring out the output. The outputs are in the form of alarm sound and display on a led panel.

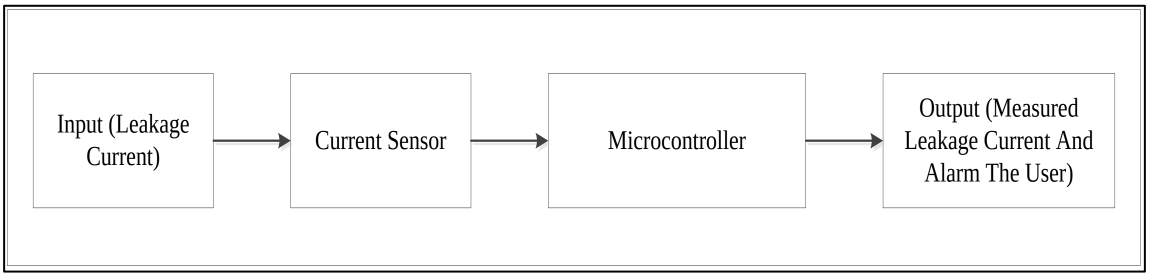

Figure 2.1: Block diagram of the Insulation Monitoring Device (IMD)

2.2 Detecting leakage current

2.2.1 Background

Previous studies have reported the method to detect a fault by using the first principles of PIM (permanent insulation monitor)[3]. Figure 2.2 is to explains about the first principles of PIM. At A, all the bulbs lit at the same rate of brightness because of the balanced three-phase load supplied throughout the bulbs. That means the current flowing consistently at same value throughout the bulbs[3]. So when the system experiencing the leakage of current, one of the bulbs is not lit and will be connected by the fault impedance, which can be seen at B. Voltage is decreasing at the terminal of the bulb 3 and, the bulb's brightness for the bulb 1 and bulb 2 are increasing until they reach the maximum voltage phase. Recent developments in fault tracking method have improved the previous method, which are needed to stop the operation of every feeder until the insulation faulty can be found. This new method can detect insulation faulty without power breaking to the system that can save more time to the user to stop each operation of feeder.

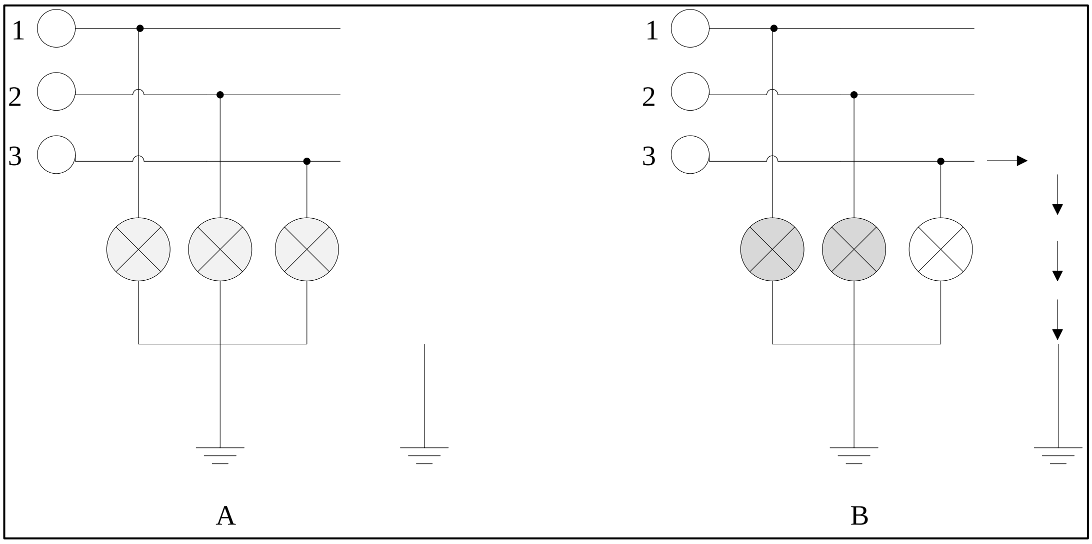

Figure 2.2: Principles of first PIM

2.2.2 Problem on detecting the leakage of current

For tracking an insulation fault, there are two ways to find the fault, which are tracking by successive de-energisation of feeders and live tracking. The operators (users) need to open every feeders starting with the main feeders for the tracking by successive de-energisation of feeder method. By applying the first principles of PIM, whenever the feeder that experiencing the leakage of current is opened, the current injected by the PIM will decrease and drop under the detection level. However, by applying this method, the users need to interrupt the operation of each feeder until the location of the insulation faulty is confirmed.