ELECTRICAL ARC FLASH HAZARD ANALYSIS IN ELECTRICAL SAFETY RISK MANAGEMENT AT HOSPITAL SEBERANG JAYA

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To my beloved parents,

Perumal Ramasamy & Amirtham Dharmalingam.

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ABSTRACT

Electrical safety issues in terms of the dangers it poses during faults or insulation breakdowns increases around the world parallel with the rise in the number of electrical switch board installations around the world. High voltage switch boards, particularly, 415 V and above exhibit an arc flash hazard to operators and facilities. Thus, this project focuses on the electrical quantification on such hazards and how the safety risk is managed by using adequate personal protective equipments (PPE). This is done so by utilizing the classical short circuit analysis approach and employing the IEEE 1584 Standard’s Arc Flash arcing current and hence the energy equations and cross-matched to the rating of the PPEs required for adequate protection and safety. This approach also determines the safe boundary parameter which presents the distance from these equipments where arc flashes don’t reach out. This electrical quantification is done manually using hand-calculations and solidified further using simulation tool namely SKM Power Tool. The simulation is much more in depth for calculation with detail switchboard parameters are input to output the desired results. This effort translates in adequately protecting people and properties from unwanted disasters by enforcing operators to wear proper PPEs during operations or maintenance. Based on the simulations, Hospital Seberang Jaya requires Category 1 and Category 2 levels of PPE. Risk management is done by labeling all the switchboards with their category ratings as a warning signal to anyone passing nearby these switchboards.

ABSTRAK

Isu-isu keselamatan elektrik dari segi bahaya yang timbul semasa insiden arus pintas atau kerosakan penebat smakin meningkat di seluruh dunia selari dengan peningkatan dalam bilangan pemasangan papan suis elektrik di seluruh dunia. Papan suis voltan tinggi, terutamanya, 415 V dan ke atas mempunyai bahya kilat arka (*'arc flash')* kepada operator dan bangunan. Oleh itu, projek ini memberi tumpuan kepada cara pengiraan bahaya elektrik tersebut dan bagaimana risiko keselamatan diuruskan dengan menggunakan peralatan perlindungan peribadi yang mencukupi (PPE). Ini dilakukan dengan menggunakan pendekatan klasik analisis litar arus pintas dan menggunakan persamaan-persamaan piawai Arka Kilat IEEE 1584. Piawai ini yang menghasilkan untuk arus kilat arka dan persamaan tenaga insiden dipadankan dipadankan untuk penarafan Alat Perlindungan Peribadi (APP) yang diperlukan untuk perlindungan dan keselamatan yang mencukupi. Pendekatan ini juga menentukan sempadan parameter selamat dengan mangolahkan jarak dari peralatan ini dan di mana pancaran arka tidak melimpah keluar. Pengiraan elektrik ini dilakukan secara manual pada mulanya dengan menggunakan pengiraan tangan dan dikukuhkan lagi dengan menggunakan perisian simulasi iaitu SKM Power Tools. Simulasi tersebut adalah lebih mendalam untuk pengiraan dengan input parameter suis terperinci dan dapa menghasilkan output yang diperlukan. Usaha ini dapat diterjemahkan kepada usaha melindungi operator dan harta benda daripada bencana yang tidak diingini dengan menguatkuasakan pengendali memakai APP yang sesuai semasa operasi atau penyelenggaraan. Berdasarkan simulasi, Hospital Seberang Jaya memerlukan peringkat PPE Kategori 1 dan Kategori 2. Pengurusan risiko dilakukan dengan melabelkan semua papan suis dengan penilaian kategori mereka sebagai isyarat amaran kepada sesiapa yang berdekatan dengan papan suis yang berkenaan.

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LIST OF SYMBOLS

dBs	-	decibels
NFPA	-	National Fire Protection Association (United States)
AC	-	Alternating Current
V	-	Voltage
I	-	Current
Z	-	Electrical Impedance
R	-	Electrical Resistance
log	-	Mathematical operator for logarithm to the base of 10
E	-	Energy
t	-	Time
%	-	Percentage
ft	-	Feet
R	-	Electrical Resistance
mA	-	miliamperes
sec	-	seconds
cal/cm^2	-	calories per centimeter squared
kA	-	kiloamperes
mm^2	-	millimeters squared
m	-	meter
kVA	-	kilo volt amperes

LIST OF ABBREVIATIONS

AFH	-	Arc Flash Hazard
NFPA	-	National Fire Protection Association (United States)
AC	-	Alternating Current
V	-	Voltage
I	-	Current
Z	-	Electrical Impedance
R	-	Electrical Resistance
CB	-	Circuit Breaker
MCCB	-	Metal Clad Circuit Breaker
ACB	-	Air Circuit Breaker
PPE	-	Personal Protective Equipment
N/A	-	Non Applicable
FR	-	Fire Retardant

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CHAPTER 1

INTRODUCTION

1.1 Background

The usage of electricity has increased over the years as exemplified by a nation's Gross Domestic Product (GDP) growth figure [1]. The higher the figure, the more developed the country is, it is said. Developed countries are far more advanced on the technological front. This means to say that these countries have high power manufacturing industries such as steel manufacturing plants, semiconductor industries, plastic moldings plants and many others. By that, electrical power is an essence in making the industrial motors and equipments run. The higher the use of electrical power, the more number of switchgears and switchboards are necessary to distribute power.

Electrical power are distributed by means of distribution boards or also known as switch boards. These switch boards handle a range of power and by right supposed to be withstanding high voltages and currents. When an electrical fault occurs, it may pose danger in the form of shock hazard or arch flash hazard. It is important to distinguish between these two forms.

Shock hazard may be referred to the electrical voltage as the root cause whereas arc flash hazard is due to the electrical fault current [2]. When there is a high voltage live conductors and being touched accidentally by any operators, he may be electrocuted with the electrical shock. The simple rule of electrical conduction states that, current would flow most through the less resistive path prevalently. This is exemplified in the Figure 1.1 below.

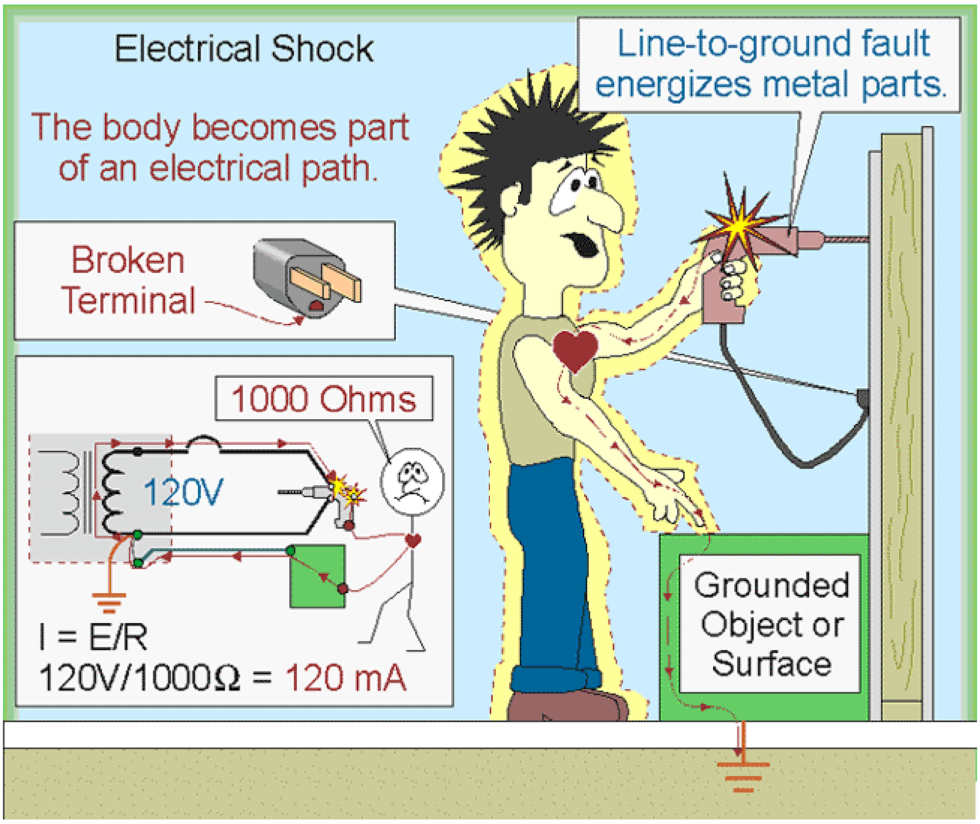

Figure 1.1 Electrical shock hazard

This project focuses more on the arc flash hazard. Arc flash is a phenomenon where insulation breakdown occurs and high conductive plasma is established in air to neutralize high tension voltages [2]. This phenomenon is similar to the lightning occurrence observed during thunderstorms. Basically, when there is a huge quantum of potential difference between the clouds and the ground, the air's with stand voltage potential is breached and an huge amount of current flows through the air from the oppositely charged mediums.

Figure 1.2 Arc flash generating a fire blast from a switchboard

On the same track, when an insulator (dielectric), say surge arrestors or transformer bushings or even busbar clampers on distribution boards loses its strength to withstand the high voltages, they will flashover. Flashover here means either by causing huge loud explosions of the material due to the high current flow or any other form of energy release.

Another term for flashover used on modern times is arc flash. The flash that occurs due to the high current flows transpires to the huge energy release based on the fundamental $E=I^2t$ equation. A high current could flow in high voltage systems when a short circuit fault occurs.

There are many types of short circuits and the most disastrous type which produces the largest current flow is the three phase bolted short circuit current. It is also known as the prospective short circuit current. This current may be calculated using classical short circuit analysis method. Hence, the energy released due to short circuit is related mathematically to the short circuit current value [3].

By knowing this energy, so-called the incident energy, safety engineers could determine the most appropriate and adequate personal protective equipments (PPEs) required for an operator to operate switch boards in electrical switch rooms as PPEs are rated by their own withstand energy [2].

Figure 1.3 Arc flash from a switchgear panel

1.2 Problem Statement

In line with occupational safety and health awareness (OSHA) requirements, electrical safety is important when dealing with energized switch boards. In Malaysia, many chargeman *('Penjaga Jentera Elektrik'*) or even laymen lose lives from accidents without following the proper procedure when operating electrical apparatuses, i.e. by wearing inadequate PPEs or none at all. Also, in Malaysia, there is no mandatory ruling by Suruhanjaya Tenaga (Energy Commission) stating that switch boards should be labeled with their appropriate PPE to be worn when operating them. Operators might be risking their lives wearing under-rated or inadequate PPEs.

Thus, quantification of this type of hazard is important to adequately protect people and properties from unwanted disasters. Besides, the quantification effort would also help facility administrators or safety engineers to properly risk manage the danger in switchrooms.

1.3 Objectives of Project

The main objective of this project is to calculate the incident energy of switchboards in order to determine the adequate PPE required when working with live or energized switch boards. This is done through the sub steps below:

(i) To determine the safe working zone for competent and non-competent people approaching the switch board by:

a. Analyzing the short circuit fault current.

b. Calculating the arcing current.

c. Calculate the incident energy and safe boundary distance using IEEE 1584 equations.

d. Determine the required PPEs.

(ii) To simulate the results using SKM Power Tools and cross-check to manual-calculated values.

(iii) Implement the risk management by labeling all switchboards with necessary information in the arc flash danger.

1.4 Scopes of Work

This project is confined to switch boards available at Hospital Seberang Jaya, Pulau Pinang as being the current workplace of the author. However, the incident energy is considered dangerous only to switch boards to the levels of AC Three Phase Network 415 V or higher. Switchboards presenting a single phase voltage or 240 V will be exempted from quantification. Arcs that are considered are arc-in-a-box types, i.e. arcs that start inside the panels of the switchboards.

Based on the above descriptions, the arc flash danger quantification will only be done to three phase network of 415 V higher rating. Transformers and open-ended equipments will be exempted as they are not considered as arc-in-a-box.

1.5 Report Outline

This project report will be presented in six chapters. They are namely Introduction, Literature Review, Methodology, Results & Analysis, Discussions and finally concluded by a Conclusion and Suggestion chapter.

Chapter 1, Introduction would present the background of the project, the problem statements or motivations governing the objectives. It is then succeeded by the scopes of work and a chapter summary. This chapter basically defines the contexts, limits and the efforts to be taken for project completion. Chapter 2, Literature Review will focus on the theoretical point of view for the project and some reviews on past papers or journals regarding arc flash.

Chapter 3, Methodology discusses the steps and approach needed towards arc flash quantification to achieve the project's objectives. This would be presented in a high level graphical flow chart outlook. The sub steps would be further elaborated mathematically. The utilization of the simulation tool would be introduced here as well. Chapter 4, Results and Analysis is a chapter where the outcomes and measurable outputs of the project is presented. It would flow in the direction route of Chapter 3, where the required data collected will be presented first followed by the calculations and simulation part. The simulation results will be shown and compared to the manual calculation for analysis and comparison purposes. Chapter 5, Discussions is the penultimate chapter, where a based on the results obtained in Chapter 5, the executive summary would be made in the forms of proposals of reducing arc flash energy and arc flash exposure. The discrepancies between manual calculation and simulation results will be discussed.

Chapter 6 is the final chapter where a look back into project objectives is done and the successfulness of the project is answered. This would be presented in a high level outlook with future work suggestions made.

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