ARC FLASH ANALYSIS ON KIMANIS POWER PLANT SWITCHGEARS BASED ON IEEE 1584 STANDARD

OLIVIA EYVONNIE GEOFFREY

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Faculty of Engineering
Universiti Teknologi Malaysia

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DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who showed me that even the most difficult endeavour can be completed if approached in small steps. Last but not least, to my lovely husband, daughter, my unborn child, and my siblings, who have been my rock throughout my academic path, encouraging me to persevere despite the many challenges I have encountered and bringing proud smiles to their faces.

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ABSTRACT

An arc flash radiates energy that can seriously burn the skin and clothing and even can lead to death. In most protection systems, the fault clearance times are based on bolted short circuit currents. In the event of an arcing fault, the lower fault current may result in a longer fault clearance time. In some cases, this may result in an increase in the fault energy, which will pose a greater risk to personnel. In many facilities, most of the equipment will have a Category 1 or 2 PPE rating. Equipment that requires Category 3 or 4 would not be able to be identified until an arc flash analysis is completed. Hence in this study, arc flash analysis is done based on the IEEE 1584 Standard by using a short-circuit analysis. Studies of normal and abnormal operations are carried out to simulate maximum and minimum fault conditions. This analysis is performed using ETAP ArcSafety - AC Arc Flash simulation software. With the short-circuit calculation and arc flash analysis done, the correct category rating of arc flash rated PPE according to the NFPA 70E clothing standard were able to be determined and other mitigation measures where necessary were recommended.

ABSTRAK

Kilat arka memancarkan tenaga yang boleh membakar kulit dan pakaian dengan serius dan juga boleh membunuh. Dalam kebanyakan sistem perlindungan, masa pelepasan ralat adalah berdasarkan arus litar pintas yang dibolt. Sekiranya berlaku keralatan arka, arus ralat yang lebih rendah boleh menyebabkan masa pelepasan ralat yang lebih lama. Dalam sesetengah kes, ini boleh menyebabkan peningkatan tenaga ralat, yang akan menimbulkan risiko yang lebih besar kepada pekerja. Dalam kebanyakn industri elektrik, kebanyakan peralatan akan mempunyai penarafan alat perlindungan perseorangan Kategori 1 atau 2. Peralatan yang memerlukan Kategori 3 atau 4 tidak akan dapat dikenalpasti sehingga analisis kilat arka diselesaikan. Oleh itu, dalam kajian ini, analisis kilat arka dilakukan berdasarkan piawaian IEEE 1584 dengan menggunakan analisis litar pintas. Kajian operasi biasa dan tidak normal dijalankan untuk mensimulasikan keadaan ralat maksimum dan minimum. Analisis ini dilakukan menggunakan perisian simulasi ETAP ArcSafety - AC Arc Flash. Dengan pengiraan litar pintas dan analisis kilat arka yang dilakukan, penarafan kategori alat perlindungan perseorangan yang betul mengikut piawaian pakaian NFPA 70E dapat ditentukan dan langkah-langkah pencegahan lain di mana dapat disyorkan.

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LIST OF ABBREVIATIONS

SC	-	Short Circuit
AR	-	Arc Rated
PPE	-	Personal Protective Equipment
AC	-	Alternating Current
IEEE	-	Institute of Electrical and Electronics Engineers
IE	-	Incident Energy
WD	-	Working Distance
3 Phase	-	Three Phase
OSHA	-	Occupational Safety and Health Administration
NFPA	-	National Fire Protection Association
AFHCS	-	Arc Flash Hazard Calculation Research
FR	-	Flame Resistant
ETAP	-	Electrical Transient Analyzer Program
KPP	-	Kimanis Power Plant
KPSB	-	Kimanis Power Sdn Bhd
GB	-	Generating Block
GTG	-	Gas Turbine Generator
STG	-	Steam Turbine Generator
BOP	-	Balance of Plant
MV	-	Medium Voltage
LV	-	Low Voltage
IAC	-	Internal Arc Classification
GIS	-	Gas-insulated Switchgear
RMU	-	Ring Main Unit
MCC	-	Motor Control Centre

LIST OF SYMBOLS

Ia	-	Short Circuit Current or Arcing Current
I_{bf}	-	Bolted Fault Current
K	-	Constant
Log	-	Log 10
V	-	Voltage
G	-	Gap of Conductors
E	-	Incident Energy
Cf	-	Calculation Factor
En	-	Incident Energy Normalised
t	-	Arcing Time
D	-	Distance from the Possible Arc Point
x	-	Distance Factor
D	-	Distance of the Boundary from the Arcing Point
EB	-	Incident Energy at the Boundary Distance
dB	-	Decibel
Cal/cm^2	-	Calories per Centimetre Squared
J/cm^2	-	Joules per Square Centimetre
M	-	Metre
kV	-	Kilo Voltage
kA	-	Kilo Ampere
mm	-	Millimetre
Hz	-	Hertz Frequency

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CHAPTER 1

INTRODUCTION

1.1 Overview of Arc Flash Analysis

Since the early 1960s, researchers have been investigating the causes and prevention of electrical arcs. Engineering design, equipment enclosure construction, structural protection changes, and, more recently, mandates for employee safe work practises have all targeted the threats of electrical arc hazards. Despite this, arcs and explosions continue to occur in electrical systems. The unforeseen release of explosive electrical energy in the workplace is caused by both human factors and equipment failures.

When working personnel are exposed to energized equipment or conductors, arc flash can happen, and the possibility to have a fatality incident is very high. Arcing fault can even occur while remotely switching and without involving any personnel. Therefore, calculation of incident energy is very important to determine the correct arc flash Personal Protective Equipment (PPE) category. With the correct PPE category, it may reduce the thermal effect towards personnel when arc flash happened and might be able to prevent fatality incidents.

1.2 Problem Background

An arc flash radiates energy that can seriously burn the skin and clothing and even can kill. There is a need to look specifically into the condition of arcing fault current. In most protection systems, the fault clearance times are based on bolted short circuit currents. In the event of an arcing fault, the lower fault current may result in a longer fault clearance time. In some cases, this may result in an increase in the fault energy, which will pose a greater risk to personnel.

1.3 Problem Statement

An arc flash rated clothing is needed to protect workers from an arc flash but purchasing the wrong clothing before an arc flash analysis can be dangerous and expensive. These types of personal protective equipment (PPE) clothing can offer protection to electrical workers to perform switching activities. Most of the equipment in the facilities will only have Category 1 or 2 PPE rating. However, equipment that requires Category 3 or 4 will only be able to be identified until an arc flash analysis is conducted.

1.4 Research Goal

1.4.1 Research Objectives

The objectives of the research are:

(a) To carry out studies of normal and abnormal operation scenarios to simulate maximum and minimum fault conditions.

(b) To calculate the incident energy released in an arcing fault and the acceptable arc flash boundary using the IEEE 1584 Standard.

(c) To determine the correct category rating arc flash rated PPE required to be worn for personnel safety against the thermal effects of electrical arcs.

1.4.2 Research Scope of Work

The scopes of work are:

(a) The approach and calculation of the analysis are based on the IEEE 1584 Standard “Guide for Performing Arc-Flash Hazard Calculations”.

(b) The calculation is limit to a 3-phase (line-to-line) AC system.

(c) The selection of arc flash rated PPE according to the NFPA 70E standard.

1.5 Chapter Summary

This chapter concludes the overall overview of this project report. Throughout this thesis, all considerations, calculations, scopes, and method are based on what have been mentioned in this chapter 1.

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