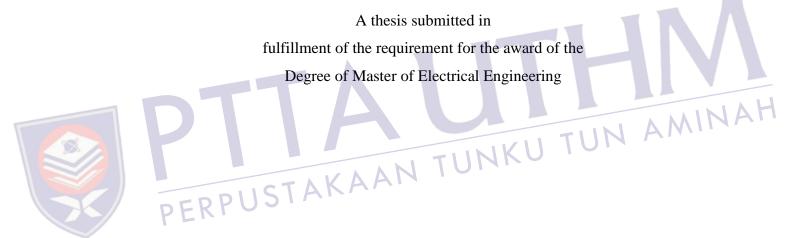
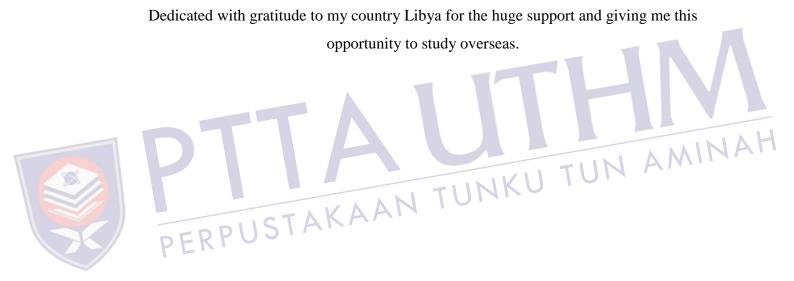
DEVELOPMENT OF WEB APPLICATION PACKAGE TO DESIGN AC SUBSTATION GROUNDING SYSTEM BASED ON IEEE STD. 80-2000 FOR CONTINUOUS EDUCATION AND PROFESSIONAL TRAINING

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ABSTRACT

Substation grounding is a very important aspect in a substation design which forms a safe grounding grid system besides functioning as a means of dissipating currents to the surrounding ground during normal and fault conditions, also prevents the ground potential rise during a fault from creating dangerous potential gradients on the substation ground surface that can endanger a life of a person in the vicinity of the grounded facility. This grounding study is based on IEEE Standard 80-2000 (Revision of IEEE Std. 80-1986) which serves as a guide to the safety in ac substation grounding. With the fast growing of the use on the Internet technology and the daily use of it in all life routines including education, it will be necessary and interesting to provide a learning and educational web application for the Internet users especially the engineers of them.



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ABSTRAK

Pembumian pada pencawang adalah aspek yang sangat penting dalam rekaan pencawang yang membentuk sistem grid asas selamat selain berfungsi sebagai satu cara untuk mengalirkan arus ke bumi pada keadaan normal dan ketika kerosakan berlaku, dan juga menghalang kenaikan potensi bumi pada ketika kerosakan dari mewujudkan kecerunan berpotensi berbahaya pada permukaan tanah pencawang yang boleh membahayakan kehidupan seseorang yang berada dalam persekitaran tempat pembumian. Kajian pembumian ini adalah berdasarkan IEEE Standard 80-2000 (IEEE Std. 80-1986) yang berfungsi sebagai panduan untuk keselamatan dalam pembumian pencawang. Dalam arus penggunaan teknologi Internet yang meningkat saban hari dan penggunaan harian dalam semua rutin kehidupan termasuk pendidikan, ia akan menjadi sesuatu keperluan serta ianya adalah menarik untuk menyediakan pembelajaran dan aplikasi laman sesawang dengan tujuan pendidikan untuk pengguna Internet terutamanya kepada golongan jurutera.



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	2-D	-	Two-Dimensional
	3-D	-	Three-Dimensional
	А	-	Ampere
	А	-	Area Occupied By The Ground Grid
	AC	-	Alternating Current
	API	-	Application Programming Interface
	ASP	-	Active Server Page (Microsoft script engine)
_	AWG	-	American Wire Gauge
	A _{mm²}	-	American Wire Gauge Conductor Cross Section Metallic Disc Radius
	b	-	Metallic Disc Radius
	BS	-	British Standard
	C PE	RP	Prefix Means Centi
	C#	-	C Sharp Programming Language
	C++	-	C Programming Language
	Cs	-	Surface Layer Derating Factor
	D	-	Spacing Between Parallel Conductors
	d	-	Diameter Of Grid Conductor
	D_{f}	-	Decrement Factor
	D_m	-	Maximum Distance Between Any Two Points On The Grid
	Е	-	Phase-To-Neutral Voltage
	EDSA	-	Electrical Distribution System Analysis
	ETAP	-	Electrical Transient and Analysis Program
	E_m	-	Actual Mesh Voltage
	Es	-	Actual Step Voltage
	Estep	-	Tolerable Step Voltage
	Etouch	-	Tolerable Touch Voltage
	ft	-	Feet

	g	-	Gram
	GPR	-	Ground Potential Rise
	h	-	Depth of The Grid
	HAMA	-	Hussein Ahmad Mohammed Aldebry
	HTML	-	Hypertext Markup Language
	Hz	-	Hertz
	hs	-	Thickness of The Surface Material
	Ι	-	Symmetrical RMS Conductor Current
	IEC	-	International Electrotechnical Commission
	IEEE	-	Institute of Electrical and Electronics Engineers
	in	-	Inch
	IS	-	Indian Standard
	Io	-	Zero-Sequence Fault Current
	IB	-	Body Current
	I_{F}	-	Asymmetrical Fault Current
	I_{f}	-	Symmetrical RMS Ground Fault Current
	IG	-	Maximum Grid Asymmetrical Current
	Ig	-	Maximum Grid Asymmetrical Current Symmetrical RMS Grid Current
	J	-	Joule
	К	- 0	Reflection Factor Between Different Material Resistivities
/	k PE	RP	Prefix Means Kilo
	kcmil	-	Kilo-Circular Mils
	\mathbf{K}_0	-	Material Constant Reciprocal of α_0
	K_{f}	-	Conductor Material Constant
	K_h	-	Corrective Weighting Factor Emphasizing The Grid Depth Effects
	Ki	-	Irregularity Factor
	K _{ii}	-	Corrective Weighting Factor That Adjusts Effects Of Inner Conductors
			On The Corner Mesh
	K _m	-	Geometrical Factor
	Ks	-	Geometrical Factor
	L _C	-	Total Length of The Conductor In The Horizontal Grid
	L _M	-	Conductor Buried Length
	L _P	-	Peripheral Length of The Grid
	L _R	-	Total Length of All Ground Rods
	Lr	-	Length of Each Ground Rod

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	Ls	-	Conductor Buried Length
	L _T	-	Total Buried Length of Conductors
	L _x	-	Maximum Length of The Grid In The X Direction
	Ly	-	Maximum Length of The Grid In The Y Direction
	Μ	-	Prefix Means Mega
	m	-	Prefix Means Milli
	m	-	Meter
	MCM	-	Million Cubic Metre
	MVC	-	Model-View-Controller
	OWL	-	Web Ontology Language
	R	-	Resistance
	R_0	-	Zero Sequence Equivalent System Resistance
	\mathbf{R}_1	-	Positive Sequence Equivalent System Resistance
	\mathbf{R}_2	-	Negative Sequence Equivalent System Resistance
	R _B	-	Body Resistance
	R_{f}	-	Ground Resistance of One Foot
	R _g	-	Substation Ground Resistance
	R _{m(2nhs)}	-	Mutual Ground Resistance Between The Two Similar, Parallel Plates,
			Separated By A Distance (2nhs), In An Infinite Medium Of Resistivity
	S	-	Second AKAAN
/	SB PE	RY	Empirical Constant Related To The Electric Shock Energy Tolerated
	$\mathbf{S}_{\mathbf{f}}$	-	Fault Current Division Factor
	TCAP	-	Thermal Capacity Per Unit Volume
	Ta	-	Ambient Temperature
	t _c	-	Duration of Conductor Current
	T_m	-	Maximum Allowable Temperature
	Tr	-	Reference Temperature for Material Constants
	ts	-	Duration of The Current Exposure
	V	-	Volt
	W	-	Watt
	XML	-	Extensible Markup Language
	X_0	-	Zero Sequence Equivalent System Reactance
	X_1	-	Positive Sequence Equivalent System Reactance
	X_2	-	Negative Sequence Equivalent System Reactance
	X/R	-	Ratio of Reactance To Resistance

Z_{Th}	-	Thevenin Equivalent Impedance
α_0	-	Thermal Coefficient of Resistivity At 0 °C
α_r	-	Thermal Coefficient of Resistivity At Reference Temperature $T_{\rm r}$
μ	-	Prefix Means Micro
π	-	Pi
ρ	-	Soil Resistivity
$ ho_r$	-	Resistivity of The Ground Conductor At Reference Temperature $T_{\rm r}$
ρ_s	-	Surface Material Resistivity
Ω	-	Ohm
°C	-	Degree Celsius



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CHAPTER 1

INTRODUCTION

1.1 Background



Grounding of high voltage substations is a very important subject in electric power technology since it is decisive when it comes to touch and step voltages that will arise within a substation area during an earth fault. High voltage substation grounding has previously been an experienced based field of work, thus it is of interest to acquire a more theoretical approach to dimensioning of high voltage substation grounding. This to ensure that safety issues are taken care of without constructing an over dimensioned, and more expensive than necessary, system [2].

In modern high voltage indoor or outdoor substation, grounding installations mainly consists of a network of a metallic conductors arranged as a grid buried underneath the surface of the substation. This grid sometimes consists of grounding rods connected to the grid which are driven into the earth mass. It is important that the substation ground has low resistance path to ground, to obtain a discharge path for short current and lightning strokes and safety features for personnel and equipment [3].

The grounding system in a substation is very important for a few reasons, all of which are related to either the protection of people and equipment and the optimal operation of the electrical system. The purpose of a grounding system at a substation can be explained as follow:

i. The grounding system provides a low resistance return path for earth faults within the substation, which protects both personnel and equipment.

- ii. For earth faults with return paths to offsite generation sources, a low resistance grounding grid relative to remote earth prevents dangerous ground potential rises (touch and step potentials).
- The grounding system provides a low resistance path (relative to remote earth) for iii. voltage transients such as lightning and surges.
- iv. Equipotential bonding helps prevent electrostatic buildup and discharge, which can cause sparks with enough energy to ignite flammable atmospheres.
- The grounding system provides a reference potential for electronic circuits and v. helps reduce electrical noise for electronic, instrumentation and communication systems [4].

The substation grounding system is connected to every individual equipment, structure and installation in the substation so that it can provide the means by which grounding currents are conducted to remote areas. The aim of the grounding design is to ensure the lowest possible and most economical resistance to earth mass for the expected fault currents flowing to earth, and to ensure that the potential difference induced by these fault currents into the grounding grid is kept within the safety margins specified by a 1.2 Problem statement AKAAN TUNKU TUN AMINAH PERPUS



People often assume that any grounded object can be safely touched. A low substation ground resistance is not, in itself, a guarantee of safety. There is no simple relation between the station ground resistance and the maximum shock current a person might be exposed to.

There are many calculation software available in the market at present which are mainly calculation tools that can design a safe grounding system; namely, ETAP, EDSA, CYMGRD and SKM as the most popular and most used grounding system software. However, and by examination these software, there is no one of them that combines the theoretical aspect of grounding together with the calculation method as one educational package. In addition, all of these applications are desktop applications that require the software to be installed in the computer to be used and not available online.

1.3 Objectives

The goals of this project on substation grounding are as follow:

- i. To develop web application based on IEEE Std. 80-2000 that will serve as both an educational website for the study of substation grounding principles and professional training and also as a calculation tool to help with the design and evaluation process.
- ii. To ensure that the developed site can be easily understood as an educational package and be able to use by the new users who are unfamiliar with the website (user-friendly.)
- iii. To make the users able of study the grounding requirements and practice on examples of grounding systems for some real substations that are provided within the website.

Scope 1.4

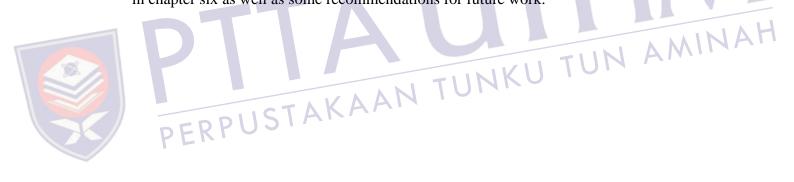


UNKU TUN AMINAH The project is executed in accordance to the followings:

- i. P The standard IEEE Std. 80-2000, which this thesis is based on, is concerned with ac substations, either conventional or gas-insulated. Therefore, grounding problems peculiar to dc substations are not covered in this thesis.
- ii. The web application will be developed using Microsoft Visual Studio for using under Windows operating systems.
- iii. The site provides a learning module which contains all the theory and principles of substation grounding that help engineers to understand the concept of grounding systems. This learning module is supported with tutorial videos about substation grounding topics, for the purposes of educate junior engineers in grounding system.
- The site contains actual ac substation grounding system designs as examples for iv. professional training purposes.

1.5 Project outline

This suction outlines the structure of the thesis and summarizes each of the chapters. The first chapter of introduction explains the problem statements, goals, scope of study, and the structure of this master project. Next is chapter two which is the chapter of literature survey. This second chapter discusses about published works by accredited scholars and researchers that associate with this project. Grounding concept and safety aspects are reviewed in this chapter. Meanwhile, the research methodology is described in chapter three. This chapter explains clearly the grounding system designing considerations and evaluating techniques. Moving to the fourth chapter which shows the details on the web application for grounding study that covers the learning theory, calculations module and the design evaluation. Chapter five is comparing the results of the designed web application with the results of other grounding designing software for some substations. Finally, a conclusion for the whole project based on the finding of the results is conducted in chapter six as well as some recommendations for future work.



CHAPTER 2

GROUNDING CONCEPT AND SAFETY ASPECTS REVIEW

2.1 Introduction



The concept of grounding systems revolves mainly on the safety of people in the vicinity of the grounded facility. The safety criteria are based on potential gradients that can exist in the area during a fault and the ability of the human body as a current path shunting those potentials to withstand the current duration and frequency.

2.2 Grounding standards

The basis of this entire thesis is on the IEEE guide for safety in ac substation grounding IEEE Std. 80-2000. However, there are other standards that are used to design safe grounding system. This section highlights some of these standards.

2.2.1 IEEE Std. 80-1986

This standard [5] is the third edition of this guide since its first issue in 1961. Major modifications involve the redefinition of simplified equations for calculating touch and

step voltages, changes in safety criteria, and expansion of examples illustrating the use of this guide. Other changes and additions concern a section on gas-insulated substations, introduction of a derating factor for crushed stone surfacing, the effects of ground rods, equations for calculation of grid resistance, current division among available ground paths, sizing of conductors of various materials, and discussion of multilayer soil models.

2.2.2 IEEE Std. 80-2000

IEEE Std. 80-2000 is the fourth edition of this guide since its first issue in 1961. It has major modifications include the further extension of the equations for calculating touch and step voltages to include L-shaped and T-shaped grids [1]. This guide is primarily concerned with outdoor ac substations, either conventional or gas-insulated. Distribution, transmission, and generating plant substations are included. With proper caution, the methods described herein are also applicable to indoor portions of such substations, or to AMINAH substations that are wholly indoors.



i.

- The specific purposes of this standard are to:
- Establish, as a basis for design, the safe limits of potential differences that can exist in a substation under fault conditions between points that can be contacted by the human body.
- ii. Review substation grounding practices with special reference to safety, and develop criteria for a safe design.
- iii. Provide a procedure for the design of practical grounding systems, based on these criteria.
- iv. Develop analytical methods as an aid in the understanding and solution of typical gradient problems.

2.2.3 BS 7430

This British Standard [6] provides recommendations and guidance on meeting the requirements for earthing land-based electrical installations in and around buildings. It does not apply to:

Ships, aircraft or offshore installations. i.

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