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

MOHAMMED ALSANOSI MOHAMMED ALDEBRY

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Universiti Tun Hussein Onn Malaysia

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Dedicated with gratitude to my country Libya for the huge support and giving me this opportunity to study overseas.

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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.

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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LIST OF SYMBOLS AND ABBREVIATIONS

2-D	-	Two-Dimensional
3-D	-	Three-Dimensional
A	-	Ampere
A	-	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_{mm^2}	-	Conductor Cross Section
b	-	Metallic Disc Radius
BS	-	British Standard
c	-	Prefix Means Centi
C#	-	C Sharp Programming Language
C++	-	C Programming Language
C_S	-	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
E	-	Phase-To-Neutral Voltage
EDSA	-	Electrical Distribution System Analysis
ETAP	-	Electrical Transient and Analysis Program
E_m	-	Actual Mesh Voltage
E_s	-	Actual Step Voltage
E_{step}	-	Tolerable Step Voltage
E_{touch}	-	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
h_s	-	Thickness of The Surface Material
I	-	Symmetrical RMS Conductor Current
IEC	-	International Electrotechnical Commission
IEEE	-	Institute of Electrical and Electronics Engineers
in	-	Inch
IS	-	Indian Standard
I_0	-	Zero-Sequence Fault Current
I_B	-	Body Current
I_F	-	Asymmetrical Fault Current
I_f	-	Symmetrical RMS Ground Fault Current
I_G	-	Maximum Grid Asymmetrical Current
I_g	-	Symmetrical RMS Grid Current
J	-	Joule
K	-	Reflection Factor Between Different Material Resistivities
k	-	Prefix Means Kilo
kcmil	-	Kilo-Circular Mils
K_0	-	Material Constant Reciprocal of α_0
K_f	-	Conductor Material Constant
K_h	-	Corrective Weighting Factor Emphasizing The Grid Depth Effects
K_i	-	Irregularity Factor
K_{ii}	-	Corrective Weighting Factor That Adjusts Effects Of Inner Conductors On The Corner Mesh
K_m	-	Geometrical Factor
K_s	-	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
L_r	-	Length of Each Ground Rod

L_S	-	Conductor Buried Length
L_T	-	Total Buried Length of Conductors
L_x	-	Maximum Length of The Grid In The X Direction
L_y	-	Maximum Length of The Grid In The Y Direction
M	-	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
R_1	-	Positive Sequence Equivalent System Resistance
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 ($2nh_s$), In An Infinite Medium Of Resistivity
s	-	Second
S_B	-	Empirical Constant Related To The Electric Shock Energy Tolerated
S_f	-	Fault Current Division Factor
TCAP	-	Thermal Capacity Per Unit Volume
T_a	-	Ambient Temperature
t_c	-	Duration of Conductor Current
T_m	-	Maximum Allowable Temperature
T_r	-	Reference Temperature for Material Constants
t_s	-	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 ^oC
α_r	-	Thermal Coefficient of Resistivity At Reference Temperature T_r
μ	-	Prefix Means Micro
π	-	Pi
ρ	-	Soil Resistivity
ρ_r	-	Resistivity of The Ground Conductor At Reference Temperature T_r
ρ_s	-	Surface Material Resistivity
Ω	-	Ohm
^oC	-	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).

iii. The grounding system provides a low resistance path (relative to remote earth) for 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.

v. The grounding system provides a reference potential for electronic circuits and 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 standard, in this case IEEE Std. 80-2000.

1.2 Problem statement

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.

1.4 Scope

The project is executed in accordance to the followings:

i. 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.
iv. The site contains actual ac substation grounding system designs as examples for 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 substations that are wholly indoors.

The specific purposes of this standard are to:

i. 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:

i. Ships, aircraft or offshore installations.

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