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FACULITY OF ENGINEERING

ELECTRICAL POWER & MACHINES DEPARTMENT

OPTIMUM DESIGN FOR CATHODIC PROTECTION SYSTEMS

BY

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A THESIS

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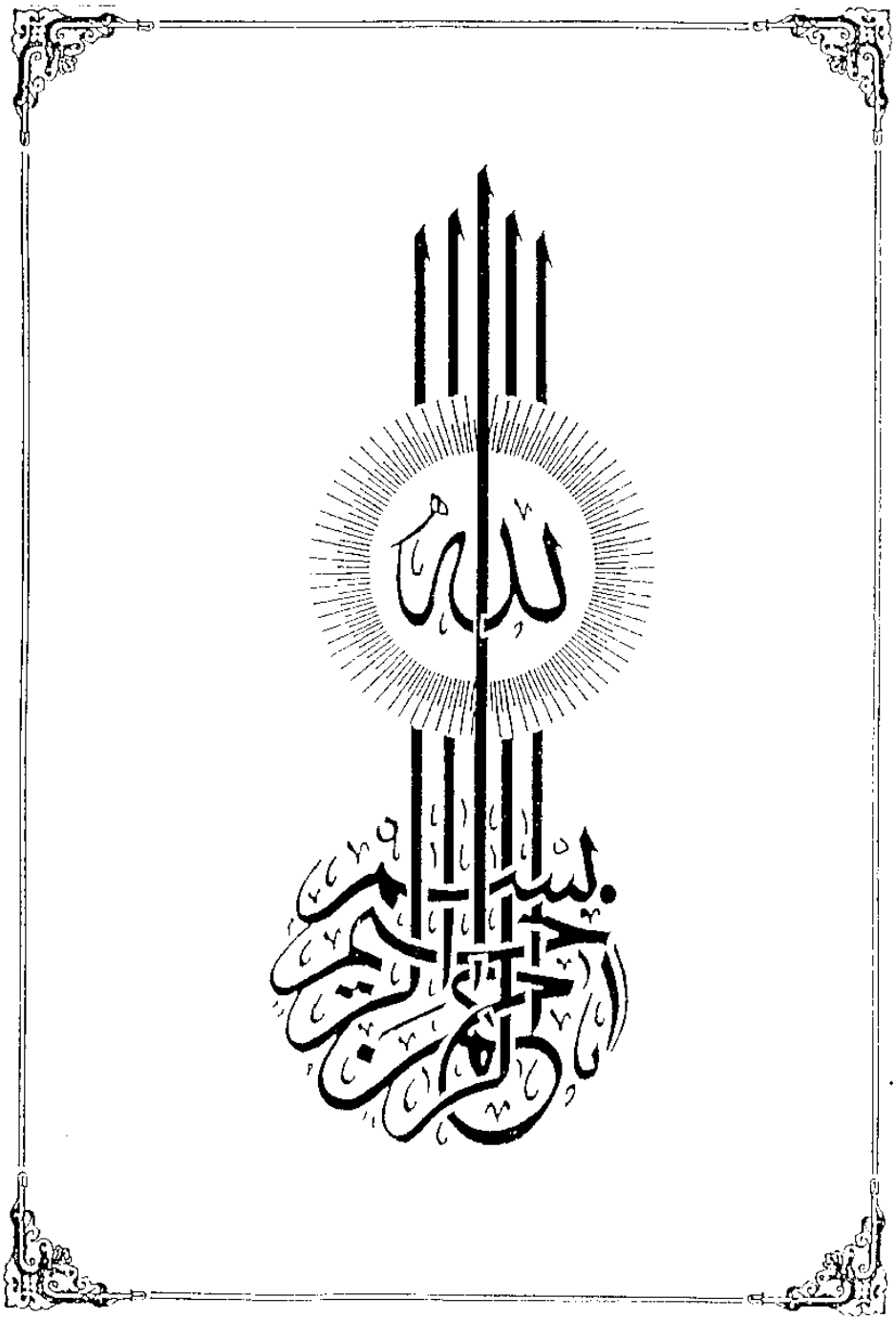

Statement

This dissertation is submitted to Ain Shams University for the degree of Master in Electrical Engineering"

The work included in this thesis was carried out by the author in the Department of Electrical Power & Machines Ain Shams University from November 1988 to november 1990

No part of this thesis has been submitted for a degree or a qualification at any other University or institution

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ABSTRACT

Cathodic protection is one of the most important methods of corrosion control for buried or submerged structures, Cathodic Protection expenditures in USA in 1983 were $ 700 Million, Petroleum industry expenditures were $ 150 Million. So, the need to utilize numerical optimization in cathodic protection system design is to aid us in rationally searching for the best design to meet our needs and reduce the total system cost.

The total anode alloy weight and current requirements of a buried or submerged structures Cathodic Protection system is greatly increasing as bigger structures are constructed and may be subject to natural or stray current corrosion. Also, design lives ranging from 20 to 35 years for deep water structures necessitate considerable quantity of anode alloy. The present thesis introduce Cathodic Protection concepts. After a brief discription of electrochemical corrosion and Cathodic Protection and how it works, A complete design package for applying Cathodic Protection to a buried or submerged structure is presented together with a computer program to aid the design and give a complete specification for the system.

The work includes applying numerical optimization techniques by random search method on Cathodic Protection system design by generating anode geometries which reduce the excess in anode alloy weight and output current to meet the life requirements. Basic computer programs are proposed by the author to enable the design of cathodic protection system by using sacrificial anodes. The design is developed for offshore platform, concentric neutral wires and pipe type cable. Two of the aforenamed designs were selected to apply random search method to obtain the optimum design.

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CHAPTER (1)

CORROSION

1.1 INTRODUCTION

Corrosion may be defined as the deterioration of a substance because its reaction with the environment[1], underground or submerged electrical cables may suffer from corrosion, soil are never dry, especially beneath the surface due to natural rain, when metals exposed to water it may be corroded. Corrosion in the presence of water is an electrochemical process. Most metals are found in nature as ores, during the refining process ores are converted to metals by the addition of energy. When this same energy is released metals convert to the corroded state. Electrical currents flows during the corrosion process the source for these currents is the energy stored in the metal by the refining process. Different metals require varying amounts of energy for refining, therefore, have different tendencies to corrode.

The driving voltage generated by a metal when put in a water solution is called potential of a metal, which is related to the energy released when the metal corrodes. This potential value is a function of the physical and chemical characteristics of water and the metal itself. The absolute value of this potential is affected by water composion, vebcily and other factors, but, the relative values remain about the same.

The electromotive force series of metals TABLE 1-1 arrange the metals according to the relative potential versus the hydrogen electode, every metal have a tendency to corrode according to its place in the series. Metals at the top need more energy for refining and have greatest tendency to corrode rather than the metals at the bottom.

1.2 ELECTROCHEMICAL NATURE OF CORROSION

During corrosion process, there will be a flow of electrical current from certain areas of a metal surface to other areas through a solution capable of conducting electric current [2]. Anode is that part of metal surface that is corroded and from which current leaves the metal to enter the solution. Cathode is used to describe the metal surface from which current leaves the solution and returns to the metal, and the circuit is completed by the solution which must cover the anode and the cathode. Fig.(1-1)

Corrosion current is returning from the cathode to the anode through a metal wires or through the metal itself. A solution which is capable of conducting electricity is called an electrolyte. Its ability to conduct electric current is due to the presence of ions. These are positively or negatively charged atoms pure water contains positively charged hydrogen ions (H^+) and negatively charged hydroxyl ions (OH^-) in equal concentration. Electrolyte can range from fresh water to the strongest alkali or acid.

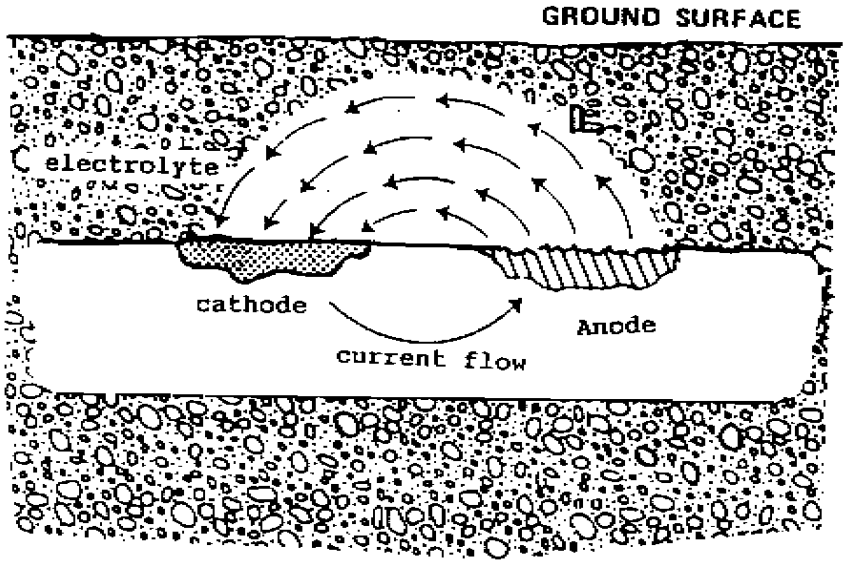

FIG (1-1) CORROSION CELL IN AN ELECTRICAL CABLE IN SOIL

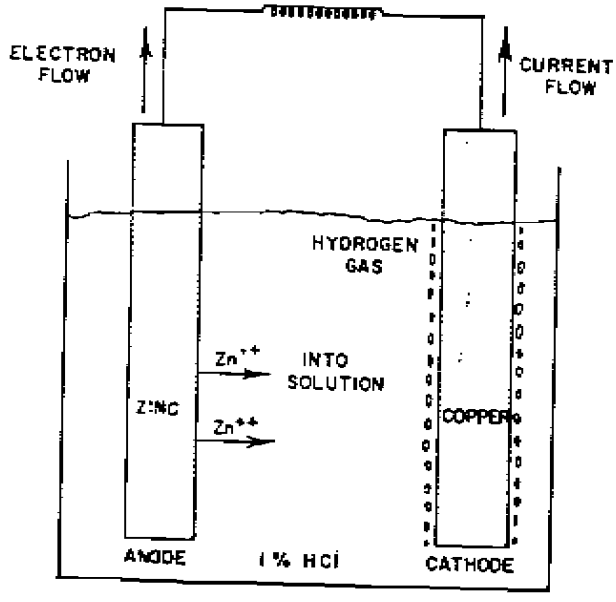

FIG (1-2) ELECTROCHEMICAL CELL COMPRISING ZINC AND COPPER ELECTRODES IN A HYDROCHLORIC ACID SOLUTION

1.2.1 ANODIC PROCESSES

At the anode area of metal surface, positively charged atoms of metal leave the solid surface and enter into the solution as ions. They have their corresponding negative charges in the form of electrons which flow through the metallic path to the cathode area. The ionized atoms can bear one or more postive charges. The chemical recreation for iron is:

$$Fe \longrightarrow Fe^{2+} + 2e^{-}$$

Iron Atom	Iron ion	Electrons

Iron atom becomes an iron ion with two positive charges and generates two electrons, these loss of electrons is called oxidation or corrosion, electrons travel through the metal or an external conductor to complete the circuit at the cathode, corresponding Metal ions goes into the solution and Anode corrodes. Whenever a Zinc electrode is connected to a copper electrode, both are immerced in the same electrolyte and connected by an external conductor, a corrosion cell is formed. Zinc will function as an anode and corrodes as indicated in Fig (1-2).

1.2.2 CATHODIC PROCESSES

The cathode area is the site of parallel reaction with the anodic process. The electrons generated by the anode have passes through the metal to the surface of the cathode areas immersed in the electrolyte.