Ain Shams University
Faculty of Engineering
Electronics and Communications Engineering Department

Design of PV System for Cathodic Protection Systems

A Thesis

Submitted in Partial Fulfillment of the Requirements of the Degree of

Master of Science in Electrical Engineering

Submitted By

Golina Samir Adly Abd El-Shaheed

Supervised By

Prof. Dr. Wagdy Refaat Anis

Professor in the Electronics and Communications Engineering Department
Faculty of Engineering – Ain Shams University

Prof. Dr. Ismail Mohamed Hafez

Professor in the Electronics and Communications Engineering Department
Faculty of Engineering – Ain Shams University

Ain Shams University
Cairo – Egypt
2017

Ain Shams University
Faculty of Engineering
Electronics and Communications Engineering Department

Name: Golina Samir Adly

Thesis: Design of PV System for Cathodic Protection Systems

Degree: Master of Science in Electrical Engineering

Examiners Committee

Name and Affiliation	Signature
Prof. Dr. Mohamed Afify Al Koosy AIT-PM Egyptian Space Program Ministry of Scientific Research National Authority For Remote Sensing and Space Science ,NARSS	.....
Prof. Dr. Abdelhalim Abdelnaby Zekry Ain Shams University, Faculty of Engineering, Electronics and Communications Engineering Dept.	.....
Prof. Dr. Ismail Mohamed Hafez Ain Shams University, Faculty of Engineering, Electronics and Communications Engineering Dept.	.....
Prof. Dr. Wagdy Refaat Anis Ain Shams University, Faculty of Engineering, Electronics and Communications Engineering Dept.	.....

Date: ..... / …… / …

STATEMENT

This thesis is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering.

The work included in this thesis was carried out by the author at the Electronics and Communications Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

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

Name: Golina Samir Adly Abd El-Shaheed

Signature :

Date : …….. / …….. / …….

ACKNOWLEDGEMENT

I would like to express my sincere gratitude, appreciation and thankfulness to **Prof. Dr. Eng. Wagdy Refaat Anis** for his permanent keenness to provide advice, support, encouragement, assistance and guidance throughout the entire thesis. In fact, he provided me with his wide knowledge and experience, lots of valuable ideas and many stimulating suggestions. Really, I will never forget the research memorizes with him. From the son and the pupil to the father and the dear professor, "*I shall never forget your help, and I shall always remember your kindness*."

I would like to express my sincere gratitude, appreciation and thankfulness to **Prof. Dr. Eng. Ismail Mohamed Hafez** for his supervision, advice, support, guidance and help to me, especially in the last stage of this thesis. Indeed, he inspired me a sense of enthusiasm, optimism and motivation. Actually, I consider him as a role model to promote to senior positions in the future.

I would like to show my deepest gratitude, appreciation and thankfulness to **Prof. Dr. Eng. Abd El Halim Abdelnaby Zekry** for his support, guidance, help and reviewing this thesis. In fact, I learned so many valuable ideas, scientific guidance and technical comments from his wide experience. Actually, he taught me how to evaluate and show work's originality, then present at it in the best form.

I would like to offer my deepest gratitude, appreciation and thankfulness to **Prof. Dr. Mohamed Afify Al Koosy** for his kindness, support, help and reviewing this thesis. Indeed, it is a great opportunity to learn from his wide knowledge in the solar-energy field and how to prepare a simple and organized thesis. Really, I learned from him how to be a simple and humility person.

I can't forget to thank my father **Eng. Samir Adly AbdEl-Shaheed** who was endless sources of advice and guidance.

I can't forget to thank my mother **Mss.Mervat Azmy** who was endless sources of advice and guidance.

I can't forget to thank my Husband **Eng.Simon Ezzat** who was endless sources of advice and guidance.

I wish to express my deepest thanks to my dear sister **Dr. Suzy Samir Adly** For her continuous encouragement, support and help.

Golina Samir

2017

ABSTRACT

The corrosion is an electrochemical reaction between metal and the surrounding environment, such as: soil and water.
The cathodic protection system prevents corrosion of a metal surface by making the structure as a cathode while a block of metal is used as sacrificing anode. A current is passed from the sacrificing anode to the cathode using external power supply.
There are two different types of cathodic protection systems; galvanic system, and impressed current cathodic protection (ICCP).
Galvanic system (sacrificial anode) protects structures from corrosion by passing current from the sacrificial anode to protect structures. The galvanic system depends on the natural potential difference between sacrificing anode (higher potential) and the cathode (lower potential).The anode in Galvanic system is corroded.The galvanic system stops corrosion by impressing DC current.Increasing in DC current causes rapid corrosion of sacrificial anode and over protection of metallic structure. The DC supply may be obtained from a conventional source using rectifiers. The other alternative is to obtain DC supply from the PV solar system. The second alternative is discussed in details in this study. Also the hybrid system of using PV and diesel generator is considered. The criterion in deciding the optimum solution is the cost of produced kWh of the system.

Keywords:

Cathodic Protection (CP), Photovoltaic (PV), Array Factor (FA). State of Charge (SOC), Diesel Generator (DG), Impressed Current Cathodic Protection (ICCP), Galvanic System (GS), Array Factor the Ratio between PV Array sizes with Average Daily Power required operating Load. Load Voltage Regulator (LVR), Battery Voltage Regulator (BVR).Short Circuit (SC), High Silicon Cast Iron (HSCI), high silicon Chromium- Bearing Cast Iron (HSCBCI).

Published paper:

A research paper has been published in international journal of scientific &technology "Design of photovoltaic powered cathodic protection system", volume 6, pp246-253, ISSN 2277-8616 ISSUE 07, July 2017

SUMMARY

This thesis discusses systems focus on using renewable-energy source as PV solar-energy source discuses the calculation the voltage and the load current in different case. The case 1: Pipelines Require CP on The Surface of soil, The case 2: Pipelines Require CP totally buried in the Soil, The case 3: Immerged Tank in Water.

In remote areas Solution: PV +batteries (stand alone), PV + Two Diesel generators, PV+ Small batteries + 1 Diesel Generator, PV +Small batteries + 2 Diesel generators Also, Systems are simulated by a MATLAB Simulation program is based on: Climatic condition of Cairo, Array tilt angle equal to the latitude angle (30), Constant load 24 hours and Three consecutive cloudy days. Economics is calculated for each system.

Chapter one:

This Chapter discusses short introduction about CP system, Earliest practical use of CP and types of CP systems, Advantage and disadvantage of the Galvanic Cathode Protection system and Impressed cathodic protection system and properties of Galvanic system and ICCP system.

Chapter two:

This Chapter discusses the simulation model for photovoltaic, solar energy source as renewable – energy powering load and advantages and disadvantages of Grid PV System.

Chapter three:

This Chapter discusses the calculation the voltage and the load current in different case.

The case 1: Pipelines Require CP on The Surface of soil.
The case 2: Pipelines Require CP totally buried in the Soil.
The case 3: Immerged Tank in Water.

Chapter four:

It discusses CP system modules for different Case overall the year and simulation MATLAB program design for each system. With the effects of climatic conditions, solar irradiance, temperature, cloudy days, tilt angles and the energy output of the PV array. PV module characteristic is included in the simulation program and discusses overview economies calculations in US dollar ($) for each system model according to mobile operator's requirements and international market prices.

Chapter five:

This chapter contains brief conclusion & future work.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Item	Abbreviation
AC	Alternated Current
ATS	Automatic transfer switch
AUG	The authentication center
BER	Bit error rate
BFU	Battery fuse unit
BSC	Base Station Controller
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
DC	Direct current
DG	Diesel generator
DOD_{max}	Depth of Discharge maximum
DOU	Digital operation unit
EDGE	EnhancedData GSM Environment
EIR	Equipment Identity Register
GPRS	General Packet Radio Services
GSM	Global system for mobile communication
HLR	Home Location Register
HSPA	High Speed Packet Access
Kbps	Kilo byte per second
LTE	Long Term Evolution
MSC	Mobile Switch Center
NOC	National Occupational Classification
PDU	Power digital unit
PSU	Power supply unit
PV	Photovoltaic
PWM	Pulse-width modulation
RBS	Ericsson’s cabinet version
SCU	Switch control unit
SOC	State of charge for battery strings
SOCn	Previous value of charge for battery strings
TN	Traffic Node
TRX	Traction Rubber X-treme
UMTS	Universal Mobile Telecommunications System
USB	Universal Serial Bus
VLR	Visitor Location Register