

Sudan University of Science and technology
College of Engineering
Electrical Engineering

**DESIGN OF HIGH VOLTAGE
TRANSMISSION SUBSTATION**

تصميم المحطة التحويلية ذات الجهد العالي

**A Project Submitted In Partial Fulfillment for the
Requirement of the Degree of B.Sc. (Honor) In Electrical
Engineering**

Prepared By:

- 1.Ola Hassan Abd_Alqadir Mubarak**
- 2. Jafer Atif Jafer Alsaied**
- 3. Mohmmmed Emad Awad Alkareem**
- 4.Abu baker Elsiddiq Altayeb Ali**

Supervised By:

Dr.Salah Qasim

October 2018

الآية

يقول الله تعالى في محكم تنزيله:

(فَتَعَالَى اللَّهُ الْمَلِكُ الْحَقُّ
وَلَا تَعْجَلْ بِالْقُرْآنِ مِنْ قَبْلِ
أَنْ يُقْضَىٰ إِلَيْكَ وَحْيُهُ
وَقُلْ رَبِّ زِدْنِي عِلْمًا)

صدق الله العظيم

سورة طه الآية رقم (114)

DEDICATION

We dedicate this study to our loving parents. A special feeling of gratitude to many friends and each member of this group for making this research possible. We also dedicate this study to our teachers and colleagues for giving us moral support. And to all students of electrical engineering. And finally a big thank to Sudan university of Science and technology.

ACKNOWLEDGMENT

First and foremost, I have to thank my research supervisor, Dr. Salah Qasim, we have been extremely lucky to have a supervisor such like him. A very special thanks to Sudanese Electrical Distribution Company, Sudanese Electrical Transmission Company for Their worthy time and recommendations throughout the period of achieving this study. Without their assistance and dedicated involvement in every step throughout the process, this research would have never been accomplished. We also appreciate the effort of Dr. Amer Hashim for explaining and illustrating the necessary steps of how to create a project in accordance with ideal scientific manner. Finally, we would like to thank anyone who helped us technically or financially.

ABSTRACT

This research discusses electrical design of power transmission substation as solution of increasing of load and entering Al_Sounot project to grid by large capacity. thesis involves planning done by analytical method, short circuit, and load flow analysis studies done by simulation using e-tab program. These studies based on a real data from national Sudanese electrical companies. As a result of these studies site was selected, capacity of transformers, number of feeders, rating of other equipment and devices were determined.

المستخلص

يناقش هذا البحث التصميم الكهربى لمحطات القدرة الكهربائية . ويشتمل على دراسات التخطيط الكهربى ودراسة إنسياب الحمولة ودراسة دوائر القصر. هذه الدراسات أجريت عن طريق النمذجة والحسابات معتمدة على بيانات أخذت بطرق مختلفة من شركات الكهرباء القومية أيضا كنتيجة لهذه الدراسات تم اختيار الموقع وتحديد السعة للمحولات والمعدات الموجودة في المحطة .

TABLE OF CONTENTS

TITLE	Page NO
الآية	i
DEDECATION	ii
ACKNOWLEDGEMENT	iii
ABSTRACT	iv
مستخلص	v
TABLE OF CONTENTS	vi
LIST OF FIGURES	xi
LIST OF TABLES	xiii
LIST OF SYMBOLS	xv
CHAPTER ONE	
INTRODUCTION	
1.1General Concept	1
1.2Problem Statement	2
1.3 Proposed Soluation	2
1.4 Objectives	2
1.5 Methodology	2
1.6 Research Layout	2
CHAPTER TWO	
SUBSTATIONS AND EQUIPMENTS	
2.Introduction	4
2.2 Functions of a Substation	4
2.3 Classification of The Substation	5

2.3.1 Classification Depends on the Nature of Duties.	5
2.3.2 Classification Depend on The Basis of Service Rendered	5
2.3.3 Classification of Substations on The Basis of Operating Voltage	5
2.3.4 Classification of Substations on the Basis of Importance	6
2.4 Power Transformer	6
2.4.1 Construction of Power Transformer	6
2.4.2 The Equivalent Circuit of Transformer	10
2.4.3 Shunt Connection of Transformers:	10
2.4.4 Cooling System of Power Transformer	11
2.4.5 Vector Group	12
2.4.6 Three Windings Transformer	13
2.4.7 Tap Changer	13
2.5. Busbar	14
2.5.1 Single bus configuration	14
2.5.2 Double bus double breaker configuration	15
2.5.3 Main and Transfer Bus Configuration	16
2.5.4 Double Bus, Single Breaker Configuration	16
2.5.5 Ring Bus Configuration	17
2.5.6 Breaker-and-a-Half Configuration	18
2.6 Surge Arrester	18
2.7 Disconnectors	19
2.8 Earth Switches	19
2.9 Circuit Breaker	20

2.9.1 Definition	20
2.9.2 Operating Principle	20
2.9.3 Important Components of Circuit Breaker	21
2.9.4 Arc Phenomenon	21
2.9.5 Methods of Arc Extinction	21
2.9.6 Primary Application	22
2.9.7 Classification of Circuit Breaker	22
2.9.8 Circuit Breaker Rating	26
2.9.9 Circuit Breaker Selection	27
2.10 Protection Equipment Definitions	27
2.10.1 Fuses	28
2.10.2 Automatic Reclosers	28
2.10.3 Sectionalizes	28
2.10.4 Protective Relays	29
2.11 Instrument Transformers	29
2.11.1 Current Transformer	29
2.11.2 Voltage Transformer	30
CHAPTER THREE METHDOLOGY	
3.1Power System Planning	31
3.1.1 The Goals of Planing	31
3.1.2The System Approach	32
3.1.3Route Selection	32
3.1.4Site Consideration	32
3.1.5 Recent Load Calculation	33

3.1.6 Feeders Calculation	33
3.1.7 Forecasting Load Calculation	34
3.2 Load Flow Study	35
3.2.1 Introduction to Load Flow	35
3.2.2 Bus Classification	35
3.2.3 Bus Admittance Matrix	37
3.2.4 Bus Loading Equations	40
3.2.5 Calculation of Net Injected Power	41
3.2.6 Load Flow Using Newton-Raphson Method	42
3.3 Short-Circuit Study	44
3.3.1. Short-Circuit Studies	44
3.3.2 Objectives of Short Circuit Calculations	44
3.3.3 Benefits of Short Circuit Analysis	44
3.3.4 Types of Short Circuits and Faults	45
3.3.4.1 Symmetrical Faults	45
3.3.4.2 Unsymmetrical Shunt Type Faults	45
3.3.4.3 Unsymmetrical Series Type Faults	45
3.3.5 Short Circuit Current Wave Shapes	46
3.3.6 Short-Circuit Calculation Standards	48
3.3.6.1 Short-Circuit Calculations Standard IEC 60909	48
3.3.6.2 Scope of IEC 60909	49
3.3.7 Type of Short Circuits	49
3.3.7.1 Near-to-Generator Short Circuit	49
3.3.7.2 Far-From-Generator Short Circuit	50
3.3.8 Short Circuit Definitions According to IEC 60909	50

3.3.9 Faults Calculation	51
3.4 Models of Three Phases Three Windings Transformers	54
3.4.1 Models of Three Phases Three Windings Transformers at Short Circuit	54
3.4.2 Models of Three Phases Three Windings Transformers at Short Circuit	55
CHAPTER FOUR RESULTS OF SUBSTATION DESIGN	
4.1 Planning Results	57
4.2 Load Flow Results	59
4.2.1 Voltage Level at Buses	59
4.2.2 Transformers Loading	61
4.2.3 Current Flow and CT Ratio	61
4.3 Short-Circuit Results	64
4.3.1 Maximum Fault Level at Normal Operation	65
4.3.2 Maximum Fault Level at Parallel (1) Operation	69
4.3.3 Maximum Fault Level at Parallel (2) Operation	69
CHAPTER FIVE CONCLUSION & RECOMMENDATION	
5.1 Conclusion	78
5.2 Recommendations	78
REFERENCES	79
APPENDICES	80

LIST OF FIGURES

Figure No	Title	Page No
2.1	Schematic Diagram of single phase core type	7
2.2	Schematic diagram of single phase shell type	8
2.3	Equivalent circuit of transformer	10
2.4	Single bus configuration	15
2.5	Double bus double breaker configuration	15
2.6	Main and transfer bus configuration	16
2.7	Double bus single breaker configuration	17
2.8	Ring bus configuration	17
2.9	Breaker and half configuration	18
3.1	The impedance diagram of sample 4 bus power system	37
3.2	The admittance diagram of Figure 3.1	38
3.3	I-TH bus of a power system	40
3.4	Types of short circuits	46
3.5	AC Current (symmetrical) with no AC decay	46
3.6	DC current	47
3.7	AC fault current including the DC offset (no AC decay)	47
3.8	AC decay current	47
3.9	Fault current including AC and DC decay	48
3.10	Near –to- generator short circuits	49
3.11	Far-from-generator short circuits	50
3.12	Three-phase symmetrical fault	51
3.13	Line-to-ground fault in a three-phase system	52
3.14	Line-to-line fault in a three-phase system	52
3.15	Double line-to-ground fault in a three-phase system	33
3.16	Per unit positive or negative network	54
3.17	Transformer model with tap setting ratio $a:1$	55
3.18	Equivalent circuit for a tap changing transformer	56
4.1	location of substation	57

4.2	Shortest path to substation	57
4.3	Marginal and critical limits of voltage	59
4.4	Substation at normal operation	65
4.5	Comparison between different short circuit current at 11kv	67
4.6	Comparison between different short circuit current at 33kv	67
4.7	Comparison between different short circuit current at 110kv	68
4.8	Comparison between different short circuit current at 0.415kv	68
4.9	Substation at parallel (1) operation	69
4.10	Comparison between different short circuit current at 11kv at parallel operation (1)	71
4.11	Comparison between different short circuit current at 33kv at parallel operation (1)	71
4.12	4.9: Comparison between different short circuit current at 110kv at parallel operation (1)	72
4.13	Comparison between different short circuit current at 0.415kv at parallel operation (1)	72
4.14	Substation at parallel (2) operation	73
4.15	Comparison between different short circuit current at 11kv at parallel operation (2)	74
4.16	Comparison between different short circuit current at 33kv at parallel operation (2)	75
4.17	Comparison between different short circuit current at 110kv at parallel operation (2)	75
4.18	Comparison between different short circuit current at 0.415kv at parallel operation (2)	76
4.19	Adding zigzag transformer to measure line to ground fault	77

LIST OF TABLES

Table No	Title	Page No
2.1	Classification of CB based on voltage	23
3.1	Bus classification	36
4.1	Results of planning	58
4.2	Buses voltage magnitude and angle	60
4.3	Transformers loading in MVA and percentage loading	61
4.4	Buses Current and CT ratio	62
4.5	Transformers Branches Currents and CT ratio	62
4.6	Currents of feeders and CT ratio	63
4.7	incoming cables current and CT ratio	63
4.8	Objectives of short circuit currents in power systems	64
4.9	Faults levels of normal operation	66
4.10	Rated current, maximum fault current and AC breaking of circuit breakers at normal operation	69
4.11	Faults levels of parallel operation (1)	70
4.12	shows faults levels of parallel (2) operation	73
4.13	AC breaking capacity	77

LIST OF ABBREVIATIONS

Y	Admittance
I	Current
R	Resistance
X	Reactance
A	Ampere
V	Volt
DF	Diversity Factor
GR	Growth Factor
TR	Transformer
CB	Circuit Breaker
CT	Current Transformer
VT	Voltage Transformer
GIS	Gas Insulated Substation
AIS	Air Insulated Substation
SK	Sikka Hadeed
MVA	Mega Volt Ampere
DC	Direct Current
AC	Alternate Current
SETCO	Sudanese Electric Transmission Company
SEDCO	Sudanese Electric Distribution Company

LIST OF SYMBOLS

P	Real power, MW
Q	Reactive power, MVAR
V	Voltage magnitude, KV
d	Voltage angle
I	Current, Ampere
Y	Admittance, Mho
R	Resistance, Ω
X	Reactance, Ω
IK	Steady state short circuit current, KA
IK''	Initial symmetrical short circuit current, KA
IB	Symmetrical short circuit breaking current, KA
IP	Peak short circuit current, KA