DESIGN OF ELECTRICAL POWER DISTRIBUTION SYSTEM IN A PETROCHEMICAL STORAGE FACILITY

NORA AFZAM BT ABD WAHAB

ELECTRICAL & ELECTRONICS ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
DEC 2006

DESIGN OF ELECTRICAL POWER DISTRIBUTION SYSTEM IN PETROCHEMICAL STORAGE FACILITY

By

NORA AFZAM ABD WAHAB

FINAL REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Universiti Teknologi Petronas
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

DESIGN OF ELECTRICAL POWER DISTRIBUTION SYSTEM IN PETROCHEMICAL STORAGE FACILITY

by

Nora Afzam Binti Abd Wahab

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved:

____
Prof. Dr. R.N. Mukerjee
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

December 2006

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Nora Afzam Binti Abd Wahab

ABSTRACT

The project title, "Design of Electrical Power Distribution System in A Petrrochemical Storage Facility", is basically an idea to have a design study on how the power distribution system is constructed for the industrial plant. This project will start from the basic knowledge, study the related field, estimating and calculating the main elements required for the design. The project is started by analysis towards the previous practice or existing network of any power distribution system. This project will focus on the power flow analysis, short circuit analysis and the procedure of designing the network elements. The network elements for electrical distribution can be transformer, conductor, protection device and others. Throughout the design procedure, the study on how the power flow and short circuit is done to give benefit for the student to learn, besides giving an idea and clear view to the student on how the overcurrent protective device, the conductors, the transformer rating, load demand and other elements are being sized and connected in a network.

ACKNOWLEDGEMENTS

Upon completing the Final Year Project titled 'Design of Electrical Power Distribution System in a Petrochemical Storage Facility', the author would like to praise to the Al-Mighty Allah for giving the chance to finish the research and study about the project.

The utmost gratitude and appreciation goes to the project supervisor, Prof R.N Mukerjee for his supervision, commitment, professionalism, adivice and guidance for completing this project. Also special thanks dedicate to engineers in Kerteh Terminals Sdn Bhd, Mr Abdul Aziz and Mr Othman Harun for their co-operation in giving the informations in order to help the author in completing this project.

The author would like to give the deepest gratitude to Electrical and Electronics Department for the support and not forgotten also to Electrical Technician, Mrs Siti Hawa, the author's parents and colleagues for all the encouragement and spirits. Last but not least, to those who help directly or indirectly in completing this project. Thank you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Electrical power is produced and distributed to the consumers by the electric public utility companies almost exclusively as alternating current. In industries, the use of three-phase alternating current services has increased rapidly. Single-phase service is used mainly for power systems supplying facilities requiring smaller loads. In power electrical, there are three major practices are encountered and learnt. They are generation, transmission and distribution system. From the very basis of electrical engineering lesson, the generation is defined as system that produces the electricity; the transmission is the system of lines that transport the electricity from generating plants to the area in which it will be used, while the distribution is the system of lines that connect the individual customer to the electrical power system.

1.1 Back ground of study

Since the project is more into the design of power distribution system, so this part will be focused at most on distribution design rather than the generation and transmission parts. The design will start by referring the real existing system network of the petrochemical storage facility of Kerteh Terminals sdn Bhd. The main purpose of this project is to learn on how the industrial electrical distribution network is constructed. The study is conducted in designing an overall system to achieve the electrical power distribution system network.

1.2 Problem Statement

In design process, consideration on the load estimation is the first to be emphasized. Type of elements and loads involved will affect the whole network. For this project, the consideration on maximum demand and total connected load in sizing all the elements are required. Furthermore, the most essential aspect to be covered is its design needs to achieve safety of life and preservation of properties and equipment. The failure of the design contributes to the safety aspect will give the problem to whole network. Besides, in establishing the electrical distribution network system, there are several of codes to be referred. Calculation of the elements in the network must be referred to the electrical standards which are available like NEC, IEC or IEE.

1.3 Significant of the Project

This project is significant to the student in order to complete the individual project assigned. The project will expand new knowledge for the student since this project is not an improvement project, but the study case project. By time, this is one of the skills where student who interested in power system area may develop and enhance the practice toward designing this system.

1.4 Objective

The primary objective of this project is to give an advantage for student to learn and understand on how the power distribution system is designed and practiced in the real system. At this point, the student must have to know that the calculation involved in this project is not merely for the purpose of designation, but also to achieve a standard requirements and safe conditions for the system. The second objective of this project is to develop an automation calculation software for the elements that are going to be sized in the electrical power distribution network. The three main elements are considered in this design, will be load connected, transformer sizing and the cable sizing.

1.5 Scope of Study

The scope of study is presented in this report. There are several topics and issue that must be considered in completing the project. The scope of study depends mainly on these few areas:

- The study on the load estimation
- The calculation for the design current in the circuit.
- The sizing of the main elements involved in the distribution network. such as connected load, transformer and cable sizing calculation procedures.
- The development of automation software design by using Excel based calculation method to size the elements.

Next section will review the literature about the project, including the concept of the controller.

CHAPTER 2

LITERATURE REVIEW/RESEARCH/THEORY

There are three major subsystems in an electrical power system which are generation, transmission and distribution system. From the very basis of electrical engineering field, the generation is defined as system that produces the electricity. The generation of electricity has been developed for the purpose of powering human equipments and as techonlogies in this world become increase, more sources of potential energy is needed. From history, the first power plants were run on the wood, but now today we are dealing on petroleum, natural gas, coal, hydroelectric and nuclear power and a small amount from hydrogen, solar energy, tidal harnesses, wind generators and geothermal sources[1].

Second is the transmission which is the system of lines that transport the electricity from generating plants to the area in which it will be used. This is called delivery of electricity to the consumers[1]. Typically, power transmission is between the power plant and substation near a populated area. However, this is differs from the third term, the distribution system. Electrical distribution is the system of lines that connect the individual customer to the electrical power system[1]. Electricity distribution is the second last process or called as penultimate process in the delivery of electricity, in other words the part between transmission and user purchase from an electricity retailer[1].

The literature review will focus more on the electrical distribution elements , and more details on the industrial calculation method. In any electrical system, the distribution system consists of the equipment and wiring methods used to carry power from the supply transformer to the service equipment's overcurrent devices[2].

2.1 Electrical Distribution Elements

In the design process, the most important thing is to highlight on which elements are existed in the industrial network. Since this project is taken on how the electrical distribution network is constructed, the example of the single-line diagram is referred. Appendix A shows the example of single-line diagram taken from IEEE Recommended Practice for Design the Electrical Power Distribution for Industrial Plant.

An electrical component is any component in the generation, transmission, distribution, or consumption of electric power. Some examples of these components would be: relays, contactors, timers, circuit breakers, fuses, and motor starters. Elements include devices (such as an inductor, resistor, capacitor, conductor, line, or cathode ray tube) with terminals at which it may be connected directly with other devices[3].

The design of any electrical circuit needs a prediction of the voltages and currents in the circuit. Referring to the IEEE standard, the engineers have classified the voltages into the groups of low voltage, medium voltage, high voltage and and extremely high voltage. Table 2 shows the voltage classes as identified from the IEEE.

The table below is adapted from the IEEE Recommended Practice for Electrical Distribution System for Industrial Plant. This Table 3 indicates the terms and conditions for voltage classes. For NEC or National Electrical Code which is basically the standard used in America, uses the term over 600 volts generally to refer to what is known as high voltage. But for the IEEE Standard, the high voltage is refer to any voltage that is higher than 1000 Volts, while the nominal voltages are expressed in terms of root-mean-square (rms).

In industrial and commercial design consideration, basically the voltage class is applicable where medium voltage extends from 1000 V to 69 kV nominal[4].The following terms and definitions, quoted from ANSI C84.1-1989,1 are used to identify the voltages and voltage classes used in electric power distribution.

Electrical Elements	Definition
Synchronous motor/Induction motor	An electric motor converts electrical energy into kinetic energy. The reverse task, that of converting kinetic energy into electrical energy, is accomplished by a generator or dynamo.
Transformer	Device that transfers energy from one circuit to another. Transformers are used to convert between high and low voltages, to change impedance, and to provide electrical isolation between circuits.
Generator	Device that moves electrical energy from a mechanical energy source using electromagnetic induction.
Circuit Breaker	An automatically-operated electrical switch which is designed to protect an electrical circuit from damage caused by overload or short circuit.
Busbar	Refers to thick strips of copper or other material that conduct electricity within a switchboard, distribution board, substation, or other electrical apparatus.
Cable/Conductor	A power cable is an assembly of two or more electrical conductors, usually held together with an overall sheath. The assembly is used for transmission of electrical power.
Capacitor bank	An equipment used to improve power factor, in industrial networks. built behind large factories because the power supplier charges the factory according to power factor instead of real power.

Table 1 : Terms and Definitions of Main Elements in Electrical Power Distribution System.

Nominal System Voltage				
	2 Wire	3 Wire	4 Wire	Maximum Voltage
Low Voltage System		Single-Phase System		127
	120			127/254
		120/240		
		Three Phase System		
			208Y/120	220Y/127
		240	240/120	245/127
		480	480Y/277	508Y/293
		600		635
Medium Voltage System		Three Phase System		
		2400		2540
		4160	4160Y/2400	4400Y/2540
		4800		5080
		6900		7260
			8320Y/4800	8800Y/5080
			12000Y/480	12700Y/7330
			12470Y/6430	13200Y/7620
			13200Y/7620	13970Y/8070
			13800Y/7970	14120Y/8380
			20780Y/12000	22000Y/12700
			22800Y/13200	24200Y/13970
		23000		24340
			24940Y/4400	26400Y/15240
		34500	34500/19920	36510Y/21080
High Voltage System		Three Phase System		
		46kV		48.3kV
		69kV		72.5kV
		115kV		121kV
		138kV		145kV
		161kV		169kV
		230kV		242kV
Extremely High Voltage		Three-Phase System		
		345kV		362kV
		500kV		550kV
		765kV		800kV
		1100kV		1200kV

Table 2 : The voltage classes for low, medium and high voltages.

Term	Definition
System voltage	The root-mean-square phase-to-phase voltage of a portion of an ac electric system. Each system voltage pertains to a portion of the system that is bounded by transformers or utilization equipment.
Nominal System Voltage	The voltage by which a portion of the system is designated and to which certain operating characteristics of the system are related.
Maximum System Voltage	The highest system voltage that occurs under normal operating conditions, and the highest system voltage for which equipment and other components are designed for satisfactory continuous operation without derating of any kind.(voltage transients and temporary overvoltages caused by abnormal system conditions, such as faults, load rejection, and the like, are excluded)

Table 3 : Terms and Definitions of voltage classes.

2.2 Industrial Calculation

This project study refers to the calculations that are suggested by standards such as NEC, IEC and IEEE. The standards recognize certain rules for computing loads for sizing and selecting elements of electrical systems used to supply power to industrial occupancies.

According to these standards, the basic requirement is the same where each service and feeder should be computed and sized with enough capacity to carry a load current that is not less that the sum of all branch-circuits it supplies in the electrical system.

Based on the study of IEEE Recommended Practice for Electrical Power Distribution for Electrical Power Distribution for Industrial Plant, the design should have a system planning. The planning must require the load survey, load requirement, load demand, peak demand, maximum demand, demand factor, diversity factor, load factor and coincident demand.

In design, the designers should also consider about the maximum demand feeder can carry before they can go to calculate the above and further parameters.

Total connected load x Demand Factor = Maximum Demand feeder must carry.

At the early stage, the study of load demand from IEEE states that :

"***2.4.1.3.5 diversity factor:*** *The ratio of the sum of the individual non-coincident maximum demands of various subdivisions of the system to the maximum demand of the complete system.The diversity factor is always 1 or greater.*" [4]

The technical definitions for the load in the design procedure as recommended from PETRONAS Technical Standard , as stated in the simplified in the table 4.

Terms	Definitions
Absorbed Load	The kW load absorbed by the driven equipment at the conditions prevalent to the estimate of maximum demand
Rating	The kW nameplate rating of the device or maximum circuit rating of an electrical feeder.
Efficiency	The efficiency of the electrical equipment at the appropriate load factor.
Load Factor	$\frac{\text{Absorbed Load}}{\text{Rating}}$
Power Factor	The power factor of the electrical load at the appropriate load factor.
Continuous load	All loads that may be required continuously for normal operation or which may be reasonably expected to occur simultaneously.
Intermittent (and spares)	All process and utility loads required for normal operation but neither operating continuously nor simultaneously.

Table 4 : Basic Technical Definition taken from Petronas Technical Standard

For the industrial load, there are two categories involved which continuous load and non-continuous load. These loads depend on their uses. A load is considered to be a continuous load if it is operating 3 hours or more at a time, while it is called a non-continuous load if it is not operating for 3 hours continuously.

The type of loads is needed to be identified in order to come out with the sizing of other elements connected to them. For example ; the conductor, where if it works to supply the current for the continuous load, it required to have an ampacity equals to 125 percent of the total connected load. However, for non-continuous loads, the conductors have to be large enough to supply 100 percent of the total connected load.

2.3 Load Flow Study

Power flow studies, commonly referred to as load flow, are the backbone of power system analysis and design. They are necessary for planning, operation, economic scheduling and exchange of power between utilities.Unlike traditional circuit analysis, a power flow study usually uses simplified notation such as a one-line diagram and per-unit system, and focuses on various forms of AC power (ie: reactive, real, and apparent) rather than voltage and current. There exist a number of software implementations of power flow studies.

In addition to a power flow study itself, sometimes called the load flow study, many software implementations perform other types of analysis, such as fault analysis and economic analysis. In particular, some programs use linear programming to find the optimal power flow, the conditions which give the lowest cost per kW generated.

The great importance of power flow or load-flow studies is in the planning the future expansion of power systems as well as in determining the best operation of existing systems. The principal information obtained from the power flow study is the magnitude and phase angle of the voltage at each bus and the real and reactive power flowing in each line.

2.4 Short Circuit Study

In design, short circuit study is essential in order to determine whether or not electrical equipment is rated properly for the maximum available fault current that the equipment may occur. A Short Circuit is important for the safe of equipment and personnel, efficient, and economical operation of any electrical distribution system. A Short Circuit Study will help to ensure that personnel and equipment are protected by establishing proper interrupting ratings.

When an electrical fault exceeds the interrupting rating of the protective device, the consequences can be devastating, including injury, damaged electrical equipment, and costly downtime.

In practical case, the short circuit current can be determined by applying the calculation at the faults point. The equivalent voltage source at the fault position is the only active voltage in the system during the calculations. We also may assume that all network feeders (feeding external grids), synchronous and asynchronous machines are replaced by their internal impedances. In addition to this, all line capacitances and parallel admittances of non-rotating loads, except those of the zero-sequence system, are neglected.

CHAPTER 3

METHODOLOGY/PROJECT WORK

There are steps taken in order to achieve the result. The steps or work flow of the project is simplified by using the flow chart as shown in the figure below.

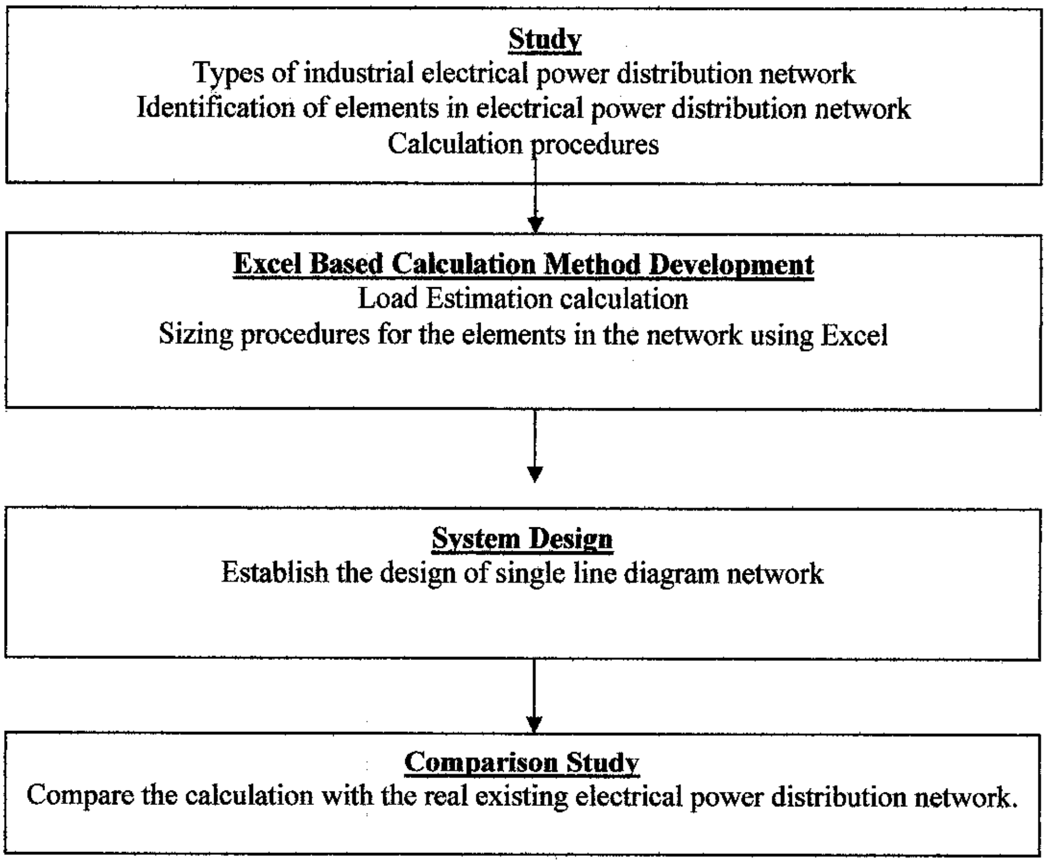


Figure 1 : Flowchart shows steps taken in electrical distribution system design

3.1 Study

The study stage is conducted at the beginning of the project. The study stage includes ;

- Types of industrial electrical power distribution network - (low short circuit current, high short circuit current, earthing plan and relaying system)
- Identification of elements in electrical power distribution network
- Calculation procedures

In order to identify the elements in electrical power distribution network, the study towards example of single-line diagram from the real existing network. The real existing electrical power distribution network of Kerteh Terminals Sdn Bhd has become the reference network.,

The calculation procedures is done based on the industrial calculation towards connected loads and elements sizing. The main elements are identified before the estimation and calculation process is made. By referring the Single Line Diagram of Kerteh Terminals Sdn Bhd in the Appendix B, the main elements of the power system are recorded which are, the loads, the transformers, the overcurrent protection device and the cable. At this point, the Single Line Diagram of Kerteh Terminals Sdn Bhd is simplified as shown in Figure 2 below. The elements involved in establishing the electrical power distribution network are identified and this will have a further discussion in Chapter 4.

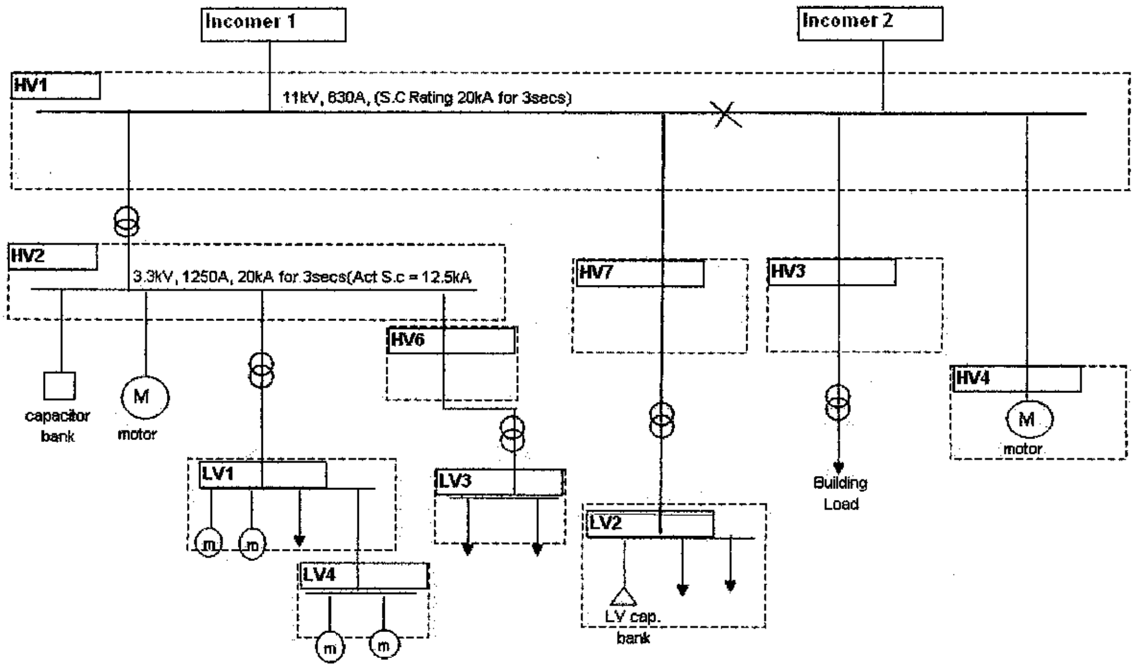


Figure 2 : Simplified Drawing for HV Single Line Diagram of Kerteh Terminals Sdn Bhd

3.2 Excel Based Calculation Method Development

The flow chart below shows the step of steps taken in order to develop the calculation system for the main elements involved.

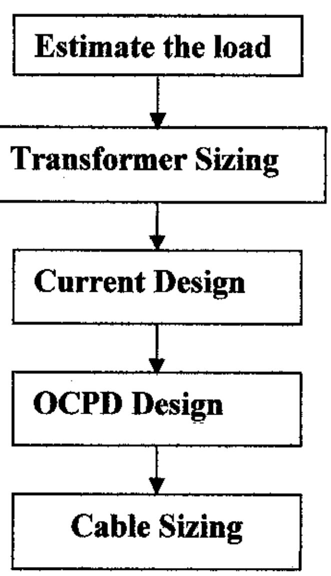


Figure 3 : Flowchart on how the Excel based calculation is developed.

3.2.1 Load Estimation

The load is estimated in kW or kilowatts for each of the branch and the feeder circuits that are connecting all the loads. Load survey for overall system is done in order to get the value of total connected load. The steps for the load survey is shown in flowchart below.

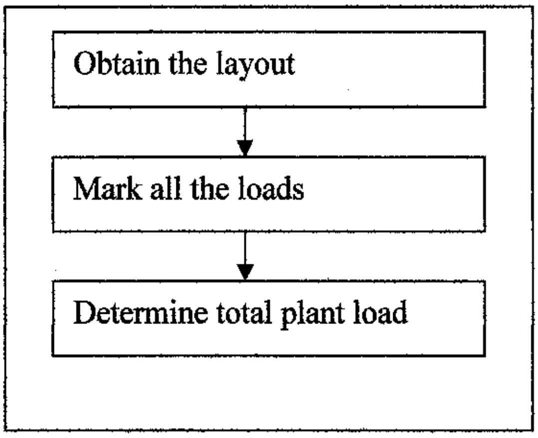


Figure 4 : Steps taken in estimating the load

The study is done by obtaining the layout to be analyzed. All the known loads are mark and calculated. The student should be able to know the general terms regarding the load survey such as load demand, peak demand, maximum demand, demand factor, diversity factor, load factor and coincident demand. The further discussion will be on the Chapter 4.

3.2.2 Transformer Sizing

After estimating the load in kW, the student has to come to the upper level of sizing the transformer. In order to size the transformer, the known values of the connected load in kVA must be required. Since at first, all the total maximum load demand is estimated and the value is known in kW, so the kW value now needs to be converted in value of kVA.

For this design, the important of knowing the load in kVA is because it is the easiest method of choosing the transformer. When the value of the load in kVA is gotten, the transformer size can be calculated by multiply the load demand in kVA with 125%.

kVA transformer rating = 125% x Maximum Demand

This is because to set the maximum increase of the power from the loads connected to the transformer. This is to ensure the transformer could afford the future increase load in the network..

3.2.3 Design Current in the Network

The design current in the network is defined as 'the magnitude of the current to be carried by a circuit in normal service'. The design current can be notation as Ib, which is can also be determined by manufacturer's detail[5].

By referring to the 16th Edition IEE Wiring Regulation Design and Verification of electrical installation, the design current can be calculated as ;

- $Ib = \frac{P}{V}$ or $\frac{P}{(V \times Eff\% \times PF)}$ .... single phase
- $Ib = \frac{P}{\sqrt{3} \times VL}$ or $\frac{P}{\sqrt{3} \times VL \times Eff\% \times PF}$ .... three phase

3.2.4 Selecting the protection devices

There is two types of overcurrent protection devices normally used, which are fuses and moulded circuit breaker. Fuses and MCBs are rated in amps. The amp rating given on the fuse or MCB body is the amount of current it will pass continuously. This is normally called the *rated current* or *nominal current.*

For this project, there is the procedure where sizing the overcurrent protection device (OCPD) must match the rating current for the cable and transformer connected to them.

For the overcurrent, basically it is devided as two term which are;

a) Overload current

b) Fault current

  i) Short circuit current (between live conductors)

  ii) Earth fault current (between phase and earth)

Table 5 is adapted from IEE Wiring Regulatio written by Brian Saddan , where it simplified the meanings of overcurrent.

Terms	Definition
Overload Current	Overcurrent occurred in healthy circuit which usually caused by inrush currents, motor starting, etc.
Fault Current	This occur when there is mechanical damage to circuits. Also caused by insulation failure or breakdown leading to bridging of conductors. The impedance of this bridge than assumed to be negligible.

Table 5 : The Terms and Definition for Overload Current and fault Current

For the overload protection, protection devices used for this purpose will be shown on the step below, where the reference link is [7].

Step 1 : The nominal setting of device, In must greater or equal to Ib $In \geq Ib$
Step 2 : Current carrying capacity in conductors, Iz less than or equal to In $Iz \leq In$
Step 3 : Current causing operation of device, Is must less than or equal to 1.45 times Iz $Is \leq 1.45 \times Iz$

Step 3 is achieved if the In is less than or equal to 0.725 times Iz.

$$In \leq 0.725 \times Iz$$

This is due to the fact that a re-wireable fuse has a fusing factor of 2, and 1.45/2 = 0.725[7].

For the protection against earth fault, the circuit breaker called ELCB or Earth Leakage Circuit Breaker is used[9]. These units are also called Residual Current Circuit Breaker (RCCB) or Residual Current Device (RDC)[9].

ELCBs/RCCBs and Earth Leakage Switches/RCDs are devices capable of sensing earth leakage current and interrupting the circuit automatically when these currents exceed a predetermined value[9]. An earth leakage current is the current flowing to earth from live parts of an installation[9].

3.2.4.1 OCPD calculation and consideration for cable

In design, there is two types of overcurrent protection devices normally used, which are fuses and miniature circuit breakers. When selecting the correct MCB or fuse to use, we have to consider its role in both over-current protection, and short-circuit protection. The basic principles as stated below;

a) *Nominal current rule*

   In the body of the MCB itself will show the nominal current. This is called In, which must be less than current rating of the cable it is protecting, but higher than the current it will carry continuously.

b) *Tripping rule*

   A current of 1.45 times the nominal current must cause the device to trip in less than 1 hour

c) *Disconnection time rule*

   In a short-circuit condition, the fuse/MCB must trip in less than a specified short time.

3.2.4.2 OCPD calculation and consideration for transformer

For the transformer overcurrent protection device, it may be placed on the primary only or both in primary and secondary. The sizing of the Overcurrent Protection Device is based on the rated voltage of the transformer. Consideration should be taken whether the transformer is rated less than 600 V or more than 600 V. The OCPD can be circuit breaker or fuses. Table 6 below shows simplified calculation which is taken form the NEC Stallcup's Design Calculation Text Book.

Transformer : Primary Side over 600V	Transformer : Prim & 2ndary over 600 V
AT PRIMARY; Sizing the CB; 1. Find FLA in Ampere $FLA = \frac{kVA \times 1000}{\sqrt{3} \times V} = x$ 2. Multiply FLA with 300% . Y = X x 300% 3. Then choose CB next higher value of Y that is available.	AT SECONDARY; Sizing the CB; 1. Find FLA in Ampere $FLA = \frac{kVA \times 1000}{\sqrt{3} \times V} = x$ 2. Multiply FLA with 125% X x 300% = Y 3. Then choose CB next higher value of Y that is available.
Sizing the Fuses 1. Find FLA in Ampere $FLA = \frac{kVA \times 1000}{\sqrt{3} \times V} = x$ 2. Multiply FLA with 250%. X x 250% = Y 3. Choose next higher value of Y that is available.	Sizing the Fuses 1. Find FLA in Ampere $FLA = \frac{kVA \times 1000}{\sqrt{3} \times V} = x$ 2. Multiply FLA with 250%. X x 250% = Y 3. Choose next higher value of Y that is available.

Table 6 : Transformer's OCPD design

3.2.5Sizing the cable

This method is based on the reference [12].

In selecting the electric cable, the most important things to be taken into account are;

- Power - This can be in kVA, kW or in Amps.
- Voltage
- Permissible voltage drop - (Usually 5%)
- Distance to load
- Fault current:
    - Short circuit (Symmetrical Fault Current)
    - Earth fault (Asymmetrical Fault Current)
- Mechanical Conditions:
    - Temperature, depth of burial, soil thermal resistivity, presence of other cables, or other heat sources.
    - Armouring requirements.
    - Sheath requirements.

The appropriate selection of cable should be referred to the current rating that the conductor could carry. There are three types of cable available as shown below in the Table .

i) XLPE Insulated (Copper, Alumium)

ii) PVC Insulated (Copper, Aluminium)

iii) PAPER Insulated (Copper, Aluminium)

These three types of cable have different value of derating factor. Consideration on the derating factor when calculating the current cable will lead to the correct method of sizing the electrical cable. In industrial calculation, there are different in calculating the cable that need to be installed for low voltage, medium voltage and high voltage. This project will focus on the low voltage and medium voltage cable sizing only.

3.3 System Design

At this part, the student has to establish a single-line network diagram. The electrical power distribution network will have connected load, the transformer and the cable size depends on its current flow in the circuit. The current flow in the circuit is depends to the maximum demand of load connected. This part will be discussed more in the Chapter 4.

3.4 Comparison Study

This part is conducted to verify whether the calculation that is developed in the Excel sheet is expected to be the same or not as used in the actual implementation in the industrial electrical distribution network system. The single-line diagram of industrial plant from Kerteh Terminals Sdn Bhd is chosen as the reference, since it is suitable because of it is an industrial plant for storage facility. This part will be discussed more in the Chapter 4.

CHAPTER 4

RESULT/DISCUSSION

4.1 Excel Based Calculation

4.1.1 Load Estimation and Transformer Sizing

The example of single line diagram in a plant is developed where the plant consists of five sub-station. Each sub-stations are connected to their own load. Figure 5 below will show the plant's condition.

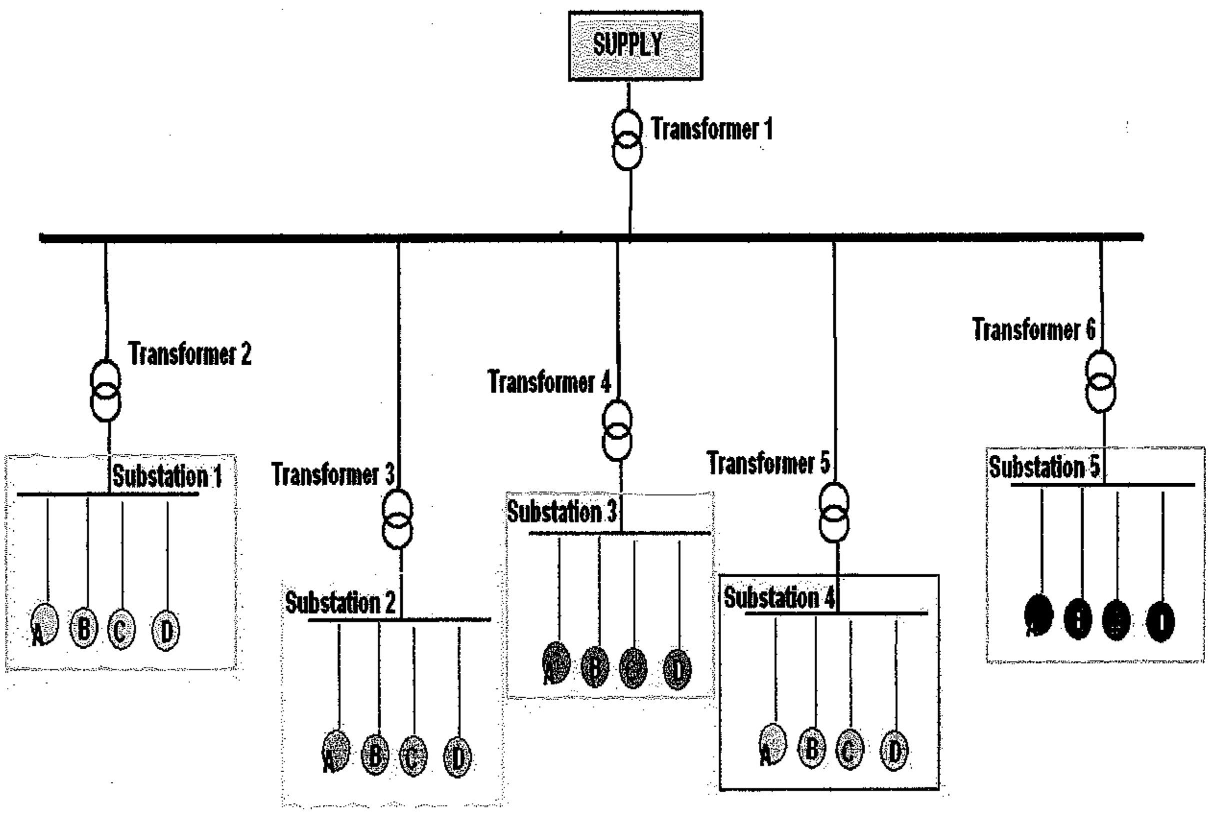


Figure 5 : Sample of one line diagram in industrial plant.

From Figure 5, each substation consists of five branches. Each branch has different loads. The loads are namely as Load A, Load B, Load C and Load D. For example, the total load at Sub-station 1 is the sum of Load A, Load B, Load C, and Load D.

The maximum demand is basically calculated from the equation ;

$$\text{Demand Factor} = \frac{\text{Maximum Demand}}{\text{Total Connected Load}}$$

In industry, the demand factor will vary between 0.8 to 0.95. For the system, the demand factor is chosen to be 0.9. From the single-line diagram shows in Figure 5, the development of the simply software to calculate the next step of the network elements is establish. Figure 5 below shows that the Excel field for load estimation process.

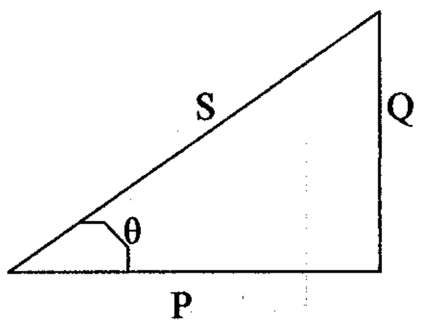
	A	B	C	D	E	F	G	H	I	J
1										
2										
3		Substation 1								
4						Maximum	Connected Load		Tx rating Size	
5		Type	Input PF	Input kV	Total kW	Demand	Calc kVA	Calc A	Tx Size	125% Tx
6		Load A								
7		Load B								
8		Load C								
9		Load D								
10		Total Amps,kW								

Figure 6 : Excel field for load estimation

Based on the Figure 5, for sub-station 1, the estimation for each load will be done when any values is inserted by the user in the column C, D, E . The column G and H will automatically give the value of the connected load in KVA and the full load current sustained in Amps for the branches. Maximum demand at column F10 will automatically calculated whenever the Total Connected Load for each branches of the sub-station 1 are summed, and multiplied with demand factor set as 0.9.

From this value, the column I10 will be set to divide any value generated at F10 with the system PF, which is any value at C. Then, column J10 will multiply the value of I10 with 125%. This is to show the final calculation for each sub-substation, which refers to the transformer size in kVA at any voltage rating for this feeder.

In order to size the transformer in kVA, by using the system power factor, it is divided with the maximum demand in kW. In power electrical engineering, there is a theory which relates the real power in kW, the reactive power in kVAR and the apparent power in kV which is called power triangle theory. Figure 7 below shows the relationship of this three powers.



$P = S \cos \theta$

$Q = S \sin \theta$

$\frac{P}{S} = \cos \theta$

$\frac{Q}{S} = \sin \theta$

$\frac{Q}{P} = \tan \theta$

Figure 7 : Power Triangle Theory

From the Figure 6 above, S is the apparent power in kVA, P is the real or active power in kW and Q is the reactive power in KVAR.

In order to get the value from the kW to the kVA, where the given load in kW is known, the equation from the right side is applicable.

$$P = S \cos \theta$$

Where P is known in kW

Cos θ represents the plant power factor which is also known,

$$S = \frac{P}{\cos \theta}$$

and now the load in kVA can be known.

	L	M	N	O	P	Q	R
21							
22	Sizing the Main Transformer						
23	No of feeder		I(Feeder)	V(Feeder)	kVA	V(supply)	Amps
24	Feeder 1						
25	Feeder 2						
26	Feeder 3						
27	Feeder 4						
28	Feeder 5						
29	Total Amps						
30	Transformer Sizing kVA						
31							

Figure 7 : Excel based calculation field for transformer sizing

Since they are five sub-stations in Figure 5, there are also five feeders where current is sustained based on the power consumed by the load and the voltage rating for each of the feeder. This current is assumed as maximum current or full load current of all connected load at each branches.

The current obtained from the automatic calculated value at H10, which stand for current generated at feeder of sub-station 1, is auto-inserted into the N24, for column N25 until N28, the currents generated at feeder 2 of substation 2 until feeder 5 at substation 5 will be auto-inserted at each column respectively. By multiplying each current by its voltage supplied to the feeder, the power in kVA is sustained at column P. From this column, the current or ampere sustained based on the main voltage supply from the system and generated kVA of each feeders. The sum of all currents is auto-calculated at column R29. In order to get the value of the transformer size at this level, for the main system as build for Figure 5, the equation at column R30 is set as;

Total current, Amps x Voltage supply kV = Transformer Size , kVA

At value R30, the rating for size of transformer is gotten here. So, the size of the transformer rating is based on the value of the load connected on each feeders.

4.1.2 Cable Sizing

The Excel based calculation is made to size the low voltage and medium voltage cable. The Figure 8 below show the Excel based sizing calculation for both low voltage cable and medium voltage cable, respectively.

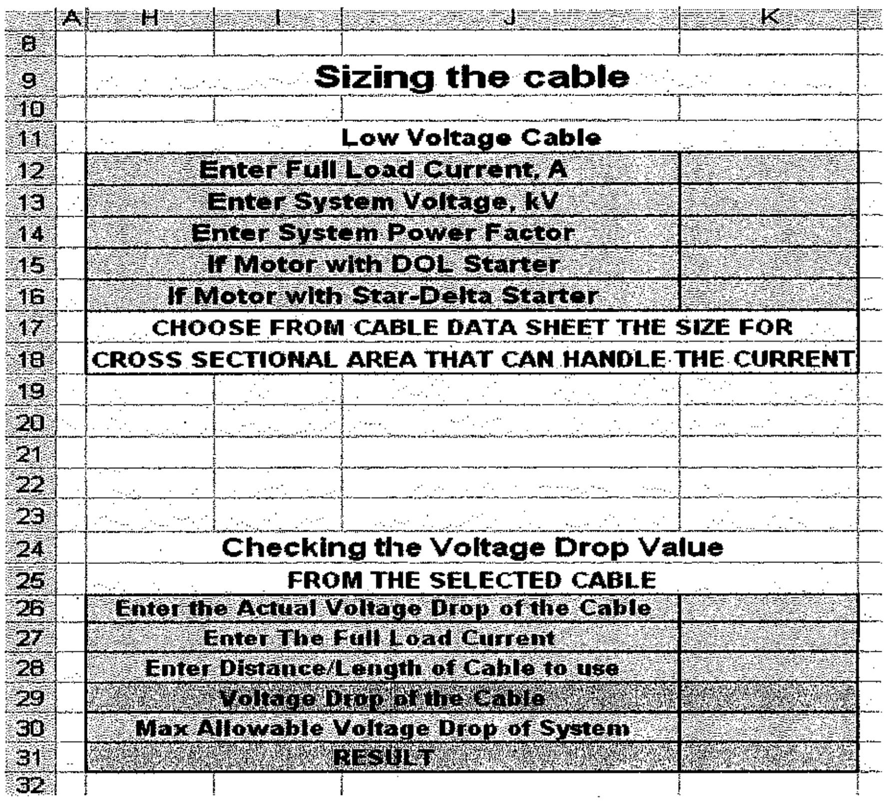


Figure 8 : Excel based calculation field for low voltage cable size

Based on the Figure 8 above, this system will calculate the size of cross sectional area for the low voltage cable. When the full load current in Amps, the Voltage rating of the system and the system power factor are known, the user may insert this information in the column K. AT column K15 and K16, the system will automatically change the value of full load current calculated when the motor's starters are considered to be the Direct On-Line Starter or Star Delta Starter.

Star Delta Starter	Direct On-Line Starter
Sustained current rating x 3	Sustained current rating x 6

The sustained currents for each motor with different starters will auto-calculated and generated at column as shown in Figure 8. After gotten the value of the sustained current or full load current, the user may have to identify from the cable data sheet, at which type of cable they are using, the cross sectional area in mm ^{2} can handle this calculated current. After choosing the suitable value for the cross-sectional area of the cable, the actual voltage drop of the cable in mV/A/m of that cable is inserted at K26. Then, the comparison between the cable's voltage drop and the system voltage drop need to be verified whether the cable can withstand the voltage drop of the system. The value of the cable's voltage drop is gotten by equation ;

Actual Vdrop of cable (mV/A/m) x Cable Length to be used (m) x Full load current (A) = Voltage Drop

From Figure 8 above, if the value at the column K29 is bigger than the value at K30, the Result at Column K31 will show output stated as NOT OK. This mean that the cable is not acceptable to be used.

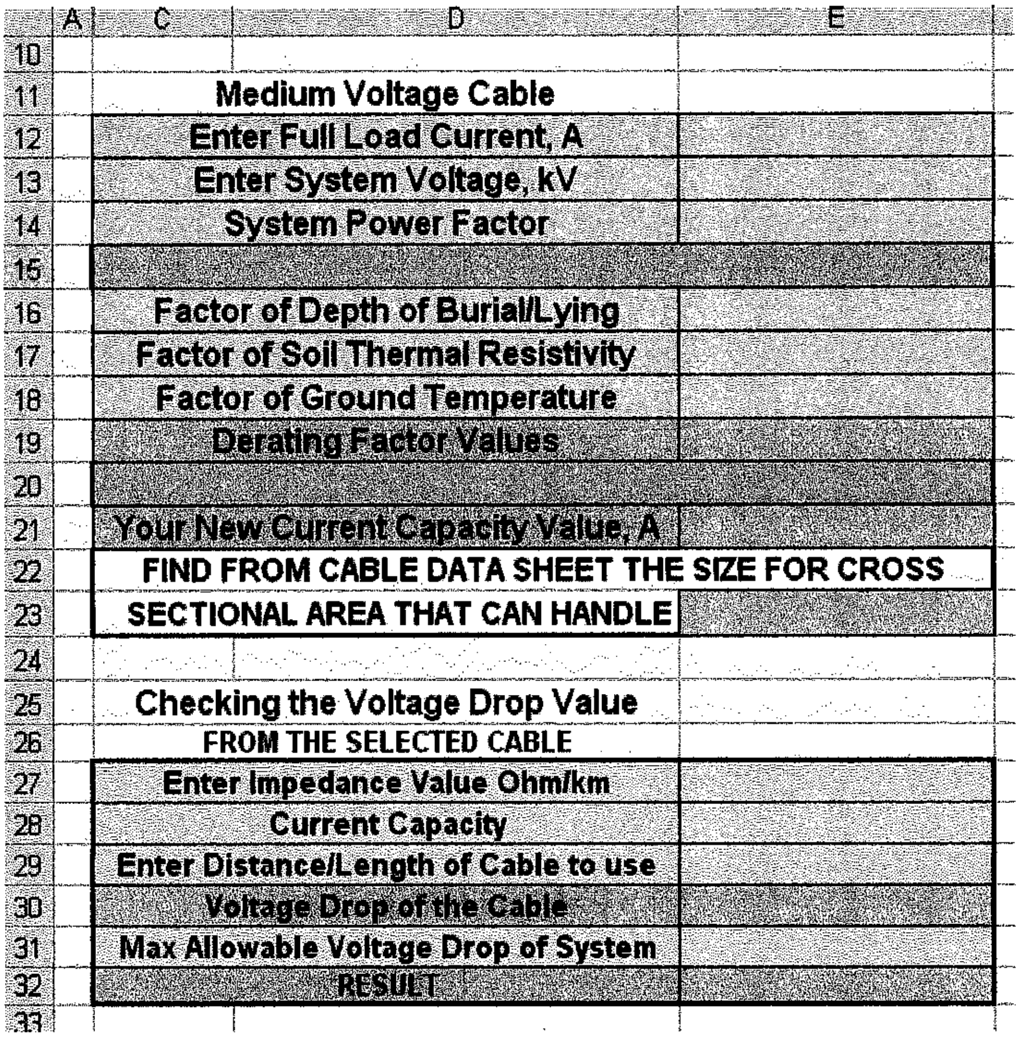


Figure 9 : Excel based calculation field for medium voltage cable

Based on the Figure 9 above, this system will calculate the size of cross sectional area for the medium voltage cable. When the full load current in Amps, the Voltage rating of the system and the system power factor are known, the user may insert this information in the column E. The derating factor is taken to be the consideration when sizing for the medium voltage cable. For column E16, E17 and E18 will let the user to insert the values depends on the factors that are available in cable data sheet from any manufacturers.

The calculated full load current from any feeders is inserted at column E12, then this value is auto-calculated at column E21, after it is divided by the derating factor which is generated at column E19.

The Derating Factor is gotten by equation;

Factor for (Depth of Burial/Lying x Soil Thermal Resistivity x Ground Temperature)

After gotten the value of the sustained current or full load current, the user may have to identify from the cable data sheet, at which type of cable they are using, the cross sectional area in mm^2 can handle this calculated current. After choosing the suitable value for the cross-sectional area of the cable, the voltage drop for this cable is verified whether it can withstand the voltage drop of the system.

When the value of cross sectional area is choosen, its impedance is taken and inserted in column E27. The voltage drop for the cable is calculated and determined by equation;

Impedance of Cable Ohm/km x Distance of cable x Full load current sustained Amps = Voltage Drop of Cable.

This value is auto-calculated at column E30. It is compared with the system voltage drop whether this cable can withstand or not the system voltage drop. The column RESULT at E32 will identify it is OK if it is acceptable to withstand and NOT OK if it is not acceptable to withstand the voltage drop of the system.

4.1.3 Overcurrent Protection Devices

As recommended by IEEE , in order to size the OCPD for the transformer, the Table 6 below give a guidance on how to rate the overload current to chose the correct protection devices.

Transformer rated impedance	Transformers with primary and secondary protection				
	Primary Over 600 V		Secondary		
			Over 600 V		600 V or below
	Circuit breaker setting	Fuse rating	Circuit breaker setting	Fuse rating	Circuit breaker setting or fuse rating
No more than 6%	600	300	300	250	250
More than 6% but no more than 10%	400	300	250	225	250

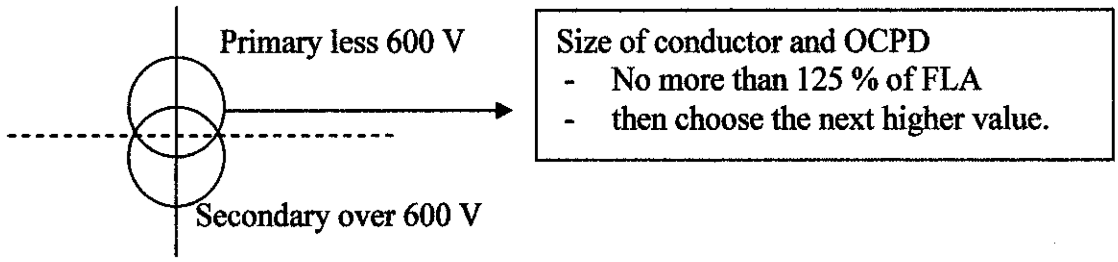
Table 6 : Transformer rating for the OCPD design.

If there is no secondary protection, transformers with primaries rated for more than 600 V require either a primary circuit breaker that will operate at no more than 300% or a fuse sized not greater than 250% of transformer full-load current. Better protection will be realized with breaker settings or fuse ratings lower than these maximum levels.

The actual value depends on the nature of the specific load involved and the characteristics of the downstream protective devices. When both primary and secondary protective devices are provided, the maximum protective levels depend on the transformer impedance and secondary voltage.

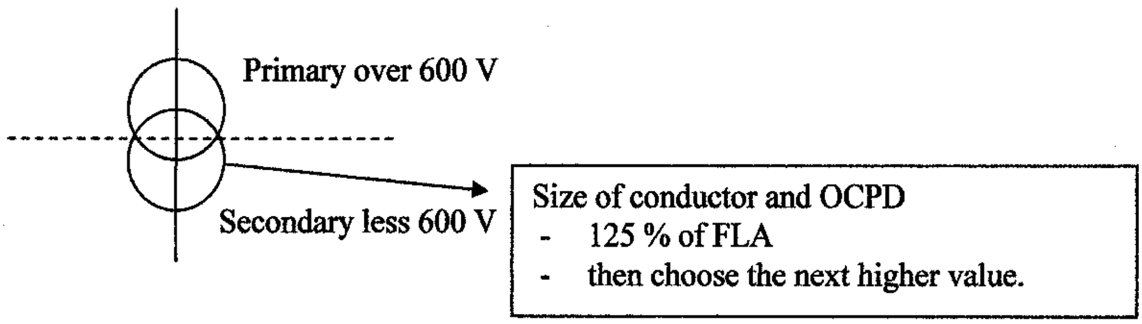
These maximum levels of protection, taken from NEC, table 450-3(a)(2)(b), are shown in Table 6. Transformers with primaries rated 600 V or less require primary protection rated at 125% of full-load current when no secondary protection is present, and 250% as the maximum rating of the primary feeder overcurrent device when secondary protection is set at no more than 125% of transformer rating.

If Primary is less than 600V ,



The reason why the value should be design at no more than 125% is to ensure the supply conductors and transformer windings are considered protected from overload condition.

If Secondary is less than 600V ,



The 125% is set because to protect the conductors and windings of the the transformer from dangerous overload condition.

In order to calculate the OCPD size, first thing to do is to calculate Full Load Current FLC at the Transformer. The equation is ;

$$\textbf{FLC in Amp} = \frac{\textbf{125\% kVA rating}}{\textbf{Supply Voltage in kV} \times \sqrt{3}}$$

In order to come out with the OCPD size at the primary of the transformer, the real equation stated from the Stallcup's Electrical Design Book is ;

OCPD size = FLC x 600%

All the elements will be automatically calculated by using the formulas as stated above. At the service feeder now, we get the value for Total Ampere at all branches when they are summed together.

4.2 Comparison Study

Comparison study is done by using the real existing system of Kerteh Terminal Sdn Berhad , the storage facility plant. Figure 10 shows the single-line diagram of the plant.

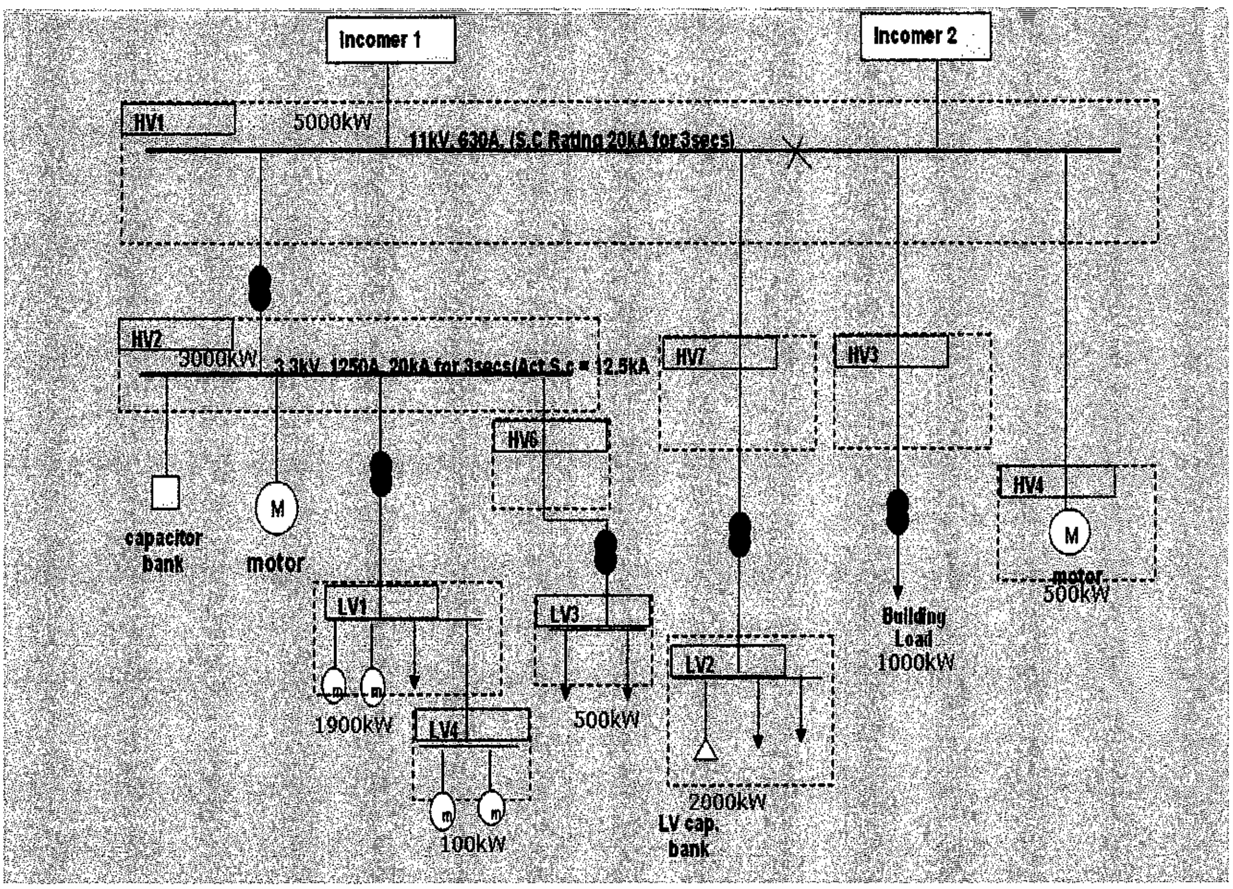


Figure 10 : Simplified Single Line Diagram for Kerteh Terminals Sdn Bhd

The comparison study for the transformer sizing and the cable sizing is shown in this chapter. By the method discussed in part 4.1.1 and 4.1.2, the example of the result obtained when comparing the data observed from the Kerteh Terminals Sdn Bhd plant with the auto-calculated value from the Excel Based Calculation field proved the similarity and the method is applicable.

4.2.1 Comparing the transformer rating

From the calculation procedures, the method to take the transformer size, it must be multiply with 125% of Maximum Demand. Based on the Figure 11, the part of LV2, Low Voltage side is taken to determine the transformer rating.

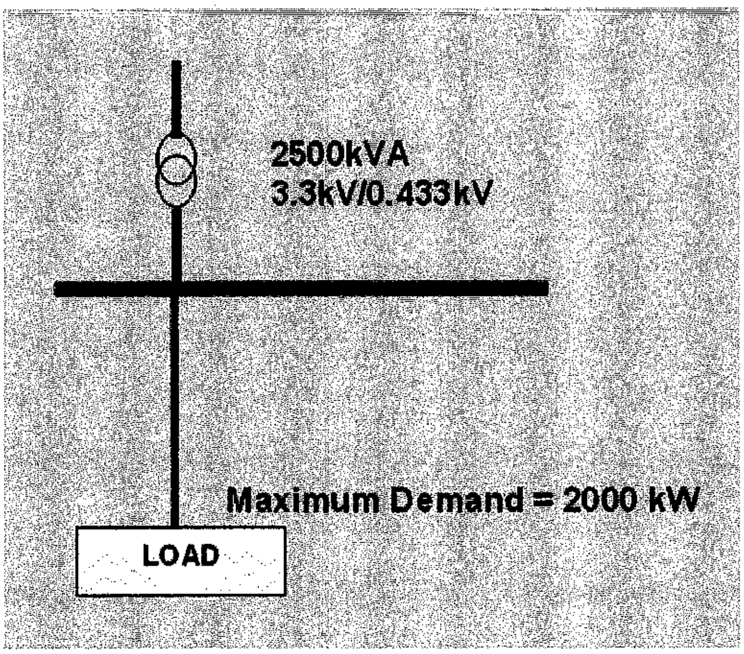


Figure 11: Simplified diagram for elements at Low Voltage 2

From the data collected, the maximum demand at Low Voltage 2 is determined as 2000 kW. Equalizing the kW with kVA, now we got the power consumed at this point is 2000 kVA. By multiplying 125% with 2000 kVA, the transformer size is 2500 kVA. The transformer with this rating is installed at this level with the same method used in calculation procedure.

4.2.2 Comparing the cable size

The comparison study is taken for value at the HV2 side, where the transformer of 2000 kVA with voltage 11 kV is connected to the cable with size 95 mm², type XLPE.

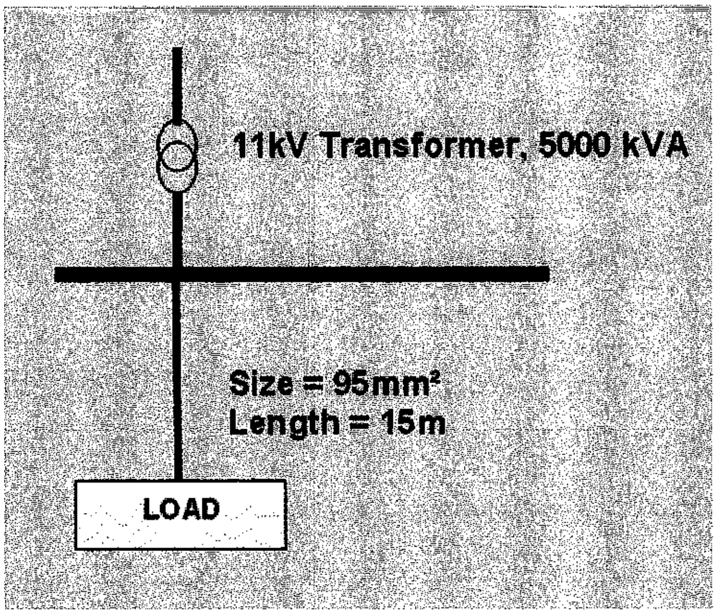


Figure 12 : Simplified diagram for element at High Voltage 2

The transformer rating 5000 kVA is divided by 11 kV. By using the equation ;

$$\text{Full Load Current} = \frac{\text{kVA}}{\sqrt{3} \times V}$$

This system can carry the current of **262.439** Ampere. For the medium voltage, calculation on the derating factor as mention in the calculation procedure should be considered. The derating factor for this system, consist of the factor on the depth of burial and lying, factor on soil thermal resistivity, and factor for ground temperature.

From data collected, and by referring to the XLPE cable data sheet as shown in the appendix, table below shows the value for the factors :

Factor	Value	Derating values
Soil Thermal Resistivity	1.2 C m/W	0.91
Ground Temperature	15 C	1
Depth of Burial/Lying	0.8 m	0.96
Total Value for derating factor		**0.8736**

Table 7 : The derating factor value used for determining the cable size of the system.

Taken the full load current just now and divided with the derating factor, gives value :

$$\frac{262.439}{0.8736} A = 300.4 A \sim 300 A$$

From the Cable Data Sheet, the cross sectional area is choosen based on the ampacity of the current that cable can carry. Figure 13 below shows the table taken as reference, to prove that the value of 300 Ampere is under the size of 95mm².

Table 4 CURRENT RATINGS FOR 3.8 / 6.6 (7.2) kV TO 8.7 / 15 (17.5) kV ARMOURED XLPE CABLE

Conductor Size	In Air			In Ground		
	Single Core[a]			Single Core[a]		
	Trefoil	Flat	3 Core	Trefoil	Flat	3 Core
(mm²)	(A)	(A)	(A)	(A)	(A)	(A)
Copper Conductor						
25_b	-	-	145	-	-	140
35_b	-	-	175	-	-	170
50_b	235	295	220	220	230	210
70	285	370	270	270	280	255
95	360	455	330	320	335	300
120	415	520	375	360	380	340

Figure 13 : Reference for XLPE Cable current ratings

Then, by referring to the Cable Data Sheet, impedance value for this 95mm² is 0.247 ohm/km. This value is inserted into the Excel based calculation field, and the length or distance of cable to be used also inserted.

Checking the Voltage Drop Value FROM THE SELECTED CABLE	
Enter Impedance Value Ohm/km	0.247
Current Capacity	300.4
Enter Distance/Length of Cable to use	0.015
Voltage Drop of the Cable	1.927741372
Max Allowable Voltage Drop of System	165
RESULT	OK

Figure. 14 :Excel based calculation field to auto-calculate the size of medium voltage cable.

Automatically this system identifies that the value of voltage drop within the cable and the voltage drop of the system is OK, where this means the voltage drop of the cable not exceeding the voltage drop of the system. The voltage drop of the system is 5% of the voltage supplied to the system. This proved that the Excel based calculation method is acceptable since it meets the requirement as compared to the size of elements in the real existing electrical power distribution network.

CHAPTER 5

CONCLUSION/RECOMMENDATION

5.1 Conclusion

This project is done to design an industrial power distribution system. Several calculations in determining the size of the elements in electrical system have been performed and they are all combined to produce a power electrical distribution network system. The Microsoft Excel work sheet has been used to create and develop the design equations where output result is automatically gotten for each electrical elements whenever the input data are entered. The project has finished the calculation for the load estimation, transformer sizing, and cable sizing. The comparison study is also done by using the Excel based calculation method that is developed to compare whether the calculation procedures meet the requirement as used in the real existing electrical power distribution network.. The transformer and cable rating used in Kerteh Terminals Sdn Bhd, gives acceptable reason for this auto-calculation method established in Excel, is applicable.

5.2 Recommendation

The recommendation towards this project is to enhance the automating design process by using Microsoft Visual Basic. The Visual Basic software is proposed to be used as software interface to generate the output data since that software is more interactive.

REFERENCE

[1] http://en.wikipedia.org/wiki/Electrical_distribution

[2] STALLCUP's ELECTRICAL DESIGN BOOK, NFPA, National Fire Protection Association, Quincy, Massachusetts, 2002.

[3] http://en.wikipedia.org/wiki/Electrical_element

[4] IEEE Recommended Practice for Electrical Distribution System for Industrial Plant.

[5] Brian Scaddan, "Design", in *IEE Wiring Regulation, Design and Verification of Electrical Installations*, Jordan Hill, Oxford OX2 8DP, Third Edition, 2001, pp.26.

[6] Brian Scaddan, "Design", in *IEE Wiring Regulation, Design and Verification of Electrical Installations*, Jordan Hill, Oxford OX2 8DP, Third Edition, 2001, pp.17.

[7] Brian Scaddan, "Design", in *IEE Wiring Regulation, Design and Verification of Electrical Installations*, Jordan Hill, Oxford OX2 8DP, Third Edition, 2001, pp.18.

[8] Brian Scaddan, "Design", in *IEE Wiring Regulation, Design and Verification of Electrical Installations*, Jordan Hill, Oxford OX2 8DP, Third Edition, 2001, pp.22

[9] http://www.cbibreakers.com/ground_fault.asp

[10] http://www.lmphotonics.com/busbarcalcs.htm

[11] http://en.wikipedia.org/wiki/Busbar

[12] http://www.aberdare.co.za/articles/cable_selection.html

[13] http://en.wikipedia.org/wiki/Synchronous_motor

[14] http://en.wikipedia.org/wiki/Transformer

APPENDIX

APPENDIX A : The example of single-line diagram taken from IEEE Recommended Practice for Design the Electrical Power Distribution for Industrial Plant.

APPENDIX B : The result of Load Flow Study from Kerteh Terminals Sdn Bhd

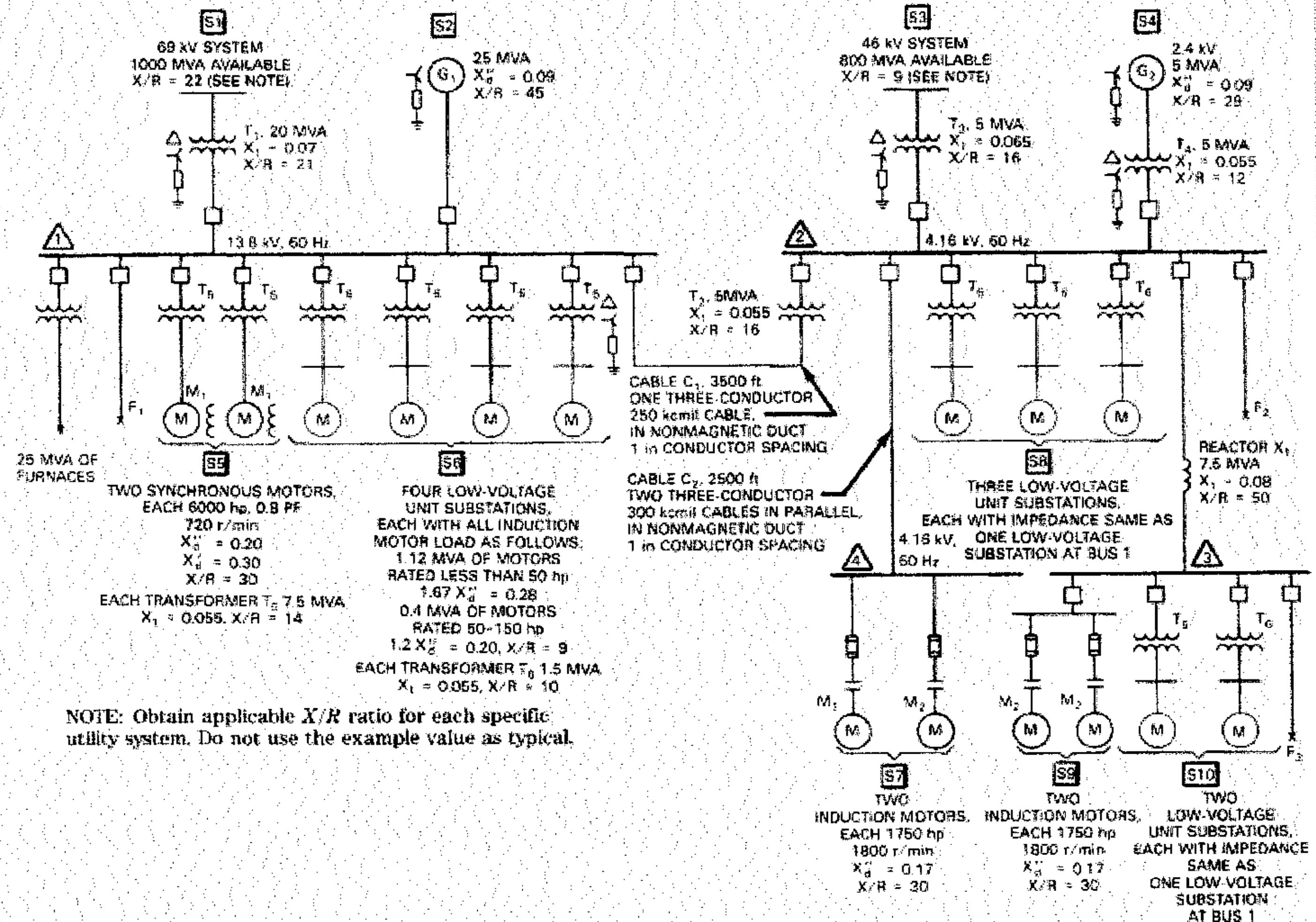
APPENDIX C : The result of Short Circuit Current Study from Kerteh Terminals Sdn Bhd.

APPENDIX D : All the load list in kW for Low Voltage and High Voltage line for Kerteh Terminals Sdn Bhd.

APPENDIX E : The Power Distribution System of the storage facility plant : HV Single Line Diagram of Kerteh Terminals Sdn Bhd.

APPENDIX F : Technical Cable Data Sheet

APPENDIX A : The example of single-line diagram taken from IEEE Recommended Practice for Design the Electrical Power Distribution for Industrial Plant.



NOTE: Obtain applicable X/R ratio for each specific utility system. Do not use the example value as typical.

Figure 4-10—One-line diagram of industrial system example

APPENDIX B : The result of Load Flow Study from Kerteh Terminals Sdn Bhd

MINAL

Abbreviation:

LF_A = load flow current.

LF_PF = load flow power factor.

LF VD% = voltage drop in % of nominal voltage.

CT _/_ A = current transformer ratio.

Z% = impedence in %.

NER = Neutral Earthing Resistance.

PriTap = Primary tapping of transformer.

Isc 3P = Balanced 3-phase short-cct current.

Isc SLG = single phase-grnd short cct current

Isc 3P Peak = 3 phase first ½ asymmetrical S.C current.

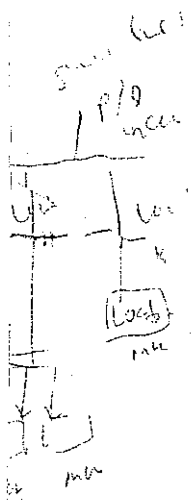
Isc SLG Peak: phase-ground first ½ short circuit current.

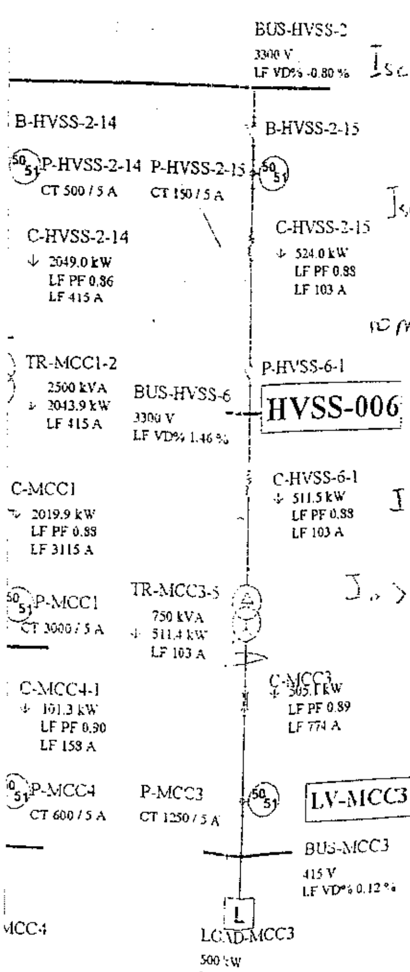
IDMT: Inverse definite minimum time curve of OC/EF relay.

I > = Phase fault setting value of OC/EF relay.

I >> = High set phase fault setting value of OC/EF relay.

I_o > = Earth fault setting value of OC/EF relay.





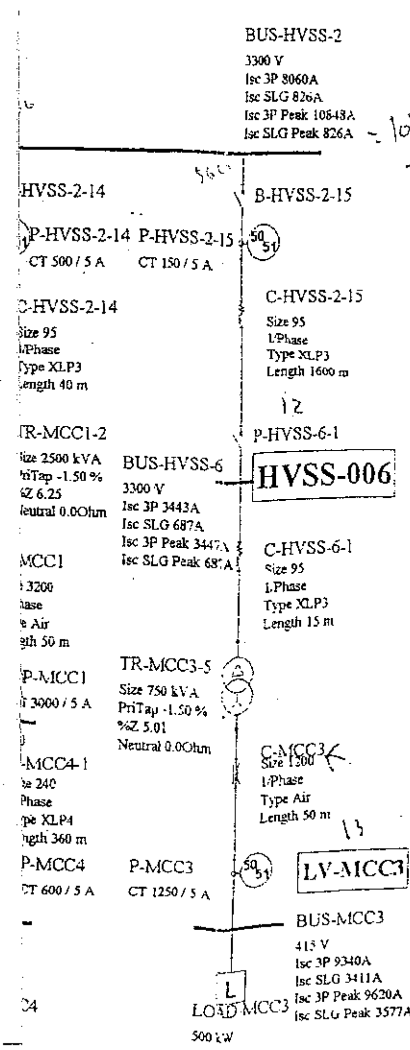
APPENDIX C : The result of Short Circuit Current Study from Kerteh Terminals Sdn Bhd.

MINAL

$Z = \frac{V^2}{S}$

$\frac{11k}{10M}$

$Z_{p.u} = \frac{Z_{actual}}{Z_{base}}$



APPENDIX D : All the load list in kW for Low Voltage and High Voltage line for Kerteh Terminals Sdn Bhd.

	Description	Detail	Remark
A	**Incomer System (CUF)**		
a	Voltage	11000 V	
d	Cable from CUF to HVSS-01	1500m of 6x1Cx240mm2 X/A/P	
d	Protection Relay Setting	(OC) EI, 1.3 PMS 0.1TMS	
		(EF) EI, 0.1 PMS 0.1TMS	
e	Transformer Size (source to HVSS-001)	20000 kVA	
f	Transformer Impedence Z%	11.4 %	
g	Neutral Earthing Resistor (NER)	6.6 Ohm	
h	NER current rating	1000 A	
i	Transformer X/R ratio	25	assumption only. Typical value.
B	**Cable Length**		
a	From HVSS-001 to TR-HVSS-1	50 m	
b	From HVSS-001 to HVSS-007	500 m	
c	From HVSS-001 to HVSS-003	500 m	
d	From HVSS-001 to HVSS-004	155 m	
e	From TR-HVSS-1 to HVSS-002	15 m	
f	From HVSS-002 to TR-MCC1-2	40 m	
g	From HVSS-002 to HVSS-006	1600 m	
h	From HVSS-002 to Motor K401A-M01	90 m	
i	From HVSS-002 to Motor K401B-M01	88 m	
j	From HVSS-002 to Motor K401C-M01	86 m	
k	From HVSS-002 to Motor P401A-M01	90 m	
l	From HVSS-002 to Motor P401B-M01	88 m	
m	From HVSS-002 to Motor P401C-M01	86 m	
n	From HVSS-002 to Motor P401D-M01	84 m	
o	From HVSS-002 to Motor P201A	160 m	
p	From HVSS-002 to Motor P201B	158 m	
q	From HVSS-002 to Motor P201C	156 m	
r	From HVSS-003 to TR-KPSB-4	15 m	
s	From HVSS-006 to TR-MCC3-5	15 m	
t	From HVSS-007 to TR-MCC2-3	15 m	
u	From LV-MCC1 to LV-MCC4	360 m	
v	From Genset DG-001 to HVSS-005	15 m	
w	From HVSS-005 to HVSS-002	15 m	
		30 m	
C	**Transformer Detail**		

	Transformer Impedence Z%	7.15 %	
	Neutral Earthing Resistor (NER)	2.2 ohm	
	Magnetising Inrush current	2481 A	
	Duration of Inrush	0.065 Sec	
b	TR-MCC1-2 (2500kVA) 2.5MVA		
	Transformer Impedence Z%	6.25 %	
	Magnetising Inrush current	4356 A	
	Duration of Inrush	0.106 Sec	
c	TR-MCC3-5 (750kVA)		
	Transformer Impedence Z%	5 %	
	Magnetising Inrush current	1564 A	
	Duration of Inrush	0.176 Sec	
d	TR-MCC2-3 (2000kVA)		
	Transformer Impedence Z%	6.25 %	
	Magnetising Inrush current	1050 A	assumption only. 10 times of FLC
	Duration of Inrush	0.2 Sec	assumption only. Typical value
e	TR-KPSB-4 (1000kVA)		
	Transformer Impedence Z%	5 %	
	Magnetising Inrush current	622 A	
	Duration of Inrush	0.139 Sec	
D	**Motor Detail**		
a	Ammonia BOG Compressor Motor	260 kW	Output power rating
	Motor K401A-M01		
	Motor K401B-M01		
	Motor K401C-M01		
	Starting method (Rotor/Auto Tx/other)	DOL	
	Starting time	2.3 (10 max) Sec	
	Starting current limit (if applicable)	4.5 Sec	Assumption only. Equal to stall time
	Full load current	53 A	
	Lock rotor current	352.2 A	
	Motor efficency	0.953 %	
	Stall time	4.5 Sec	

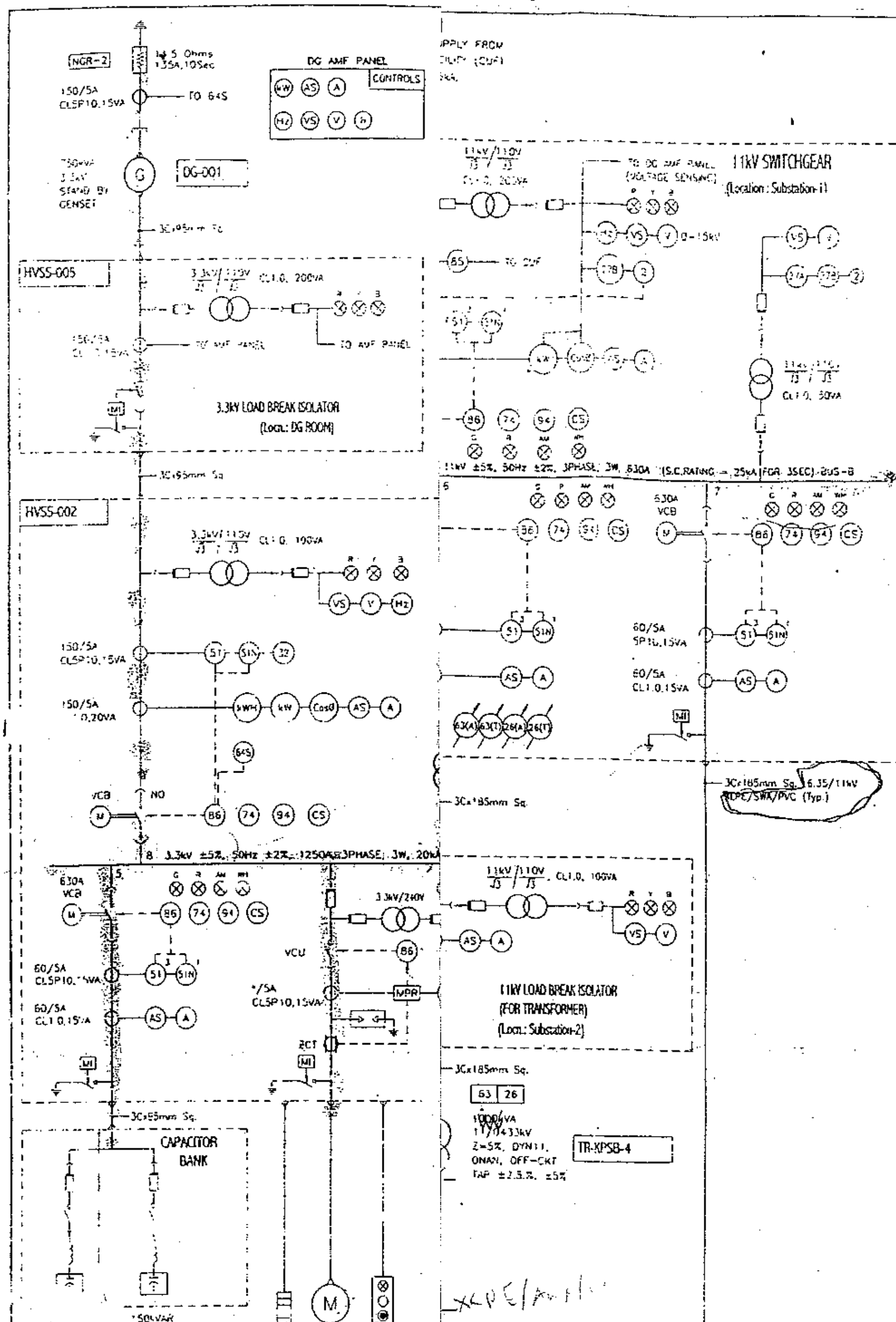
Item	Description	Detail	
		250 kW	Output power rating
b	Ammonia Refrigerated Export Pump		
	Motor P401A-M01		
	Motor P401B-M01		
	Motor P401C-M01		
	Motor P401D-M01	DOL	
	Starting method (Rotor/Auto Tx/other)	2(10 max) Sec	
	Starting time	10 Sec	Assumption only. Equal to stall time
	Starting current limit (if applicable)	51 A	
	Full load current	321.9 A	
	Lock rotor current	0.88 %	
	Motor efficency	10 Sec	
	Stall time		
		220 kW	Output power rating
c	Paralyxene Transfer Pump		
	Motor P201A		
	Motor P201B		
	Motor P201C	DOL	
	Starting method (Rotor/Auto Tx/other)	7 Sec	
	Starting time	5.5 Sec	
	Starting current limit (if applicable)	44 A	
	Full load current	243.9 A	
	Lock rotor current	95.7 %	
	Motor efficency	5.5 Sec	
	Stall time	208.4 A	
	scc		
		500 kW	Output power rating
d	*Fire Water Pump Motor (500kW)*	DOL	
	Starting method (Rotor/Auto Tx/other)	6.5 Sec	
	Starting time	NA Sec	
	Starting current limit (if applicable)	28 A	
	Full load current	182 A	
	Lock rotor current	95 %	
	Motor efficency	5.5 Sec	Assumption only.
	Stall time		
E	**Generator Detail**	33 %	Base on assumption only. Typical for 800kVA rating
	Direct axis synchronous reactance unsaturated, Xd	218 %	Base on assumption only. Typical for 800kVA rating
	Quadrature axis synchronous reactance unsaturated, Xq	2200 ms	Base on assumption only. Typical for 800kVA rating
	Open circuit time constant, T'do	17.6 %	Base on assumption only. Typical for 800kVA rating
	Direct axis transient reactance saturated, X'd		

Item	Description	Detail	Remark
	Direct axis subtransient reactance saturated, X"d	10.4 %	Base on assumption only. Typical for 800kVA rating
	Subtransient time constant, T"d	22 ms	Base on assumption only. Typical for 800kVA rating
	Armature time constant, Ta	22 ms	Base on assumption only. Typical for 800kVA rating
	Neutral earthing resistance	14.5 ohm	
F	**Maximum Load Demand**		
	HVSS-001	5000 kW	Given. Group diversity factor not applied
	HVSS-002	3000 kW	Given. Group diversity factor not applied
	HVSS-003	1000 kW	Given. Group diversity factor not applied
	HVSS-004	500 kW	Given. Group diversity factor not applied
	HVSS-006	500 kW	Given. Group diversity factor not applied
	HVSS-007	2000 kW	Given. Group diversity factor not applied
	LV-MCC1	2000 kW	Given. Group diversity factor not applied
	LV-MCC2	2000 kW	Given. Group diversity factor not applied
	LV-MCC3	500 kW	Given. Group diversity factor not applied
	LV-MCC4	100 kW	Given. Group diversity factor not applied
G	**CT Ratio and Type of OC/EF protection**		
	LV-MCC1	CT 3000/5A, IDMT OC/EF	
	LV-MCC2	CT 4000/5A, IDMT OC/EF	
	LV-MCC3	CT 1250/5A, IDMT OC/EF	
	LV-MCC4	CT 600/5A, IDMT OC/EF	
	LV-KPSB-ADMIN	CT 1500/5A, IDMT OC/EF	Arbitrary CT ratio

Note :

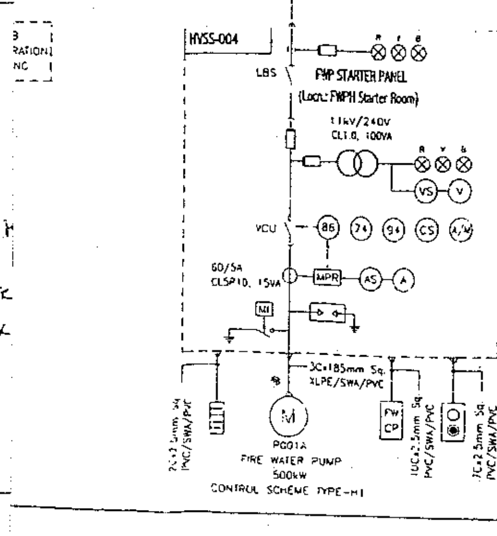
1 Drawing reference : HV Single Line Diagram for Kertih Centralised Tankage Facility Project, Kertih
Drawing no : KCTF-E-0-0001 (Revision 3)

APPENDIX E : The Power Distribution System of the storage facility plant : HV Single Line Diagram of Kerteh Terminals Sdn Bhd.



TAG NO	DESCRIPTION	kW	CABLE SIZE	CT	CO SC
K401A-M01	BOG COMPRESSOR	260	3C×35 mm Sq.	75A	
K401B-M01	BOG COMPRESSOR	260	3C×35 mm Sq.	75A	
K401C-M01	BOG COMPRESSOR	260	3C×35 mm Sq.	75A	
P401A-M01	REFRIGERATED EXPORT PUMP	250	3C×35 mm Sq.	75A	
P401B-M01	REFRIGERATED EXPORT PUMP	250	3C×35 mm Sq.	75A	
P401C-M01	REFRIGERATED EXPORT PUMP	250	3C×35 mm Sq	75A	
P401D-M01	REFRIGERATED EXPORT PUMP	250	3C×35 mm Sq.	75A	
P201A	PARAXYLENE JETTY LOADING PUMP	200	3C×35 mm Sq.	100A	
P201B	PARAXYLENE JETTY LOADING PUMP	200	3C×35 mm Sq.	100A	
P201C	PARAXYLENE JETTY LOADING PUMP	200	3C×35 mm Sq.	100A	

Maximum Load Demand.
HV-SS-001 = 5000
HV-SS-002 = 3000
HV-SS-003 = 1000 k
HV-SS-004 = 500 k



NOTES:

1. MECHANICAL INTERLOCK SHALL BE PROVIDED BETWEEN EARTH SWITCH & ASSOCIATED VCB/VCU/LOAD BREAK SWITCH SUCH THAT EARTH SWITCH CAN NOT BE SWITCHED "ON" UNLESS VCB/VCU/LOAD BREAK SWITCH IS "OFF"
2. AUTO/MANUAL CHANGEOVER SYSTEM SHALL BE PROVIDED FOR INCOMERS OF THE 11kV SWITCHGEAR

LEGEND

SYMBOL	DESCRIPTION
MI	MECHANICAL INTERLOCK
	VOLTAGE TRANSFORMER.
	POWER/CONTROL FUSE.
	WITHDRAWABLE UNIT
	INDICATING LAMP G-GREEN BKR/CONTACTOR OPEN, R-RED-BKR/CONTACTOR CLOSE, WH-WHITE-TRIP CAT HEALTH
R Y B	SUPPLY INDICATING LAMPS
	CURRENT TRANSFORMER
VCB	VACUUM CIRCUIT BREAKER
VCU	FUSED VACUUM CONTACTOR UNIT
ZCT	ZERO SEQUENCE CURRENT TRANSFORMER
	TWO WINDING TRANSFORMER WITH DELTA PRIMARY & STAR SECONDARY
	TRANSFORMER/GENERATOR NEUTRAL GROUNDING RESISTOR
ATS	AUTO/MANUAL CHANGEOVER SCHEME
NO	NORMALLY OPEN
	LOAD BREAKER SWITCH (LBS).
	EARTHING SWITCH.
	DOL STARTER
ATR	AUTO-TRANSFORMER STARTER
	HV CAPACITOR.
AS	AMMETER SELECTOR SWITCH
VS	VOLTMETER SELECTOR SWITCH.
CS	T/N/C BREAKER CONTROL SWITCH
50	INSTANTANEOUS OVER CURRENT RELAY (3Nos.)
50N	INSTANTANEOUS EARTH FAULT RELAY (1No.).
51	IDMT O/C RELAY (3Nos.)
51N	IDMT E/F RELAY (1No.)
86	LOCKOUT RELAY (MVAJ13 OR EQUIV.).
74	TRIP CIRCUIT SUPERVISION RELAY (MVAX21 OR EQUIV.)
94	ANTIPUMPING RELAY.
87T	TRANSFORMER DIFFERENTIAL (MBCH12 OR EQUIV.)
85	PILOT WIRE DIFFERENTIAL RELAY
32	REVERSE POWER RELAY.
	AUXILIARY RELAY WITH FLAG INDICATOR FOR : a) 63(A) - GAS PRESSURE (ALARM STAGE). b) 63(T) ½ GAS PRESSURE (TRIP STAGE). c) 26(A) - OIL TEMPERATURE (ALARM STAGE) d) 26(T) - OIL TEMPERATURE (TRIP STAGE)
MPR	MOTOR PROTECTION RELAY (P & B MICRO GOLD OR EQUIV.)
64R 64S	RESTRICTED E/F RELAY & STAND BY E/F RELAY
27A 27B	UNDER VOLTAGE RELAY
2	TIMER.
63	OIL PRESSURE (TWO STAGE) RELAY ON TRANSFORMER
26	OIL TEMPERATURE (TWO STAGE) RELAY ON TRANSFORMER
	MOTOR SPACE HEATER.
	LOCAL CONTROL STATION WITH START & STOP PUSH BUTTONS.
	LOCAL CONTROL STATION WITH RED INDICATING LAMP START & STOP PUSH BUTTONS.
	BUSDUCT.
	LV CAPACITOR.

REV.	DESCRIPTION	BY	CHK'D	APPR.	DATE
1	AS BUILT	YJ	TKM	LTM	19.12
0	APPROVED FOR CONSTRUCTION	SCA	TGF	TSL	11.07
D	REVISED TR-MCCZ-3 DATA	KSH	TGF	TSL	JUN'0
C	REVISED AS SHOWN	SCA	TGF	TSL	06.03
B	REISSUED FOR COMMENTS	KSH	TGF	TSL	03.03
A	ISSUED FOR COMMENTS	KSH	TGF	TSL	31.01

PROJECT TITLE

KERTIH CENTRALISED TANKAGE FACILITY PROJECT
KERTIH TERENGGANU, MALAYSIA

OWNER:

KERTIH TERMINALS SDN. BHD.

EPCC CONTRACTOR :

DIALOG E & C SDN. BHD.

DRAWING TITLE :

HV SINGLE LINE DIAGRAM

SCALE	N.T.S	CHECKED	TGF
DRAWN	KSH	APPROVED	TSL
DATE	05.09.99	FILENAME	KCTF2-E-0-0001-1
DWG. NO	KCTF2-E-0-0001	REVISION	1

APPENDIX F : Technical Cable Data Sheet

Table 3 CURRENT RATINGS FOR

1.9 / 3.3 (3.6) kV ARMOURED XLPE CABLE

Conductor Size (mm²)	In Air			In Ground		
	Single Core[a]			Single Core[a]		
	Trefoil (A)	Flat (A)	3 Core (A)	Trefoil (A)	Flat (A)	3 Core (A)
Copper Conductor						
16	-	-	108	-	-	114
25	-	-	143	-	-	147
35	-	-	170	-	-	175
50	230	287	204	222	230	207
70	288	357	257	271	279	254
95	353	434	315	324	331	305
120	411	492	365	366	369	345
150	468	553	415	409	409	387
185	534	622	476	460	454	436
240	630	715	560	528	512	502
300	717	793	640	589	560	563
400	817	851	734	651	595	633
500	924	929	-	720	641	-
630	1041	1007	-	789	684	-
800	1131	1054	-	831	703	-
1000	1227	1121	-	880	735	-
Aluminium Conductor						
16	-	-	82	-	-	87
25	-	-	108	-	-	113
35	-	-	128	-	-	134
50	173	217	155	170	176	158
70	216	270	194	208	215	194
95	264	328	237	248	256	233
120	308	377	276	282	288	265
150	350	424	313	315	320	297
185	402	483	360	355	359	336
240	475	561	425	410	409	389
300	544	631	489	460	453	439

[a] Single core cables with aluminium wire armour

Table 4 CURRENT RATINGS FOR 3.8 / 6.6 (7.2) kV TO 8.7 / 15 (17.5) kV ARMOURED XLPE CABLE

Conductor Size	In Air			In Ground		
	Single Core[a]			Single Core[a]		
	Trefoil	Flat	3 Core	Trefoil	Flat	3 Core
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)
Copper Conductor						
25_b	-	-	145	-	-	140
35_b	-	-	175	-	-	170
50_b	235	295	220	220	230	210
70	285	370	270	270	280	255
95	360	455	330	320	335	300
120	415	520	375	360	380	340
150	470	600	430	410	430	380
185	540	690	490	460	485	430
240	640	820	570	530	560	490
300	740	940	650	600	640	540
400	840	1100	740	680	730	600
500	990	1280	-	750	830	-
630	1110	1500	-	830	940	-
800	1270	1720	-	920	1070	-
Aluminium Conductor						
25_b	-	-	115	-	-	115
35_b	-	-	140	-	-	135
50_b	180	230	170	170	175	160
70	225	290	210	210	215	195
95	280	350	250	250	260	230
120	320	410	295	280	295	265
150	365	465	330	320	330	300
185	425	530	385	360	375	335
240	500	640	450	415	440	380
300	580	730	510	475	495	-
400	670	860	590	540	570	435
500	790	1010	-	610	650	490
630	910	1190	-	680	750	-
800	1060	1330	-	770	860	-

[a] Copper wire screened, unarmoured

$_b$ Not applicable to all voltages. See dimension tables for availability

Table 5 **CURRENT RATINGS FOR 12.7 / 22 (24) kV TO 19 / 33 (36) kV ARMOURED XLPE CABLE**

Conductor Size	In Air			In Ground		
	Single Core[a]			Single Core[a]		
(mm²)	Trefoil (A)	Flat (A)	3 Core (A)	Trefoil (A)	Flat (A)	3 Core (A)
Copper Conductor						
35	-	-	180	-	-	170
50	245	295	225	220	230	210
70	300	365	275	270	280	255
95	360	450	330	320	335	295
120	425	520	380	360	380	335
150	485	590	430	410	430	375
185	550	670	490	460	485	420
240	650	800	570	530	560	480
300	740	920	650	600	640	530
[illegible]	[illegible]	1070	740	690	730	590
500	980	1250	-	760	830	-
630	1130	1450	-	850	950	-
800	1280	1710	-	930	1070	-
Aluminium Conductor						
35	-	-	145	-	-	135
50	190	230	175	170	175	160
70	235	285	215	210	215	195
95	280	345	260	250	260	230
120	330	400	[illegible]	[illegible]	[illegible]	[illegible]
150	375	455	335	320	330	290
[illegible]	420	520	390	360	375	330
240	510	620	460	415	440	380
300	580	710	520	475	495	425
400	680	840	600	550	570	[illegible]
500	790	980	-	610	650	-
[illegible]	920	1060	-	690	750	-
[illegible]	[illegible]	1370	-	770	860	-

[a] Copper wire screened, unarmoured