Faculty of Electrical Engineering

DESIGN OF ELECTRICAL DISTRIBUTION SYSTEM FOR INDUSTRIAL PLANT

Wong Tee Foo

Master of Electrical Engineering

(Industrial Power)

2017

DESIGN OF ELECTRICAL DISTRIBUTION SYSTEM FOR INDUSTRIAL PLANT

WONG TEE FOO

A dissertation submitted
In partially fulfilment of the requirements for the degree of Master of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this dissertation, entitled "Design of Electrical Distribution System for Industrial Plant" is the result of my own research, except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : .....

Name : ….....

Date : .....

APPROVAL

I hereby declare that I have read this dissertation, and in my opinion, this dissertation is sufficient in terms of scope and quality for the award of Master of Electrical Engineering (Industrial Power).

Signature : .....

Supervisor Name : ….....

Date : .....

DEDICATION

I would like to express my gratitude to my family members, especially my parents who have been supporting me throughout the Master program. Lots of appreciation and thank to my wife, Sylvia Gan Li Ming, for taking good care of the kids, during preparation of this dissertation. Their support, encouragement and assistance in completing this dissertation will be unforgettable to me.

ABSTRACT

Electrical distribution system plays an important role in our daily living, as electrical energy is necessary to run our home and industrial appliances. Consumers demand the delivery of electrical energy to be continuous and seldom to be interrupted, but there is occurrence of breakdown sometimes during the day or night time. Electrical energy is generated by power station, converted from thermal energy into mechanical energy by turbine, and then transformed into electrical energy by generator. The generated electrical energy is transmitted to the load centers via high voltage transmission networks. From the load center (power distribution substation), electrical power supply will be distributed via power transformer to distribution substation and stepped down to lower voltage level for electrical distribution system networks. This research was conducted to evaluate design of electrical distribution system, from 11kV to 400V electrical distribution system up to the final circuits for an upgrading power supply from an existing warehouse building into a manufacturing factory. In this study, aspects determined by follow design procedure for the selection of medium voltage switch gear, type of distribution transformer, low voltage switch board, low voltage components, electrical cable, conductor of its current carrying capacity capability and earth fault protection. The subsequent technical analysis in this dissertation discusses about power factor improvement and relay protection unit that plays an important role in low voltage electrical distribution system. The key finding that the proposed electrical distribution system able to provide adequate, safety, compliances voltage regulation and reliable system and keep it the minimum of interruption electricity power supply.

ABSTRAK

Sistem pengedaran elektrik memainkan peranan penting dalam kehidupan harian kita, disebabkan tenaga elektrik diperlukan untuk mengendalikan peralatan di rumah mahupun untuk industri. Pengguna sememangnya menginginkan penghantaran tenaga elektrik sentiasa berterusan dan jarang akan terganggu namum kadang kala terdapat kejadian pecahan kadang kala pada waktu siang atau malam. Tenaga elektrik dijana oleh stesen janakuasa, ditukar daripada tenaga haba kepada tenaga mekanikal oleh turbin, dan kemudian ditukar menjadi tenaga elektrik oleh penjana. Tenaga elektrik yang dihasilkan dihantar ke pusat beban melalui rangkaian penghantaran voltan tinggi. Dari pusat beban (pencawang kuasa pengagihan), bekalan kuasa elektrik akan diedarkan melalui pengubah kuasa ke pencawang pengedaran dan melangkah ke tahap voltan yang lebih rendah untuk rangkaian sistem pengedaran elektrik. Kajian ini bertujuan untuk menilai reka bentuk sistem pengedaran elektrik dari 11kV hingga 400V sistem pengagihan elektrik sehingga litar akhir untuk naik taraf sistem bekalan elektrik dari bangunan gudang sedia ada ke kilang pembuatan. Dalam kajian ini, aspek yang ditentukan mengikut prosedur reka bentuk untuk pemilihan gear suis voltan sederhana, jenis pengubah pengedaran, papan suis voltan rendah, komponen voltan rendah, kabel elektrik, konduktor keupayaan kapasiti semasa dan perlindungan kerosakan bumi. Analisis teknikal di dalam disertasi kajian ini akan membincangkan tentang peningkatan faktor kuasa dan perlindungan relay unit yang memainkan peranan penting dalam sistem pengagihan elektrik voltan rendah. Penemuan utama bahawa sistem pengedaran elektrik yang dicadangkan dapat menyediakan regulasi voltan yang memadai, keselamatan, pematuhan dan sistem yang boleh dipercayai dan menjadikannya minimum gangguan bekalan tenaga elektrik.

ACKNOWLEDGEMENTS

I would like to express my gratitude and appreciation to my supervisor, Associates Professor Dr. Gan Chin Kim for his guidance, support and advice during the whole master program and completing this dissertation.

I would also like to thank my classmates, Mr. Hamza Zohdi Abunima, for his guidance, advices, helpful recommendations, opinions and ideas which have been handy guide in composing this dissertation. I would also like to thank other fellow classmates, Mr. Noorsharin Mohamed Nawawi, Mr. Ahmed and Mr. Bashar who have helped each other during the coursework classes.

I also appreciate my family members who have supported throughout this Master's program.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	Alternative Current
Amp	Ampere
BS	British Standard
BSI	British Institution Standard
CT	Current Transformer
DC	Direct Current
EN	European Standard
ESAH	Electricity Supply Application Hand Book
IAC	internal arc classification
IEC	International Electrotechnical Commission
IEE	Institute of Electrical Engineers
IEEE	Institute of Electrical and Electronic Engineers
IP	international protection
kV	Kilo Volt
kW	Kilo Watt
MS	Malaysia Standard
M.D	Maximum Demand
HV	High voltage
HVDC	High Voltage Direct Current
HT	High Tension
LV	Low Voltage

PF	Power Factor
PVC	Polyvinyl Chloride
PILC	Paper-insulated lead sheath
SCADA	Supervisory Control and Data Acquisition
TNB	Tenaga Nasional Berhad
THD	Total Harmonic Distortion
uF	Micro Farad
UTeM	University Teknikal Malaysia Melaka
XLPE	cross-linked polyethylene
TPN	Three Phase Neutral

CHAPTER 1

INTRODUCTION

1.1 Background

Electrical power system is comprised of generation system, transmission system and distribution system. The main objective of this dissertation is to propose electrical distribution system, by which is a requirement for additional electrical power system for an upgrade of an existing warehouse building into a larger manufacturing processing factory. Collecting of data includes machines loading to determine the additional electrical loading, and allocation for estimated future electrical loading. The initial received medium voltage from local power utility company, Tenaga Nasional Berhad (TNB) is 11kV, which is then stepped down to the 3-phases voltage supply in neutral condition at 400V level. (MS IEC 60038) Therefore, there are numerous requirements for electrical appliances which need to be considered and studied for long term serving, safety and smooth delivery of electrical power system to the factory. There are many aspects and factors to be measured to overcome the unforeseen breakdown incidents, such as fault currents, overload, short circuits, overheating, thermal problem and et cetera. Some other problems may also arise due to the quality of electrical products or inappropriate selection of breaking capability of circuit breaker to terminate the fault current, which causes failure of switch gear from overheating. This dissertation presents evaluation and analysis on medium and low voltage components switch gear, various types of circuit breakers and functionality, electrical cable and conductor current carrying capacity according to the 16th IEE wiring regulation. In this study, required information had been systematically collected by selection of appropriate size and type of switch gear and electrical cables for the proposed electrical distribution

system to upgrade the factory. The best and most appropriate setup of low voltage distribution system network will ensure smooth and secure delivery of electrical energy.

1.2 Problem Statement

Electrical distribution network normally consists of radial, ring and network systems. For the design of electrical distribution system may determine the load characteristic, load centers, maximum demand of load center and any standby system requirements. In the electrical distribution system, selecting suitable size or capacity of any equipment's like circuit breakers, conductor, and protection devices. Besides that, there are numerous of established codes such as IEE wiring regulation or IEC standards should be referred to ensure the safety requirements of the electrical distribution system.

Calculation and selection method is crucial and prudent for designers to determine the most appropriate electrical distribution system for commercial, residential, and industrial applications.

1.3 Research Objective

The research objective is ensuring safe and secure step-down transmission of the incoming power supply of 11kv medium voltage to low voltage of 400V three phase neutral (TPN). All specification and procedures have been in accordance to the regulations by the local utility power company, Tenaga Nasional Berhad (TNB), within permitted period for the new substation building design. For this upgrade, actual design of electrical distribution system scope for an industrial building needs to be adapted. The high voltage, medium voltage and low voltage distribution system installation must comply with all the relevant Malaysia Standard (MS), British Standard (BS), IEE wiring regulation and IEC standard.

1.4 Scope

The scope of this dissertation revolves around the upgrade of an existing warehouse to a manufacturing process factory, by additional electricity power supply for additional machines, equipment, and others. This study is initiated with the project survey, by preparing the technical report. The following process is data collection regarding additional electrical power loading, and space requirement and availability for Tenaga Nasional Berhad to house the electrical equipment for the proposed factory. The design also considers future upgrading and maintenance purpose. Below are the design procedures and method referring to 16th IEE wiring regulation and MS IEC 60364 standards to achieve the project objective like data collection for additional loads (machinery, lightings, blowers, and HVAC systems).

- Design procedure, estimation of design current and cable sizing based on load distribution and consumptions
- Design of cable routing and method of installations
- Design of power factor correction methods
- Design of power system protection and monitoring, such as instruments of overcurrent and earth fault relay and power meters

The next important step is to consider selection of medium voltage switch gear, distribution transformer, type of low voltage switch board, low voltage switch gears components, electrical cables, and others. Technical analysis considers the power factor control and protection unit relay for the low voltage distribution system. For this step, the information regarding materials and components can be obtained directly from the manufacturer's data sheets. The low voltage distribution system functions to step down the medium voltage to low voltage, to be suitable for components and machines load, thus every part of the system is essential for their roles. The scope of this dissertation also caters how

the low voltage distribution system is built up, suitable selection of the value of components, protection & prevention from over load, fault current, short circuit and thermal rise which might occur in the circuits.

1.5 Dissertation Content

The dissertation is divided into five chapters as follows:

1. Chapter 1 presents the general concept of the electrical low voltage distribution system, which comprises of the ideals, problem statement and main objective of this dissertation.
2. Chapter 2 reviews related study papers, journals and researches on electrical distribution system, which contain important aspects for consideration in this research.
3. Chapter 3 discusses about the fundamental design of the proposed low voltage system, which includes estimation of electricity load and conductor current carrying capacity, as well as selection of appropriate substation building, distribution transformer, HV switch gear, and LV switch gear.
4. Chapter 4 presents the technical analysis results of the proposed low voltage distribution system, improvement of power factor and protection relay unit.
5. Chapter 5 presents the conclusion on the whole dissertation, inclusive of opinions, finding and results.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Electrical power distribution system in industrial plant is a common and popular issued raised due to increasing power demand and uncertain rise of market demand, as consequence of increasing production output by the additional of machines to meet growing interest. This chapter presents investigation on electrical distribution system in accordance to International Electrotechnical Commission (IEC), Institute of Electrical and Electronic Engineers (IEEE) standards and 16th edition IEE wiring regulation. This chapter provides relevant IEC standards and information on low voltage distribution system design, including literature review on switch gear components, low voltage components and electrical cables, to ease understanding on the onward research chapters.

2.2 Relevant Industrial Technical Standard

In the industry, there are some relevant industrial technical standards such as IEC, IEEE standards, IEE wiring regulation 16th edition, British Institution Standard (BSI) and European Standard (EN), which are used reference. Most of the IEC & IEEE standards are indeed the base reference standards for our local Malaysia Standard (MS), while some refer to BS and EN standards. The IEC standards are adapted for medium and low voltage system components, such as 11kV switch gears, distribution transformer, 400V switch boards, low voltage switch gears and electrical cables.

2.3 Medium Voltage 11kV switch gears IEC standards

The medium voltage 11kV switch gears which comply with IEC standard rules are as in Table 2.1 (ABB Unigear, 2016).

Table 2.1 Medium and High Voltage switchgear IEC Standard

IEC Standard No.	**Scope of IEC Standard**
IEC 62271-1	Being general purposes.
IEC 62271-200	Being the switch gear components
IEC 62271-102	Being the earth switch.
IEC 62271-100	Being the circuit breakers
IEC 60071-2	Being the insulation coordination.
IEC 62271-106	Being the contactors.
IEC 60265-1	Being the switch-disconnectors.
IEC 60529	Being the degree of protections.

The above IEC standards are also adopted for medium or high voltage range switch gears characteristic performance, at the same time referred to the global medium or high voltage switch gears manufacturers such as ABB, L&T and Tamco. The IEC standards listed above are to ensure that all medium or high voltage switch gears equipment are designed and tested according to the specific standards. The IEC 62271 series was firstly published in 2001 and incorporated materials from others now supersede the IEC standard several decades older. The scopes of the IEC 62271 series are covered by the standards listed as above (Marcelos Valdes, 2012). IEC 62271-102 is the standard for earthing devices, covering most range of applications inclusive of high voltage distribution application. Under this IEC standard, earthing devices are rated to perform for >2000 operations and the withstand ratings should have the same rating with the circuit breaker capabilities. The

earthing switch is combined together with the circuit breaker, but while it is interlocked in between the grounding switch and never closed, the corresponding circuit breaker is in closed position. Normally, the grounding switch should be able to interact and coordinate together with the system source to ensure live busbar not to be grounded (Marcelo Valdes, 2012).

The IEC 62271-200 is intended for HV switch gear metal-enclosure and control gear up to 52kV range, being the scope of specific type test of internal arcing condition due to internal fault. The fault current occurrence in the switch board by the arcing fault may produce pressure wave, which often causes explosion in the HV switchgear & control gear and LV assemblies. Under this IEC standard, there is management of risks inclusive of risk reduction, priority, inherent safe design, good protective design, and sufficient safety information. To reduce the internal arcing fault risk, some mitigations researches have been carried out to prevent the pressure wave occurrence during the arcing fault by means of fast-acting mechanism protection device (Hazel, 2011). Pressure relief mechanism is one of the pressure relief control method able to prevent catastrophic failure. Additional insulation and segregation to the insulated copper busbar are done by using barrier between the panels in busbar chambers. These will not eliminate the arcing fault current risk but will reduce further damage to the switch gears. Light detection by sensitive light sensor can be installed in HV switchgear to sense the light produced by the internal arc and for monitoring, and upon detection, the incoming circuit breaker is immediately tripped, which then initiates the upstream circuit breaker inter-trip. Eventually, the pressure wave may still occur but the heat generated may not damage further. There is another method to determine occurrence of arcing within the enclosure, which is by using limit switches on the pressure relief flaps. This mechanism will act once pressure increases in the compartment, which causes the device to actuate when flaps open, and then sends the tripping signal to the circuit breaker

to isolate the switchboard completely. If by means any of the above detection mechanism is not used, normally protection relay will be used to delay the tripping of the incoming circuit breakers to ensure selective tripping. The delay may further the thermal damage onto the switch gear, and even lead the duration exceeding the manufacturer's recommended value prescribed (Hazel, 2011). To eliminate the pressure wave, shunting of the arc must occur within a few ms to prevent the heating of the air within the metal enclosure. Fast response switches and light sensors are used to determine if the fault current is within a compartment, which will trigger the shorting switch. The arc duration stated in the IAC classification is only a few milliseconds because the arc is shunted after that time. The designation of internal arc classification (IAC) is intended for protection of personnel under normal operating condition in term of accessibility by A, B or C. A refers to authorized personnel only, B is to the public, and C to pole-mounted equipment (Hazel, 2011).

IEC-60529 standard caters the degree of protection provided by enclosures (IP code). Most of the medium and high voltage switch gears, either indoor or outdoor type, are to be protected by the enclosure and classification in international protection (IP) rating as specified in this IEC standard (Don Gies, 2006).

Table 2.2 Arrangement of the IP codes (IEC 60529)

IP	2	3	C	H
Code letters (International Protection)	First characteristic numeral 0 to 6 or letter X	Second characteristic numeral 0 to 8 or letter X	Additional letter (optional) (Letter A,B,C,D)	Supplementary letter(Optional) (Letter H,M,S,W)