MODELLING AND ASSESSMENT OF ENERGY LOSSES FOR MEDIUM VOLTAGE DISTRIBUTION NETWORK AT UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DECLARATION

I declare that this thesis entitled "MODELLING AND ASSESSMENT OF ENERGY LOSSES FOR MEDIUM VOLTAGE DISTRIBUTION NETWORK AT UNIVERSITI TEKNIKAL MALAYSIA MELAKA is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : --

Name : --

Date : --

APPROVAL

I hereby declare that I have checked this report entitled "MODELLING AND ASSESSMENT OF ENERGY LOSSES FOR MEDIUM VOLTAGE DISTRIBUTION NETWORK AT UNIVERSITI TEKNIKAL MALAYSIA MELAKA" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

For energy planning and analytical purposes, information about losses and useful energy give a broader perspective on energy consumption and its harmful consequences for supplied energy consumption. When energy is consumed for end-use, some of the potential energy content is lost due to technical loss or non-technical loss. Technical losses (TL) in distribution network is causing substantial economic and financial losses annually to Universiti Teknikal Malaysia, Melaka. In this report, medium voltage actual feeders were developed using Digsilent Powerfactory Software and applied to energy flow model of Medium Voltage (MV) network to develop load flow graph to estimate energy inflow from 33/11 kV to 11/0.4 kV MV feeders and distribute to the load. The same MV actual feeders network also were applied to Quasi Dynamic Simulation of MV network to estimate its TL. Actual MV feeders were developed based on statistical analysis of MV feeders from Pejabat Pembangunan to categorize MV feeders according to their characteristics. The TL estimation approach and energy flow model is applicable to MV distribution network with energy meters at distribution interface substation, which register daily inflow energy and peak demand to the distribution networks. Feeder 7 has the highest energy consumption and energy losses because it has the most amount of load than other feeder. Feeder 7 estimated has 21,141.75 kWh energy consumption and 601.4636 kWh energy losses. Feeder 7 estimated cost for energy losses is RM222.54 per day. Feeder 4 and 5 has no load so its has no energy consumption but it has energy loss because of the leakage of electric flow. The TL estimation based on load flow over time can be developed into useful tool to evaluate TL of MV distribution network model in UTeM.

ABSTRAK

Untuk perancangan tenaga dan tujuan analisis, maklumat mengenai kerugian dan tenaga berguna memberikan perspektif yang lebih luas mengenai penggunaan tenaga dan akibat berbahaya untuk penggunaan tenaga yang dibekalkan. Apabila tenaga digunakan untuk kegunaan akhir, beberapa kandungan tenaga berpotensi hilang disebabkan kehilangan teknikal atau kehilangan bukan teknikal. Kerugian teknikal (TL) dalam rangkaian pengedaran menyebabkan kerugian ekonomi dan kewangan yang besar setiap tahun kepada Universiti Teknikal Malaysia, Melaka. Dalam laporan ini, feeder sebenar voltan sederhana dibangunkan menggunakan Perisian Digsilent Powerfactory dan digunakan untuk model aliran tenaga rangkaian Voltan Sederhana (MV) untuk membangunkan graf aliran beban untuk menganggarkan aliran masuk tenaga dari 33/11 kV ke 11 / 0.4 kV MV dan mengedarkan kepada beban. Rangkaian suapan sebenar MV yang sama juga digunakan untuk rangkaian Simulasi Dinamik Quasi untuk menganggarkan TLnya. Feeder MV sebenar telah dibangunkan berdasarkan analisis statistik feeder MV dari Pejabat Pembangunan untuk mengkategorikan feeder MV mengikut ciri-ciri mereka. Pendekatan anggaran TL dan model aliran tenaga boleh digunakan untuk rangkaian pengedaran MV dengan meter tenaga pada pencawang antara pengedaran, yang mendaftarkan tenaga aliran masuk harian dan permintaan puncak ke rangkaian pengedaran. Feeder 7 mempunyai penggunaan tenaga yang paling tinggi dan kehilangan tenaga kerana ia mempunyai jumlah beban yang paling banyak daripada feeder lain. Anggaran pengumpan 7 mempunyai 21,141.75 penggunaan tenaga kWh dan kehilangan tenaga 601.4636 kWh. Kos penganggar tenaga makanan 7 untuk kerugian tenaga ialah RM222.54 sehari. Feeder 4 dan 5 tidak mempunyai beban sehingga tidak mempunyai penggunaan tenaga tetapi ia mempunyai kehilangan tenaga kerana kebocoran aliran elektrik. Perkiraan TL berdasarkan aliran beban dari masa ke masa dapat dikembangkan menjadi alat yang berguna untuk menilai TL dari model jaringan distribusi MV di UTeM.

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MV	-	Medium Voltage
TL	-	Technical Losses
LV	-	Low Voltage

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CHAPTER 1

INTRODUCTION

1.1 Background

Electricity losses occur at the power distribution process. Distribution reflects the overall operation to distribute electricity from power plants to consumer where it is utilized by homes, businesses and institutions. For more productive transportation of electricity, transformers are used to increase the voltage and decrease the voltage back to the suitable level for residential, commercial and industrial use. Power losses occur in both transmission and distribution lines and in transformers. It began from the step-up transformers that attach power plants to the transmission system and ending with the consumer wiring. [1]

Distribution losses refer to the dissimilarity between the amount of energy distributed to the distribution system and the amount of energy customer is charged. Distribution line losses consist of two types, which are technical losses and non-technical losses. Technical losses occur during transmission and distribution and involve substation, transformer and line related losses. Technical losses are due to a current flowing in the electrical network and generate the following types of losses:

i) Losses due to overloading and low voltage.

ii) Losses due to the poor standard of equipment.

iii) Unbalanced loading.

Load flow studies are important for 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. [3] [4]

1.2 Motivation

The purpose of power flow studies is to plan and account for various hypothetical situations. For example, if a transmission line is taken off line for maintenance, can the remaining lines in the system handle the required loads without exceeding their rated values. One of the ways to study power flow analysis in the distribution system was by calculate the electricity losses occur at the power distribution process.

In nature, during the process of transmitting and distributing electricity, the electricity loss was referred to as line losses. To reduce energy loss, electricity generated in power stations is raised to a very high voltage for transmission. A high transmission voltage means only a relatively small current flow through the transmission cables. The current produces a heating effect when flowing through the cables with resistance. Electricity has to be transmitted from large power plants to the consumers via extensive networks. The transmission over long distances creates power losses.

1.3 Problem Statement

Electricity loss during the transmitting and distributing electricity along the cable is one of the problems in the industry. This is because, the process to distribute electricity have a long distribution line, low power factor, overloading of lines and load imbalance among the phases. Load flow studies determine if system voltages remain within specified limits under normal or emergency operating conditions and whether equipment such as transformers and conductors are overloaded. Load flow studies are commonly used to optimize component or circuit loading. No research has been done in UTeM to analyze load flow analysis in UTeM.

The ability to understanding the technical losses and reduce its lead to having a stable and comfortable electricity at lower cost. Fighting non-technical losses leads to increase the income to the electrical company and make the company have an ability to make an improvement to the grid.

1.4 Project Objective

The main aim of this project is to propose a systematic and efficient methodology to estimate power losses in Medium Voltage (MV) distribution network with reasonable accuracy. The objectives are as follows:

i) To study the 33kV and 11kV network and load in UTeM.

ii) To model and perform load flow simulation 33kv and 11kv network model in UTeM using Digsilent Powerfactory software.

iii) To analyze energy losses of each medium voltage feeder and transformers in UTeM.

1.5 Project Scope

The project scopes included:

i) Design medium voltage model network in UTeM using Digsilent Powerfactory Software.

ii) Calculate energy losses in the cable for 33kV and 11 kV feeder and transformer from the main distribution substation in UTeM.

iii) Illustrate load flow simulation using Digsilent Powerfactory Software.

iv) Develop a systematic approach to estimating power losses for a medium voltage distribution network.

v) Analyze load flow profile in UTeM by electricity over time.

1.6 Project Report Summary

This report is arranged into five chapters and this section delivers a brief overview of the chapters.

Chapter 1: Introduction

This section will explain the main objectives of this report. It also consists of the introduction of load flow analysis and energy losses with project scopes.

Chapter2: Literature Review

This section provides the simple concept and explanation based on the previous work of related literature studies. Two categories of losses in power system which is technical and non-technical losses also been reviewed in this section

Chapter 3: Methodology

This section, the project flow and methodology to accomplish this project is stated. The load flow profile will be discuss in this section.

Chapter 4: Result and Discussion

This section shows the single line diagram of the medium voltage distribution network model in UTeM by using Digsilent Powerfactory Software. The technical losses were studied using load flow profile produced by the software by inserting the data that has been collected from Pejabat Pembangunan UTeM.

Chapter 5: Conclusion and Future Works

This section concluded the whole methodologies that have been used in this project. The suggestion of works that need to add on in this project is included in this section.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, energy efficiency was identify as key strategies to address rising issues in rising fuel cost, market competition, tightening regulation, climate changed and energy crisis due to decreasing fossil fuels resources. Energy losses occur in the process of supplying electricity to consumers due to technical losses. The technical losses are due to energy dissipated in the conductors and equipment used for transmission, transformation, sub-transmission and distribution of power. These technical losses are essential in a system and could be reduce to an optimum level. Over extensive geographical areas, power distribution networks in each supply stretched and have large variety of characteristics. The losses in MV was group in Sub transmission losses, which are involving 33kV and 11kV. To analyze the power and energy flow its related technical losses for every distribution circuit normally need immense data input and precise computation effort. It is essential to develop an effective power losses estimation methodology, which is practically suitable for utilities.

2.2 Medium Voltage Network Model

Distribution substations connect to the transmission system and lower the transmission voltage to medium voltage ranging between 2 kV and 35 kV with the use of transformers. Primary distribution lines carry this medium voltage power to distribution transformers located near the customer's premises. Distribution transformers again lower the voltage to the utilization voltage used by lighting, industrial equipment or household appliances [5]. Voltages from 600 V to 69 kV are referred to as “medium voltage,”. Medium voltage fuses are those intended for voltage range from 2400 to 38000 VAC [6]. Medium voltage distribution implies a medium voltage or higher service voltage and will result in higher costs of equipment, installation, and maintenance than low voltage distribution. However, this must be consider along with the fact that medium voltage distribution will generally result in smaller conductor sizes and will take control of voltage drop easier [7].

When designing a Medium Voltage (MV) distribution system, special attention must be gave to equipment dimensions, ratings, and their tolerances. The equipment dimensions are greater for MV systems as compared with Low Voltage (LV) systems. Therefore, space dedicated to equipment becomes very important and should be allocate early in the design process.

MV equipment does not have the same flexibility as LV equipment. For LV systems, there are circuit breakers of all sizes, and larger breakers are equipped with easily adjustable trip units. For simple MV systems, fused switches can be using for protection, and these fuses come in many sizes as well. However, in complex MV distribution systems, such as in mission-critical facilities, using MV breakers becomes a necessity. The smallest circuit breaker for a nominal 13.8 kV system (15-kV switchgear) was rate at 1200 amps. The next size up is 2000 ampere, then 3000 amperes. The great advantage of MV systems is that the current is low, but there is currently no breaker small enough for these systems. [8]

2.3 Losses in Electrical Distribution System

Total power losses of distribution network was define as a difference between registered income energy from the transmission system and the sum of registered and supplied (output) energies to end-users. There are two categories of losses in the power system, which is technical and non-technical losses. It is very important to get the actual values of both losses forms to improve many activities in distribution network [6].

Energy losses occur in the process of supplying electricity to consumers due to technical and non-technical losses. Technical losses known as power dissipation in transmission lines due to the impedance of the line. These technical losses are inherent in a system and can be reduce to an optimum level. Technical losses can be determined by using various techniques such as load flow. Nontechnical losses are a phenomenon, which spread in all countries especially poor countries. Non-technical losses known as theft of the electricity this leads to economic damage in the electricity industry [9].

The losses in any system depend on the pattern of energy use, intensity of load demand, load density, and potential and design of the transmission and distribution system that vary for various system elements. A clear understanding of the magnitude of technical and non-technical losses is the first step to reduce transmission and distribution loss. This system helps the utility in bringing accountability and efficiency in its working. [10]

2.4 Load Flow Studies

A load flow study is a steady state analysis whose target is to determine the voltages, currents, and real and reactive power flows in a system under given load conditions. The purpose of load flow studies is to plan and account for various hypothetical situations [3].

A load profile defines how an electricity customer uses its electricity over time. It is created using measurements of a customer's electricity use at regular intervals, typically one hour, thirty or fifteen minutes, and provides an accurate representation of a customer's usage pattern [11].

Load flow analysis is the most important and essential approach to investigate problems in power system operating and planning. Based on a specified generating state and transmission network structure, load flow analysis solves the steady operation state with node voltages and branch power flow in the power system. The system can operate safely if there are equipment overloads, or some node voltages are too low or too high. [4]

Load-flow studies are probably the most common of all power system for analysis calculations. They used in planning studies to determine when specific elements will become overloaded. Major investment decisions begin with reinforcement strategies based on a load-flow analysis. In operating studies, a load-flow analysis was use to ensure that each generator runs at the optimum operating point; demand will be met without overloading facilities and maintenance plans can proceed without undermining the security of the system [12].

The objective of load flow analysis is to produce the following information:

• Voltage magnitude and phase angle at each bus.

• Real and reactive power flowing in each element.

• Reactive power loading on each generator.

2.5 Implementation of Load Profile

Load profile was use to improve operational efficiency and enhance power grid reliability. Consumers come from all type; completely have different electrical consumption patterns. Load profiling, which refers to an electricity consumption pattern for a customer over a given period, was perform. The Load Servicing Entities (LSEs) will emerge in large numbers and form a more competitive electricity market, especially on the demand side, thus challenging the current distribution and supply structures. In this context, LSEs would be need to make full use of detailed electrical power consumption data of individual customer obtained by Advanced Metering Infrastructure (AMI) to gain a better understanding of consumer behavior. [10]

Load profiling has many applications including demand response, load forecasting, and non-technical loss detecting, etc. Demand response is an effective way of promoting the accommodation of renewable energy and reducing the difference between peaks and valleys of electrical load [11] [12]. The electricity consumption data and load profiles extracted from these data are vital for demand response studies. [13–17].

This help both LSEs and electrical customers enhance the understanding of electrical consumption patterns for realizing personalized power management and activating the interaction between LSE and electrical customers in a competitive electric power retail market. [18]

2.6 Methodology to Evaluate Technical Losses.

To develop an effective way to manage technical losses in the distribution system is to identify the location, sources and level of technical losses in the system. This will assist utilities to determine the optimum selection of technical losses reduction options. A considerable amount of research was found to concentrate on the development of different methods to measure and evaluate the distribution of technical losses. [19]

In general, to determine technical losses in the distribution system is based on energy metering data [20]. Technical losses can be calculated as the difference between the energy input at the main substation and the sum of the power that is delivered to the destination nodes in the same period, as shown in Equation (**2-1** [21], [22]. Non-technical losses contribution was neglected. However, if non-technical losses (NTL) was considered, technical losses (TL) can be determined as a difference between E_{loss} and E_{loss}^{NTL}, as shown in Equation 2.2.

$$E_{loss} = E_{source} - \sum_{V_i} E_{destination}(i) \tag{2-1}$$

$$E_{loss}^{TL} = E_{loss} - E_{loss}^{NTL} \tag{2-2}$$

Where:

E_{loss}	= Technical losses in the distribution network in MWh
E_{source}	= Total energy delivered o the distribution network measured at source in MWh
$E_{destination}$	= Energy measured at the destination meters
i	= Destination energy meter
E_{loss}^{TL}	= Technical losses in MWh
E_{loss}^{NTL}	= Non-technical losses in MWh

The main advantage is it does not require vast operational and network data as well as a complex and sophisticated computational model to calculate total distribution losses. Total distribution losses for each network and entire system are easy to obtain and widely used by utilities since energy inflow data from grid supply system and normally captured in real-time at the system level using data located at distribution interface substation, as well as the total energy billing data of the customer end [23].

Besides, technical losses can also be calculated using I^2R loss formulae in distribution feeder and transformer. In [23], Chang using I^2R formulation to determine annual technical losses which is for both active and reactive losses for primary feeder, transformer and considered technical losses reduction due to the capacitor bank. This method assumed constant voltage throughout feeder. The method also considered a combination of concentrated and uniformly distribution loads, which require load data