FUSE BLOW SCHEME AND ITS IMPACT ON OVERHEAD DISTRIBUTION SYSTEM RELIABILITY

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ABSTRACT

Electricity has become a major necessity in the modern world, and the availability has to reach to not only the city area but to the rural areas of population as well. To ensure the electrical distribution system is healthy, protection schemes have to be in place and one such method is the use of fuse blow method. This method is extensively used by the electric utility's distribution system in Sabah and has shown effective protection requirements. However, this comes as a tradeoff to customers experiencing outages of electric supply. The study was carried out to identify the impact of fuse blow method and the accompanying results from actual performance of the overhead distribution system in a selected area, which in this case is the Kota Belud area. Many factors influence the reliability of the system such as the length of the distribution feeders, number of customers in each point of the system and placement of the fuses. The method used was the enumerative analysis to calculate the reliability impact of the fuse blow method. From the calculations, the result is then compared with the actual performance of the system in a one year period. The length of the feeders has the biggest impact to the reliability calculation and this is reflected by the data of actual performance of the feeders. A delicate balance of fusing coordination and limiting of feeder length is needed to ensure that the impact of the fuse blow method to the customer is adequately mitigated.

ABSTRAK

Elektrik telah menjadi keperluan utama di dunia moden dan ianya perlu disalurkan bukan sahaja kepada kawasan bandar tetapi di penduduk luar bandar juga. Bagi menjamin kesihatan system pembahagian elektrik, skema perlindungan perlu diadakan dan salah satu kaedah yang digunapakai ialah kaedah "fuse blow". Kaedah ini digunakan secara meluas oleh syarikat utiliti elektrik bagi system pembahgian di Sabah dan telah menunjukkan keperluan perlindungan yang efektif. Walaubagaimanapun, ini memberi kesan kepada pengguna elektrik yang akan mengalami gangguan bekalan elektrik. Kajian ini dijalankan bagi mengenalpasti impak kaedah "fuse blow" kepada prestasi sebenar bagi sistem pembahagian talian atas di suatu kawasan yang dipilih, iaitu kawasan Kota Belud. Banyak faktor mempengaruhi kedayaharapan sistem seperti panjang talian pembekal pembahagian, jumlah pelanggan bagi setiap talian dan lokasi fius yang dipasang. Kaedah yang digunakan ialah "enumerative analysis" bagi membuat kiraan impak kedayaharapan "fuse blow" ini. Daripada pengiraan yang dibuat, hasilnya dibandingkan dengan prestasi sebenar setiap talian . Panjang talian mempunyai impak terbesar kepada pengiraan kedayaharapan dan ini dikukuhkan dengan data prestasi sebenar talian. Keseimbangan dari segi koordinasi pemasangan fius dan menghadkan panjang talian diperlukan bagi memastikan impak kaedah "fuse blow" kepada pelanggan dapat dikurangkan sewajarnya.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Electric utility companies around the world use bare overhead conductors as one of the more economical methods of transmitting and distributing electricity to customers. To better sectionalise as well as offer some form of protection in the electricity system, fuse blow method is used as one of the cheaper alternatives.

Alternatively, fuse saving methods provide a means for the power utility company to provide allowance in the system for faults to clear on its own and avoid sending precious manpower to the site for fuse replacement. However, the downside is the increment in momentary interruption to the customers.

In the increasingly high demand of continuous and stable power supply from the customers even in the rural areas, more stringent and efficient methods are required to provide the acceptable level of service to the customers.

In Sabah state utility, the fuse blow method is extensively used throughout the overhead line system for the purpose of sectionalising and protection of the circuit in the event that a fault occurs in the system. When a temporary fault occurs which can be caused by vegetation or animals, the protected section would be isolated by blowing the fuse which in turn would cause the whole section to be without power.

This project addresses the impact of a fuse blow philosophy on long lines commonly found in rural electric utilities as well as shorter lines in more urban areas. It also assesses the differences in the impact of these schemes in terms of both power quality and reliability issues.

Improvements in the system would be beneficial to increase the satisfaction of customers in the state.

1.2 Problem Statements

Fuse saving method was used almost universally until the late 1980s, however as power quality concerns grew, utilities had to switch to fuse blowing mode. The fine balance required in using the fuse saving method and fuse blow method is critical in providing a reliable and stable power supply.

Using the fuse blow method, the interruption to the customers is greatly impacted as there little discrimination between a transient fault and a permanent fault in the circuit protected by the fuse. This study is to assess the impact of the fuse blow method to the reliability of the system. Several areas will be selected to be the case study for this thesis for a broader perspective on the issue.

This project is expected to analyse in detail the impact on the utility system and look into the improvements that can be made to improve the performance of the fuse blow philosophy which would in turn provide the utility a better system performance.

Data collection and data integrity would be an issue in the event that unreported incidences occurring on site is not reported would have an impact on the analysis carried out.

Subsequently, the method of analysis may be subject to further scrutiny in the event that any inconsistencies appear in the study.

However, whatever methods that are proposed will need to take into account the economic benefits of implementing and executing the proposed method into practice by the utility as this project study will only look into the technical aspects of the method.

1.3 Project Objectives

The major objective of this research is to identify the impact of fuse blow scheme to reliability and power quality in an electric utility.

Its measurable objectives are as follows:

a) To identify the number of incidences of fuse blow in the system under study

b) To determine the causes of incidences
c) To identify the SAIDI figures for a certain duration and the impact due to the incidences
d) To identify the SAIFI figures for a certain duration and the impact due to the incidences

1.4 Project Scope

This project is primarily concerned with the impact of the fuse blow philosophy in the usage of the electric utility. The scopes of this project are:

a) Rural electrical lines
b) Urban area electrical lines
c) Protection system involving fuses

The project is limited by the scope of electrical overhead distribution lines only and does not include the fully underground cables feeders or transmission lines used by the electric utility. However, a mixture of overhead and minimal underground cables in the feeder will be considered in this study.

The area of interest will be concentrated on the rural as well as urban area, and the differences in impact of the schemes in terms of power quality and reliability issues.

This project will not look into the economical or feasible implications of utilising or implementing the proposed methods discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Fuse blow method, fuse saving methods and combinations of both has been used by electric utilities since there is need for a distribution system was installed to protect the equipment in the system. This study will focus on the fuse blow method only and will include the relevant materials to the impact it has to the distribution system.

The reliability of a distribution system would be readily measured by the performance that is shown in the historical database of the electric utility and based on this, several studies have been done to measure the factors and parameters needed to study the distribution system reliability.

Some of the most used methods to study the distribution reliability are the Markov Chain model, RELRAD model, series system and parallel system.

2.2 Theories

Fuse blow scheme is a method where the tripping of the circuit breaker or a re-closer is excluded and the fuse is operated for any faults in the system whether it is permanent or temporary fault.

The typical fuse blow scheme is depicted in Figure 2.1 as follows. When a fault occurs on a lateral / spur line of the feeder, the fuse will operate to disconnect the affected section from the rest of the system, thereby effectively containing the outage to the downstream area of the fuse protection zone.

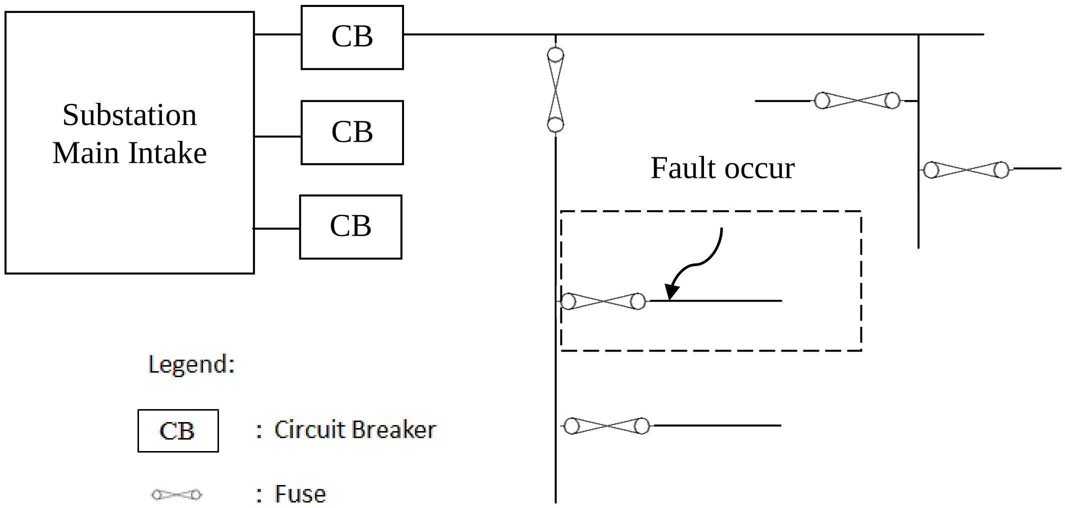

Figure 2.1: Typical fuse blow scheme operation

A single fuse can clear most line-to-neutral faults, line-to-ground as well as single phase line-to-line faults. However, when two fuses operate simultaneously it can clear a 3-phase line-to-line faults.

2.3 Description of Previous Methods

Several previous studies on the impact of fuse blow method and fuse save method have been explored and detailed out with respect to the power utility and the usage of the different methods are very much dependant on the location and type of feeders that is featured in the study. The seasonal changes in a particular geographic location are not considered in this study.

Researchers have proposed a combined fuse saving and fuse blow method to be used as a more effective utilization of the fusing methodology for protection by looking at the fuse operating time curve and operating it in an optimal fashion. However, due to economical and capability constraints, not all utilities can afford to implement the fuse blow and fuse saving method effectively. Therefore, in terms of practicality and feasibility, some utilities will only employ the fuse blow method.

The reliability indices used in this study are the SAIDI and SAIFI where, System Average Interruption Duration Index or SAIDI is the average outage duration each customer experiences.

$$\text{SAIDI} = \frac{\sum U_i N_i}{N_T} \tag{2.1}$$

$$\text{SAIDI} = \frac{\text{sum of all customer interruption durations}}{\text{total number of customers served}} \tag{2.2}$$

System Average Interruption Frequency Index or SAIFI is the average number of interruptions a consumer experiences.

$$\text{SAIFI} = \frac{\sum \lambda_i N_i}{N_T} \tag{2.4}$$

$$\text{SAIFI} = \frac{\text{total number of customer interruptions}}{\text{total number of customers served}} \tag{2.5}$$

Description of a distribution system illustrates the many features of a distribution system which makes it unique. In the state of Sabah, the voltage level of a distribution system ranges from 11kV up to 33kV. The 33kV system serves considerably longer lines, however the 11kV system may also be serving long lines with low load density.

Short circuit levels at the substation would depend on the voltage level and substation size.[1] There are typically two types of faults, low impedance and high impedance. Faults which can be detected by normal protection devices are usually low impedance faults.

The time-current characteristic (TCC) of the fuse operation is also a study by itself and contributes to the setting and different mode of operations in the utility system protection sequence. Current limiting fuse (CLF) and non-current limiting fuse are some of the other different types of methods used to coordinate the system's protection settings.

CHAPTER 3

METHODOLOGY

3.1 Project Methodology

There are two main approaches that can be utilised which are analytical and simulation methods. Simulation generally requires large amount of computing time and analytical models and techniques have been sufficient to provide the results needed to make objective decision [2]. For this study, the analytical method or enumerative analysis is used.

The system under study is represented in a mathematical model and the reliability indices are evaluated using numerical calculations. Using the basis of a Markov model, a simple formula can be developed to calculate the reliability of the distribution network [3]. In this method, two criterions are focused on which is the frequency of failure (λ) and the repair time (r), where the calculation for the frequency of failure is as follows:

$$\lambda = \frac{\text{Number of outages of a component in a set duration}}{\text{Total time the component is in operation}} \qquad (3.1)$$

The distribution systems in Sabah is basically designed and operated in radial system with the mesh system usually only utilised in urban and high density areas. A radial system would consist of a series of components such as circuit breakers, re-closer, lines, switches, transformers and the customer. The equations needed to calculate the basic indices are as follows:

Average failure rate of the system:

$$\lambda_s = \lambda_1 + \lambda_s = \sum_{i=1}^{2} \lambda_i \tag{3.2}$$

Average Outage duration or Repair time of the system:

$$r_s = \frac{\lambda_1 r_1 + \lambda_2 r_2 + \lambda_1 \lambda_2 r_1 r_2}{\lambda_1 + \lambda_2} = \frac{\sum \lambda_i r_i}{\sum \lambda_i} = \frac{U_s}{\lambda_s} \tag{3.3}$$

If $\lambda_1 \lambda_2 r_1 r_2 << \lambda_1 r_1$ *or* $\lambda_2 r_1 r_2$

Average Annual Outage time:

$$Us = fs \,.\, rs = \lambda s \,.\, rs \tag{3.4}$$

Where $\boldsymbol{\lambda_i}$ is the failure rate at node i, $\boldsymbol{r_i}$ is the outage time at node i.

The system network of 11kV feeders in the study is translated into reliability sections which are sectionalised by the location of the main line fuses and lateral / spur fuses. Once the reliability sections have been identified, the system is modelled according to each individual feeder and its accompanying components. For the purpose of this study, only the overhead line components will be included in the modelling, such as the main trunk line and the lateral / spur lines components. The expected values from the statistical distribution of failure rates and repair times for all components in the system are then generated and the calculation for reliability indices for each load point of each component is accumulated. Finally with all the fault contribution is available, the total accumulated indices can be generated.

The flowchart for this study is shown in Figure 3.1 on the following page.

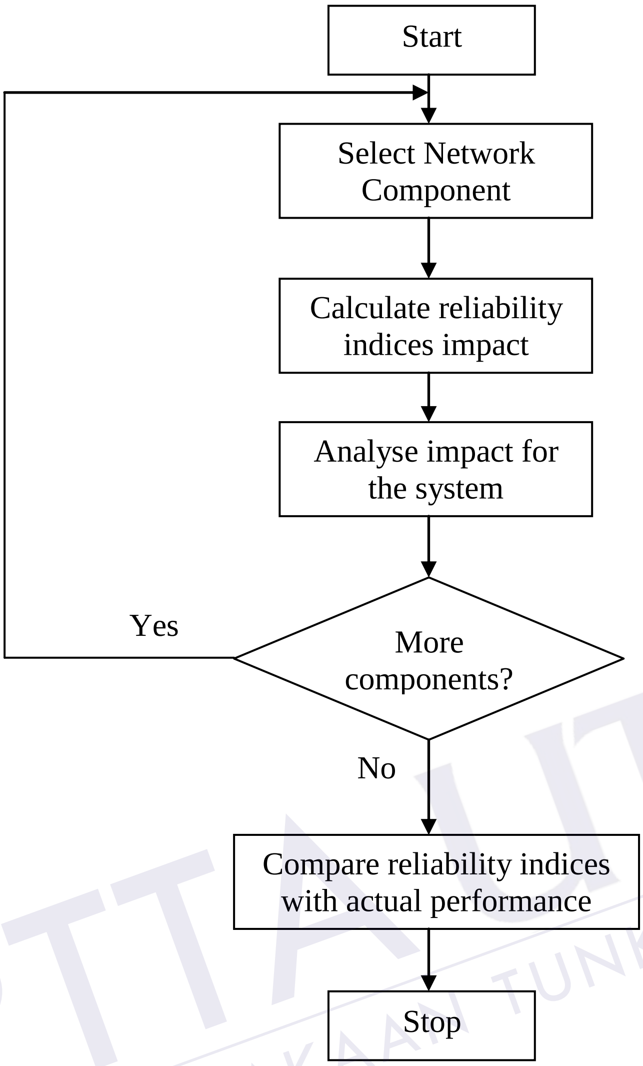

Figure 3.1: Flow chart for calculation of reliability indices

With the results of the numerical calculations, actual performance data of the feeders will be extracted from the LGBNet (SESB's reliability indices records) to compare the calculations and annual performance of the feeders in the study.

CHAPTER 4

DATA ANALYSIS AND RESULTS

4.1 Data analysis

The duration of the study is from 1st September 2012 up to 31st August 2013, which is the state utility's financial year and is used due to the financial year reporting of their data which will greatly simplify the comparison process later.

The selected area for this study is the 11kV feeders in Kota Belud area which is located towards the north of the capital city of Kota Kinabalu. An overview single line diagram of Kota Belud area is as shown in Figure 4.1 which basically shows how the interconnection of the feeders radiate from the Main Intake Substation or PMU (*Pencawang Masuk Utama).*

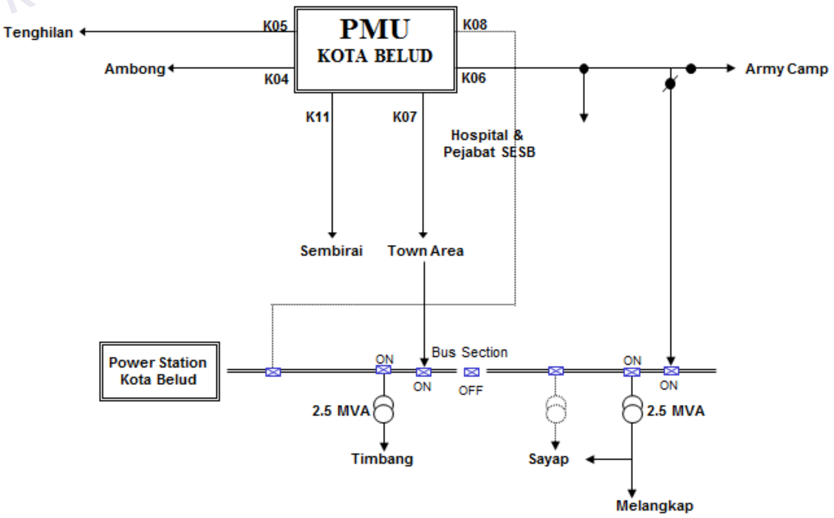

Figure 4.1: Overview Single Line Diagram for Kota Belud area

The number of customers can be segregated by types into 3 different categories, namely Domestic, Commercial and Industrial customers. Domestic users are the houses and consumption is usually under 1000kwh per month. Commercial users are the users who are involved in business and have a higher unit rate tariff. Industrial users are those that involve the bigger scale consumption of electricity. For the purpose of this study, the total customers per feeder are used. The table 4.1 shows the types and number of customers according to individual feeders.

Table 4.1: Types and number of customers by Feeder

Feeder Name	Feeder Number	Number of Customers			
		Domestic	Commercial	Industrial	Total
Army Camp I	K08	1,131	39	1	1,171
Army Camp II	B04	2,765	79	3	2,847
Ambong	K04	921	23	0	944
Sayap	B03	1,799	34	1	1,834
Tenghilan	K05	2,937	53	2	2,992
Timbang	B01	2,036	84	2	2,122
Melangkap	B02	3,665	112	6	3,783
Town	K07	1,058	1,359	14	2,431
Sembirai	K11	4,412	100	1	4,513
Total		20,724	1,883	30	22,637

The fuses used in the scheme are critical to be coordinated accordingly to the lateral / spur section that it is assigned as the rating of the fuse is deterministic of its protection capability.

The main lines or the trunk lines of the feeder is normally installed with high rated fuses such as 100A and above, however in the rural feeders, these fuse ratings may be reduced accordingly due to the low load in those areas. Subsequently, the downstream fuses has to be smaller to allow the affected of faulty areas become isolated in the event that an outage does occur. When the downstream fuse blows, the upstream fuses should not be affected and continue to supply the customers without interruption.

The failure rate may be defined as the rate at which a failure occurs per unit time under specified operating conditions and for electrical equipment this may be assumed to follow an exponential distribution [4]. As such, the reliability of the equipment can be shown as:

$$R(t) = e^{-\lambda t} \tag{4.1}$$

From previous studies and survey works done on distribution systems, one such typical permanent failure rates of the equipment are shown in Table 4.2 [5]. The equipment in a distribution system has a relatively constant failure rate (λ) [1]. Overhead line failure rates for temporary faults was assumed to be 3 times that for a permanent fault. [1]

Table 4.2 Failure rate of overhead distribution components (R.E. Brown)

Description	Failure Rate, λ (per circuit mile / year)		
	Low	Typical	High
Overhead primary trunk	0.020	0.100	0.300
Overhead Lateral Tap	0.020	0.160	0.300
Fuse Cutout	0.004	0.009	0.030
Line Recloser	0.005	0.015	0.030
Shunt Capacitor	0.011	0.020	0.085
Voltage Regulator	0.010	0.029	0.100
Disconnect Switch	0.004	0.014	0.140

From a study, the typical 1.6km (1 mile) will have on average a failure rate of 15.5% assuming that all abnormalities at or downstream of the distribution transformers are cleared and prevented from going upstream beyond the transformer fuse cutout [1].

The calculation for the probability of failing is equal to $(1 - e^{-\lambda t})$ for overhead primary trunk and overhead lateral or spur tap, is as shown in the following page:

$$\text{Probability of failure} = 1 - e^{-(0.100 + 0.160) \times 1} = 22.9\% \tag{4.2}$$

Another study shows a different failure rate, where the values differ significantly from those shown in Table 4.2. The study by Statnett (2002) average temporary and sustained failure rates for power system components in Norway, for the period 1993 through 2002, are presented as shown in Table 4.3 below.

Table 4.3: Failure rate for Distribution Lines (Statnett)

Failure rate for Distribution Lines (Underground Cable, UG and Overhead Line, OHL)	per 100km/year		per km/ year	
	Temporary	Permanent	Temporary	Permanent
OHL (33kV - 110 kV)	1.0400	0.5000	0.0104	0.0050
UG (33kV - 110 kV)	0.1500	0.9500	0.0015	0.0095

The history and characteristic of the laterals (spurs) along with the probability of developing a fault are worth investigating in determining whether to allow the lateral (spur) fuse to blow or the feeder breaker / recloser to trip and reclose. [1]

The 11kV Single Line Diagrams for each of the feeders in the Kota Belud distribution systems are analysed to look into the layout and the connections of the fuses in the scheme. The layout is then translated into the reliability sections to enable the numerical calculations to be carried out. For this study, the failure rate from Table 4.3 is used.

The first feeder to be analysed is the Feeder Army Camp I. The single line diagram is as shown in Figure 4.2 and is then translated into Figure 4.3. From the single line diagram in Figure 4.2, there are a total of 17 nos. of substation with transformers that supply the customers in that particular area. This will then be translated into load points in Figure 4.3.

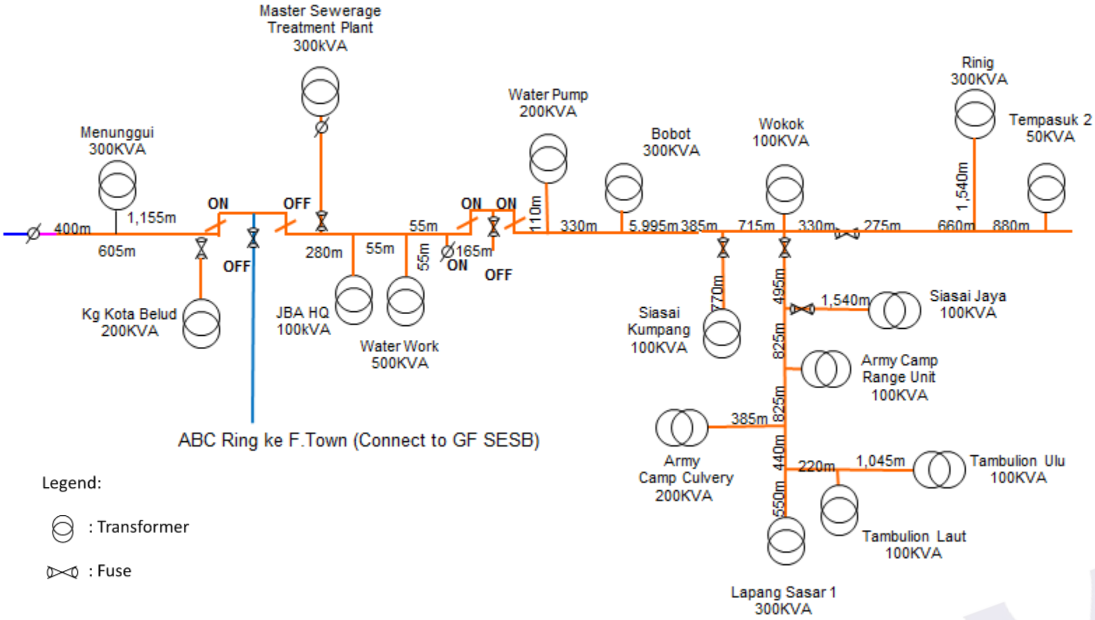

Figure 4.2: Single Line Diagram for Feeder Army Camp I

There is a total of 17 load points with 2 main fuse sections and 3 lateral fuse sections for Feeder Army Camp I as shown in Figure 4.3 below.

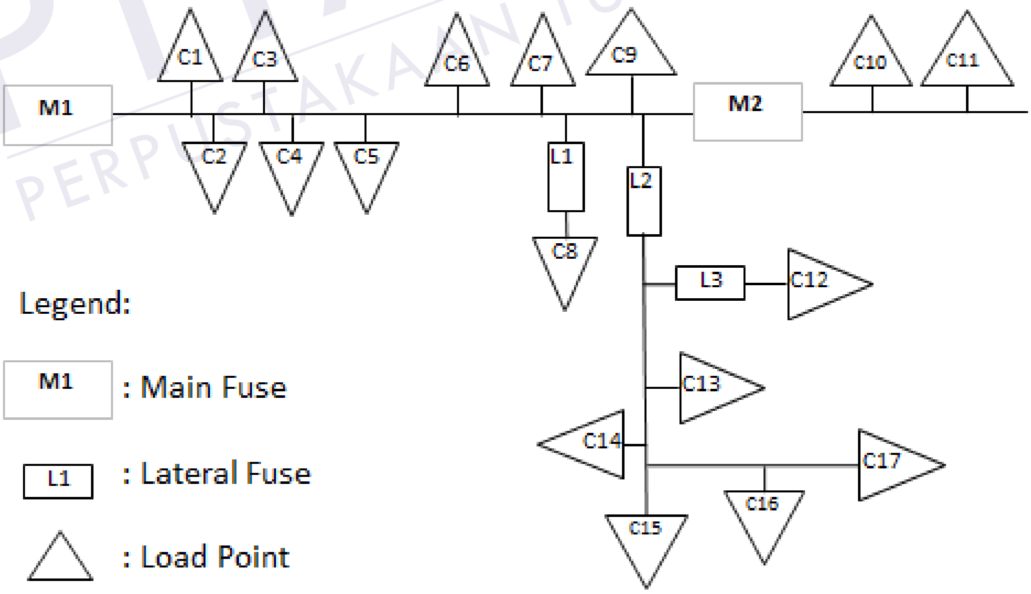

Figure 4.3: Reliability sections for Feeder Army Camp I

The reliability sections for Feeder Army Camp I is then tabulated into the numerical calculation sheet with the relevant parameters to get the SAIDI and SAIFI calculations. The sections with fuses are identified from the single line diagram and the length of each reliability section is calculated.

The Table 4.4 shows the parameters used in the numerical calculations which correspond with the failure rate of the components, number of customers per section and recovery time for Feeder Army Camp I where the designation M1 up to M2 represent the main line fuses and L1 up to L3 represent the lateral or spur fuses installed in the feeder.

Table 4.4: Parameters used for reliability indices calculation in Army Camp I

Reliability Section Feeder Army Camp I	Overhead Line Parameters		
	Length (km)	Failure Rate, λ	Repair time, r (hour)
M1	9.975	0.1037	54.0167
M2	1.815	0.0189	54.0167
L1	0.770	0.0080	54.0167
L2	3.960	0.0412	54.0167
L3	1.540	0.0160	54.0167

The number of customers for each load points is also considered as an input for the indices calculation. Table 4.5 shows the individual number of customers for each load points which is needed to calculate the reliability indices.

Table 4.5: No. of customers by area for Feeder Army Camp I

Area	No. of Customers			
	Domestic	Commercial	Industry	Total
Menunggui	130	2		132
Kg kota belud	135	1		136
JBA HQ		1		1
Master Sewarage T.Plan		1		1
Water work		1		1
Water pump		2		2
Bobot	139	3		142
Wokok	40	1		41
Siasai kumpang	66			66

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