ANALYSIS OF TECHNICAL LOSSES IN DISTRIBUTION LINE

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A project report submitted in partial
Fulfilment of the requirement for the award of the
Degree of Master of Electrical Engineering

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JULY 2014

ABSTRACT

This project presents an evaluation of the power losses in Sabah Electricity Sdn. Bhd. (SESB) distribution system area and submit proposals and appropriate solutions and suggestions to reduce the losses. This analysis used calculation and PSS/ Adept program. For considering the technical loss in distribution system included the power transformer losses and distribution line losses. The evaluation will be compared technical loss both two parts and compared technical loss from calculation and measurement which data included technical loss and technical loss. From this research found that transformer losses and distribution line losses have maximum value at 26% and technical loss was at 11,739. So in controlling or decrease technical loss have to select appropriate and correctly method by must investigate both cost and most worthily.

ABSTRAK

Projek ini membentangkan penilaian terhadap kerugian kuasa di Sabah Electricity Sdn. Bhd (SESB) di sistem pengagihan dan akan dikemukakan cadangan berserta untuk mengurangkan kerugian dalam sistem pengagihan. Analisis ini menggunakan program perisian PSS / Adept. Bertujuan untuk mempertimbangkan kerugian teknikal dalam sistem pengagihan termasuk kerugian kuasa alat ubah dan kerugian sistem pengagihan. Penilaian ini dibuat dengan membandingkan kehilangan teknikal kedua-dua bahagian dan kehilangan teknikal berbanding daripada pengiraan dan pengukuran yang termasuk data teknikal kehilangan dan kerugian teknikal. Daripada kajian mendapati kerugian alat ubah dan kerugian sistem pengagihan mempunyai nilai maksimum pada 26% dan kehilangan teknikal adalah di 11,739. Secara tidak langsung, dapat mengawal atau mengurangkan kerugian teknikal dengan memilih kaedah yang sesuai dan betul bagi menyiasat dan menilai kedua-dua kos yang berpatutan.

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I	-	current
P	-	power
R	-	resistance
kV	-	kilo Volt
DG	-	Distributed generation
kawasan	-	region/ area
PSSE	-	Power System Simulation Engineering
PSS/ A	-	Power System Simulation Engineering Adapt software
SESB	-	Sabah Electricity Sdn. Bhd.
ST	-	Suruhanjaya Tenaga
T & D	-	Transmission and distribution
TNB	-	Tenaga Nasional Berhad

CHAPTER 1

INTRODUCTION

1.1 Project Background

Distribution network is characterized by multi-power plants, multi-branch lines, multi-load points, and complex structures [1]. The line loss of distribution network is always affected by the network voltage, current, load factor, power factor, the capacity and location of the compensation device, run time, table settings, and many other factors [2]. So the line loss analysis process is relatively complicated, even balancing the line loss factor is more difficult. However, these analysis should be used in power distribution equipment location information and related information.

The utility industry today has placed a high level of importance on improving efficiency. A proper review of losses experienced on a utility's system can provide valuable insight into ways to manage these losses and improve efficiency while reducing wholesale power costs, improving voltage levels, and freeing up system capacity, potentially reducing costly investment in system improvements.

There are several ways to reduce losses in distribution system. Many methods need new equipments for installation within the system, and add to the financial burden for companies [3]. The distribution network reconfiguration is very important and able to operate for reduce losses of distribution system and improve system security. There are normally closed and normally open switches in distribution system [4].

The computer program finds the network configuration with minimum power losses. This configuration can change open/ closed of state switching devices on tie lines. In distribution system, network reconfiguration and capacitor control are used to reduce real power losses and to improve voltage profile [5], [6].

In electrical distribution systems, except the usual measurements from stations, there is little information about the state of network. As a result, there is at any moment a generalized uncertainty about the power demand conditions and therefore about the network loading, voltage level, power losses, etc. Therefore, it is important to monitor the power losses from distribution system.

In this paper an alternative to the settlement based on Power System Simulation Engineering (PSSE) Adapt software, to calculate the line distribution losses. Power System Engineering Inc. is on the leading edge of research efforts to develop innovative techniques to evaluate system losses in today's environment. The goal of these evaluations is to strike an economic balance between investment to lower the true cost of losses while considering all power supply and delivery costing periods, and the benefit derived from those lowered losses. Added detail in terms of the loss locations incurred across the system enhances the understanding of the relative contributions of various system components to total losses. Added detail in terms of the timing of losses allows more precise methods of valuing those losses. In combination, refined loss estimates can lead to improvements in identifying cost-effective loss reduction measures.

Sabah Electricity Sdn. Bhd. (SESB) is an electrical company that generates, transmits and distributes electricity mainly in Sabah and Federal Territory of Labuan. It supplies electrical power to 413,983 customers distributed over a wide area of 74,000 km^2. 82.8% of the customers are domestic customers consuming only 28.8% of the power generated. This company employs more than 2,300 employees and the main stakeholders of this company are Tenaga Nasional Berhad (TNB) (80%) and Sabah State Government (20%). The electricity in Sabah is under the responsibility of Sabah Electricity Sdn Bhd (SESB) utility company.

SESB is the one and only power utility industry in Sabah with core activities of electric generation, transmission and distribution to over 1 million customers throughout Sabah region. The highest power losses load recorded for Sabah is a 25.21% on 2011, 23.26% on 2012 and 37.10% on 2013 which includes all main regions in west coast, east coast and Wilayah Persekutuan Labuan of Sabah. As the main utility, SESB is responsible to ensure that the daily operation are always is a reliable and secure condition in supplying power to the consumers. Any minor as well as major disturbances need to be handled and solved immediately to avoid power losses and maximum efficiency of the system in SESB.

For SESB itself, the existing Power Losses has been collecting the data since 2011, 2012 and 2013 for this paper research. Basically, there are 11 areas in Sabah Grid will be monitor but these papers only focus Sandakan area. As the power losses of electricity keep on loss is required to be installed in the whole system for a better planning and delivering of electrical power. Hence it is hope this study could be a contribution to reduce the power losses interruptions which can lead to system collapse and also provide a good principle of effective operation and help to maintain the quality of electricity supply in this region.

1.2 Problem Statements

In Sabah Electricity Sdn. Bhd. (SESB) power losses was once a reason contributing to the deficiency of the power system. However losses during peak times are of particular importance because this is when losses and their costs are typically at their highest other than that minimum efficiency. Technical losses generally vary with the square of the load current being distributed. As a result, losses will increase as more capacity is used. Losses are also proportional to the length of the line. The technical losses comprise both variable and fixed components. The fixed component of technical losses depends largely on the system configuration, pattern of loading of distribution lines. The variable component is due to weak and inadequate distribution lines, inadequate sizing of conductors used, lengthy distribution lines and inadequate reactive compensation in the system.

During the last decades, SESB has developed several improvements to their power distribution systems. Due to high costs involved in electrical energy generation, transmission and distribution, the efficient usage of the available energy along with the efficient management of the network are fundamental issues to be tackled. Energy efficiency measures can represent the difference between having power quality at affordable prices and having energy shortages or with poor quality [7].

After electric power is generated, it was sent through the transmission lines to the many distribution areas. The purpose of the distribution system is to take that power from the transmission system and deliver it to the consumers to serve their need. However, a significant portion of the power that a utility generates is lost in the distribution process which losses occur in numerous small components in the distribution system, such as transformers and distribution lines. Due to the lower power level of these components, the losses inherent in each component are lower than those in comparable components of the transmission system. While each of these components may have relatively small losses, the large number of components involved makes it important to examine the losses in the distribution system.

There are two major sources of losses in power distribution systems; these are the transformers and power lines. Additionally, there are two major types of losses that occur in these components. These losses are often referred to as core losses and copper, or I^2R losses. Core losses in transformers account for the majority of losses at low power levels. As load increases, the copper losses become more significant, until they are approximately equal to the core losses at peak load [8].

Since distribution losses cost the utilities a sizable amount of profit, it is necessary to examine the various methods of reducing these losses. While many of lowering losses can be used on existing systems, other methods are easiest to use during the initial design and installation of a new distribution system. An example of one of these methods is to carefully select the location of the substation so as to minimise the needed length of distribution lines.

Usually on technical losses that contribute to power losses are caused by length cable means getting longer and much transmission power to a particular area, the more power loss occurs, another reason cause of power factor and parameter. Especially in Sandakan the power losses is 7.83% on 2013 from the data by *Kawasan*. Hence it is hope that the power losses study proposes could be a contribution to reduce the losses interruptions which can lead to system inefficiency and also provide a good principle of effective operation and help to maintain the quality of electricity supply in this region.

In this project, shunt capacitor banks are used to compensate for reactive loads in order to provide a highly resistive total load and a near unity power factor. Hence there is less current flow in the line and lower losses. The capacitors are strategically placed to provide the best voltage support and current reduction.

1.3 Project Objectives

This research is aimed to present technical loss evaluation in Sandakan. Sabah Electricity Sdn. Bhd. (SESB) the state utility company that is responsible for transmission and distribution of electricity in Sabah. The objectives purposes of the project are:

(a) To analyse the energy losses of SESB distribution network

(b) To reduce the losses of operation by implementing the reactive power management.

1.4 Project Scopes

Correct calculations of energy losses in distribution line are important for several reasons. The accurate identification and the precise calculation of electricity losses enables the clear specification of the critical points and segments in the network and consequently the effective prioritisation of actions and interventions in order to reduce those electricity losses and problems. Moreover, the work already performed on this issue, the existing approaches focus mainly on applied data. Hence, a basic method that can be used to study technical energy losses is using power system simulation to identify power losses in SESB distribution system for normal, fault and outage condition. These propose a platform for the management of the appropriate solutions and suggestions to optimise the distribution power losses using possible reactive power control devices such as capacitor bank.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Losses reduction initiatives in distribution systems have been activated due to the utilities in shape of incentives and penalties. Recently, SESB have been incentivised to reduce the distribution technical losses with an equal annual reduction rate for three (3) years. Because of distribution network is the end of transmission and distribution systems, directly facing the majority of electricity customers, so the reliability of the distribution network directly relates to the satisfaction of customer’s need. How to improve the reliability of the distribution network is also an important aspect that power system is working on and paying attention to, especially when during the highly developed information technology time. Furthermore, the customers demand more and more depend on the incessant of the supply of electricity, so the reliability of the distribution network is badly needed to be solved.

Distribution networks are conventionally designed by planning transformers and distribution lines for minimizing the line loss, maximizing the system reliability and improving the voltage profile. Capacitor banks, voltage regulars and the load tap changer of the transformers are three elements which can help the conventional planning to improve the line loss and voltage profile more. However, these devices cannot influence the system reliability. On the other hand, Distributed Generations (DG) significantly improves the system reliability. Distributed generation can decrease the line loss, but they are so expensive that are not justified to be installed only for minimizing the line loss. Load growth, as an important factor in planning, is conventionally supported by upgrading transformers and distribution lines. The above point highlights the need for a combination of capacitors and distributed generations to decrease the total cost.

Improving system reliability can be achieved by using distributed generation. However, since they are expensive devices, capacitor banks are acceptable alternatives for helping these costly elements particularly in urban and rural areas.

2.2 Reactive Power Management

2.2.1 Capacitor Bank

Shunt capacitor banks are mainly installed to provide capacitive reactive compensation/ power factor correction. The use of capacitor banks has increased because they are relatively inexpensive, easy and quick to install and can be deployed virtually anywhere in the network. Its installation has other beneficial effects on the system such as: improvement of the voltage at the load, better voltage regulation if they were adequately designed reduction of losses and reduction or postponement of investments in transmission.

2.2.2 Bank Configurations

The use of fuses for protecting the capacitor units and it location (inside the capacitor unit on each element or outside the unit) is an important subject in the design of capacitor bank. They also affect the failure mode of the capacitor unit and influence the design of the bank protection. Depending on the application any of the following configurations are suitable for shunt capacitor banks:

2.2.3.1 Externally Fused

An individual fuse, externally mounted between the capacitor unit and the capacitor bank fuse bus, typically protects each capacitor unit. The capacitor unit can be designed for a relatively high voltage because the external fuse is capable of interrupting a high-voltage fault. Use of capacitors with the highest possible voltage rating will result in a capacitive bank with the fewest number of series groups.

A failure of a capacitor element welds the foils together and short circuits the other capacitor elements connected in parallel in the same group. The remaining capacitor elements in the unit remain in service with a higher voltage across them than before the failure and an increased in capacitor unit current. If a second element fails the process repeats itself resulting in an even higher voltage for the remaining elements. Successive failures within the same unit will make the fuse to operate, disconnecting the capacitor unit and indicating the failed one. Externally fused SCBs are configured using one or more series groups of parallel-connected capacitor units per phase (Figure 2.1). The available unbalance signal level decreases as the number of series groups of capacitors is increased or as the number of capacitor units in parallel per series group is increased.

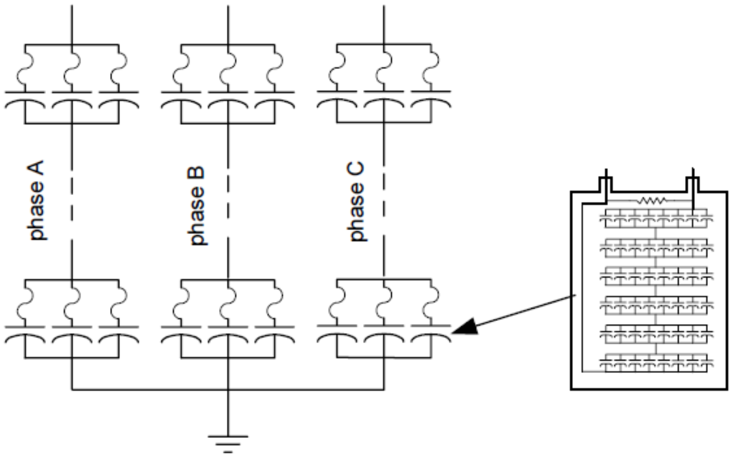


Figure 2.1: Externally fused shunt capacitor bank and capacitor unit

2.2.3.2 Internally Fused

Each capacitor element is fused inside the capacitor unit. The fuse is a simple piece of wire enough to limit the current and encapsulated in a wrapper able to withstand the heat produced by the arc. Upon a capacitor element failure, the fuse removes the affected element only. The other elements, connected in parallel in the same group, remain in service but with a slightly higher voltage across them. Figure 2.2 illustrates a typical capacitor bank utilizing internally fused capacitor units. In general, banks employing internally fused capacitor units are configured with fewer capacitor units in parallel and more series groups of units than are used in banks employing externally fused capacitor units. The capacitor units are normally large because a complete unit is not expected to fail.

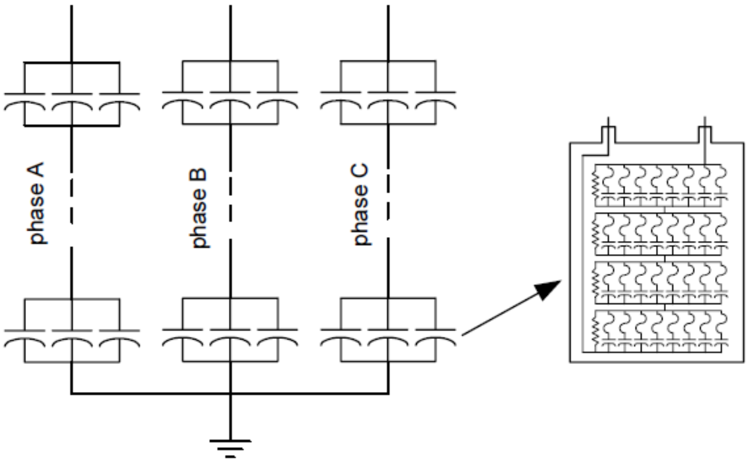


Figure 2.2: Internally fused shunt capacitor bank and capacitor unit

2.2.3 Capacitor Bank Design

The protection of shunt capacitor banks requires understanding the basics of capacitor bank design and capacitor unit connections. Shunt capacitors banks are arrangements of series/ paralleled connected units. Capacitor units connected in paralleled make up a group and series connected groups form a single-phase capacitor bank. However, for distribution capacitor banks may be connected wye or delta. Some banks use an H configuration on each of the phases with a current transformer in the connecting branch to detect the unbalance.

2.2.3.1 Grounded Wye-Connected Banks

Grounded wye capacitor banks are composed of series and parallel-connected capacitor units per phase and provide a low impedance path to ground. Figure 2.3 and Figure 2.4 shows typical bank arrangements.

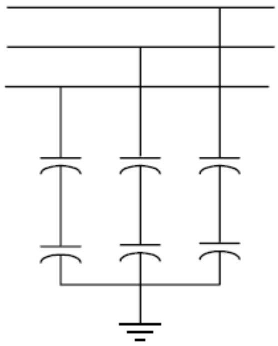


Figure 2.3: Multiple units grounded single Wye

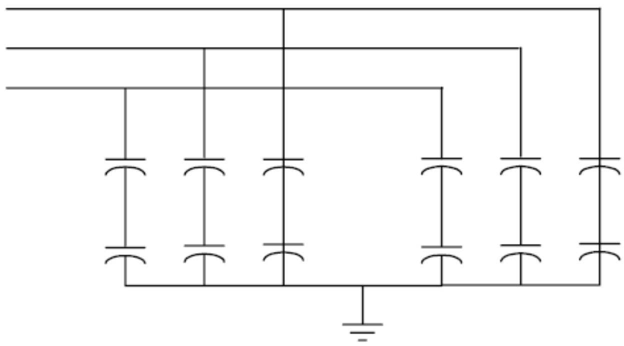


Figure 2.4: Multiple units grounded double Wye

Advantages of the grounded capacitor banks include:

- Its low-impedance path to ground provides inherent self-protection for lightning surge currents and give some protection from surge voltages. Banks can be operated without surge arresters taking advantage of the capability of the capacitors to absorb the surge.
- Offer a low impedance path for high frequency currents and so they can be used as filters in systems with high harmonic content. However, caution shall be taken to avoid resonance between the SCB and the system.
- Reduced transient recovery voltages for circuit breakers and other switching equipment.

2.2.3.2 Ungrounded Wye-Connected Banks

Typical bank arrangements of ungrounded Wye SCB are shown in Figure 2.5 and Figure 2.6. Ungrounded wye banks do not permit zero sequence currents, third harmonic currents, or large capacitor discharge currents during system ground faults to flow. (Phase-to-phase faults may still occur and will result in large discharge currents). Other advantage is that overvoltages appearing at the current transformer secondaries are not as high as in the case of grounded banks. However, the neutral should be insulated for full line voltage because it is momentarily at phase potential when the bank is switched or when one capacitor unit fails in a bank configured with a single group of units.

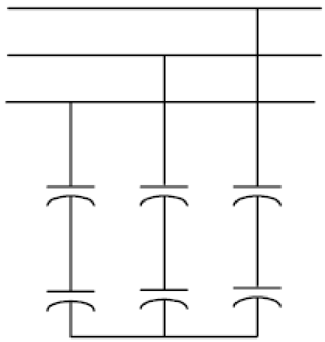


Figure 2.5: Multiple units undergrounded single Wye

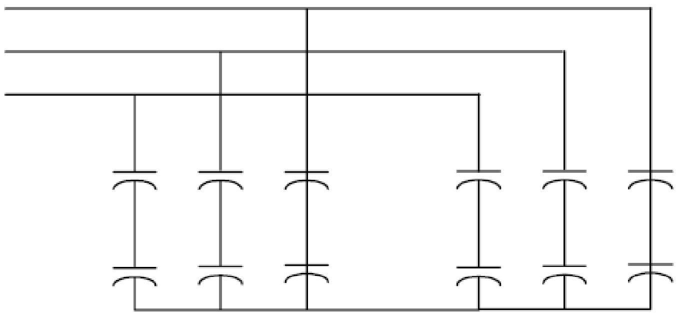


Figure 2.6: Multiple units undergrounded double Wye

2.2.3.3 Delta-connected Banks

Delta-connected banks are generally used only at distributions voltages and are configured with a single series group of capacitors rated at line-to-line voltage. With only one series group of units no overvoltage occurs across the remaining capacitor units from the isolation of a faulted capacitor unit.

2.2.3.4 H-Configuration

Some larger banks use an H configuration in each phase with a current transformer connected between the two legs to compare the current down each leg. As long as all capacitors are normal, no current will flow through the current transformer. If a capacitor fuse operates, some current will flow through the current transformer. This bridge connection can be very sensitive. This arrangement is used on large banks with many capacitor units in parallel [9].

2.3 Allocation and Sizing of Distributed Generators

The generation of electrical energy and avoiding greenhouse gas emissions issue are currently challenging issues. As a result of this, the renewable energy sources are presently known as a reasonable solution. The interest in using the renewable energy sources is increasing due to the decrease of the production cost, environmental impact and line loss as well as the improvement of reliability indices.

A variety of solution techniques have been employed to find the location and size of distributed generations. The discrete nature of this problem leads the objective function to have several local minima. As random based methods, the heuristic methods deal properly with the local minima. Therefore, they are employed more than the analytical methods for planning of distributed generations [10].

Although these methods optimise the location and rating of distributed degenerations for different load levels, they do not include their computation while supporting the load growth is one of the main benefits of using DGs.

2.4 Concept of Switching Optimization

One of the effective ways for technical loss reduction is changing the feeder configuration by switching devices, called switching optimization. This is the most cost effective countermeasure for technical loss reduction because it only needs to relocate the existing switching device or install new one to the adequate position. The cost of switching device is relatively low compared with reconductor or new feeder installation, even if it requires several new devices. Switching optimization depends on the size of loads, size and length of conductor.

This concept is needed for protection devices such as fuses, breakers, sectionalizer and reclosers. Among these devices, sectionalizers have more attracted more attention. Using these devices is studied in two aspects, investment cost and system reliability. In order to increase system reliability, more investment is required and vice versa. To satisfy these two aspects simultaneously, an optimization procedure is needed to lump them into one objectives function. This show the importance of the allocation of switches problem.

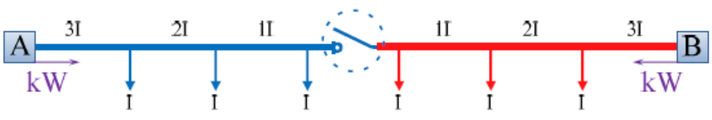
Line losses in the distribution system occur in the primary as well as the secondary feeders. They are functions of the square of permissible current through the conductors of resistance, such as line loss is directly proportional to the size of the conductor and square of the current passing through it as in equation (2.1).

$$P_l = \sum_{i=1}^{n} |I|^2 R \qquad (2.1)$$

Where "n" is total number of branches in the system, "R" is the resistance of conductor in branch "i" and "$|I|$" is the magnitude of current flow in branch "I", for three phase system the losses of feeder becomes $3I^2R$.

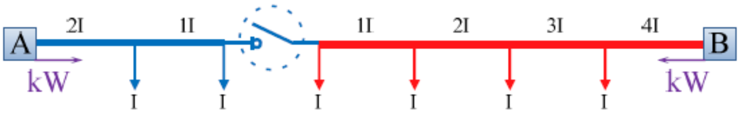
The formula about the conductor losses makes clear that power distribution loss reduction can be achieved by the decrease a conductor resistance or a current. The decrease a conductor resistance can be achieved through system reinforcement such as cross-section conductor (reconductor) or additional new lines. The decreased current can be achieved by the installation of capacitors through power factor correction and levelling of distribution load or switching optimization.

The concept of switching optimization considers from equation (2.1). As seen in Figure 2.7 shows the concept of switching optimization.



Loss on feeder A $= ((3I)^2 + (2I)^2 + (I)^2)\ X\ R = 14.0I^2R$
Loss on feeder B $= ((3I)^2 + (2I)^2 + (I)^2)\ X\ 0.5R = 7.0I^2R$
Total losses $= 21.0\ I^2R$

(a) Original system



$$\text{Loss on feeder A} = ((2I)^2 + (I)^2)\ X\ R = 5.0I^2R$$
$$\text{Loss on feeder B} = ((4I)^2 + (3I)^2 + (2I)^2)\ X\ 0.5R + (I)^2\ X\ R = 15.5I^2R$$
$$\text{Total losses} = 20.5\ I^2R$$

(b) Optimized system by switching

Figure 2.7**:** Concept of switching optimization

In the original system on Figure 2.7 (a), both substations have the same amounts of load (3 x I), but the feeder A and feeder B supply the power with thin conductor (high resistance) and big conductor (low resistance) respectively. Suppose that the conductor resistances are 1.0R and 0.5R, current of each load is "I" and all of the section lengths are same. Total losses on the original system would be $21.0I^2R$. On the other hand, the total loss in the optimum system is reduced to $20.5I^2R$ as shown in Figure 2.7 (b). The better feeder configuration would be obtained by switching optimization due to inappropriate position of switching devices in the original system [11].

Switching optimization searches for the better configuration of the feeders based on the loss reduction by conducting one by one switching operation. The optimum system saves loss $0.5I^2R$ compared with the original system. In the optimum system, the location of switching device is changed to substation A-side and load is transferred from substation A to B. This load becomes far from substation in comparison with the original system and the power from substation B increases so that losses on feeder B would increase. However, the current of the load passes thick conductor from substation B, and the loads on feeder A become adequate size considering the conductor size, which means that total losses on feeder A and B would decrease. The total loads on the feeder A and B become and respectively. Switching optimization minimizes the loss but overload of substation should be noted.

CHAPTER 3

METHODOLOGY

3.0 Project Methodology

3.1 Basic of Power Losses

Technical power losses are consequents of transport electricity by the network, between generator to the transmission and distribution system. Technical losses are a part of the electrical power losses of the system, resulting of losses on transmission device, losses for corona effect, iron losses on transformer, losses by eddy current and dielectric losses. Technical losses generally vary with the square of the load current being distributed. As a result, losses will increase as more capacity is used. Losses are also proportional to the length of the line. The technical losses comprise both variable and fixed components. The fixed component of technical losses depends largely on the system configuration, pattern of loading of transmission and distribution lines, magnitude and types of loads, characteristics of equipment etc. The variable component is due to weak and inadequate sub-transmission and distribution lines, inadequate sizing of conductors used, lengthy transmission and distribution lines and inadequate reactive compensation in the system. In this project, focused only on technical losses caused by line and transformer distribution losses.

The main objective of this project to minimise the distribution power losses using reactive power management method. The following data is required for the capacitor replacement:

(a) Capacitor bank unit size

(b) Loading conditions (3 step loading levels: light, normal and peak load). PSSA is capable of calculating the appropriate amount of equipment according to the loading level. The loading level is determined by the required for the light load period, it can calculate the amount of equipment for normal load and heavy load period as on-off switchable equipment. In addition to the loading level setting, it must to determine 3 steps loading level continues in a year. Desired power factor is also required.

(c) The fixed equipment allocation, which, definition are during all load snapshots (light, normal and peak load) minimum loss reduction, after the fixed equipment allocation stops. Optimal equipment placement will continue to place the switched equipment and will find all the eligible buses to allocate switched equipment.

3.2 Technical Loss

The high costs necessary to build new power-generating units, the preoccupation with the depletion of natural resources and, above all, the importance of energetic efficiency lead the utility companies to try to minimize as much as possible the energy losses in distribution power systems. Energy losses may be technical or non-technical [12].

Technical loss is the amount of energy consumed by effect during the energy distribution process, caused by internal resistance of conduits and transmission/ distribution equipments. To reduce losses is necessary to know how much and where the energy is lost. For this reason, many works [13] have been developed for calculating technical losses in distributions systems.

In this project, they propose an analysis of technical losses that consider all the segments. It is based on typical load curves to represent the customers load. However, the analysis described in does not consider technical losses arising of energy circulation related to non-technical losses [14]. Therefore, there is a difference between the sum of consumers measured energy with the technical losses calculated and the energy effectively distributed on the substations.

In addition, this project presents a new method of analysis of technical active power losses. It is based on analytical computer code calculation with examples from the actual power system. Based on the incoming data from the remote control supervising system as well as technical and commercial information data, the result of the calculation is technical losses for every single element of the network. Further calculation result analysis enables global understanding of commercial losses as well as more quality planning and operating of the distribution network.

Technical loss occurred heat in winding, conductors or work parts in transformer and other electric instrument. As such included losses which ensured from connecting of insulation equipments, corona or partial discharge too. This technical loss depend on current in lines: Losses = I^2R. Technical loss was provided 4 types:

a) transmission line losses
b) power transformer losses
c) distribution line losses
d) low-voltage transformer

3.2.1 Transmission Line Losses

Calculations of losses in power systems have been attempted since long. Earlier efforts concentrated on energy loss estimation on a yearly basis and power loss estimations for maximum load situations. The estimated line losses in PSS/ Adept were important data when calculating the energy losses and planning grids [15] as in equation (1) and equation (2).

There is no difference between a transmission line and a distribution line except for the voltage level and power handling capability. Transmission lines are usually capable of transmitting large quantities of electric energy over great distances [16]. They operate at high voltages. Distribution lines carry limited quantities of power over shorter distances. Voltage drops in line are in relation to the resistance and reactance of line, length and the current drawn. For the same quantity of power handled, lower the voltage, higher the current drawn and higher the voltage drop. The current drawn is inversely proportional to the voltage level for the same quantity of power handled.

$$Transmission\ line\ loss\ (kWh) = loss\ factor_{tx}\ \times line\ loss_{tx}\ \times peroid \qquad (1)$$

$$Load\ factor = \frac{Average\ load\ (kW_{ave})}{Peak\ load\ (kW_{peak})} \qquad (2)$$

3.2.2 Power Transformer Losses

Location of the transformer is very important as far as distribution loss is concerned. Transformer receives high voltage from the grid and steps it down to the required voltage. Transformers should be placed close to the load centre, considering other features like optimization needs for centralized control, operational flexibility etc. This will bring down the distribution loss in cables [16].

Transformer losses consist of two parts:

a) No-load loss (also called core loss) is the power consumed to sustain the magnetic field in the transformer's steel core. Core loss occurs whenever the transformer is energized; core loss does not vary with load. Core losses are caused by two factors: hysteresis and eddy current losses. Hysteresis loss is that energy lost by reversing the magnetic field in the core as the magnetizing AC rises and falls and reverses direction. Eddy current loss is a result of induced currents circulating in the core.

b) Load loss (also called copper loss) is associated with full load current flow in the transformer windings. From the beginning this losses was called copper losses but in recent transformer used aluminium replace copper so it was called winding losses. Winding Losses correspond in equation (3). Copper loss is power lost in the primary and secondary windings of a transformer due to the ohm resistance of the windings. Copper loss varies with the square of the load current. ($P = I^2R$) [17].

$$Power\ transformer\ losses = Windings\ losses + No\ load\ losses \qquad (3)$$

3.2.3 Distribution Line Losses

In an electrical system often the constant no load losses and the variable load losses are to be assessed alongside, over long reference duration, towards energy loss estimation. Identifying and calculating the sum of the individual contributing loss components in equation (4) and equation (2) is a challenging one, requiring extensive experience and knowledge of all the factors impacting the operating efficiencies of each of these components [17].

$$Distribution\ line\ loss\ (kWh) = loss\ factor_{dx}\ \times line\ loss_{dx}\ \times peroid \quad (4)$$

3.2.4 Low-voltage Transformer

Losses in a distribution system cannot be accurately determined on a system wide basis. In a distribution feeder, losses occur for the following reasons:

a) line losses on phase conductors

b) line losses on ground wire

c) transformer core and leakage losses

d) excess losses due to lack of coordination of var elements

e) excess loses due to load characteristics

f) excess losses due to load imbalance on the phases.

The proper selection of the conductor size usually limits the line losses on phase conductors. The introduction of single-phase and two-phase systems causes additional losses on ground wires. Unbalanced load also adds line losses. The core losses of distribution transformer are sensitive to magnitude of system voltage. The quality of the transformer also effects the core loss. Since loads vary day to night and season to season the power factors along the feeder also vary. Without proper switchable var elements additional line losses occurs due to the poor power factor throughout the systems. The load characteristics also play a role in distribution system losses [18] in equation (5), (6) and (7).

With load;

$$Distribution\ transformer\ losses = Windings\ losses + No\ load\ losses \quad (5)$$

Without load from SESB standard;

$$Winding\ losses = \frac{kVA_{peak}^2}{kVA_{rated}^2} \times Load\ loss \times Loss\ factor \quad (6)$$

Load Losses from SESB standard;

$$Loss\ factor = 0.2LF + 0.8L^2 \quad (7)$$

Table 3.1: Distribution Transformer Losses from SESB Standard

Transformer Rating (kVA)	3-phase Watt Losses				(Old) Load Loss at 75ºC	(New) Load Loss at 75ºC
	No-load Losses for System Voltage of:					
	22kV (old)	22kV (new)	33kV (old)	33kV (new)		
30	130	130	-	-	500	500
50	210	160	230	170	1,050	950
100	340	250	350	260	1,750	1,550
160	480	360	500	370	2,350	2,100
200	570	-	590	-	2,800	-
250	670	500	700	520	3,250	2,950
315	800	600	850	630	3,900	3,500
400	960	720	1,000	750	4,600	4,150
500	1,150	860	1,200	900	5,500	4,950
630	1,350	1,010	1,400	1,050	6,500	5,850
800	1,600	1,200	1,700	1,270	11,000	9,900
1,000	1,950	1,270	2,000	1,300	13,500	12,150
1,250	2,300	1,500	2,350	1,530	16,400	14,750
1,500	2,800	1,820	2,850	1,850	19,800	17,850
2,000	3,250	2,110	3,300	2,140	24,000	21,600
2,500	3,500	3,500	3,800	3,800	28,500	28,500
3,000	4,100	4,100	4,600	4,600	33,000	33,000
4,000	5,000	5,000	5,500	5,500	38,000	38,000
5,000	6,000	6,000	6,500	6,500	45,000	45,000
Transformer Rating (kVA)	1-phase Watt Losses				(Old) Load Loss at 75ºC	(New) Load Loss at 75ºC
	No-load Losses for System Voltage of:					
	22kV (old)	22kV (new)	33kV (old)	33kV (new)		
10	75	60	75	60	160	145
20	120	90	120	90	330	300
30	160	120	150	120	480	430
50	200	150	200	150	740	670

Table 3.2: Loss distribution line and transformer

Loss Distribution line and Transformer											
	Loss Distribution line (watt)				Loss Transformer			Total Loss			
size Tr	U.F.=0.5	Trade	Town	Rural	Trade	Town	Rural	Trade	Town	Rural	
Loss Factor		0.53	0.40	0.26	0.50	0.36	0.22				
50	331.65	176.30	132.40	85.89	416.31	359.46	301.23	592.60	491.85	387.12	3 phase
100	1,115.60	593.02	445.35	288.91	639.44	556.93	472.41	1,232.46	1,002.28	761.32	
160	2,837.15	1,508.14	1,132.59	734.74	778.11	695.96	611.82	2,286.25	1,828.55	1,346.57	
200											
250	2,366.28	1,257.84	944.62	612.80	1,190.09	1,046.78	899.98	2,447.93	1,991.40	1,512.78	
315	3,635.73	1,932.64	1,451.38	941.55	1,626.60	1,398.82	1,165.52	3,559.24	2,850.20	2,107.07	
400	1,740.30	925.09	694.73	450.69	1,508.45	1,357.32	1,202.52	2,433.54	2,052.05	1,653.21	
500	3,320.82	1,765.24	1,325.67	860.00	2,007.11	1,770.93	1,529.01	3,772.35	3,096.59	2,389.01	
10	64.26	34.16	25.65	16.64	109.11	99.71	90.08	143.27	125.37	106.73	1 phase
20	278.80	148.20	111.30	72.20	170.79	156.79	142.46	318.99	268.09	214.66	
30	126.97	67.49	50.69	32.88	289.33	253.69	217.19	356.82	304.38	250.07	
50	396.78	210.92	158.39	102.75	429.38	366.18	301.43	640.30	524.57	404.19	

3.2.5 PSS/ Adept Program

Program which brought to calculate technical loss was PSS/Adept 5.0 of Power Technologies, INC.A Shaw Group Company which has step to use:

(a) model transmission lines or distribution lines

(b) feed parameter in model

(c) run program

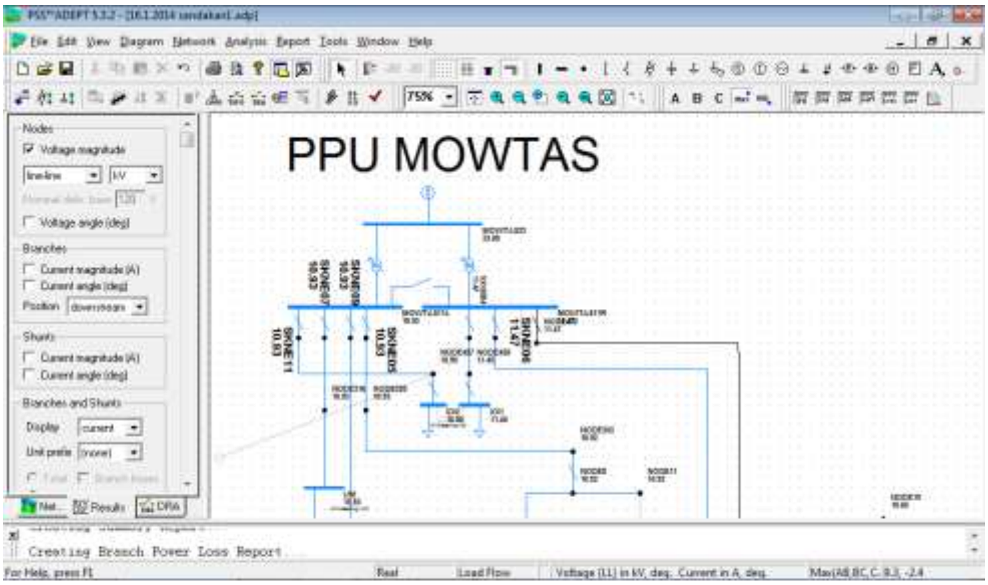


Figure 3.3. PSS/Adept program

3.3 Review of existing Power Losses in SESB

Different utility companies have their own power of losses. The designing of the system is based on their requirements, the overall power system network, country's demographic and etc. Currently, the statistic of power losses in SESB more than 20% that means losses in an electric system should be around 3% to 6%. In developed countries, it is not greater than 10%. However, in develop countries; the percentage of active power losses is around 20% [12].

The capacitor is capable of compensating reactive power which is required by system load as shown in Figure 3.1. By installing capacitor, current flow in the distribution system is reduced, thus, the system loss reduction as well. Capacitor also has voltage maintaining characteristic. It can reduce voltage drop during heavy load period. When capacitors are connected to the distribution feeder, they inject the reactive power (current) that reduces the current flow. During the light load period, capacitor may earn voltage rise that exceeds the permissible voltage range. It should be cautioned. Capacitor is not so expensive that it is easily applied [11].

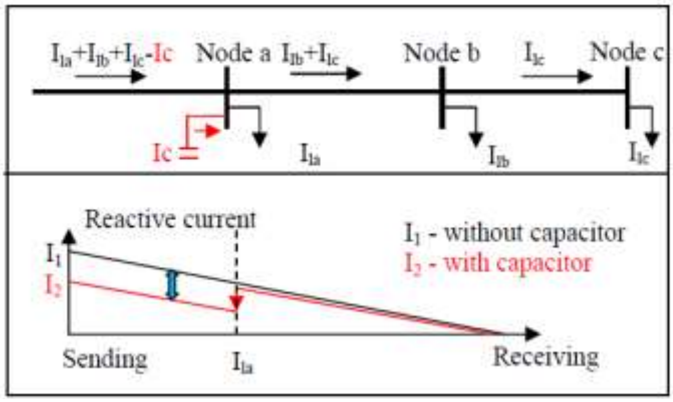


Figure 3.4: Reactive power compensation

Series capacitors are installed in transmission system mainly in order to compensate the line reactance, reduce voltage drop, and increase the power transfer capability and to reduce losses by optimizing load distribution between parallel transmission lines [12]. Series capacitor can also improve the voltage stability of the network when it installed in distribution systems. In series capacitor have the following benefits [13]:

(a) Improve voltage condition

(b) Enhanced stability performance

(c) Aid in load distribution and control overall transmission losses

The high-voltage shunt capacitors are primarily used to improve the power factor (cos φ) in the network, improve the voltage quality of transmission and distribution network, and compensate the reactive power. Shunt capacitor installation is composed of shunt capacitors, series reactor (damping reactors, tuning reactors), Zinc Oxide arrester and isolated earthing switch, etc. The capacitors are mounted on the steel rack made of profiled bar and connected according to certain electrical diagram. The installation can be transported entirely and mounted readily, and the installation can be available for various combine manners at special request of customer [8]. By applying shunt capacitors adjacent to equipment consuming reactive power, several advantages are obtained:

(a) Improved power factor

(b) Improved voltage quality

(c) Compensate the reactive power

(d) Reduced losses and investment

In SESB itself, power losses on distribution site its more than transmission line. This practice is carried out to ensure that Sabah Grid Code requirement with respect to severe system is satisfied following the low losses in distribution line. The insufficient power flow the distribution line cause to minimum efficiency of the system, maximum cost maintenance and minimum power quality.

3.4 Operational Framework

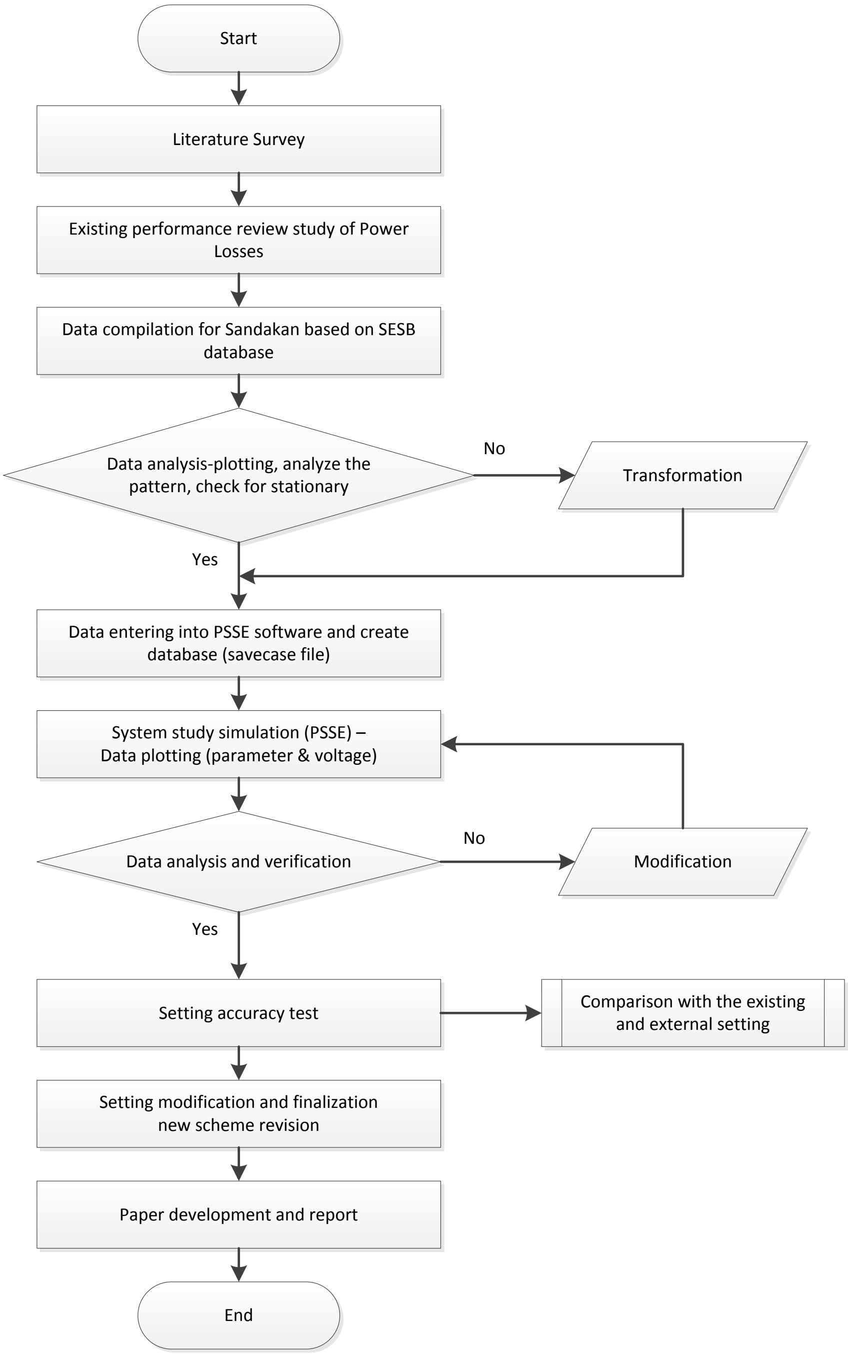


Figure 3.5: Operational Framework

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