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Calculation and Prediction of Technical Losses and Line Feeder Size Effect on Distribution Line Losses using PSS/Adept Program AS A Case Study

***Abstract**. This study was aimed to present a Technical loss analysis of the Provincial Electricity Authority (PEA) in Hatyai. To determine the technical loss in the distribution system included are Transmission Line Losses, Power Transformer Losses, Distribution Line Losses and Low-voltage Transformer and Distribution Line Losses. It was found that Low-voltage Transformer and Distribution Line Losses had a maximum value of 79 % and Technical loss was at 3.43. So in controlling or decrease Technical loss, the appropriate and correct method had to be selected by investigating both cost and worth. This study was also to determine distribution line losses by electrical model and to report on the power losses evaluation method as an improvement method to reduce the investigation cost for both transformer and capacitor selection. The study further aims at increasing the efficiency and reliability of the distribution system by reducing Technical Losses by increasing feeder size, power factor correction, reducing feeder impedance, lower transformer losses. It was discovered that line losses have much value at the end line. This was found to decrease when loads have constant distribution and are near the source. That is, line losses have lower value when lead lines have a larger size. Both load distribution and lead line sizes were observed to affect distribution line losses.*

Streszczenie.** Niniejsze opracowanie miało na celu przedstawienie analizy strat technicznych Urzędu Prowincji Energii Elektrycznej (PEA) w Hatyai. W celu określenia strat technicznych w systemie dystrybucyjnym uwzględnia się straty linii przesyłowej, straty transformatora mocy, straty linii dystrybucyjnej oraz straty transformatora niskiego napięcia i linii dystrybucyjnej. Stwierdzono, że straty transformatora i linii rozdzielczej niskiego napięcia miały maksymalną wartość 79%, a straty techniczne 3,43.. Badanie to miało również na celu określenie strat linii rozdzielczych za pomocą modelu elektrycznego i przedstawienie metody oceny strat mocy jako metody poprawy w celu zmniejszenia kosztów badania zarówno doboru transformatora, jak i kondensatora. Ponadto badanie ma na celu zwiększenie wydajności i niezawodności systemu dystrybucyjnego poprzez zmniejszenie strat technicznych poprzez zwiększenie rozmiaru zasilacza, korekcję współczynnika mocy, zmniejszenie impedancji zasilacza i zmniejszenie strat transformatora. Stwierdzono, że straty linii mają dużą wartość na linii końcowej. Stwierdzono, że zmniejsza się to, gdy obciążenia mają stały rozkład i znajdują się blisko źródła. Oznacza to, że straty linii mają mniejszą wartość, gdy linie prowadzące mają większy rozmiar. Zaobserwowano, że zarówno rozkład obciążenia, jak i rozmiary linii ołowianych wpływają na straty w linii dystrybucyjnej.* (Obliczanie i prognozowanie strat technicznych i wpływu rozmiaru linii zasilającej na straty linii dystrybucyjnej za pomocą programu PSS/Adept***)

Keywords: line losses, distribution line, loss factor, power flow, Newton-Raphson
Słowa kluczowe: straty mocy, linia dystrybucyjna, PSS/Adept

1.Introduction

Electrical Energy is the cleanest form of energy. Electrical energy is converted from various forms of conventional and non-conventional energy sources at suitable locations, transmitted at a high voltage over long distance and distributed to the consumers at a medium or low voltage. Generally, the definition of an electric power system includes a generation, transmission and distribution system [1]-[4]. Total system loss is the account of purchased energy over the sold one. In other words, total system loss indicates how effectively and efficiently a power system is delivering power to its customers. Hence became one of the controlling factor while planning and operating strategies. Most of the power utilities have high Transmission and Distribution (T&D) losses which occurs due to technical and nontechnical i.e. commercial losses. Total system losses consists of transmission and distribution losses. As the nontechnical transmission losses are negligible, total system losses consists of technical transmission loss and technical and nontechnical distribution losses. A distribution system is that of power system which distributes power to the consumers for local use. It consists of a large number of distribution transformers, feeders, and service mains,. The distribution system losses have two components, namely, technical and nontechnical or commercial, together called "total distribution loss" [3]-[6].

This research was to analyze technical loss of the Provincial Electricity Authority (PEA) in Hatyai. The analysis utilized calculation and PSS/Adept program. The evaluation was compared to Technical loss from calculation and measurement whose data included Technical loss and Non-technical loss for plan to select appropriate and correct method [4].

2.Technical losses in power system

Losses in electrical system can be determined in different ways. Electric technical losses occur as current flows through resistive materials and the magnetizing energy in the lines transformers and motors. However, the losses incurred in resistance materials can be reduced by adopting the following means, reducing line impedance, reducing current, and minimizing voltages [3]-[4].

Electrical power system losses can be computed using several formulae in considering the pattern of generation and loads, [7]-[9] by means of any of the following methods:

1. Computing transmission losses as $\left(I^2R\right)$
2. Using the differential power loss method.
3. Determining line flows and line losses.
4. Analyzing system parameters
5. Simulation of Load flow

3. Parameters Effect on Technical losses in Distribution systems

Technical losses in distribution systems are contributed by the high voltage (HV) to medium voltage (MV) substation transformers as well as by the MV distribution circuits, the MV to low voltage (LV) transformers, the LV circuits, the customer service drops, and the end-user meters. Loss ratios in the LV circuits, customer service drops, and end-user meters are estimated as approximately 2-3%. Transformer core (no-load) losses were estimated from the following [10]-[12].:

- The number of transformers for each region of the system.
- The average transformer kilovolt ampere capacity, calculated from available information.
- The magnitude of core losses in typical transformers.

4.Power flow in distribution system

The load-flow analysis is done by analyzing power system in steady-state in order to determine out the appropriate work point. In general, power system model was used and constant loads were distributed [1][13]-[15]. The power-flow equations take the following formula

(1) $$P_i + jQ_i = E_i I_i^*$$

when

(2) $$I_i = \sum_{k=1}^{N} Y_{ik} E_k$$

Substituting (2) in (1)

(3) $$P_i + jQ_i = E_i \left[\sum_{k=1}^{N} Y_{ik} E_k \right]^*$$

(4) $$P_i = |V_i| \left\{ \sum_{j \in \hat{\alpha}_i} |V_j| \, g_{ij} \cos(\delta_i - \delta_j) + \sum_{j \in \alpha_i} |V_j| \, b_{ij} \sin(\delta_i - \delta_j) \right\}$$

$$Q_i = |V_i| \left\{ \sum_{j \in \alpha_i} |V_j| \, g_{ij} \sin(\delta_i - \delta_j) - \sum_{j \in \hat{\alpha}_i} |V_j| \, b_{ij} \cos(\delta_i - \delta_j) \right\}$$

where: g_{ij} and b_{ij} b are the real and imaginary components of the entries of the nodal admittance matrix, δ_i is the angle of V_i, α_i denotes all neighbors or node i excluding i itself, and $\hat{\alpha}_i$ denotes the neighbors of i including i itself. We can analyze power-flow by Newton-Raphson method, which is repeated analysis.

The linearized power-flow equation can be written as follows:

(5) $$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{P\theta} & J_{PV} \\ J_{Q\theta} & J_{QV} \end{bmatrix} \begin{bmatrix} \Delta \theta \\ \Delta V \end{bmatrix}$$

where

$$\begin{bmatrix} J_{P\theta} & J_{PV} \\ J_{Q\theta} & J_{QV} \end{bmatrix} : \ Jacobian\ Matrix$$

where: ΔP - real power mismatch, ΔQ - Reactive power mismatch

Given an initial set of bus voltages, the real and reactive powers are calculated from the power-flow equations. The changes in power are the differences between the scheduled and calculated values

(6) $$\Delta P_i^k = P_{i(scheduled)} - P_i^k$$

(7) $$\Delta Q_i^k = Q_{i(scheduled)} - Q_i^k$$

We can analyze magnitudes and phase angle voltage in order to determine new results until real power error is admitted and the section is in the range of 10^{-4}-10^{-6}

(8) $$\theta^{(k+1)} = \theta^{(k)} + \Delta\theta^{(k)}$$

(9) $$V^{(k+1)} = V^{(k+1)} + \Delta V^{(k)}$$

The process continues until ΔP_i^k and ΔQ_i^k for all buses are within a specified tolerance. The sequence of steps for the load flow solution by the Newton-Raphson method is shown in Fig.1

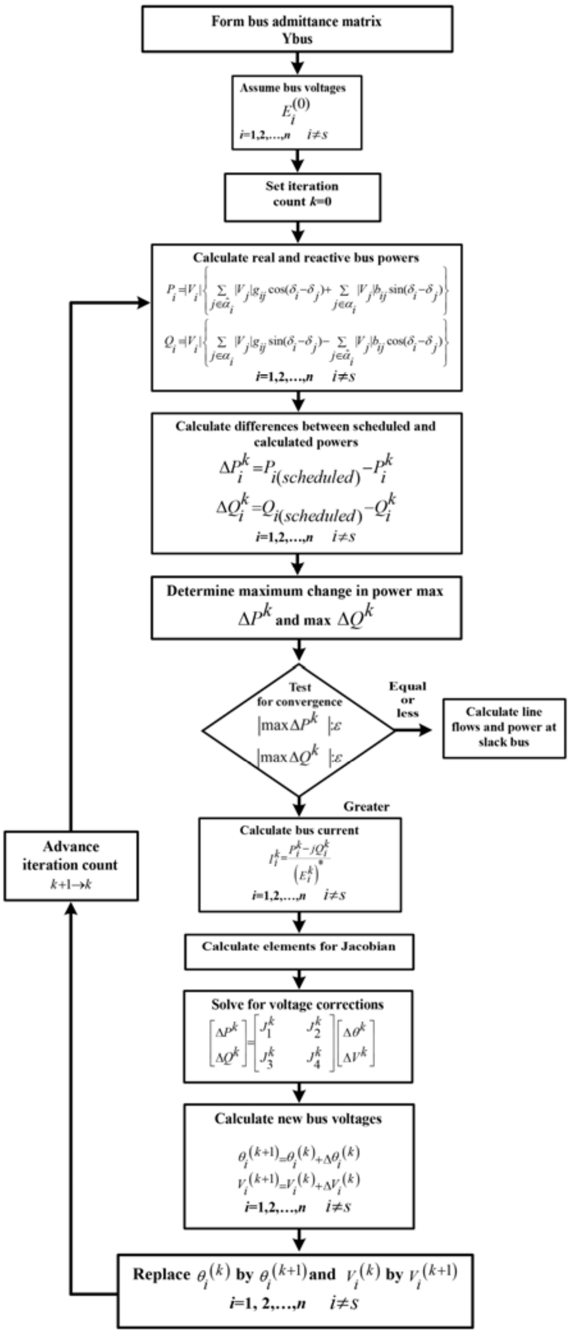

Fig1. The procedure for determining the power flow by the Newton-Raphson Method

5. Principle of power loss valuation [16]-[18].

The power loss in the power distribution system can be divided into two main parts:

1. Technical power loss is power loss that is related to the heat generated in the windings or conductor cable or the part resulting from the operation of the transformer and various electrical equipment. This includes the power loss caused by connecting insulating devices. The corona or

partial discharge in the electrical system as well. This technical loss unit follows the Losses $= I^2R$ rule, i.e. if the current is less, the unit loses less. Therefore, to supply the same power, if the higher voltage is applied, the less current unit loses less as well. The unit loss in the distribution system depends on the line type and load condition.

The technical power loss in the power distribution system is mainly It is caused by various components, which can be divided into 4 main parts:

- Loss in the feed line
- Power loss in distribution transformers
- Power loss in device connection
- Power loss in low voltage lines

2.Non-technical losses are power losses associated with incorrect power measurements. Tolerances of electrical metering devices or install a meter incomplete electricity as well as incomplete registration of electricity consumption units and billing of customers and illegal use of electricity, etc. [1][4]

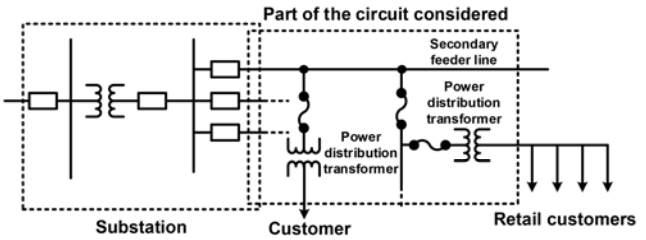

Fig 2. Determination of power loss in the primary circuit of the PEA distribution system

6. Technical Power Dissipation Evaluation

Using Electrical Modeling power loss (PL) in a power system depends on three main factors or parameters: [1][19]-[21]

- Type, Size and arrangement Network topology, τ
- Voltage magnitude and angle (V)
- The amount of electricity demand at different points (D)

The relationship between power loss and the main parameters are as follows

(10) $$PL = f(V, D, \tau)$$

In practice, the network topology (τ) is known through a single line diagram, and the accompanying data for accurate estimation of the technical power loss requires a clear working point in terms of V, D and τ. Estimated values are usually known from a load flow simulation.

P_1 and P_2, the power loss in the low load and high load ranges is P_{L1} and P_{L2} respectively.

(11) $$LF = \frac{P_{av}}{P_2}$$

where $\text{Load Factor(LF)} = \frac{\text{Average load}(\text{kW}_{\text{avg}})}{\text{Maximum load}(\text{kW}_{\text{peak}})}$

If the low load and high load values are assumed to be Determine load average

(12) $$P_{av} = \frac{P_2 \times t \times P_1(T-t)}{T}$$

where: t - High load times, T-t - low load time

So

$$LF = \frac{P_2 \times t \times P_1(T-t)}{P_2 \times T} = \frac{t}{T} + \frac{P_1}{P_2}\frac{(T-t)}{T}$$

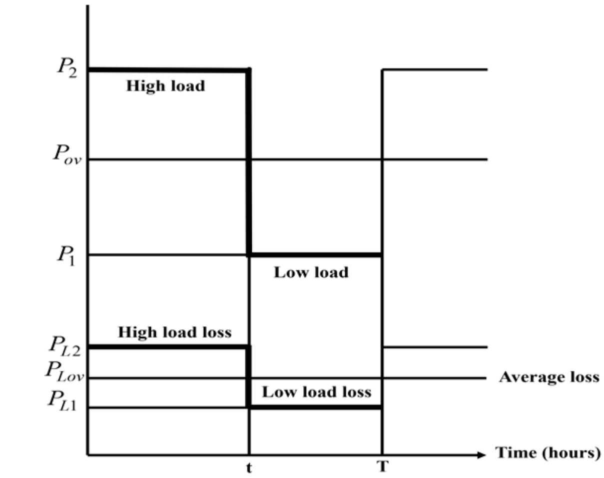

Fig.3. Load of feeder cable

From the definition of the power loss factor, it can be seen that

(13) $$LSF = \frac{P_{L,av}}{P_{L2}}$$

where: $P_{L,av}$ - Average loss power, P_{L2} - Power loss during peak load

$$P_{L,av} = \frac{P_{12} \times t \times P_{L1}(T-t)}{T}$$

So

$$LSF = \frac{P_{12} \times t \times P_{L1}(T-t)}{P_{L2} \times T}$$

The power loss in the conductor is normally proportional to the square of the load or current.

$$P_{L1} = k \times P_1^2$$
$$P_{L2} = k \times P_2^2$$

where k is a constant

$$LSF = \frac{k \times P_2^2 \times t \times k \times P_1^2(T-t)}{k \times P_2^2 \times T}$$
$$= \frac{t}{T} + \left(\frac{P_1}{P_2}\right)^2 \frac{(T-t)}{T}$$

We can determine the relationship between load factor and power loss factor by dividing it into three cases as follows.

Case 1 Low load is zero. $P_1 = 0$

So

$$LF = LSF = \frac{t}{T}$$

Case 2 The duration of high load is very low. ($t \to 0$)

So $\frac{(T-t)}{T}$ is close to 1

Therefore, LSF has a value approaching $(CF)^2$

Case 3 The load is always constant (t → T), e.g. in the case of loading in a petrochemical plant. etc., it is found that LSF is closer to LF.

From the above three cases, the relationship between the loss power factor and the load factor can be summarized as follows:

$$LF^2 < LSF < LF$$

The equation shows that the LSF is less than 1.0, but we cannot determine the power loss factor directly from the load factor because the power factor is losing load size and duration occurrence of the load. However, there have been studies to estimate the relationship between the loss power factor and the load factor as follows:

(14) $$LSF = 0.33LF + 0.67LF^2$$

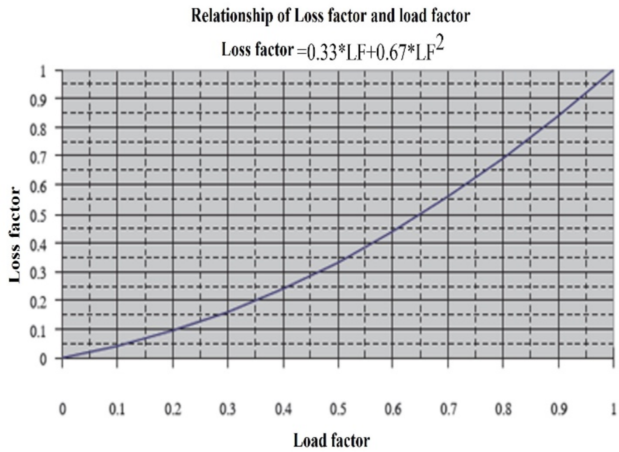

Fig.4. Loss factor and load factor relationship values

7.Estimating power loss based on load distribution

In assessing the power loss in the PEA's high voltage distribution system, take the Single Line diagram and details of the equipment in the feeder line such as the power supplied to the feed line recorded at the power station. It is used to estimate and allocate the load to each transformer installed in the distribution system[22]-[24].

The power supplied to the feed line is in accordance with the equation [4]

(15) $$P_{sub} = P_{load} + P_{loss}$$
$$Q_{sub} = Q_{load} + Q_{loss}$$

where: P_{sub}, Q_{sub} - Active and reactive power saved in substations, P_{load}, Q_{load} -The sum of active and reactive power at all load points, P_{loss}, Q_{loss} - Active and reactive power loss in power distribution system

To modify the individual transformer load values, the proportion according to the distribution transformer size and the utilization rate was used
which is defined at that load point (α_i) as follows:

(16) $$\alpha_i = \frac{UF_i \cdot kVA_{Tr(i)}}{\sum_i^N UF_i \cdot kVA_{Tr(i)}}$$

Therefore, the equation used for the load modification for the i-th transformer

(17) $$P_{Load(i)}^{(k+1)} = P_{Load(i)}^{(k)} - \alpha P_{err}^{(k)}$$

(18) $$Q_{Load(i)}^{(k+1)} = Q_{Load(i)}^{(k)} - \alpha_i Q_{err}^{(k)}$$

where: $P_{err}^{K}, Q_{err}^{(k)}$ -Tolerances for active and reactive power at the source (Slack bus) or point of supply to the feed line

8. Power Dissipation Assessment in Transmission Line System in the transmission line system.

The electrical power is transmitted at a voltage of 115 kV. Balanced three-phase loads are supplied. by various information in the system such as the power supplied to the system, Power supplied to the load at different times and transmission line information in the system will be recorded in its entirety in the meter at the point of purchase of electricity from the Electricity Generating Authority of Thailand and at the CSCS system of the power station. To assess the power loss in the transmission line system[23]-[26],the calculation of the unit loss in the transmission line can be calculated from the formula
Transmission Line Losses

(19) = Loss Factor x Line Losses xTime Period

The calculation procedure is

1. Determine the Loss Factor of each line from the formula

(20) $$\text{LossFactor}=0.33\text{LF}\times 0.67\text{LF}^2$$

2. Determine the average load (kW_{avg}) of each line

$$\text{kW}_{avg} \frac{\text{Distribution unit}}{\text{period}}$$

3. Determine the maximum load (kW_{peak}) of each line

It can be found from the monthly highest-lowest load report (Load 01) of the power station.

4. Determining the Load Factor (LF) of each line

(21) $$\text{Load Factor(LF)}=\frac{\text{Average load}(\text{kW}_{avg})}{\text{maximum load}(\text{kW}_{peak})}$$

5. Determine the Line Losses of each line.

This calculates Line Losses using PSS/ADEPT 5.0 program of Power Technologies, INC.A Shaw Group Company.

Where period = 24 x 365 = 8760

9. Evaluation of power loss in power transformers

The technical loss unit in a transformer consists of two main parts: [1][4]-[5]

1.No Load Losses is the unit of loss incurred in the transformer iron core caused by the current inducing magnetic lines in the transformer iron core when the transformer is energized, provided that the core loss is constant (at voltage fixed)

2. Load Losses is the unit of losses incurred in the transformer windings. It occurs when the transformer is supplied to the load. That is, there is an electric current flowing through the coil. Formerly known as Copper Losses, now transformers use aluminum coils instead of copper coils. Therefore, this unit of loss is called Winding Losses. The loss unit in this winding corresponds to the equation for calculating the loss unit that Losses $= I^2 R$ .Because the unit loss in this section will occur only when there is current flowing through the coil and from the equation it was found that the unit loss in the winding is proportional to the square of the load current; so, it is called Load Losses. Therefore, when the transformer load is used more, the unit loss in this section will be greater. This type of loss unit is therefore considered important because it is the most common loss unit occurring in the transformer.

10. Calculation of unit losses in power transformers can be calculated from the formula

Transformer Losses

(22) = *Winding Losses + No Load Losses*

The calculation procedure consists of two loss units:

1. No Load Losses

1.1 Collect power transformer data to Determine No Load Losses from the Transformer Loss Unit Table. The information that must be known is

- Power transformer size (MVA)
- Power transformer brand

from the size information and the brand of the transformer to know the Core Losses and Copper Losses or is the value No Load Losses and Load Losses (Full Load) in the calculation formula. This information can be obtained from the test report of the transformer company or from the PEA standard [4].

2. Winding Losses [4][5]

This is because the Winding Losses unit varies with the rated load on the transformer. It varies according to square value of load current. Therefore, the unit of maximum load loss (Peak Load Losses) can be calculated from the formula

Winding Losses

$$= \frac{MVA_{peak}^2}{MVA_{rated}^2} \times LoadLosses \times LossFactor \quad (23)$$

$\left[\frac{MVA_{peak}^2}{MVA_{rated}^2} \times LoadLosses\right]$ Determine the Load Losses at that Peak Load value. $\left[\frac{MVA_{peak}^2}{MVA_{rated}^2}\right]$

Equal to the UF^2 value, the UF value can be obtained from the report, the monthly maximum-minimum load report (Load 01).

Due to $UF=\frac{I_{peak}}{I_{rated}}$ so at the same pressure

$$\frac{MVA_{peak}}{MVA_{rated}} = \frac{I_{peak}}{I_{rated}} = UF \quad (24)$$

The procedure for calculating Winding Losses is as follows:

2.1 The Load Losses value can be found from the Test Report of the transformer company or from PEA standard, which the value obtained is the value of Load Loss at Full Load. The loss unit obtained from the table is therefore the unit of loss at the maximum load (Peak Loss).

2.2 Determining the Loss Factor can be calculated to determine the Loss Factor from the formula

Loss Factor

$$= 0.2\times(\text{Load Factor}) + 0.8\times(\text{Load Factor})^2 \quad (25)$$

The relationship between the maximum load and the average load are called Load Factor. It can be calculated from

Loss Factor

$$LF = \frac{kW_{avg}}{kW_{peak}} = \frac{MVA_{avg}}{MVA_{peak}} \quad (26)$$

1.Determine the average load of the transformer. (MVA_{avg})()

If the reading of the power transformer meter is not readable at the outgoing of each feeder which is in kWh divided by the period to convert to kW and then divided by the PF value of that power transformer to convert the unit to kVA.

2.Determine the maximum load of the transformer (MVA_{peak}).

The maximum load of each power transformer can be obtained from the monthly maximum-minimum load report (Load 01) of the Power Supply Control Department and convert the value from MW to MVA by dividing the maximum load by the PF of that power transformer.

3. Determine the Load Factor (LF)

Load Factor is the ratio between average load and maximum load. Therefore, the Load Factor can be found by taking the average load (MVA_{avg}) in (25) is divided by the maximum load. (MVA_{peak}) in (26).

4.Determine the Loss Factor of each power transformer.

5.Determine the $\left[\frac{MVA_{peak}^2}{MVA_{rated}^2}\right]$ or the power factor of the Peak Loading Factor is the ratio between the maximum load of the transformer and the transformer size)

6.Determine the Transformer Losses to the formula

11.Power Dissipation Evaluation in High Voltage Distribution System

To estimate the power loss, information from the Single Line Diagram is used, The details of the equipment in the feeder line and the power supplied to the feed line recorded at the power station every 1 hour to be used for estimation and allocate the load to each distribution transformer according to the transformer size. The calculation of the unit loss in a high voltage distribution system can be calculated from the formula [12]-[14].

Distribution Line Losses

(27) = Loss Factor x Line Losses x period

The calculation procedure is

1.Determine the Loss Factor for each feeder from the equation.

$$\text{LossFactor} = 0.33\text{LF} \times 0.67\text{LF}^2$$

2. Determining the average load (kW_{avg}) of each feeder

$$\text{kW}_{\text{avg}} = \frac{\text{Distribution unit}}{\text{time}}$$

3.Determination of the maximum load (kW_{peak}) of each feeder

It can be found from the monthly highest-lowest load report (Load 01) of the power station.

4. Determining the Load Factor (LF) of each feeder

$$\text{Load Factor(LF)} = \frac{\text{Average load}(\text{kW}_{\text{avg}})}{\text{maximum load}(\text{kW}_{\text{peak}})}$$

5. Determine the Line Losses of each feeder using Power Technologies, INC.A Shaw Group Company PSS/ADEPT 5.0

Table **1**. Determination of unit loss of distribution transformer

PEA STANDARD LOSSES						
Transformer rating	3 Phase Watt Losses				(OLD) Load Losses	(NEW) Load Losses
	No-Load Losses for system voltage of:					
kVA	22 kV(old)	22 kV(new)	33 kV(old)	33 kV(new)	at 75 C	at 75 C
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

PEA STANDARD LOSSES						
Transformer rating	3 Phase Watt Losses				(OLD) Load Losses	(NEW) Load Losses
	No-Load Losses for system voltage of:					
kVA	22 kV(old)	22 kV(new)	33 kV(old)	33 kV(new)	at 75 C	at 75 C
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

PEA STANDARD LOSSES						
Transformer rating	1 Phase Watt Losses				(OLD) Load Losses	(NEW) Load Losses
	No-Load Losses for system voltage of:					
kVA	22 kV(old)	22 kV(new)	33 kV(old)	33 kV(new)	at 75 C	at 75 C
10	75	60	75	60	160	145
20	120	90	120	90	330	300
30	160	120	160	120	480	430
50	200	150	200	150	740	670

12. Calculation of power loss in distribution transformers [1]-[4][27][28]

The calculation of the unit losses in the transformer can be calculated from the equation

Transformer Losses

$$= \left[\frac{kVA_{peak}^2}{kVA_{rated}^2} \times LoadLosses \times LossFactor \right] + NoloadLosses \tag{28}$$

The procedure for calculating unit losses in distribution transformers is as follows.

1. Determine No Load Losses Values of No Load Losses or Core Losses of each size of distribution transformer can be found from PEA Standard Losses Table.

2.Determining the Loss Factor can be calculated. Determine the Loss Factor from the formula

Loss Factor = 0.2× (Load Factor) + 0.8×(Load Factor)

relationship between the maximum load and the average load are called Load Factor. It can be calculated from

$$LoadFactor = LF = \frac{kW_{avg}}{kW_{peak}} = \frac{kVA_{avg}}{kVA_{peak}}$$

1.Determine the average load of the transformer.

The average transformer load (kVA_{avg}) can be obtained from the distribution sum of all meters supplied from that distribution transformer which is in kWh. Convert to kW by dividing by period. and converted to kVA by dividing by PF (which according to the agreement between EGAT and PEA is 0.875).

2.Determine the transformer maximum load

It can be obtained from the transformer load measurement data during the peak load time of the EGAT site, which is measured once a year in kW, converted to kVA by dividing by the PF value (which according to the agreement between EGAT and PEA equal to 0.875)

3. Determine the Load Factor (LF) of the transformer.

Load Factor (LF) is the ratio between average load and maximum load. Therefore, the Load Factor can be found by taking the average load $\left(kVA_{avg}\right)$ in (25) and dividing by the maximum load $\left(kVA_{peak}\right)$ in (26).

4. Determine the Loss Factor of each transformer.

5. Determine the $\left[\frac{kVA_{peak}^2}{kVA_{rated}^2}\right]$ in other words, the power factor of Peak Loading Factor is the ratio between the maximum load of the transformer and the transformer size), which can be obtained from the maximum load value from 2.2.2 and the transformer size from 1.1.

6. Determine the Transformer Losses the formula

7. Determine Distribution Transformer Losses by multiplying the number of installed transformers by Transformer Losses.

13. Calculation of power loss in a low voltage distribution system

Unit loss in a low voltage distribution system follows the Losses $= I^2 R$ rule. In the low voltage distribution system, the minimum value can be done in 2 ways:

1.Install the conductor cable so that the load carrying size is larger than the requirement of the installed load.

2. Supply electricity with the shortest distance between the transformer and the consumer. That is the length of the conductors is as small as possible.

In a low voltage distribution system, the unit loss depends on the load distribution. There are 3 types:

1. The load is evenly distributed.
2. Most of the loads are at the end of the feeder cable.
3. Most loads are at the beginning of the feed line.

$$Loss_{LV} = I_{eq}^2 R_b L_{eq} \tag{29}$$

where: I_{eq} - Equivalent load current (It is known from the load estimation for each transformer based on the transformer size and the amount of electricity supplied by the station.), R_b - Resistance in cable size 50 ACSR, L_{eq} - Equivalent length

$$I_{eq} = \sum_{i=1}^{n} I_i \tag{30}$$

where: I_i - load current of each power user, *n* - Number of power consumers behind distribution transformers

Because the low-voltage conductors are of different sizes. Therefore, for the convenience of computation at this stage, the wire resistance type 50 ACSR is chosen as the base value used in the equivalent circuit. We can show the relationship between the fundamental value (R_b) and the resistance of other conductor sizes.

(31) $$R_i = \alpha_i R_b$$

where: R_i -The impedance of the conductors of various sizes (know from an estimate of the load to each transformer based on the size of the transformer and the amount of electricity supplied by the station), α_i - Line resistance conversion coefficient

Equivalent length of the circuit on the low voltage side can be calculated according to equation

(32) $$L_{eq} = \frac{\sum_{i=1}^{n} I_i^2 \alpha_i L_i}{I_{eq}^2}$$

By the Provincial Electricity Authority, The power loss in the low voltage distribution system is determined. As follows, the calculation of the unit loss in the distribution system can be calculated from the formula

Unit loss in low voltage distribution system

(33) = Loss Factor x Line Losses x period

The calculation procedure is

1.Determine the Loss Factor of each Feeder from the equation

$$\text{Loss Factor} = 0.33\ LF + 0.67\ LF^2$$

1.1 Determine the Load Factor (LF)

Since Load Factor (LF) is the ratio between average load $\left(kW_{avg}\right)$ and peak load $\left(kW_{peak}\right)$, but in a low voltage distribution system, no load data is stored, the Load Factor (LF) of the transformer is used in the calculation, i.e.

$$LoadFactor = LF = \frac{kW_{avg}}{kW_{peak}} = \frac{kVA_{avg}}{kVA_{peak}}$$

1.Determine the average load of the transformer.

The average transformer load $\left(kVA_{avg}\right)$ can be obtained from the distribution sum of all meters supplied from that distribution transformer, which is in kWh. Convert to kW by dividing by period and converted to kVA by dividing by PF (which according to the agreement between EGAT and PEA is 0.875).

2.Determine the maximum load of the transformer.

It can be obtained from the transformer load measurement data during the peak load time of EGAT on site, which is measured once a year, which is in kW, converted to kVA by dividing by the PF value (which according to the agreement between EGAT and PEA are 0.875)

3.Determine the Load Factor (LF) of the transformer.

Load Factor (LF) is the ratio between average load and maximum load. Therefore, the Load Factor can be found by taking the average load $\left(kVA_{avg}\right)$ in (25) divided by the maximum load $\left(kVA_{peak}\right)$ in (26).

4.Determine the loss factor of each transformer.

Table **2**. The table show determination of unit losses in distribution transformers and low voltage distribution lines

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				3 phase
50	331.65	176.30	32.40	85.89	416.31	359.46	301.23	592.60	491.85	387.12	
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	
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	

14.Determine the Line Losses of each circuit using Power Technologies, INC. A Shaw Group Company's PSS/ADEPT 5.0 program.

In this regard, PEA was used to analyze the Loss Distribution Line & Transformer according to the table for ease of use in the analysis of the loss distribution in low voltage distribution systems and distribution transformers.

The program to calculate technical loss was PSS/Adept 5.0 of Power Technologies, INC.A Shaw Group Company. The steps were:

1. model transmission lines or distribution lines
2. feed parameter in model
3. run Program

The program has the features to determine the power flow as follows. [7]

- Solve problems under steady conditions
- Compatible with three-phase systems
- Used with Y-bus problem solving techniques.
- Compatible with multi-source and complex networks
- Starting at 1.0 pu voltage at each point (node)
- Transformer taps can be adjusted during power flow determination.

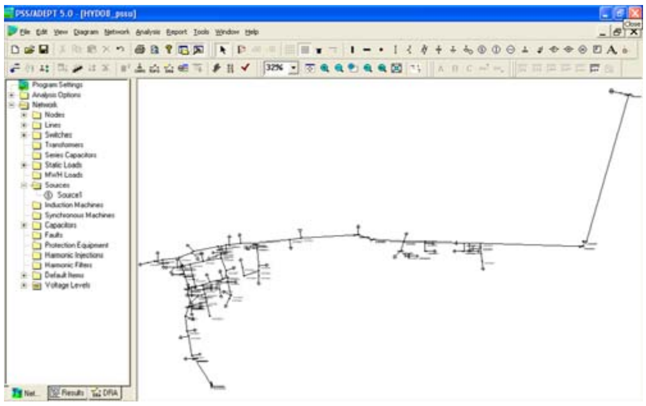

Fig.5. PSS/Adept program

15.Guidelines for improving the power loss of PEA [4].

15.1 Reducing power losses in transformers

1. Reducing the size of the transformer

To improve power quality, we may consider starting from the improvement of transformer sizing guidelines.

Currently, the transformers installed in the system are too large. Optimizing the size of the transformer will reduce the electrical energy loss. In determining the criteria for transformer size selection, consider that "the normal maximum load of the transformer should be approximately 80% of the transformer size". Theoretically this may be appropriate, but if in practice, the estimate of the peak load of the power user is inflated. More so, not taking the Coincident factor or diversity factor into consideration will cause the maximum load of the feeder circuit to be inflated. This leads to the choice of transformer size that is too large. Additionally, the peak load estimation of power consumers tends to be inflated. This may be due to the size tolerance of the load, which will make it safe to choose equipment and operations. Therefore, considering the transformer sizing based only on the maximum load value alone, may not be appropriate and lead to transformer sizing that is too large. Taking the average load into consideration should make the selection of transformer size better, for example, PEA has an overall load factor of about 0.6, Therefore, the criteria for selecting a transformer size based on average load may be around 0.6. × 0.8 = 0.48 of the transformer sizes, etc. The proposed selection of transformer sizes may be improved as follows: "Normal maximum load of the transformer should be no more than 80% and the average load of the transformer should be not less than 45% of the transformer size" etc. However, if at the time of installation of the transformer, the maximum load is approximately 70% of the transformer size and the load increases at approximately 5% per year, each newly installed transformer will supply the load for approximately 7-8 years until the load is increased to its full rated value. Such actions would increase the workload of the officers. On the other hand, PEA's electricity distribution efficiency will improve as well.

2. Increasing Transformer Utilization
For the transformer installed in the original system, the normal usage factor should be higher as well. In order to make full use of the transformer and increase efficiency according to the principle of improving efficiency by calculating the Load factor, Utilization factor of the feeder transformer It will help PEA's load distribution to be more efficient.

15.2 Reducing power loss in line

Guidelines for reducing power loss in the line include:

1. Improve the power factor of the line.

The improvement of the load power factor allows a lower magnitude of the current flowing in the feed line, resulting in lower real power loss.

2. Increase the size of the conductors appropriately

In order to increase the size of the low voltage conductor, the PEA has set the standard for the selection of conductor sizes according to the transformer size and circuit characteristics of low voltage cables. However, it must take into account the voltage drop in the cable per ampere per kilometer, which can be calculated as follows [4][5][9]

(34) $$V.D. = \sqrt{3}\times I\times(r\cos\theta + x\sin\theta)\times L$$

(35) $$\overline{V.D.} = \sqrt{3}\times(r\cos\theta + x\sin\theta)$$

where: $V.D$ - The voltage drops at the end of the feed line, I - The average current flowing in each phase of the feed line, r - The resistance in kilometers-meters of the feeder cable, x -The average reactance per kilometer of the feed line, θ -The phase angle between the phase voltage and the current of each feed line can be calculated from the power factor (θ = $cos^{-1}(p.f.)$), L -The length of the feed line in kilometers, $\overline{V.D}$ -*The* voltage drops per ampere per kilometer.

The focus of this research was to study the technical loss at the Provincial Electricity Authority Region 3 (Southern) Yala Province, including Hat Yai District, Songkhla Province, by considering the Power Loss value that occurred using PSS/ADEPT 5.0 program, which is a program that the Provincial Electricity Authority use in calculating Technical Loss in transmission lines and high voltage distribution systems

16. Power Dissipation in Power Transformer

Provincial Electricity Authority Hat Yai District has 8 power transformers at the power station to convert voltage from 115 kV to 33 kV as follows:

1.Hat Yai Power Station 3 has 2 units, each with a size of 50 megavolt amps, ABB products.

2.Hat Yai Power Station 4 has 2 units, each with a size of 50 megavolt amps, ABB products.

3.Rattaphum Power Station, there are 2 units, each with a size of 50 megavolts amps, EKAART DAIHEN products.

4.Chalung Power Station has 1 unit, size 50 megavolt amps, ABB product.

5.Ban Phru Electricity Station has 1 unit, size 50 megavolts amp, ABB product.

17.Power Dissipation in Distribution System 33 kV

In the Provincial Electricity Authority, Hat Yai District, there are a total of 7 power stations, 33 kV distribution system as follows:

1. Hat Yai Power Station 1
2. Hat Yai Power Station 2
3. Hat Yai Power Station 3
4. Hat Yai Power Station 4
5. Rattaphum Electricity Station
6. Chalung Electricity Station
7. Ban Phru Electricity Station

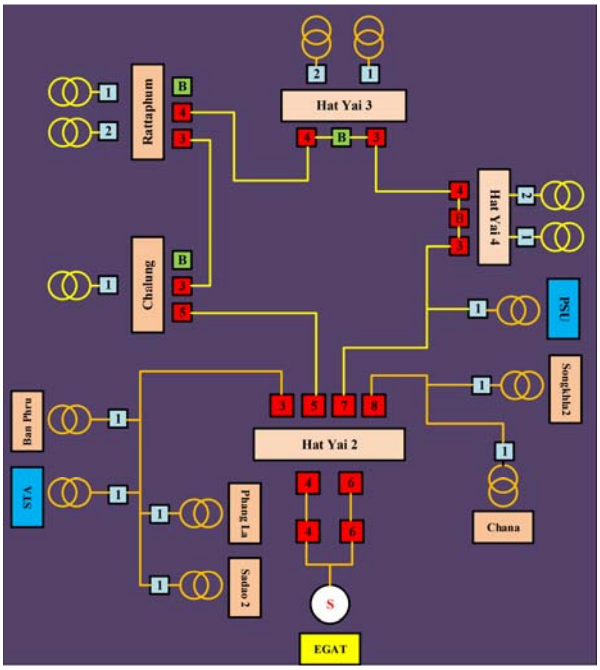

Fig 6. Single Line Diagram 115 kV system

18.Power Dissipation in Transmission Line System

Provincial Electricity Authority, Hat Yai District Receive electricity from the Electricity Generating Authority of

Thailand (EGAT) through a 115 kV transmission line including the following:

- Line1 supplies electricity to Hat Yai 4 Electricity Station and Prince of Songkla University.
- Line2 supplies electricity to Hat Yai Power Station 3, Chalung and Rattaphum.

The Single Line Diagram of the 115 kV system of the Provincial Electricity Authority is shown in Figure 6. It has a closed loop style which is currently being supplied in the manner of Line 1 and 2, but if there is a power failure, there will be a change in the power supply as shown in the fig. 6.

Transmission line including is line1 supplies electricity to Hat Yai 4 Electricity Station and Prince of Songkla University and line2 supplies electricity to Hat Yai Power Station3, Chalung and Rattaphum.

19.Power dissipation in distribution transformer and low voltage distribution system

In the Provincial Electricity Authority, Hat Yai District, there are 3,198 transformers for sale, divided by size as follows: Size 30 kVA of 996 units, size 50 kVA of 349 units, size 100 kVA of 648 units, Size 160 kVA of 448 units, size 250 kVA of 430 units, size 315 kVA of 83 units, size 400 kVA of 99 units and size 500 kVA of 145 units.

From this data, we can provide procedure 2 steps include:

1.Calculation for transmission and distribution line losses. In calculation for transmission and distribution line losses, we can determine line losses by PSS/Adept.

2.Calculation for power and distribution transformer losses

In calculation for transformer losses, we have to know brand and size to Determine no load Losses and Load Losses from Test Report of manufacturer.

20.Determine the power loss in distribution transformers and low voltage distribution systems.

In determining the power loss in a distribution transformer and low voltage distribution system, PEA has analyzed the power loss by using load distribution method which uses the loss factor as a criterion to divide the area. This loss factor is determined from the maximum-minimum load data of each feed. The spider measured from the power station therefore, is to determine the power loss in distribution transformers and low voltage distribution systems considering the size and the number of transformers installed to be calculated with the Losses values.

21. Technical Loss Unit Analysis Procedure

1.The technical loss power of each type was compared to determine the percentage of power loss in the system of the Provincial Electricity Authority, Hat Yai District.

2.The technical loss unit value and the power purchase unit from the Electricity Generating Authority of Thailand was calculated to determine the percentage of technical losses. This was then compared with the measurement criteria of the Provincial Electricity Authority in Hat Yai District.

3. A suitable method to reduce the technical power loss that occurs in each category was determined.

22.Results

22.1 Power loss in transmission lines

The Provincial Electricity Authority of Hat Yai District receives electricity from the Electricity Generating Authority of Thailand (EGAT) through two 115 kV transmission lines, namely: Line1 supplies electricity to Hat Yai Electricity Station 4 and cc. Line2 distributes electricity to Hat-Yai Electricity Station 3, Chalung and Rattaphum.

The result of the calculation of the unit loss in the transmission line is shown in Table 3.

Table 3. The value of the unit of loss in the transmission line of the Provincial Electricity Authority, Hat Yai District

Line	MW_{avg}	MW_{peak}	LF	Loss Factor	peak Loss (kW.) From PSS/Adept	Transmission Line Loss including the circuit (kWh. /Year)
Line 1	57.830	91.1	0.635	0.479	116.721	490,248
Line 2	28.916	38.4	0.753	0.628	651.694	3,587,514
Total Transmission Line Losses						4,077,762

22.2 Power Dissipation in Power Transformers

The Provincial Electricity Authority of Hat Yai District has 8 power transformers at the power station, namely: Hat Yai power station 3, Hat Yai power station 4, Rattaphum power station, Chalung power station and Ban Phru power station. But Ban Phru Power station unit of measurement could not be read because there was no measuring device.

Table 4. Unit loss in power transformers of the Provincial Electricity Authority, Hat Yai District

Power station	Loss in 1 year
Hat Yai 3	544,832
Hat Yai 4	647,157
Rattaphum	453,935
Chalung	320,157
Ban Phru	-
Total Power Transformer Losses	1,966,081

22.3 Power Dissipation in Distribution System 33 kV

The unit loss in the distribution system of all 7 stations of 65 circuits can be summarized as the loss in the distribution system of the Provincial Electricity Authority, Hat Yai District, according to Table 5.

Table 5. Unit loss in the distribution system of the Provincial Electricity Authority, Hat Yai District

Power station	Loss in 1 year
Hat Yai 1	489,849
Hat Yai 2	296,785
Hat Yai 3	436,204
Hat Yai 4	549,701
Rattaphum	286,703
Chalung	568,672
Ban Phru	307,853
Total Distribution Line Losses	2,935,767

22.4 Power dissipation in distribution transformers and low voltage distribution systems

The result of calculating unit losses in distribution transformers and low voltage distribution systems is shown in Table 6.

Table 6. Unit loss in distribution transformers and low-voltage distribution systems of the Provincial Electricity Authority, Hat Yai District

Transformer size	Number (machine)	In the distribution system			In distribution transformer			Total Losses
		Total Loss/ 1 unit (w)	Total Loss (w)	Total Loss in 1 year (kwhr)	Total Loss/ 1 unit (w)	Total Loss/ 1 unit (w)	Total Loss in 1 year (kwhr)	
30	996	32.88	32,748	286,877	217.19	216,321	1,894,974	2,181,851
50	349	85.89	29,976	262,586	301.23	105,129	920,932	1,183,519
100	648	445.35	288,587	2,528,020	556.93	360,891	3,161,402	5,689,422
160	448	1,132.59	507,400	4,444,827	695.96	311,790	2,731,281	7,176,108
250	430	944.62	406,187	3,558,195	1,046.78	450,115	3,943,011	7,501,206
315	83	1,932.64	160,409	1,405,184	1,626.60	135,008	1,182,668	2,587,852
400	99	925.09	91,584	802,275	1,508.45	149,337	1,308,188	2,110,463
500	145	1,765.24	255,960	2,242,208	2,007.11	291,031	2,549,431	4,791,639
Total		15,530,172			17,691,888			33,222,060

22.5 Technical Losses

The calculation of the technical losses in all 4 types of Provincial Electricity Authority in Hat Yai District are:

1. Power Dissipation in Transmission Line 115 kV
2. Power Loss in Power Transformer
3. Power Dissipation in Distribution System 33 kV
4. Power Dissipation in Distribution Transformers and low voltage distribution system

The result was shown in Table 7 and Figure 7.

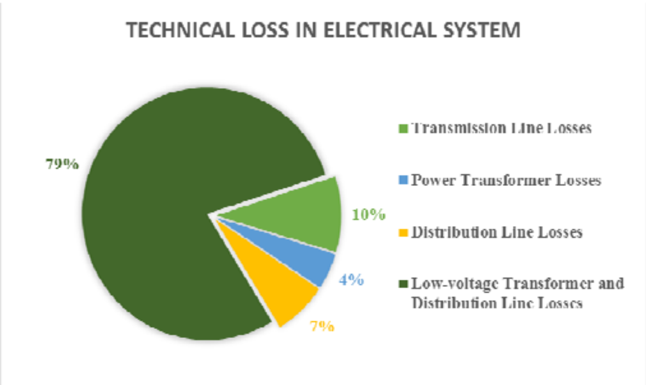

Fig. 7. Technical Loss in Distribution system

Table 7. Technical loss in Distribution system

Type of Loss	Loss (kwhr)	%Loss
Transmission Line Losses	4,077,762	10%
Power Transformer Losses	1,966,081	4%
Distribution Line Losses	2,935,767	7%
Low-voltage Transformer and Distribution Line Losses	33,222,060	79%
Total	**42,201,670**	**100%**

23. Simulation Distribution Line Losses in Feeder Line (Sample of feeder line size, 95 mm^2 and 185 mm^2)

In line loss evaluation, single line diagram and real network parameter are used to estimate and scale loads [7]-[8].

Basic equation of power losses:

$$P = I^2 R$$

We investigated load with 5.3 MW, 1.6 MVAR, PF 0.957, 33 kV system, and 10 km distance.

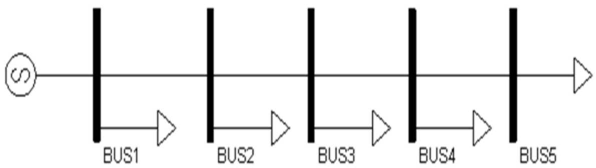

Fig.8. Case 1 lead line size 185 mm^2

Case 1 lead line size 185mm^2

Table 8. lead line size 185mm^2

Load	R	X	P (kW)	Q (kVAR)	I (A)	Ploss (kW)	PF
Constant	0.21	0.41	5317	1561	96.9	17.88	0.96
End	0.21	0.41	5338	1590	97.4	38.44	0.958
origin	0.21	0.41	5310	1551	96.8	10.90	0.96

Case 2 lead line size 95 mm^2

Table 9. lead line size 95mm^2

Load	R	X	P (kW)	Q (kVAR)	I (A)	Ploss (kW)	PF
Constant	0.41	0.59	5335	1601	97.4	35.29	0.958
End	0.41	0.59	5376	1644	98.3	76.28	0.956
origin	0.41	0.59	5321	1586	97.1	21.44	0.958

In case of higher size of line feeder, it was found that power consumption of bigger sizes has lower loss in the system as Table 8. Alternatively, the power quality big size of line feeder is higher than small size line feeder as Table 9.

24. Distribution Line losses Reduction

Line losses improvement should be investigated at the end line and low voltage side.

1.Ways to decrease losses in distribution transformer

- decrease transformer size by the ratio of 80%
- increase transformer utilization

2.Ways to decrease losses in feeder

- improve power factor by capacitor installation.
- increase lead line size for decrease voltage drop in line

In distribution system, line losses have much value at end line and will decrease when loads have constant distribution and they are near the source. Line losses have lower value when lead lines have higher size. Both load distribution and lead line size have effect on distribution line losses. This paper proposes how to calculate line loss in feeder and improve line loss problem. Therefore, to solve this problem, appropriate methods should be selected which must investigate both cost and safety to electric distribution in an efficient manner and get the best use of energy [29].

25. Conclusion

This research was aimed to present Technical loss analysis of Provincial Electricity Authority (PEA) in Hatyai. This analysis used calculation and PSS/Adept program.

We can conclude this research that:

1.Technical loss from calculation was at 3.43 when compared with loss from measurement which was at 4.33 or 79 %. So it is necessary to reduce technical loss and control non-technical loss too.

2.Maximum technical loss occurred in low-voltage transformer and distribution line was at 79%. Next was Transmission Line at 10 %, Distribution Line at 7 and Power Transformer at 4 %.

From the analysis, the technical loss of power in various parts of the Provincial Electricity Authority in Hat Yai was estimated. This is mainly caused by distribution transformers and low voltage distribution systems. Therefore, we can summarize the guidelines for reducing such technical power loss for the power quality and sustainable energy as follows:

1.Reduce the transformer size in the distribution system to be suitable for the load. By selecting the transformer size, the normal maximum load of the transformer should be no more than 80%, and the average load of the transformer should be not less than 45% of the transformer size.

2.Increase the utilization of the transformer for the transformer installed in the original system should also have a higher usual usage factor to have the full use of the transformer and increase efficiency.

3.Supply the transformer's load to be phase balanced with a percentage of phase unbalance not more than 10%.

4.Improving the line power factor by improving the load power factor to helps to reduce the magnitude of the current flowing in the feed line resulting in lower actual power loss, for example, by installing a capacitor unit. Etc.

5.Increase the size of the conductors to be suitable for increasing the size of the low voltage conductors will reduce the power loss. PEA has set the standard for selecting conductor sizes according to transformer size and low-voltage cable circuit characteristics. But increasing the cable size must consider the voltage drop in the feed line per amperes per kilometer.

The results of this PSS/Adept program data analysis for urban electric networks can help implement planning for rural electricity consumption.

The result is to reduce the loss of the power system and increase the efficiency of power distribution in combination with clean energy such as solar power, wind power, etc. In addition, this analysis will serve as a model for future co-generation system planning.

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