

## ANALYSIS OF TECHNICAL ENERGY LOSSES BY USING SIMULATION

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### Abstract

Model is a representation of a system. Through model, it can be easier to forecast and control the changing of each element system. Electricity distribution is also a system. Losses are general problem that exist in a distribution network system. But with the right methods, specifically technical energy losses can be reduced in order to increase the efficiency. By making model of the distribution network, the value of technical energy losses in the whole network as well as in every line can be observed. Simulation can also be used to see all losses reduction alternatives. By comparing results from each alternatives, the best alternative, which gives best result can be decided and implemented.

*Keywords: simulation, technical energy losses, system modelling, electricity*

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### 1. Introduction

Nowadays, humans' lives are dependent mostly on electricity. It cannot be imagined if there are problems in electricity distribution in a long period, which cause all electronic device to stop functioning. Without electricity, almost every activity will not work normally. That reasons are why the Indonesian government decides that the electricity management are being managed by PT PLN (Persero) as the only company that manage electricity distribution in Indonesia

As the only company that manages electricity distribution in Indonesia, the role of PT PLN (Persero) is very important to the citizens. Practically, there are many problems that the company faced. That problems cause the company cannot get maximum income. One of the problems is transmission and distribution losses which mean there are some energies that loss from transformers to the customers [1]. Since the income of PT PLN (Persero) is based to the energies that are being received by customers, and the customers only pay based on the energies that they received, so energy losses is a big financial losses for PT PLN (Persero). In PT PLN (Persero) West Java Distribution Area, transmission and distribution losses make financial loss as big as 3 trillion rupiahs every year.

According to theory, it is known that that there are 2 factors that influence technical energy losses. They are current value and resistance value. But there are also other factors that control the value of resistance, which

are cable length, material resistivity and also the cable area. In this research, the two factors: cable length and the cable area would become independent variables in making model and doing simulation.

As far now, losses reduction efforts that being done by PT PLN (Persero) are not optimal. These can be happened because there is no modeling method to count the value of distribution losses. Until now, losses reduction efforts are not based on valid data that cause ineffective losses reduction.

One best method to see a system is by making model and doing simulation. To make a good simulation, it needs a model based on real condition. The making of this model must be based on real and valid data so the model can represents real condition [2].

The advantage of doing simulation is we can do changes in the model and see the result of the changes [3]. By looking the most optimal solution, then we can do changes in the real system. Simulation can reduce the possibility of wrong decision-making in real system due to unthinkable factors [4-5].

In losses reduction efforts in distribution networks, faults can cause fatal result. Without good planning and investigation, reduction efforts can damage current system, or the efforts only produce little losses reduction, and not proportional to the efforts. By using simulation, it is expected that the losses in every point can be seen, so PT PLN (Persero) can make improve-

ment in points that have the most losses, in order to give maximum result of this reduction efforts.

**2. Methods**

This research is done in DTF distribution station, a distribution station which has operated since 1970s. The research will focus on low voltage network (JTR) and will only count technical energy losses.

There are some stage of research, the first one is the early stage which are defining problem and creating research purposes. Then data collecting stages by doing literature studies, interviews, and data observation and data collecting in the real system. Next stages is constructing models which is followed by model simulations with the analysis. Finally, by compare of each alternatives' results, the best alternative wich gives most profits to the company can be determined [6-7]. The research flow-chart can be seen in Figure 1.

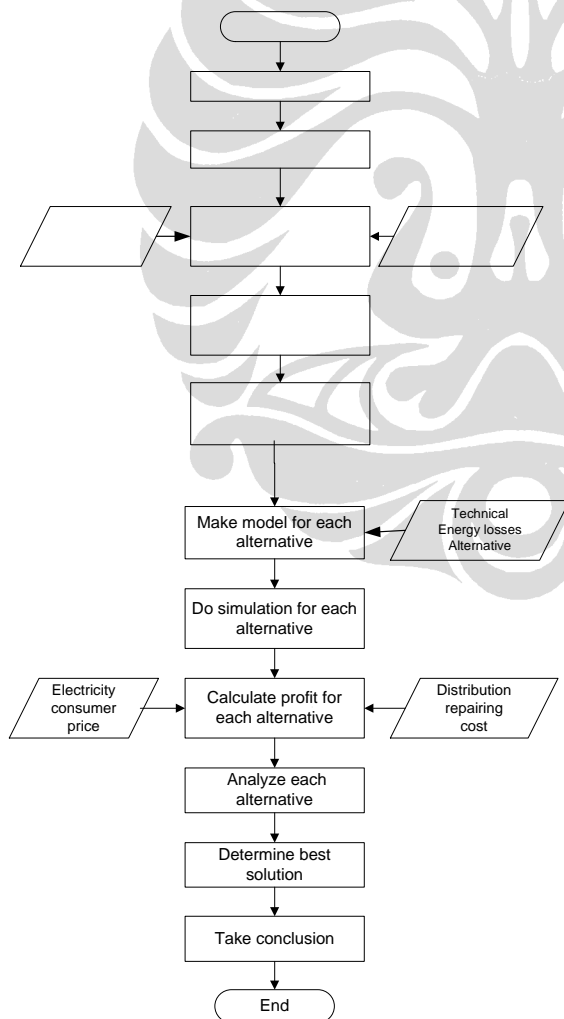


Figure 1. Research Flow Chart

The basic of this research is based on basic electricity formula [8]. In simple manner, losses can be counted based on formula below:

$$Losses = \frac{N_s - N_i}{N_s} \times 100\% \quad (1)$$

Where  $N_s$  is total energy that being distributed to customers, and  $N_i$  is total energy that are being accepted by customers.

$$\Delta E = \sum_{i=1}^n I_i^2 \cdot R \cdot t \quad (2)$$

Where  $\Delta E$  is technical energy losses that happened,  $I$  is the flowing current,  $R$  is the resistance, and  $t$  is time.

It can be concluded that there are 2 factors that influence technical energy losses. They are current value and resistance value. But since the current  $I$  is displayed in quadratic form, then the current value is having more influence than the resistance value.

But there are also other factors that control the value of resistance, which are cable length, material resistivity and also the cable area. This can be seen in the formula below.

$$R = \frac{\rho \cdot L}{A} \quad (3)$$

Where  $R$  is resistance value,  $\rho$  is material resistivity,  $L$  is cable length and  $A$  cable area.

Figure 2 shows distribution cable in JTR system using 3 phase and 1 neutral phase cables. It means there are 3 cables that distribute current to the customers. In another word, if there is a 50 sized cable (which means the cable area is 50 mm<sup>2</sup>), then totally the area of the cables are 150 mm<sup>2</sup>.

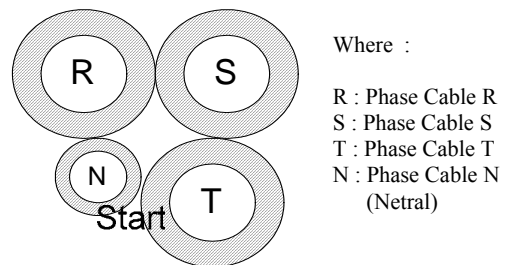


Figure 2. Cable Cut Section

Determine the research's goal

Resistivity factor also depends on material being used. Each material has different resistivity value, which can be seen in Table 1. But the materials used commonly in low voltage network are aluminum and copper. Specifically, Indonesia only use aluminum as material in the network system, so the independent variables in this model are cable area and cable length.

This research is constructed by collecting map of DTF station system. In the map, it is also displayed pole number and distance between poles. In DTF distribution station network, there are 5 lines that come out from the station, line 1 and 5 which going to the north, and line 2, 3, and 4 to the east, south, and west respectively.

To see the number of energy which distributed from the station and which received by customers, 20 customers'

Table 1. Material Resistivity Comparison

Metal	Resistivity /( $\Omega$ . m)	Material	Resistivity /( $\Omega$ . m)
Silver	$1.6 \times 10^{-8}$	Carbon	$35 \text{ to } 5000 \times 10^{-8}$
Copper	$1.7 \times 10^{-8}$	graphite	$800 \times 10^{-8}$
Aluminium	$3.2 \times 10^{-8}$	germanium	0.65
Lead	$21.0 \times 10^{-8}$	Silicon	$2.3 \times 10^{-3}$
manganin (alloy)	$44.0 \times 10^{-8}$	pyrex glass	$10^{12}$
eureka (alloy)	$49.0 \times 10^{-8}$	PTFE	$10^{12} \text{ to } \times 10^{16}$
steel (varies)	$10 \text{ to } 100 \times 10^{-8}$	quartz	$5 \times 10^{16}$

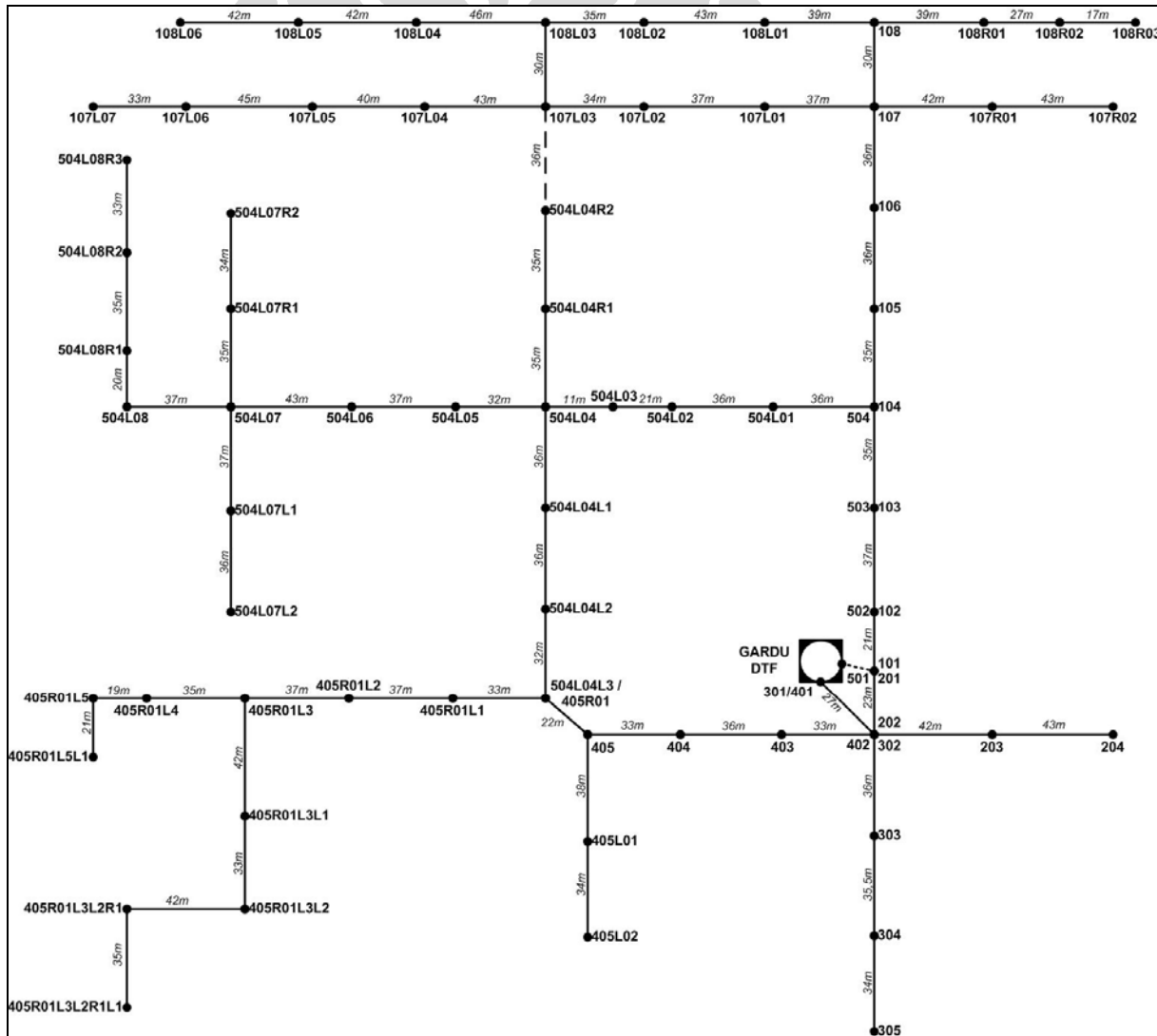


Figure 3. DTF Distribution Station Map

daily use are collected, and also supporting data as well as cable area, cable length, etc. These data will be processed to construct the model of DTF distribution station system which can be seen in Figure 3.

In model construction, it is used Simulink software which is packaged with Matlab ver. 6.5.1. In Simulink, it is known as subsystem construction. It means that main model can be construct simpler by using subsystems, and for complicated formula can be placed in those subsystems. This will make the main model look simple. In model construction, there are 3 main subsystems: pole subsystems (Figure 4), cable subsystems (Figure 5), and station subsystems (Figure 6).

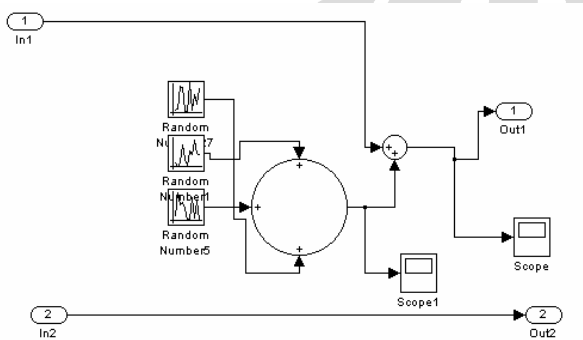


Figure 4. Pole Subsystem

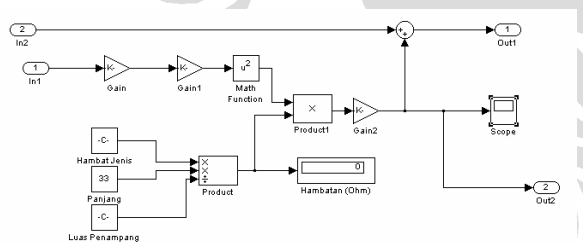


Figure 5. Cable Subsystem

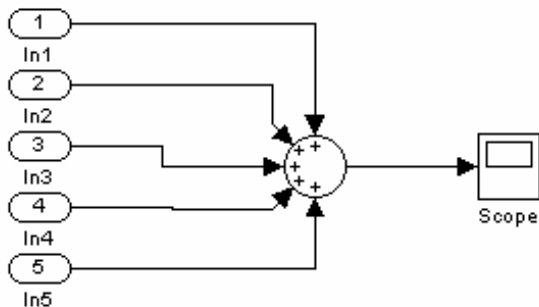


Figure 6. Station Subsystem

### 3. Result and Discussion

In present model, simulation displays varied total energy and total losses. Figure 7 shows the energy total and Figure 8 shows the losses total. But in short, total average energy which come out from the station is 4,831.345 kWh per day with average daily losses as big as 203.4023 kWh. In means losses are 4.21 % from total energy.

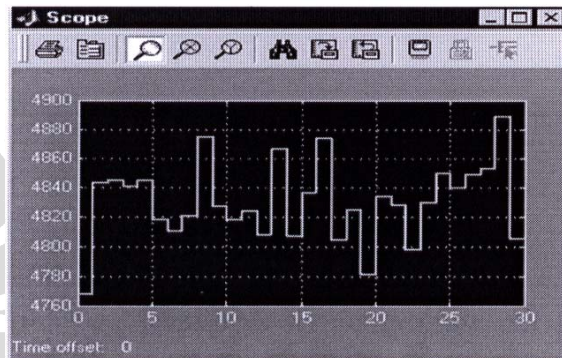


Figure 7. Energy Total Present Model

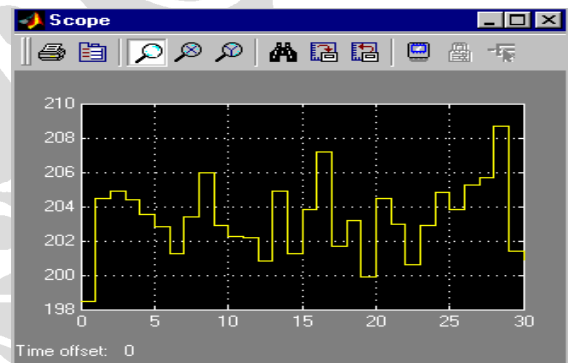


Figure 8. Losses Total Present Model

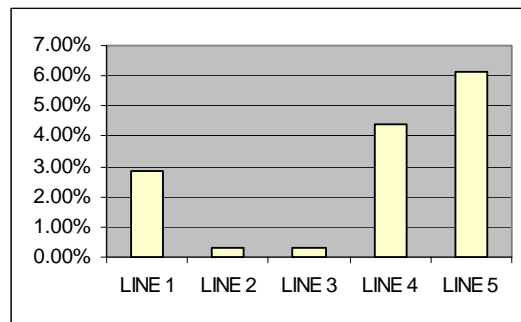


Figure 9. Comparison of Line Losses in Present Model

Furthermore from Figure 9, if being analyzed, biggest losses come from line 4 and line 5. It means that losses reduction efforts must be focused on both lines. Based on interview with the company representatives, finally 7 alternatives are determined. Double lines in Figure 10, Figure 11, Figure 12 and Figure 13 show locations where changes are made.

Alternative 1, change the cable area in main line to 70 mm<sup>2</sup> aluminum cables. Main lines are lines between pole 101 to pole 108, lines between pole 501 to pole 504L08R3, and lines between pole 401 to pole 405R01L5L1.

Alternative 2, add new line for poles: 504L05, 504L06, 504L07, 504L08, 504L07L1, 504L07L2, 504L07R1, 504L07R2, 504L08R1, 504L08R2, and 504L08R3, which are named line 9 (going north) with 50mm<sup>2</sup> aluminum cables.

Alternative 3, add new line for poles: 504L05, 504L06, 504L07, 504L08, 504L07L1, 504L07L2, 504L07R1, 504L07R2, 504L08R1, 504L08R2, and 504L08R3 that are named line 9 (going north) with 70mm<sup>2</sup> aluminum cables.

Alternative 4, add new lines for poles: 405R01, 405R01L1, 405R01L2, 405R01L3, 405R01L4, 405R01L5, 405R01L3L1, 405R01L3L2, 405R01L3L2R1, 405R01L3L2R1L1, and 405R01L5L1 that are named line 8 (going west) with 50 mm<sup>2</sup> aluminum cables.

Alternative 5, add new lines for poles: 405R01, 405R01L1, 405R01L2, 405R01L3, 405R01L4, 405R01L5, 405R01L3L1, 405R01L3L2, 405R01L3L2R1, 405R01L3L2R1L1, and 405R01L5L1 that are named line 8 (going west) with 70 mm<sup>2</sup> aluminum cables.

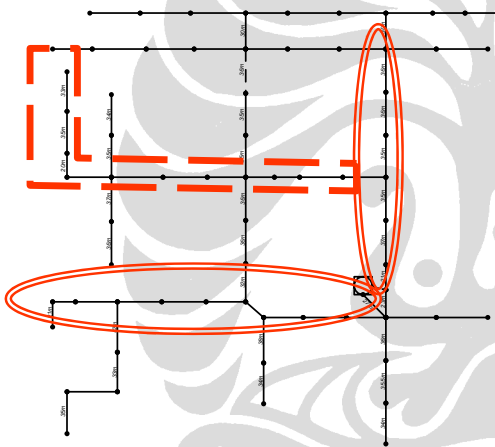


Figure 10. Alternative 1

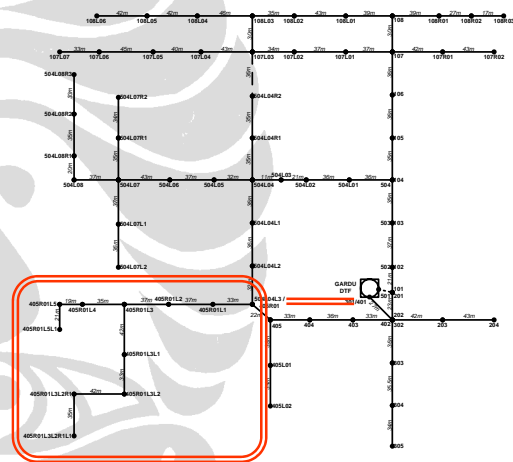


Figure 12. Alternative 4 and Alternative 5

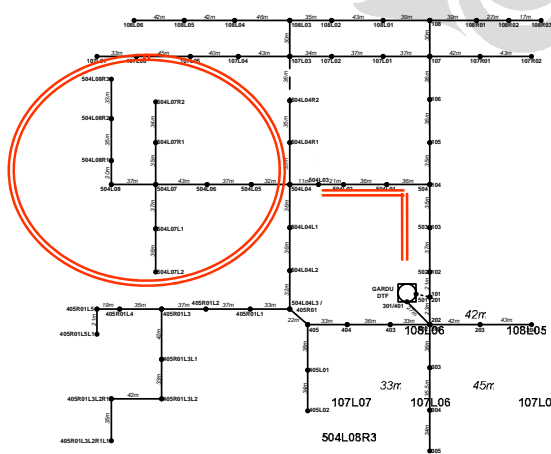


Figure 11. Alternative 2 and Alternative 3

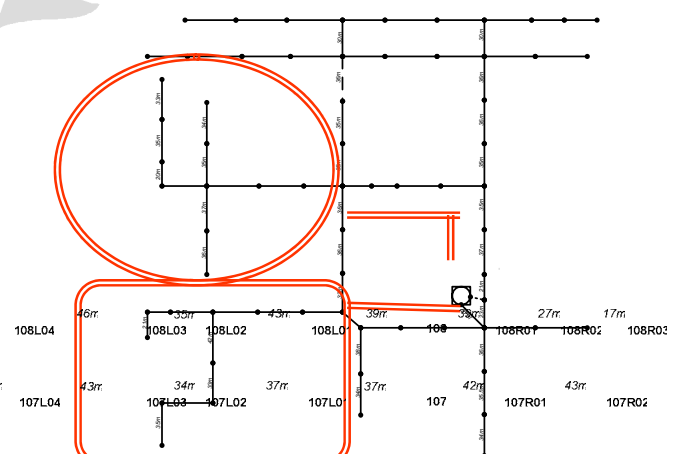


Figure 13. Alternative 6 and Alternative 7

504L08R' 504L08R' 504L08R' 37rr 43rr 37rr 32rr 11m 504L03' 21rr 36rr 36rr 104 504L08 504L07 504L06 504L05 504L04 504L02 504L0' 504 107L07 107L06 107L05 107L04 108L04 108L03 108L02 108L0 107L03 107L02 107L0 107 107R01 107R02 108R01 108R02 108R03 504L04R2 106 504L04R' 105

Alternative 6, combine alternative 2 dan alternative 4 which add new line for poles: 504L05, 504L06, 504L07, 504L08, 504L07L1, 504L07L2, 504L07R1, 504L07R2, 504L08R1, 504L08R2, and 504L08R3 that are named line 9 (going north) and add new line for poles: 405R01, 405R01L1, 405R01L2, 405R01L3, 405R01L4, 405R01L5, 405R01L3L1, 405R01L3L2, 405R01L3L2R1, 405R01L3L2R1L1, and 405R01L5L1 that are named line 8 (going west) with 50 mm<sup>2</sup> aluminum cables.

Alternative 7, combine alternative 3 dan alternative 5 which add new line for poles: 504L05, 504L06, 504L07, 504L08, 504L07L1, 504L07L2, 504L07R1, 504L07R2, 504L08R1, 504L08R2, and 504L08R3 that are named line 9 (going north) and add new line for poles: 405R01, 405R01L1, 405R01L2, 405R01L3, 405R01L4, 405R01L5, 405R01L3L1, 405R01L3L2, 405R01L3L2R1, 405R01L3L2R1L1, and 405R01L5L1 that are named line 8 (going west) with 70 mm<sup>2</sup> aluminum cables.

For each alternative, it can be counted losses energy using simulink and the result is Table 2.

Good analysis must not only see the value of losses reduction, but also must see the cost to construct each

alternative and also profit that can be saved by the company.

Cost that must be spent by the company are cable material cost, 50mm<sup>2</sup> aluminum cable with price Rp 19.000,00 / meter and 70mm<sup>2</sup> aluminum cable with price Rp 25.000,00 / meter. Suspension costs Rp 26.120,00 / poles. Cable attachment service cost, Rp 52.900,00 between 2 poles. Conector attachment service cost, Rp 5.360,00 / pole.

Based on simulation results which is based on daily result, the projection for 1 year is made and the comparison of the profit can be seen in Table 3.

It can be seen that alternative 7 is best alternative with best losses reduction and also with best profit. That means the company must implement alternative 7 that is adding new line for poles: 504L05, 504L06, 504L07, 504L08, 504L07L1, 504L07L2, 504L07R1, 504L07R2, 504L08R1, 504L08R2, and 504L08R3 that are named line 9 (going north) and adding new line for poles: 405R01, 405R01L1, 405R01L2, 405R01L3, 405R01L4, 405R01L5, 405R01L3L1, 405R01L3L2, 405R01L3L2R1, 405R01L3L2R1L1, and 405R01L5L1 that are named line 8 (going west) with 70 mm<sup>2</sup> aluminum cables.

**Table 2. Simulation Result Comparisons**

	Losses	Total Energy	% Losses
Model Present	203.4023	4831.345	4.21%
Alternative 1	145.8234	4773.742	3.05%
Alternative 2	157.763	4785.7086	3.30%
Alternative 3	149.349	4777.294	3.13%
Alternative 4	183.264	4811.212	3.81%
Alternative 5	176.904	4804.852	3.68%
Alternative 6	137.6254	4765.576	2.89%
Alternative 7	122.852	4750.802	2.59%

**Table 3. Profit Result Comparisons**

	Daily losses reduction (kWh)	Revenue from Daily Losses Reduction	Revenue from Losses Reduction in a year	Cost in a year	Net Profit in a Year
Alternative 1	57.5789	Rp. 33,626.08	Rp. 12,273,518.32	Rp. 27,709,680.00	- Rp.15,436,161.68
Alternative 2	45.6392	Rp. 26,653.29	Rp. 9,728,451.87	Rp. 5,023,560.00	Rp. 4,704,681.87
Alternative 3	54.0529	Rp. 31,566.89	Rp. 11,521,916.16	Rp. 6,397,560.00	Rp. 5,124,356.16
Alternative 4	20.1377	Rp. 11,760.42	Rp. 4,292,552.13	Rp. 2,818,760.00	Rp. 1,473,792.13
Alternative 5	26.4974	Rp. 15,474.48	Rp. 5,648,185.78	Rp. 3,592,760.00	Rp. 2,055,425.78
Alternative 6	65.7769	Rp. 38,413.71	Rp. 14,021,004.00	Rp. 7,842,320.00	Rp. 6,178,684.00
<b>Alternative 7</b>	<b>80.5503</b>	<b>Rp. 47,041.38</b>	<b>Rp. 17,170,101.95</b>	<b>Rp. 9,990,320.00</b>	<b>Rp. 7,179,781.95</b>

#### 4. Conclusion

Simulation in present model resulting high losses value, which is 203.4023 kWh / day or 4.21 % of total energy in DTF distribution station. Each alternatives that are given by the company representatives is simulated to determine best alternative which gives greatest losses reduction and also greatest profit to the company. Simulation result shows that best solution is alternative 7. This alternative will gives losses reduction as big as 80.5503 kWh / day and will give the profit estimation Rp 7,179,781.95 for 1 year ahead. By using this method to other distribution stations, there will be bigger savings in PT PLN (Persero).

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