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High Voltage Distribution System (HVDS) as a better system compared to Low Voltage Distribution System (LVDS) applied at Medan city power network

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Abstract. In the current distribution system, a large-capacity distribution transformer supplies loads to remote locations. The use of 220/380 V network is nowadays less common compared to 20 kV network. This results in losses due to the non-optimal distribution transformer, which neglected the load location, poor consumer profile, and large power losses along the carrier. This paper discusses how high voltage distribution systems (HVDS) can be a better system used in distribution networks than the currently used distribution system (Low Voltage Distribution System, LVDS). The proposed change of the system into the new configuration is done by replacing a large-capacity distribution transformer with some smaller-capacity distribution transformers and installed them in positions that closest to the load. The use of high voltage distribution systems will result in better voltage profiles and fewer power losses. From the non-technical side, the annual savings and payback periods on high voltage distribution systems will also be the advantage.

1. Introduction

The distribution system is the most critical part of electrical power systems performance as it is close to the users. AC Voltage (Alternating Current) with 3 phase 20 kV supplied from the transmission line will be received by the primary distribution system. The power transformer at the distribution substation will provide 20 kV voltage to the industrial loads. The distribution system will then lower the voltage of 20 kV into 220/380 V by using distribution transformers scattered at various points to provide power to household loads.

The main problem with current configuration is too many technical losses in the distribution system especially when it is planning with insufficient knowledge and cost, including low voltage channel 380 V (LT / Low Tension) compared to 20 kV channel which in this case is considered high voltage (HT / High Tension). This system we assumed as LVDS (Low Voltage Distribution System) because the majority of the voltage that is distributed is a voltage of 380 V rather than 20 kV. This results in a loss in the location of a non-optimal distribution transformer that ignores the load location, the development of irregular transmission and distribution networks, and so forth.

A high voltage distribution system or HVDS (High Voltage Distribution System) will use 20 kV voltage lines longer than the 380 V voltage line. In other words, this HVDS system will distribute in the voltage 20 kV; then it will be lowered to 380 V at certain positions. This HVDS system is basically the location change and the capacity of the adjusted distribution transformer. We did a simulation to see the comparison of the old system (LVDS) with the new system (HVDS). The simulation will be

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done using software for a case study of a large capacity distribution transformer of the large load in Medan city.

2. Materials and Methods

2.1 Distribution System
The distribution system is defined as the part of the power system located between the distribution substation and the point of entry of customer service [1].In general, the distribution system can be grouped into two levels, namely primary distribution system or medium voltage network (JTM) and secondary distribution system or low voltage network (JTR). The part of the electrical service system that lies between the distribution substation and the distribution transformer is called the primary distribution system. Meanwhile, the part that lies between the distribution transformer and the service load drop point is called the secondary distribution system.

2.2 Distribution Transformer
The distribution transformer is a step-down transformer that serves to lower the voltage from the primary distribution system (20 kV) into a voltage for the secondary distribution system (220/380 V).

2.3 Loss
The losses to be addressed herein are losses in the distribution transformer, power losses, and non-technical losses. The losses contained in the distribution transformer are divided into copper losses (full load loss) and iron loss (loss without load). Electric theft belongs to the important part as a non-technical loss.

2.4 Cost
To ensure that the HVDS system is better than the LVDS system in non-technical aspect, it is also necessary to determine the advantages of the HVDS system in terms of economic or financial, such as the amount of annual savings, the capital outlay, and the payback period.

2.5 Low Voltage Distribution System (LVDS)
The existing distribution system in Indonesia uses a three-phase mainframe distribution of 20 kV and a three-phase distribution transformer that converts a voltage of 20 kV to 220/380 V. This system is referred to as LVDS (Low Voltage Distribution System) or low voltage distribution system because the majority of the voltage that is distributed is a voltage of 380 V rather than 20 kV. This distribution system includes a ratio of almost 2: 1 at low and high voltage network lengths [2-4].

2.6 High Voltage Distribution System (HVDS)
This High Voltage Distribution System (HVDS) system will use a 20kV voltage line longer than the 220/380 V line. In this system, the 20 kV network extends as close to the load as possible and installs a small capacity distribution transformer which extends the supply of electricity to the consumer via a short low-voltage network [2].

2.7 Research Design
This research was conducted on a network of one distribution transformer installed at Jalan Kartini (Kantor PTPN IV), Medan City and the network of distribution transformer installed at the intersection between Jalan Diponegoro and Jalan Sudirman, Medan City. The research was conducted for 2 (two) months. The variables observed in this study are the voltage profile, power loss, and transformer loss generated on LVDS and HVDS. The flow diagram can be seen in Figure 1.

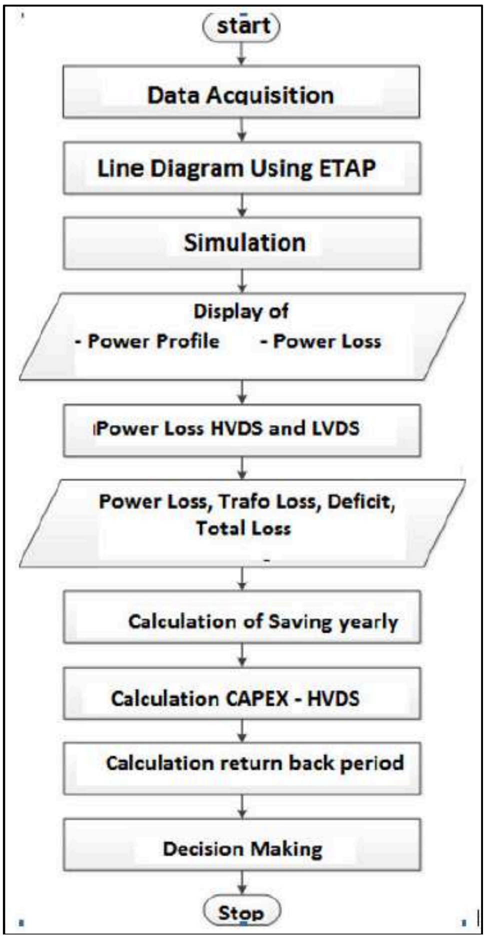

Figure 1. Flow Diagram of Research

2.8 Data Analysis

Data collection of distribution of secondary distribution network is done in PT PLN (PERSERO) AREA MEDAN. ETAP (Electrical Transient and Analysis Program) Power Station is a program that displays the GUI (Graphical User Interface) on power system analysis. The ETAP program was created by the company Operation Technology, Inc. (OTI) from 1995 [5,6]. ETAP calculates the voltage of each bus, the power factor of each branch, the current, and the flow of power throughout the electrical system [7]. A simulated power flow for the old and new system is done using ETAP software on the computer. The result of a voltage profile and simulated losses is used to perform manual side technical calculations on both systems and the new non-technical side of the system

3. Results and Discussions

The results of this study are consumer voltage profiles on both systems, losses on both systems, annual savings on both systems, capital expenditure on HVDS, and payback times on HVDS. There are two distribution network configurations studied in this paper based on the degree of load capacity variation. The first configuration (the level of variation of large load capacity) is on the network of one distribution transformer with code MK053 installed at Jalan Kartini (Kantor PTPN IV), Medan City. While the second configuration (the level of variation in load capacity is small or almost uniform) is on the network of one distribution transformer with code MK098 installed at the intersection between Jalan Diponegoro and Jalan Sudirman, Medan City. Both of these transformers are equally attached to LK 6 repeater, Electric Substation. Both transformers have double pole construction (fitted with two poles) and a capacity of 200 kVA. This 3 phases transformer delivers power to 13 loads (MK053 transformers) and 9 loads (MK098 transformers) with varying usage.

3.1 First Configuration (Variation Rate of Large Load Capacity)

There were loads of very small capacity and loads with very large capacity on this network. The one-line diagram of MK053 transformer network diagram can be seen in Figure 2. The new one-line diagram of the system, after changes in the use of conductors and transformers, can be seen in Figure 3. To reduce technical losses, LVDS (Low Voltage Distribution System) is converted to HVDS (High Voltage Distribution System). This case study was made by considering the length of the primary and secondary distribution networks.

The long-run low-voltage line to the consumer was replaced by a long high-voltage line and then converted into a low voltage conduit at the point closest to the consumer by a small-capacity transformer. For comparison of the length of conductor and transformer used LVDS and HVDS in configuration 1 can be seen in Table 1.

From the overall analysis result in configuration 1, we can get comparison table between LVDS and HVDS like Table 2 and Table 3. The annual savings on HVDS can be determined to multiply the power purchase price of electricity, in this case, the Rp 1,352 / kWh, the difference between the total loss amounted HVDS with LVDS 69334.3488 kWh, in order to obtain the results of Rp 93,740,039. Capital expenditure on HVDS is determined by summing the total cost for a transformer purchase that is assumed to be Rp 300,000,000, and the total other assumed costs of Rp 400,000,000. So obtained capital expenditure of Rp 700,000,000.

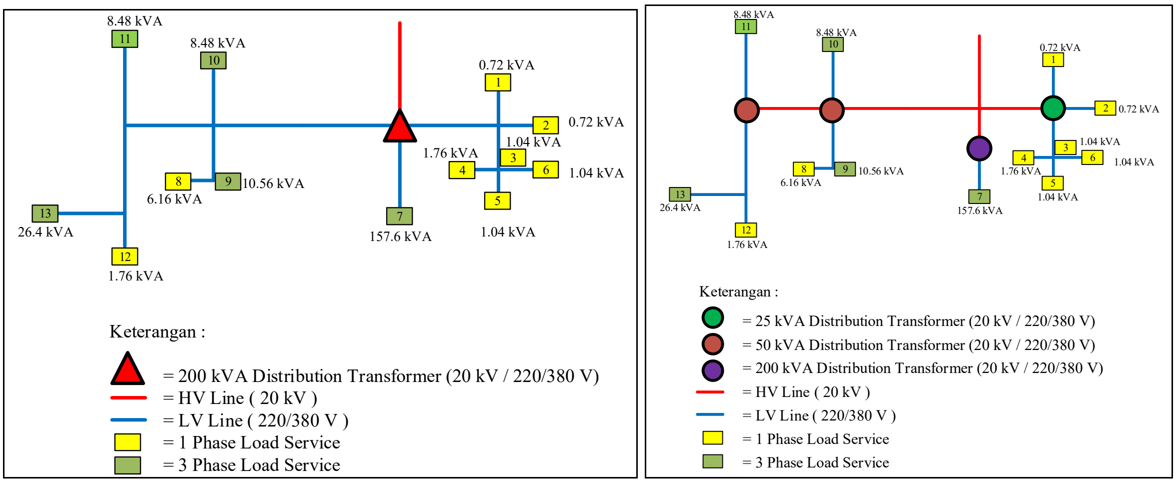

Figure 2. One Line Diagram Simple Network Transformer MK053 (a) LVDS and (b) HVDS

The duration of the payback period can be determined by dividing the capital expenditure by the annual savings so that the result is 7.47 years.

3.2 Second Configuration (Variation Level of Small or Almost Small Load Capacity)

There are no loads with very small or very large capacity on this network. The one-line diagram of MK098 transformer network diagram is simply shown in Figure 4. While the new one-line diagram form of the system, i.e., after changing the use of conductors and transformers, can be seen in Figure 5. For the comparison of the length of the conductor and transformer used LVDS and HVDS on Configuration 2 can be seen in Table 4.From the overall analysis result in configuration 2, we can get comparison table between LVDS and HVDS like Table 5 and Table 6.

The annual savings on HVDS can be determined by multiplying the purchase price of electric power from PLN, in this case, Rp 1,352 / kWh, with the total difference between HVDS and LVDS losses of 56475.3696 kWh, resulting in Rp 76,354,700.Capital expenditures on HVDS are determined by summing the total cost for a transformer purchase that is assumed to be Rp 250,000,000, and the total assumed the cost of Rp 500,000,000. So obtained capital expenditure of Rp 750,000,000. The duration of the payback period can be determined by dividing the capital expenditure by the annual savings so that the result is 9.82 years.

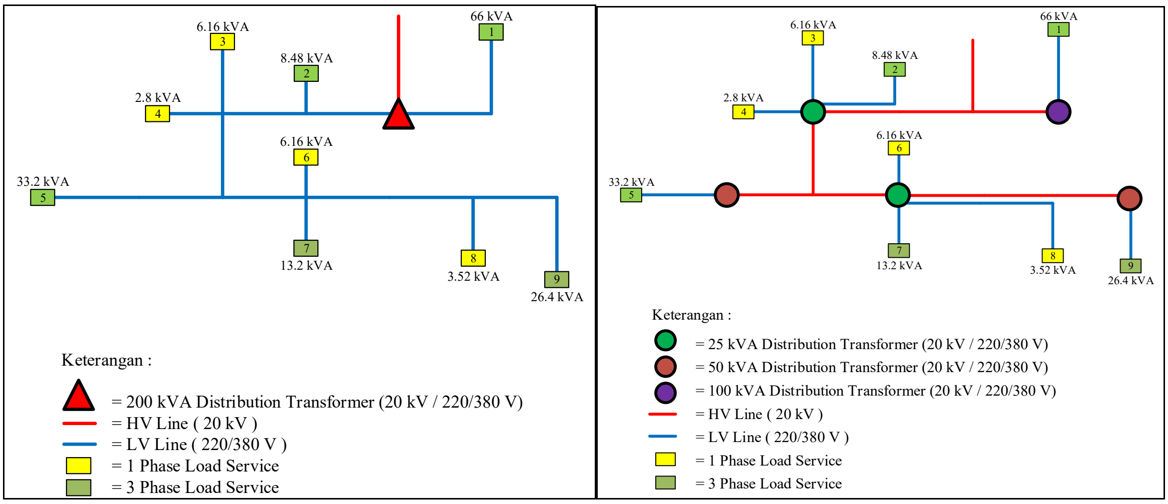

Figure 3. One Line Diagram Simple Network Transformer MK098 (a) LVDS and (b)HVDS

Results of measurements are shown in Table 1, 2, and 3.

Table 1. Comparison of Conductor and Transformer

Parameter	Conf 1		Conf 2	
	LVDS	HVDS	LVDS	HVDS
Conductor Length 20 kV	0.5 Km	0.675 Km	0.5 Km	0.86 Km
Conductor Length 220/380 V	0.52 Km	0.353 Km	0.62 Km	0.38 Km
Total Conductor Length	1.02 Km	1.028 Km	1.12 Km	1.24 Km
		25 kVA	200 kVA	25 kVA
		50 kVA		25 kVA
Distribution Transformator	200 kVA			
		50 kVA		50 kVA
		200 kVA		50 kVA
				200 kVA

Table 2. Comparison of Consumer Voltage

No.	Consumers	VOLTAGE	
		LVDS	HVDS
1	0857121	209.154	217.206
2	0906560	209.154	217.206
3	0809975	209	217.03
4	0827987	208.648	216.678
5	0809987	208.934	216.964
6	0809999	208.736	216.766
7	0139297	359.0696	367.388
8	0915072	202.004	211.86
9	0136634	354.5628	371.879
10	0139563	354.8022	372.134
11	0126602	352.3056	368.722
12	0169169	202.84	212.3
13	0661509	350.36	366.685

Table 3. Comparison of System Loss

No.	Parameter	Conf 1		Conf 2	
		LVDS (kW)	HVDS (kW)	LVDS (kW)	HVDS (kW)
1	Total Power Losses	9.234	4.726	7.562	3.571
2	Total Iron Losses	0.355	0.68	0.355	0.61
3	Total Copper Losses	2.35	4.375	2.35	3.87
4	Total Transformer Losses	2.705	5.055	2.705	4.48
5	Total Theft Losses	5.75688	0	4.23096	0
6	Total Losses	17.69588	9.781	14.49796	8.051

4. Conclusions

The voltage profile of the consumer-generated by the high voltage distribution system (HVDS) was proved to be better than the low-voltage distribution system (LVDS). In configuration 1, the total loss of power at LVDS is 9,234 kW, whereas in HVDS it is 4,726 kW, almost half of current configuration. In configuration 2, the total loss of power in the LVDS is 7,562 kW, while the HVDS is 3.571 kW. In this case, HVDS produces power losses. Then, in configuration 1, the total loss of the transformer in LVDS is 2,705 kW, whereas in HVDS it is 5,055 kW. In configuration 2, the total loss of the transformer in the LVDS is 2,705 kW, while the HVDS is 4.48 kW. HVDS has larger transformer losses due to the use of more transformers.

By using high voltage distribution system, it can be obtained cost savings of Rp 93,740,039 per year in configuration 1 and Rp 76,354,700 per year in configuration 2. While for large capital expenditure on HVDS, the length of time required for payback is 7.47 Years in configurations 1 and 9.82 years in configuration 2.

Although it requires a large cost at the beginning, for long-term high voltage distribution system proved to be better applied to the distribution network than the low-voltage distribution system because it has lower losses and better voltage profile.

Once converted to HVDS, in configuration 1, the old transformer still cannot be replaced into another smaller capacity transformer because there is a very large load capacity. While in configuration 2, the old pure transformer is replaced by transformers that have smaller capacities due to variations in the small or nearly uniform load capacity for transformer loading.

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