Impacts of Addition Electrical Distribution Substation Allocation on Overloading Feeder

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Abstract. Percentage of maximum loading on distribution transformers according to the provisions does not exceed 80% of the capacity of the transformer. If the loading is more than 80%, it can disrupt the quality and continuity of the distribution of electric power to consumers. The analysis aimed to: determine the amount of voltage drop and power loss that occurs before the installation of the addition electrical distribution substation. The analysis done by taking a case study on existing distribution substation (named MRK 051), its have 4 (four) electrical line services (line A, line B, line C and line D) and addition electrical distribution substation (named: MRK 267) at Muli feeder in PT. PLN (The National Electricity Company) Region Merauke. Impact of addition electrical distribution substation was conducted by using analytical mathematic to compare two variable: drop voltage and power losses. The result revealed that: drop voltage at MRK 051 before addition electrical distribution substation allocation are value meanly more than 10% and power losses are 1,22 kW (kilo-Watt) at line C. After addition electrical distribution substation allocation, drop voltage reduced to smaller than 10% and power loss reduced to 1,06 kW (kilo-Watt) at line C.

1. Introduction

Electric power distribution system functions to distribute electric power from the transmission line to consumers, among others electric power consumers with voltage levels of 20 kV or 220/380 V [1]. Then, Increasing population growth causes electricity demand to increase. This affects the amount of electric power supplied to consumers so that one day the capacity of the transformer is no longer able to carry the burden of consumers [2]. This condition is referred to as a transformer that has been overloaded and if it occurs for a long time it will cause the installed transformer to overheat so that it disrupts the continuity of the distribution of electric power to the load [3]. To anticipate the damage of the distribution transformer or distribution substation the additional electrical distribution substations are carried out [4]. Additional substations functions to divide the load served by one of the substations that have been installed in a feeder.

2. Drop Voltage and Electrical Power Loss

Drops voltage on electrical distribution systems include drop voltage on feeder, distribution transformer, line of low level distribution and electrical installation of consumer [5]. Voltage drop can be calculated in percentage [6], namely:

\[ \Delta V = I \cdot (R + jX) = I \cdot Z \] (1)
where,
\[ \Delta V = \text{drop voltage (Volt)} \]
\[ \Delta V(\%) = \text{percentage of drop voltage} \]
\[ I = \text{line current (Ampere)} \]
\[ R = \text{line resistance (Ohm)} \]
\[ X = \text{line inductance (Hendry)} \]
\[ Z = \text{line impedance / absolute value of line resistance and inductance (Ohm)} \]

The power losses in distribution network caused by line resistance and reactance Power losses are calculated using equations [7], namely:
\[ \Delta P = \frac{1}{3} (I_R^2 + I_S^2 + I_T^2 + I_N^2) \cdot R \cdot L \]

Where,
\[ \Delta P = \text{power losses (kilo-Watt)} \]
\[ I_R = \text{current at phase R (Ampere)} \]
\[ I_S = \text{current at phase S (Ampere)} \]
\[ I_T = \text{current at phase T (Ampere)} \]
\[ I_N = \text{current at netral connection (Ampere)} \]
\[ R = \text{line resistance (Ohm)} \]
\[ L = \text{line length (meter)} \]

3. Materials and Method
The case study was taken in the Muli feeder, as shown in figure 1 [8].

![Figure 1. Layout of Muli feeder](image-url)
The existing distribution substation (MRK 051) with the data shown in table 1.

| Substation Code | MRK-051-1 |
|-----------------|-----------|
| Location        | Martadinata Street |
| Feeder          | Muli |
| Capacity (kVA)  | 160 |
| Nominal Voltage (kV) | 20 |
| TAP Position    | 3/5 |
| Phase           | 3 |
| Serial Number   | 90203195 |
| Merk            | Starlite |
| Connection      | Δ-Y |

MRK 051 have 4 (four) line of electrical services to consumers, namely: line A, line B, line C and line D. Then, load measurement data of MRK 051 given in table 2 and table 3.

Table 2. The measurement data of electrical loading at MRK 051 at out of load peak time (before addition electrical distribution allocation)

| Line Phase | Outgoing (Ampere) | Incoming (Ampere) |
|------------|-------------------|-------------------|
|            | Line A            | Line B            | Line C            | Line D            | Current (Ampere) | Load Percentage (%) |
| R          | 60                | 3                 | 92                | 50               | 205              | 89                |
| S          | 60                | 7                 | 81                | 51               | 199              | 86                |
| T          | 38                | 2                 | 77                | 35               | 152              | 66                |
| N          | 18                | 5                 | 16                | 10               | 49               | 21                |
| Total measurement of electrical power load = | 80,25 |

Table 3. The measurement data of electrical loading at MRK 051 at in of load peak time (before addition electrical distribution allocation)

| Line Phase | Outgoing (Ampere) | Incoming (Ampere) |
|------------|-------------------|-------------------|
|            | Line A            | Line B            | Line C            | Line D            | Current (Ampere) | Load Percentage (%) |
| R          | 56                | 4                 | 100               | 56               | 216              | 93                |
| S          | 45                | 9                 | 83                | 50               | 187              | 81                |
| T          | 38                | 6                 | 81                | 22               | 147              | 64                |
| N          | 29                | 9                 | 31                | 21               | 90               | 39                |
| Total measurement of electrical power load = | 79,38 |

As shown in table 1, power loading condition of MRK 051 more than 80%. If this condition occurs for a long period of time it will cause overheating of the transformer winding. Therefore, it needs a addition electrical distribution substation allocation (namely: MRK 267) between MRK 051 and load as shown in figure 2.
4. Result and Discussion

The results of the analysis are calculated using a mathematical analysis based on equation (2) and (3) obtained as seen in table 3 and table 4.

Table 3. Percentage of voltage drop before and after load manuver with addition electrical distribution at line C

| Line | Phase | Before Load Manuver ΔV (%) | After Load Manuver ΔV(%) |
|------|-------|---------------------------|--------------------------|
| A    | R     | 15,70                     | 4,09                     |
|      | S     | 16,70                     | 4,50                     |
|      | T     | 16,25                     | 4,09                     |
| B    | R     | 0,40                      | 0,44                     |
|      | S     | 1,30                      | 0,88                     |
|      | T     | 0,90                      | 0,44                     |
| C    | R     | 16,80                     | 3,60                     |
|      | S     | 17,40                     | 4,50                     |
|      | T     | 16,80                     | 3,60                     |
| D    | R     | 15,15                     | 4,09                     |
|      | S     | 16,16                     | 0,44                     |
|      | T     | 15,60                     | 4,09                     |

Table 4. Power losses before and after load manuver with addition electrical distribution at line C

| Line | Before Load Manuver AP (kilo-Watt) | After Load Manuver AP (kilo-Watt) |
|------|-----------------------------------|----------------------------------|
| A    | 0,342                             | 0,307                            |
| B    | 0,005                             | 0,003                            |
| C    | 1,221                             | 1,064                            |
| D    | 0,937                             | 0,237                            |
The results obtained as shown in table 3 and table 4, the allocation of addition electrical distribution substation had a very significant impact to reduce the voltage drop and power losses in all lines that served by Muli feeders. the allocation of addition electrical distribution substation on line C is due to the burden on that line had greater load than the other lines.

5. Conclusion
Based on the analysis of addition electrical distribution substation allocation on overload feeder, the conclusions are obtained: the allocation of additional electrical distribution substation at the part of the Muli feeder which has an overloading condition will had a very significant impact on the amount of drop voltage and power losses.

Drop voltage at lines that serviced by Muli feeder before addition electrical distribution substation allocation are valued meanly more than 10% and power losses are 1,22 kW (kilo-Watt) at line C. After addition electrical distribution substation allocation, drop voltage reduced to smaller than 10% and power loss reduced to 1,06 kW (kilo-Watt) at line C.

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