Reconfiguration of Power Supply System Distribution 20 Kv: PT. PLN (Persero) Dumai Area Case

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Abstract: The electricity in Bagan Siapiapi is distributed 20 kV feeder distribution system. The main supply of Bagan Siapi-api from the Diesel Power Plant which is located ± 1.5 kms from the load center and the main substation of Duri is ± 102 kms from Bagan Siapi-api city through the Substation circuit Ujung Tanjung. The long distances between the Duri Mainstation and Bagan Siapi-api city resulted in a 14.85 kV end-voltage and a power loss of 988.7 kW. Voltage loss results in a lack of optimum service to the consumer and a large loss of network power become uneconomical for power supply operation. The result of end voltage calculation is 11,542 kV, and the power loss is 988.7 kW. After the main relay station in the village of Pedamaran operates, reconfiguration-1 produces the lowest end voltage calculation of 16.21 kV and a power loss of 136.59 kW, while reconfiguration-2 produces a low-end stress calculation of 17.37 kV and a power loss of 56.93 kW.

Keywords: Feeder 20 kV, Voltage Drop, Power Loss, Substation, Reconfiguration

1. Introduction

PT PLN (Persero) Dumai Area with Rayon BaganSiapi-api unit as the implementer is a unit that provides electricity service directly to consumers in RokanHilir district. The power source comes from PLTD Bagan Siapiapi with a capacity of 12,340 MW and Duri substation (90 MVA) through a feeder distribution system of 20 kV to Ujung Tanjung substation and then to BaganSiapiapi City with a total length of 102 kms, and the electrical system follows a pattern Radial system.

The amount of load supplied can increase the voltage drop and power loss in the feeder system 20 kV. This is due to the parameters that determine the voltage drop and the power losses other than the impedance are the currents that flow through the system coming from the load. Power loss is a function of the square of the current on the system, so the greater the current will increase power losses and voltage drops. Therefore, to reduce the voltage drop and power losses by shortening the distance of the load center and the source of its power supply. The way to shorten the channeling distance between the power supply and the load center is to reconfigure the load after the build-up of the substation. The purpose of this study is to analyze whether the development of BaganSiapi-fire substations by shortening the channeling can be one of the solutions in improving the characteristics of 20 kV feeder between Ujung Tanjung substation to Bagan Siapi-api City, which includes voltage drop, current Loads, and power losses.

2. Research Method

Muhammad Nasir Malik states that the large drop of stress and total power loss in the primary distribution network repeater Adyaksa Panakukang Makassar Substation Panels with descriptive research method. Danang Ramadhianto mentions that the magnitude of the shrinkage of energy that occurs in the power distribution network as well as to analyze the energy shrinkage value, through the method of measurement and calculation and then compare the results of both. Fery Jusmedy, states that the stresses and losses in the 115 kV PT system, Chevron Pacific Indonesia using ETAP 4.0 software.
Electric power system consists of three main components, namely power generation, transmission, and distribution. At the center of power is done by generating electricity by utilizing synchronous generator. The electric power that has been generated at the center will be transmitted through the transmission system. Before it is transmitted, the voltage is increased by a step-up transformer at the center of the power. The voltage is raised to a high voltage level (between 70 kV to 150 kV) or extra high voltage (above 150 kV).

The transmission system used can be either air or ground cable system. (Hutauruk: 1985). Furthermore, this high voltage power supply is transmitted through the transmission system to be sent to the, which then the voltage is lowered by using a step-down transformer into a medium voltage or also called the primary distribution voltage. The medium voltage used by PLN is 20 kV. At this medium voltage level, electric power can be used directly by consumers who have large connected power such as large industries.

Figure 1. The Process of Generation, Transmission, And Distribution

The distribution network consists of two types, medium voltage distribution network, and low voltage distribution network. For medium voltage distribution networks, there are three types of configurations. Among them are radial configuration, lup configuration and spindle configuration. (Pabla, USA: 1994)

Radial configuration is an interconnection between substations distribution, where several distributed series distribution substations supplied by a busbar Substation. This configuration consists of several repeats that come out of the substation, and the voltage source is only one direction only. In the repeater, there are distribution substations equipped by the voltage-lowering transformer into low voltage. This configuration is the simplest and easiest configuration in operation.

Figure 2. One-Line Diagram Of The Radial Configuration Distribution System
The loop configuration is an interconnection between the distribution substations that form a closed loop. In this configuration, there may be more than one substation busbar, and each of the buffers forms a closed circuit with a substation. The advantage of this loop configuration is that the power supply from the substation is more secure. Because if one substation is interrupted, then the feeder will still get supplies from another substation that is not disturbed. And disturbed substations can be repaired without fear of disturbing the power supply to a distribution substation.

![Figure 3. Type Of Loop Configuration.](image)

The spindle configuration is a series connection between the distribution substations which both ends are connected by the substation busbar and substation, which is the hallmark of this network is the existence of an express feeder. This express repeater serves as a repeater reserve that will supply the load power when one of the feeders is interrupted. In this spindle network, there are several feeders supplied by substation and end up in a relay substation.

![Figure 4. Diagram One Line Spindle Configuration Distribution System](image)

Generally, the loads contained in the power system are resistive-inductive. The load will absorb the active power and reactive power generated by the generator. The absorption of the reactive power induced by the inductive load will cause a voltage drop across the voltage supplied by the generator. As a result, the value of the voltage on the recipient's side will be different from the voltage value on the sender's side. The equation of voltage drop can be seen in equation 2.1.

\[ \Delta V = I \times Z \]  

(2.1)

Information:

\[ \Delta V = \text{voltage drop (volts)} \]

\[ I = \text{current (Amper)} \]

\[ Z = \text{impedance (ohms)} \]
In this theory the meaning of the voltage drop ($\Delta V$) is the difference between the sending voltage ($V_S$) and the received voltage ($V_R$), then the voltage drop can be defined in equation 2.2.

$$\Delta V = V_S \times V_R$$

(2.2)

Information:

$\Delta V =$ voltage drop (volts)

$V_S =$ send voltage

$V_R =$ receive voltage

Power losses are the amount of power lost in a network, which is equal to the power supplied from the source less the amount of power received. Selection of cable types to be used in the distribution network is an important factor to be considered in the planning of a power system. Types of cables with small resistance values will be able to minimize power losses. The number of power losses in the distribution network can be written as follows:

$$\Delta P = I^2 \cdot R \text{ (watts)}$$

(2.3)

Information:

$\Delta P =$ Power loss on the network  (watts)

$I =$ The load current on the network (amper)

$R =$ Pure Resistance  (ohms)

For power losses on three-phase networks expressed by the equation:

$$\Delta P = \sqrt{3} \cdot I^2 \cdot R \text{ (watts)}$$

(2.4)

By ignoring capacitive currents in the system, the currents along the length of the wire can be considered equal and the magnitude is equal to the current at the receiving end.

$$I = \frac{P}{\sqrt{3} \cdot V \cdot I \cdot \cos \phi} \text{ (amperes)}$$

(2.5)

The amount of power in the three-phase system is:

$$P = \sqrt{3} \cdot V \cdot I \cdot \cos \phi \text{ (watts)}$$

(2.6)

Information:

$P =$ load power at the receiving end of the system (watts)

$V =$ phase voltage (volt)

$\cos \phi =$ load power factor

Voltage is also very influential on power losses, the greater the voltage on a system, the smaller the current on the system. While the current is one of the factors that affect the magnitude of power losses on a system.

3. Findings and Discussion

The distribution system of 20 kV Duri Substation to City Bagan Siapi-api uses AAAC (All Aluminum Alloy Conductor) wire with 240 mm$^2$ cross-section for the main system, and 150 mm$^2$ with 70 mm$^2$ for branching system. All three wire conductor is composed of 19 fibers. The system configuration is horizontal with the distance between phases 75 cm. The average temperature of the distribution system environment used temperature 30$^\circ$C. The DC resistance at temperature 20$^\circ$C and the temperature coefficient ($\alpha$) at temperature 20$^\circ$C as follows:
Table 1. DC Resistance and Temperature Coefficient

| Conductor | Resistance DC (temperature 20 °C) | Temperature Coefficient At 20°C (\(\alpha_{20}\)) |
|-----------|-----------------------------------|-----------------------------------------------|
| AAAC 70 mm² | 0.438                             | 0.00360 / °C                                   |
| AAAC 150 mm² | 0.210                             |                                               |
| AAAC 240 mm² | 0.137                             |                                               |

Source: Standard of State Electricity Company (SPLN 41-8: 1981)

Then the impedance can be calculated as follows:

**a. For a 240 mm² cross-section area**

DC Resistance:

\[
R_{dc} (30°C) = R_{dc} (20°C) \times [1 + \alpha_{20}(30°C - 20°C)]
\]

The amount of skin effect factor (mr) is:

\[
mr = 0.0118 \times \sqrt{f} = 0.0118 \times \sqrt{50} = 0.08343
\]

Resistansiac:

\[
R_{ac} = \frac{1}{2} R_{dc} \times \left[ \sqrt{1 + \left(\frac{0.08343}{48}\right)^4} + 1 \right]
\]

\[
= 0.5 \times 0.141932 \times 2 = 0.141932 Ohm / km
\]

\[
GMR = 0.4345 \times \sqrt{A}
\]

\[
= 0.4345 \times \sqrt{72.4} = 0.67312 cm
\]

\[
GMD = \sqrt[3]{D_{rs} \times D_{st} \times D_{tr}}
\]

\[
= \sqrt[3]{75 \times 75 \times 150} = 94.5 cm
\]

\[
X = (2.\pi.f) \times (2 \times 10^{-4}) \times \ln \left(\frac{GMD}{GMR}\right)
\]

\[
= (2 \times 3.14 \times 50) \times (2 \times 10^{-4}) \times \ln \left(\frac{94.5}{0.67312}\right) = 0.3105Ohm / km
\]

\[
Z = 0.1419 + j 0.3105
\]

\[
= \sqrt{(0.1419)^2 + (0.3105)^2} = 0.34139Ohm / km
\]

**b. For cross-sectional area 150 mm²**

Resistansiadc:

\[
R_{dc} (30°C) = R_{dc} (20°C) \times [1 + \alpha_{20}(30°C - 20°C)]
\]

\[
= 0.21 \times [1 + 0.00403(10)] = 0.21846Ohm / km
\]

\[
= 0.21 \times [1 + 0.0403] = 0.21846Ohm / km
\]
The amount of skin effect factor (mr) is:

\[ mr = 0.0118 \times \sqrt{f} = 0.0118 \times \sqrt{50} = 0.08343 \]

Resistansiac:

\[
R_{ac} = \frac{1}{2} R_{dc} \times \left[ \sqrt{1 + \left(\frac{0.08343}{48}\right)^4} + 1 \right]
\]

= 0.2187 Ohm / km

\[ GMR = 0.4345 \times \sqrt{A} \]

= 0.4345 \times \sqrt{1.5}

= 0.53215 cm

\[ GMD = \frac{2}{D_r} \times D_{st} \times D_{tr} \]

= \frac{3}{75} \times (75) \times (150)

= 94.5 cm

\[ X = (2 \cdot \pi \cdot f) \times (2 \times 10^{-4}) \times \ln \left( \frac{GMD}{GMR} \right) \]

= (2 \times 3.14 \times 50) \times (2 \times 10^{-4}) \times \ln \left( \frac{94.5}{0.53215} \right)

= 0.32527 Ohm / km

\[ Z = 0.21847 + j 0.32527 \]

\[ Z = \sqrt{(0.21847)^2 + (0.32527)^2} \]

= 0.39183 Ohm / km

c. For cross-sectional area 70 mm²

Resistanside:

\[ R_{dc} (30^oC) = R_{dc} (20^oC) \times [1 + \alpha_{20} (30^o - 20^o)] \]

= 0.438 \times [1 + 0.00403(10)]

= 0.438 \times [1 + 0.0403]

= 0.45565 Ohm / km

The amount of skin effect factor (mr) is:

\[ mr = 0.0118 \times \sqrt{f} = 0.0118 \times \sqrt{50} = 0.08343 \]

Resistance AC:

\[
R_{ac} = \frac{1}{2} R_{dc} \times \left[ \sqrt{1 + \left(\frac{0.08343}{48}\right)^4} + 1 \right]
\]

= \frac{1}{2} (0.45565) \times \left[ \sqrt{1 + \left(\frac{0.08343}{48}\right)^4} + 1 \right]

= 0.45565 Ohm / km

\[ GMR = 0.4345 \times \sqrt{A} \]

= 0.4345 \times \sqrt{0.7}

= 0.36352 cm
\[
GMD = \sqrt[3]{D_{rs} \times D_{st} \times D_{tr}} \\
= \sqrt[3]{(75) \times (75) \times (150)} \\
= 94.5 \text{ cm}
\]

\[
X = (2 \pi f) \times (2 \times 10^{-4}) \times \ln\left(\frac{GMD}{GMR}\right) \\
= (2 \times 3.14 \times 50) \times (2 \times 10^{-4}) \times \ln\left(\frac{94.5}{0.36352}\right) \\
= 0.34920 \text{ Ohm/km}
\]

\[
Z = 0.45565 + j 0.34920 \\
= \sqrt{(0.45565)^2 + (0.34920)^2} \\
= 0.57437 \text{ Ohm/km}
\]

To determine the current value on the primary side of the transformer, the writer first observes the transformer load value on the secondary side. For secondary current values, the authors assume using current values under balanced load conditions. To determine the balanced current value, the authors calculate the average value of the sum of load per phase as the following calculation example:

For transformer T.001 secondary side flows;

\[
Ir = 104 \text{ A}, \ Is = 43 \text{ A}, \ It = 83 \text{ A}
\]

Balance stream:

\[
ISC = \frac{(104 + 43 + 83)}{3} \\
ISC = 76667 \text{ A}
\]

After obtaining the current value at equilibrium condition, then to calculate the value of current on the primary side using the way the secondary side current value at balanced condition divided by the ratio of voltage regulation in tap changer or calculated as follows:

For transformers T.001 primary side flows;

\[
IPR = 76.667 / ((18000/380)) = 1.619 \text{ A}
\]

From the result of the calculation of losses and voltage of medium voltage network tip for the condition, reconfiguration 1 and reconfiguration 2 got the result as follows Table 2 The result of losses and stresses of each configuration.

4. Conclusions

From the result of the discussion, it can be concluded that the voltage profile and power loss condition of power distribution from Ujung Tanjung to Kota Bagan Siapi-api with the result of end stress calculation is 11.542 kV and the power loss is 988.7 kW. After the new substation is in operation, the reconfiguration-1 produces the lowest end voltage calculation of 16.21 kV and a power loss of 136.59 kW, while reconfiguration-2 produces the lowest end voltage calculation of 17.37 kV and a power loss of 56.93 kW.
Table 2. Results Calculation of Voltage Drop And Power Loss Each Configuration

| Configuration | Power loss | Send Voltage | Edge Voltage | Total Trafo $V_p<18$ kV |
|---------------|------------|--------------|--------------|-------------------------|
|               | Watt       | Volt         | Volt         | Unit                    |
| Existing      | 988.048    | 20.400       | 11.642       | 112                     |
| Reconfig 1    | 136.591    | 20.400       | 16.212       | 54                      |
| Reconfig 2    | 56.932     | 20.400       | 17.372       | 26                      |

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