Load Shedding Analysis Because of Contingency Damage (N-2) at Transmission Lines 150 kV Subsystem Cirata

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Abstract. Cirata subsystem is part of the 150 kV interconnection system 150 kV West Java which is supplied by two units of IBT 500/150 kV with a power capacity of each IBT is 500 MVA. It has 15 transmission line connecting the substation 13 (GI), while the generation units that exist in the subsystem Cirata is PLTP Patuha with a power of 55 MW and 180 MW hydropower Jatiluhur. The reliability of the power system must be maintained in order to supply power from the generator to the consumer to keep going well. At peak load conditions and contingencies, an electric power system will undergo changes in value, both current and voltage. In this study, which analyzed disorder is a contingency (N-2), a discharge of the two components of transmission line system and generator. The aim is to evaluate and improve the reliability of electric power systems of 150 kV Subsystem Cirata, analyzing the effects of disturbance contingency (N-2) to changes in current and voltage, identify the bus voltage is outside the operating limits, identifying the transmission line that experienced the imposition of critical / exceeds limit operation, and perform load shedding (load sheeding) to overcome the weaknesses of the power system due to disruption contingency N-2. The study was conducted by collecting data required for power flow simulation using Newton-Raphson method in ETAP 12.6.0. The simulation results show the power flow interruption due to voltage profile under the standard contingency SPLN 150 kV +5% and -10%, and becomes critical channel loading over 50% of the nominal current conductor. While after the release of the load (load sheeding) voltage profile in Subsystem Cirata back normal or standardized SPLN and loading the channel becomes lighter.

1. Introduction

Electric Power System is a set of Electricity Center and Substation (Center of Burden) which each other connected by Transmission network, so it is an interconnection unit [1]. The main role of the electric power system provides and distributes electrical energy reliably and continuously to the load. This means that the reliability of the power system is determined by the ability of the system to supply sufficient electrical energy to satisfied customers satisfactorily in order for the system to survive abrupt disturbances such as short circuit or unanticipated system element loss [2].

One of the things related to the reliability of the system is the release of generating units or transmission lines that need to be taken into account in the security of the system. If one of the generators is off, the current system will experience a lack of power to service the load. If a transmission line is loose, its load will be transferred to another remaining channel, so that the remaining channel will be heavier and may result in overload followed by channel release [3].
Contingency analysis is a study of the release of tissue elements such as transmission lines, transformers and generators, and the result is the post-contingency effect on the power flow and bus voltages in system [1]. Contingency analysis will see limitations such as bus stress, channel loading, and the availability of spinning reserves. The N-2 contingency is the contingency that results from the release of two system elements such as one transmission line and one generator.

Based on the report of PLN West Java, there are 24 interruptions during the range of 2013 - 2015 in the form of contingency (N-1) on the channel 150 kV West Java [4]. In other words, the disruption of one channel in the system has often happened. It indicates that the level of reliability of the system still needs to be improved because of the impact of the electrical system's unreliableness can be widespread and result in the release of the system in stages.

To provide reliable service, the power system must remain intact and able to overcome various kinds of disturbances that may occur. Thus it is very important that the system should be planned and operated in order to be in a contingency state or the release of two elements of the system be it the generator or transmission line will not lose the load.

Load Shedding (Load Shedding) is a form of automatic or manual load release action to secure the operation of generating units from the possibility of black out. Load discharges are automatically performed because the amount of power supply is reduced. Load discharges are automatically performed by detecting the frequency or by observing the condition of an inoperable power plant source [1]. Load discharges can occur due to a decrease in the frequency of imbalance between the generated power generator and the load consumption [5].

The reliability of the power system is determined by adequacy assessment and security assessment. Assessment of adequacy relates to the ability of the system to supply electrical energy to satisfied customers in a satisfactory manner. Security assessments relate to the ability of the electric power system to remain resilient due to sudden disturbances such as short circuit or loss of unanticipated system elements. This includes system responses resulting from the release of generators and transmission lines [2]. One important factor in the operation of electrical power systems is the desire to maintain system security (system security). System security includes activities planned to maintain system operation in case of system component failure For example, a generating unit may have to be off-line due to auxiliary equipment failures. By maintaining a number of appropriate rotary spare plants, the remaining generating units in the system can overcome the power shortage without falling too low or without the need for load shedding. In the generation and delivery of electric power, if a transmission line is damaged by a storm causing the channel to break, the remaining transmission channel will carry a larger load but still within the allowable range [2,6].

2. Research Methods

After the data has been collected, the design and framework of this study are as follows: (a) Model the power system of 150 kV South Bandung subsystem in ETAP; (b) Performing data inputs: generators, loads, buses and channel parameters; (c) Conducting power flow analysis on the Cirata subsystem power system under normal circumstances under ETAP 12.6; (d) Choosing the type of contingency; (e) Conducting a power flow analysis on the Cirata subsystem power system in a contingency state with the ETAP 12.6 program; (f) Identify weak power system (bus and transmission line) elements of the power flow analysis during normal and contingency states (N-2); (g) Performing system improvements, ie load shedding until the return voltage at the limit is permitted; (h) Checking the effectiveness of system reliability improvements as measured by voltage and channel loading. Flow of data analysis research can see in figure 1.
3. Results and Discussions

3.1. Peak Load Condition

The magnitude of the system bus voltage at the time of no interference (normal) is at least 127.58 kV at Dawuan load bus and the greatest voltage is 140.81 kV on the bus Cirata. Figure 2 shows that the system voltage at peak load condition is below the standard SPLN seven rails that meet SPLN standards, namely Cirata rail (140.81 kV), Cikumpay (135.65 kV), Pbran (135.60 kV), Kamojang (135.56 kV), and Darajat (135.58 kV). The system bus voltage profile under normal circumstances is as follows:

Table 1. Channel Load Charge Data on Simulation Results.

| NO | CHANNEL (From To) | I NOMINAL (A) | LOADING (%) |
|----|-------------------|---------------|-------------|
| 1  | CIRATA - CKPAY    | 1620          | 26.95       |
| 2  | CKPAY - PBRAN     | 1620          | 0.98        |
| 3  | CIRATA - PWKT     | 1620          | 35.68       |
| 4  | CKPAY - PWKT      | 1620          | 8.20        |
| 5  | CIRATA - PDLRNG   | 1400          | 90.04       |
| 6  | PDLRNG - LGDAR    | 580           | 12.39       |
| 7  | PTUHA - LGDAR     | 1600          | 4.87        |
| 8  | BDUTR - PDLRNG    | 580           | 46.80       |
| 9  | CBBRU - PDLRNG    | 1200          | 15.80       |
| 10 | CBBAT - PDLRNG    | 1200          | 36.48       |
| 11 | CBBRU - CBBAT     | 580           | 6.23        |
| 12 | PDLRNG - JTLHR    | 580           | 40.77       |
| 13 | JTLHR - TTJBR     | 1160          | 43.52       |
| 14 | TTJBR - KSBRU     | 1160          | 28.62       |
| 15 | KSBRU - DWUAN     | 580           | 31.58       |
The minimum transmittal (%) of the transmission line (%) is 0.98% on the largest CKPAY-PBRAN transmission line and the loading (%) is 90.04% on the CIRATA-PDLRNG transmission line segment. From Table 1 it can be seen that under peak load conditions, one channel is overloaded.

3.2. Contingency Conditions
Contingency 1 is the state of the system when there is interference on two transmission lines ie CKPAY-CIRATA & BDUTR1-PDLRNG1 buses which result in the release of two channels.

Figure 2. Condition of Contingency system.
Figure 3 is bus voltage profile in normal and contingency conditions. In the event of disruption will affect the occurrence of changes in bus voltage, especially buses adjacent to the location of the disturbance. Several buses experienced considerable voltage drop, even some buses decreased to below the defined limit of 135 kV. In the case of contingency, the release of the Cikumpay-Cirata and North Bandung-Padalarang transmission lines made three buses with considerable drops in value, ie Cikumpay bus (129.32 kV), Pbran (129.28 kV), and Purwakarta (131.26 kV). Almost all buses in the Cirata subsystem have decreased to the lower limit of the rated system nominal voltage of 135 kV, except for four buses still within the limits of the SPLN operations ie Cirata buses (140.35 kV), Padalarang (135.16 kV), Lagadar (135.15 kV), and Patuha (137.27).

Table 2. Loading Transmission on Normal Conditions and during Contingency.

| Conditions | Channel (From To) | \( I_{\text{nominal}} \) (A) | \( I_{\text{operating}} \) (A) |
|------------|------------------|-----------------|-----------------|
| Normal     | CKPAY - CIRATA   | 1620            | 476.91          |
|            | CIRATA – PWKT    | 1620            | 689.18          |
|            | BDUTR 1 – PDLRNG 1 | 580          | 271.46          |
|            | BDUTR 2 – PDLRNG 2 | 580          | 271.46          |
| Failurer   | CKPAY - CIRATA   | 1620            | -               |
|            | CIRATA - PWKT    | 1620            | 1166.09         |
|            | BDUTR 1 – PDLRNG 1 | 580          | -               |
|            | BDUTR 2 – PDLRNG 2 | 580          | 542.92          |

In table 2 when there is disturbance on the transmission line CKPAY-CIRATA and BDUTR1-PDLRNG will cause the transmission loading changes especially in the buses are connected and close to the channels that come out of the system. In the CKPAY-CIRATA and BDUTR1-PDLRNG channels there are two channels that each channel is loaded at 476.91 A and 271.46 A under normal conditions. Based on the power flow analysis, when there is a disturbance on one channel, the other channel has a load of 1166.09 A and 542.92 A. The carrying current carrying capacity of CIRATA-PWKT is 1620 A while the current carrying current of BDUTR2-PDLRNG2 is 580 A. Thus, the CIRATA-PWKT channel has a load of 1166.09 / 1620 x 100% = 71.98%, and BDUTR 2-PDLRNG 2 has 542.92 / 580 x 100% = 93.60%. The price of the CKPAY-CIRATA and BDUTR2-PDLRNG2 channel loading is smaller than 125% in conductor then in this condition the channel does not exit the system, but only the critical loading.

3.3. Load Shedding Solution

Contingency system repair solution (N-2) there are two ways that is by adding the channel to the disruption and do load shedding.
Table 3. Load Release of Each Case.

| No | Name of Solution | Bus load in -Load Shedding | Information |
|----|------------------|---------------------------|--------------|
| 1  | Load Shedding    | CKPAY, CIRATA, PWKTA, BDUTR, PDLRNG, CBBAT, CBBRU, JTLHR, TTJBR, KSBRU, DWUAN | Contingency Condition Solution |

Load Shedding Simulation is a solution for contingency conditions [7]. The data from Table 3 can be concluded that by the release of 30% load on each bus whose voltage is less than the SPLN standard of 135 kV when the contingency state 1, causing the CKPAY-CIRATA and BDUTR2-PDLRNG2 ducts to decrease and the tension on the buses whose voltage is less than 135 kV has changed its value to normal, which is at the limit of SPLN.

Table 4. Load Shedding of Simulation Results.

| Condition | Bus | Bus Voltage (kV) | Line (Channel) | I_{nom} (A) | I_{operating} (A) |
|-----------|-----|-----------------|----------------|------------|-----------------|
| Before Load Shedding | CIRATA | 140.35 | CKPAY-CIRATA | 1620 | - |
| | CKPAY | 129.32 | CIRATA-PWKTA | 1620 | 1166.09 |
| | PWKTA | 131.26 | - | - | - |
| | CBBAT | 133.64 | - | - | - |
| | CBBRU | 133.45 | - | - | - |
| | PDLRNG | 135.16 | BDUTR1-PDLRNG1 | 580 | - |
| | | | BDUTR2-PDLRNG2 | 580 | 542.92 |
| | BDUTR | 132.02 | - | - | - |
| | JTLHR | 133.45 | - | - | - |
| | TTJBR | 129.55 | - | - | - |
| | KSBRU | 127.75 | - | - | - |
| | DWUAN | 127 | - | - | - |
| After Load Shedding | CIRATA | 144.82 | CKPAY-CIRATA | 1620 | - |
| | CKPAY | 137.84 | CIRATA-PWKTA | 1620 | 775.86 |
| | PWKTA | 139.16 | - | - | - |
| | CBBAT | 141.09 | - | - | - |
| | CBBRU | 140.97 | - | - | - |
| | PDLRNG | 142.08 | BDUTR1-PDLRNG1 | 580 | - |
| | | | BDUTR2-PDLRNG2 | 580 | 431.26 |
| | BDUTR | 139.72 | - | - | - |
| | JTLHR | 143.19 | - | - | - |
| | TTJBR | 140.59 | - | - | - |
| | KSBRU | 139.39 | - | - | - |
| | DWUAN | 138.9 | - | - | - |

Table 4 is load shedding of simulation results, the impact of doing Load Shedding is a power loss. Power discharged in the event of a contingency disruption. This is done to keep the system safe and secure. Total loss of power at the time of LS load discharge (30%) is 285.51 MW.

The results of system testing performed with the analysis of power flow on the system that has been improved both in normal conditions and contingency conditions, indicating that the system improvements made to fix the weaknesses of existing systems. This is demonstrated by the results of tests performed with the analysis of power flow on the system that has been improved. Both under normal conditions and contingency conditions indicate that system improvements made by the Load Shedding method successfully fix the existing system weaknesses. As shown in Figure 4 below:
Figure 4. Improved system with Load Shedding method.

- Once the system is repaired there is no bus voltage that violates the limits of operation either in normal circumstances, contingency state.
- System improvements have successfully overcome the loading that exceeds the nominal current of the carrier on the transmission line.

Thus, the N-2 security reliability criteria are met, ie, in the contingency state (N-2), there are no system quantities that violate the specified operating limits. It shows that the system improvement is effective.

4. Conclusions and Recommendation

4.1. Conclusions
Based on data analysis and discussion can be concluded as follows:

- The voltage values on the substations relay in all contingency case studies (N-2) decreased below the lower limit of the SPLN, ie -10%. So at the time of contingency (N-2) the stress on the Cirata 150 kV subsystem is not reliable.
- There are some critical transmission channels that are CIRATA-PWKT transmission line, BDUTR2-PDLRNG2, JTLHR2-TTJBR2, PDLRNG-CBBRU
- System improvements due to contingency disorder can be done by way of load loading (load shedding).
- The discharge load loss due to contingency 1 is 285.51 MW.

4.2. Recommendations
The recommendations of this study are as follows:

- The results of this study should be used as input for PT. PLN to develop the system in order to improve the reliability of Cirata 150 kV subsystem.
- To improve the system during contingency, in addition to using a load-release method, it can also be done by adding channels from either new generator / GI or old generator / GI.
- The need for continuous electrical system operation planning in anticipation of the development of load and the development of transmission network configuration in order to improve the safety and reliability of power system.
- Calculation analysis techniques in this study using ETAP program, for it can also be developed by using other programs as a comparison.
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