CONTINUITY ANALYSIS OF SUBSTATION DISTRIBUTION IN N-1 CONDITIONS FOR LOAD ADDITION OF PEMALANG SUBSYSTEM

Muhammad Lukmanul Hakim[1], Mochammad Facta,ST.,MT.,Ph.D[2], Dr. Susatyo Handoko,S.T.,M.T.[3]

[123]*Diponegoro University, Faculty of Engineering, Department of Electrical Engineering, Master's Program*

ABSTRACT

Reliable electric power systems and electrical energy with good quality or meet standards significantly contribute to modern society's life. A continuous electricity supply without outages is necessary for the Electric Power System. Under certain contingency conditions, N-1 IBT Pemalang was not met, so a Defense Scheme scheme was needed to anticipate system failures that might cause widespread outages. The application of Automatic Load Shedding in the Pemalang Sub System is expected to make the system more potent and can prevent widespread outages. This Thesis will be discussed the functions and advantages of applying Automatic Load Shedding to the Pemalang Sub System. The Digsilent Power Factory application is used to analyze the impact of the Automatic Load Shedding on the Pemalang Sub System.

Keywords:- *Defense Scheme, Outages, Digsilent, Automatic Load Shedding*

---

1. INTRODUCTION

Java Bali Electric Power System is Indonesia's most extensive electric power system. In 2021 based on the 2021 EOT (Annual Operations Evaluation) in General, can be seen in the following table:

Table -1 Overview of the Java Bali electricity system in 2021

No.	Nama	Jumlah
1	Peak Load	28,094 MW
2	Energy	197.068 TWH (growth of 3.70%)
3	Load Factor	80,08 %
4	Transmission Shrinkage	1,92%
5	Cost of Goods Produced	914,334 Rp/kWh

6	Highest transfer east to west	3.195 MW

A reliable electric power system and electrical energy with good quality or meeting standards have a significant contribution to the life of modern society because of their dominant role in the fields of industry, information, mining, public transportation, and others, all of which can operate due to the availability of electrical energy. The three operating criteria of the Electric Power System are reliability, economical, and quality. Reliability is the main criterion that must be maintained to minimize not served energy or widespread disruption to consumers. There are generally two aspects of supply: supply availability (adequacy) and securities (contingency and stability).

IBT 500/150 kV in the Jamali System during the highest loading period, there are some IBT 500/150 kV burdened above 50%. This is not a problem when the system is running normally. However, when the system is interrupted by one of the parallel configured IBTs, this will cause the other IBT transformer to be overloaded by more than 100%. Based on the relay setting data, the relay OCR (Over Current Relay) has a set of 1.2 In, so if the IBT has been burdened 120% of In (nominal current limit), then the Rele OCR will order the PMT (Power Breaker) to open so that it can isolate the IBT. If that happens, it will cause an outage of the Sub System under the IBT. This can affect the reliability of electricity supply to customers so that PLN has the potential to suffer losses because it cannot sell electricity and the potential to decline PLN's image in the community in serving electricity supply to customers.

Under normal operating conditions, the GITET Pemalang IBT Sub System has an IBT capacity below 50% for each IBT with a parallel configuration. Contingency is a condition caused by the discharge or failure of one or more generators and or equipment of a transmission system. Criterion N-1 is the operating criterion of electrical systems approved and used worldwide (generally). Reliability while maintaining the safety level of the N-1 is approximately following the fulfillment of the balance between load demand and production volume. Therefore, a reliable electric power system must meet at least the N-1 safety reliability criteria. The N-1 reliability criterion must be met regardless of the cost.[1] This is an ideal condition during regular operation because the Pemalang Sub System is supplied by IBT with N-1 reliability fulfilled. However, operating patterns may change under certain conditions to optimize existing Distribution and Electric Power Systems. In this case, the Pemalang Sub System bears or takes over the loading of GI Kebasen and GI Brebes. This must be mitigated so that the Pemalang Sub System does not experience a complete outage in the event of a disturbance in one of the IBTs when the Sub System is operating under conditions N-1 is not met. When there is a disturbance in one of the IBTs, the overcurrent relay (Over Current Relay) will work to order the PMT (Power breaker) on the IBT to remove / open. Thus, the electricity supply to the two IBTs will be lost because the two IBTs that supply the Pemalang Sub System are loose from the Pemalang Sub System.

Under normal operating conditions, the Pemalang Sub System can be seen in the following figure:

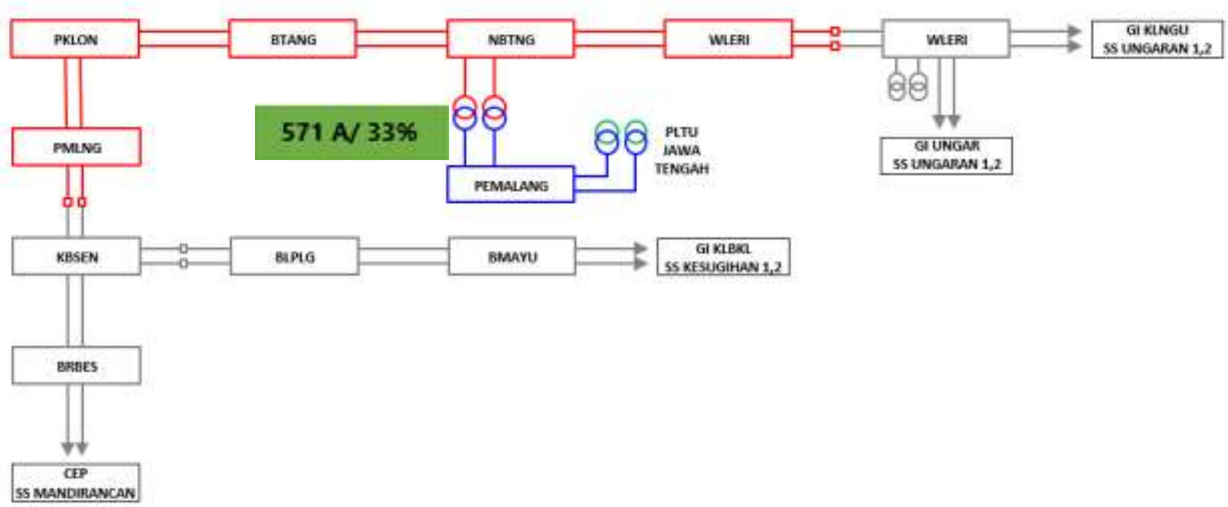

Fig -1 Normal configuration of operation SS Pemalang 1,2

The picture above shows that the load of each IBT is in the range of 33%, so when there is a disturbance in one of the IBT conditions. The Pemalang Subsystem condition can still be said to be safe because the IBT load that is still operating is still below the OCR relay setting.

Figure 2 below is the configuration condition of Pemalang Sub System 1.2 when taking over a load of GI Kebasen and GI Brebes, which are part of the Mandirancan Sub System. Configurations such as the following are performed when there is a disruption to the CEP plant so that the supply to the Mandirancan Sub System is reduced. So to avoid outages, GI Kebasen and GI Brebes were taken over or temporarily entrusted to Sus Sistem Pemalang. However, this caused Pemalang IBT to increase the load to around 64% for each IBT. This can still be accommodated even though there is a vulnerability, namely, when N-1 IBT or a disturbance occurs in one of the IBTs, the burden borne by the still operating IBT becomes around 136%, as shown in figure 3. Figure 3 shows that IBT is burdened beyond its OCR setting of 1.2 or 136% of its capacity. This can lead to an outage or 136% of its ability. This can cause an outage or blackout in the Pemalang Sub System, so it is necessary to take mitigation measures to secure the Pemalang Sub System.

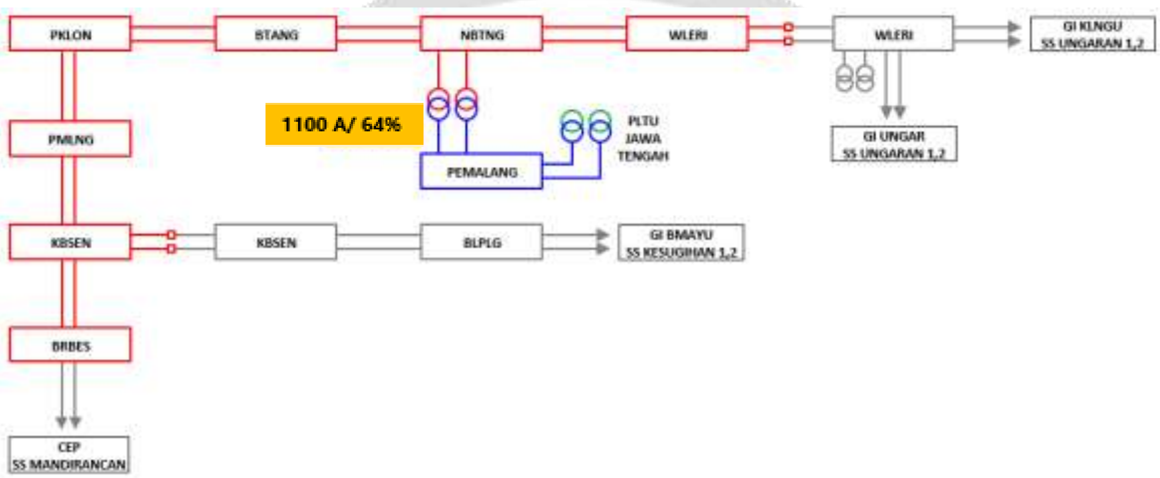

Fig -2 Configuration of SS Pemalang 1,2 plus GI Kebasen & GI Brebes

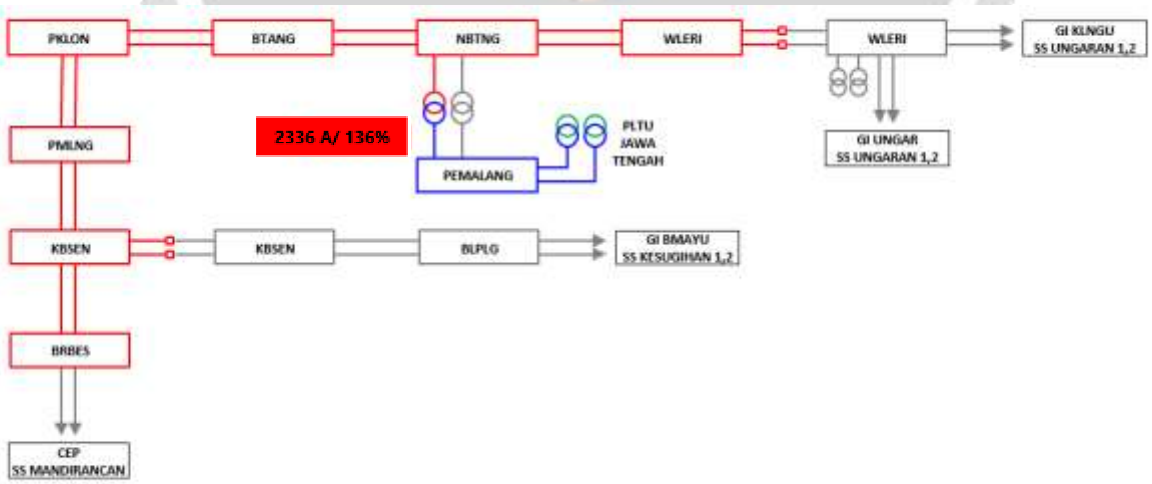

Fig -3 SS Pemalang1.2 Configuration plus GI Kebasen & GI Brebes condition N-1 IBT

PT. PLN (Persero) must conduct a system operational study to maintain system reliability against abnormal system conditions.[2] Under normal conditions, when IBT loading reaches above 120% of the nominal current, what happens is that the OCR relay works.[3] If the OCR works under the N-1 condition of the Pemalang Sub System, then the Pemalang Sub System will have a complete outage or BlackOut. Based on this, it is necessary to research to mitigate or solve problems so that the Pemalang Sub System does not experience a complete outage when there is a disturbance in one of the IBT when the N-1 condition is not met.

1.1. Limitations of the Problem

The limitations of the problem in the preparation of this Thesis are as follows:

- Only discuss the GITET Pemalang IBT Subsystem.
- Only discusses the condition of N-1 IBT GITET Pemalang.
- The software used by the compiler in designing and doing this Thesis is using Digsilent Power factory 15.1

1.2. Research Object

The objectives of this study include the following:

- Knowing the impact on the IBT GITET Pemalang Sub System in the event of N-1 contingency conditions and when there is a change/increase in load on the Sub System.
- I am looking for possible solutions to prevent or avoid blackouts on the IBT GITET Pemalang Sub System.

2. THEORETICAL FOUNDATIONS

2.1. Relay

A relay is a device designed to detect faults, measure and start detecting abnormal electrical equipment, and automatically open the switch to isolate damaged equipment or system parts, as well as a signal in the form of a bell or lamp.[4]

The relay in the electric power system has the following functions:

- Sense, measure, and determine the part of the broken system and isolate it as soon as possible so that the other system can operate normally.
- Reduces more severe damage to disrupted equipmentMengurangi kerusakan serius yang disebabkan oleh perangkat yang terdampak gangguan.
- Reduce the interference effects of other undisturbed system parts in the system. It also prevents the spread of disturbances and minimizes environmental risk.

2.2. OverLoad Shedding (OLS)

Overload shedding is a form of load reduction activity that occurs automatically or manually, which is helpful for managing the operating system to avoid and prevent total power failure (Blackout).[4] The load to be removed must be determined in advance and will be carried out in stages at each specified stage. In the application of OLS, several things must be considered, namely, the amount of customer load that will be removed from the system, the stages of operation, the time lag between one step and another, and the loading rating at which each stage is released.

- Nominal Current

Nominal current is a protection equipment parameter working on cables and IBT. The tiny current value can be hung using the following formula:

$$In = \frac{S_{base}}{\sqrt{3}V_{base}} \quad (2.1)$$

With :

In: Nominal Current (A)

S_{base} : Pseudopower (kVA)

V_{base} : Voltage of Phase secondary (kV)

- CT Ratio

The scheme is applied to determine the CT ratio used in overload shedding to determine the nominal current of equipment in the electric power system. In general, CT has a ratio of 1/2000 and 5/2000. To find out the CT ratio to be used can be calculated using the following formula:

$$I_{sett}(primer) = 1{,}1xI_{nominal}\,CT \tag{2.2}$$

$$I_{sett}(skunder) = I_{set\,(primer)}x\ \frac{1}{rasio\ CT}\ A \tag{2.3}$$

- Operation Time

To determine the time multiple setting to be used in overload shedding is calculated using the following formula:

$$t\ =\ \frac{k}{(I_{fault})^{0.02}-1}\ x\,TMS \tag{2.4}$$

3. RESEARCH METHODS

- The subject of the study is the IBT GITET Pemalang Subsystem
- The tool used is to use a computer to process research data
- How to collect data with Literature Studies and Interviews
- Data analysis uses quantitative methods based on specific value values that reference the results of the processed data.

4. CONCLUSION

4.1. OLS Relay setting

- Current Nominal

The nominal working current of the equipment is as follows:

$$In\ =\ \frac{S_{base}}{\sqrt{3}V_{base}}$$

$$In\ =\ \frac{500.000\ kVA}{\sqrt{3}\ 168\ kV} = 1718\text{ A}$$

Based on the calculation above, a nominal current of 1718 A is obtained, which is the specification of the equipment or IBT and following the IBT nameplate, and refers to the declaration of readiness of UPT equipment (PLN Transmission Unit) as the owner of the asset, IBT in the Pemalang Sub System has a nominal current of 1718 A.

- CT Ratio

PLN provides relay settings installed on the protection system that can be calculated based on the nominal IBT current.

For the current relay in the set of 1.1 x nominal current, while for the OCR relay in the set of 1.2 to 1.3 x nominal current (according to the defense scheme book). Other parameters must be met when the overcurrent relay time adjustment must adjust to the conditions of such systems. In general, the application of the minimum time setting is at least 0.3 seconds. This decision was made to prevent the relay from tripping in the event of a significant current surge when IBT 2 was shut down due to interference.[5] The current setting can be calculated as follows:

Primary side setting current:

$$I_{sett}(primer) = 1{,}1xI_{nominal}$$

$$I_{sett}(primer) = 1{,}1\ x\ 1718\ A$$

$$= 1889{,}9\ A$$

From this calculation, it is obtained that the setting current on the primary side is 1889.9 A and rounded to 1900 A. While the secondary side setting current is as follows:

$$I_{sett}(skunder) = I_{set\ (primer)}x\ \frac{1}{rasio\ CT}\ A$$

$$I_{sett}(skunder) = 1900\ x\ \frac{1}{2000}\ A$$

$$= 0.95\ A$$

From the results of the calculation of the primary nominal current and secondary nominal current, it can be determined the CT ratio used in this scheme. With a primary nominal current of 1900 A and a nominal current of 0.95, CT can be used with a ratio of 1/2000 A.

4.2. OLS Scheme

For the OCR relay not to work when the IBT is burdened by In when the N-1 condition occurs with the addition of the Kebasen GI and GI Brebes loads, it is necessary to create an OLS scheme or partial load shedding to reduce the IBT load. In its implementation, it is essential to know which equipment can be removed from the operating system. It is necessary to have mediation with the distribution party, which helps understand the VIP and VVIP customer side. Here are the loading targets that will be removed from the operating system.

Table -2 Stage 1 load shedding targets

No.	Target			Information
	GI	Tools	Load	
1	Kebasen	TD 1	34,8 MW	Stage 1 (3 Second)
2	Kebasen	TD3	30,9 MW	
3	Kebasen	TD4	28.8 MW	
4	Brebes	TD1	52,9 MW	
5	Brebes	TD3	35 MW	
Total			182,3 MW	

Table -3 Stage 2 load shedding targets

Target		Information
Tools	Load	

TRANSMISSION PEMALANG-KEBASEN	249 MW	Stage 2 (4 Second)

The following is a target scheme of OLS operations with stage 1 load shedding GI Kebasen TD1, TD3, and TD4 and GI Brebes TD1 and TD3 with a load of 182 MW. When stage one has not been fulfilled, the OLS relay will work in stage two by opening the Pemalang GI PMT to the Kebasen GI so that the load of 249 MW is released.

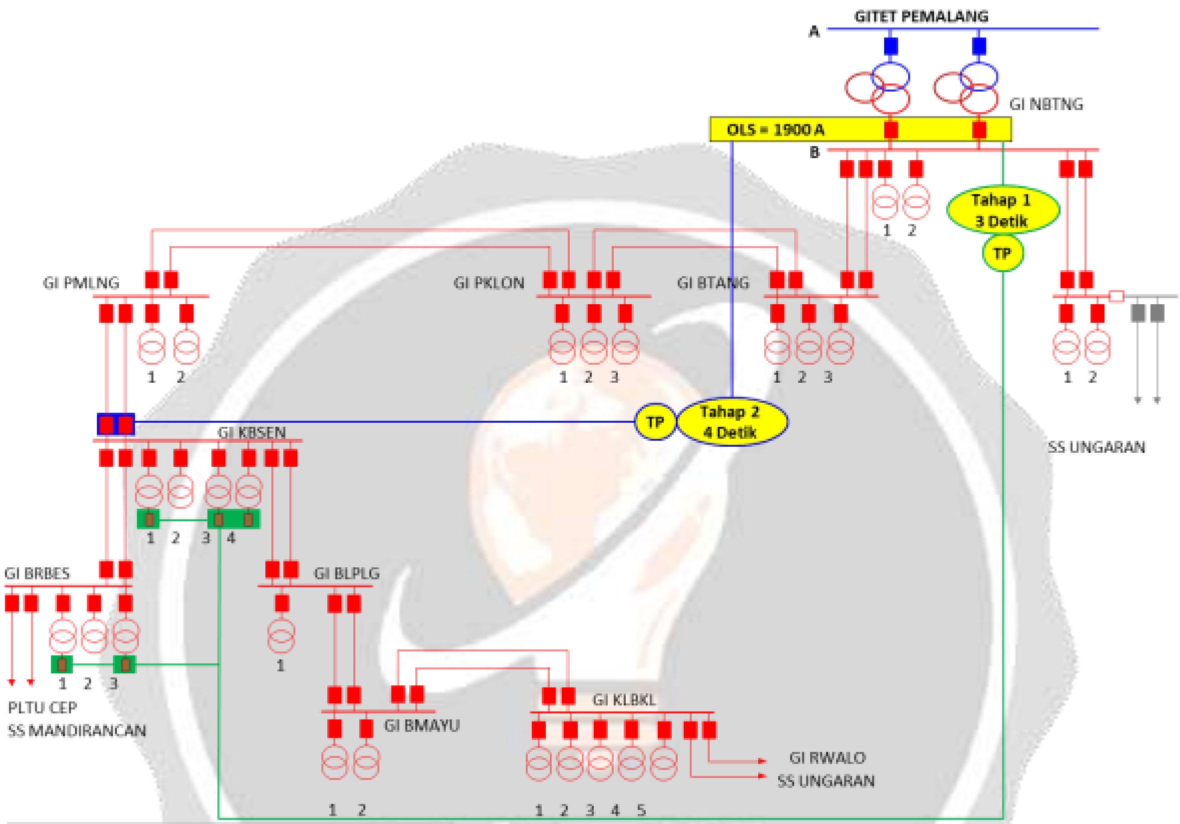

Fig -4 OLS scheme configuration SS Pemalang 1.2 plus GI Kebasen & GI Brebes

4.3. OLS Simulation

Can be seen figure 10 is a load release simulation ordered by an overcurrent relay during N-1 IBT conditions with an SS Pemalang 1.2 configuration plus GI Kebasen & GI Brebes. There is a red circle mark on some transformers indicating that the PMT on the transformer has opened or closed and released the load to obtain a steady-state condition on the IBT that is still operating.

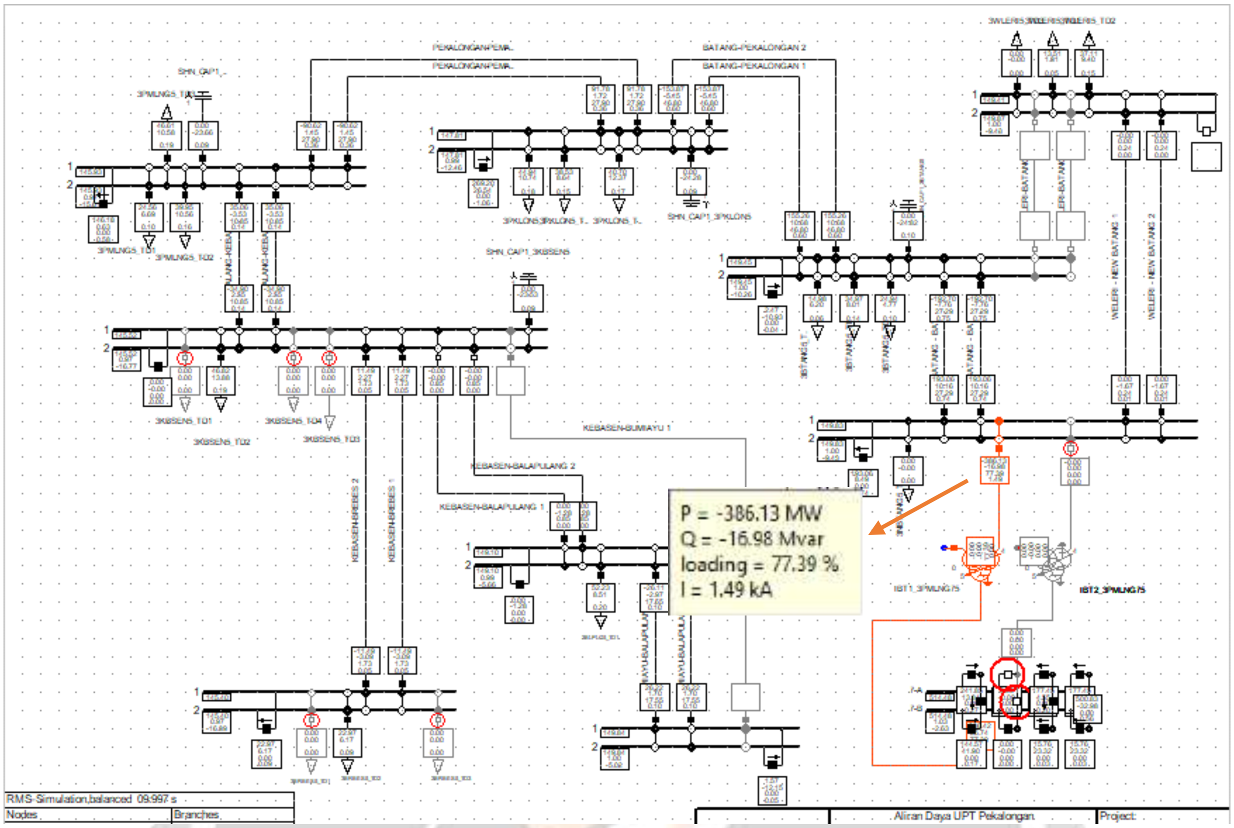

Fig -5 Working simulation of OLS configuration SS Pemalang 1.2 plus GI Kebasen & GI brebes

4.4. Load Calculation

In order for the Sub System not to experience blackout due to overload, the OLS rele must work before setting the time and setting the OCR rele current which works to protect IBT. Dapat dillihat dari gambar berikut, sampai di detik ke 0.999 s kedua IBT beroperasi normal dan dibebani 1100 A, kemudian untuk memenuhi kriteria keandalan N-1 diasumsikan IBT 2 Sub Sistem Pemalang mengalami gangguan yang menyebabkan tripnya IBT tersebut pada detik ke satu sehingga IBT 1 akan terbebani 2215 A. In this condition, the OLS rele will work to release the loads that are set to be removed from the system to secure IBT 1. After rele OLS work, the loading of IBT 1 becomes 1488 A and rele OCR does not work securing IBT. As a result, PLN did not suffer losses due to loss of customer burden and the Company's image was maintained.

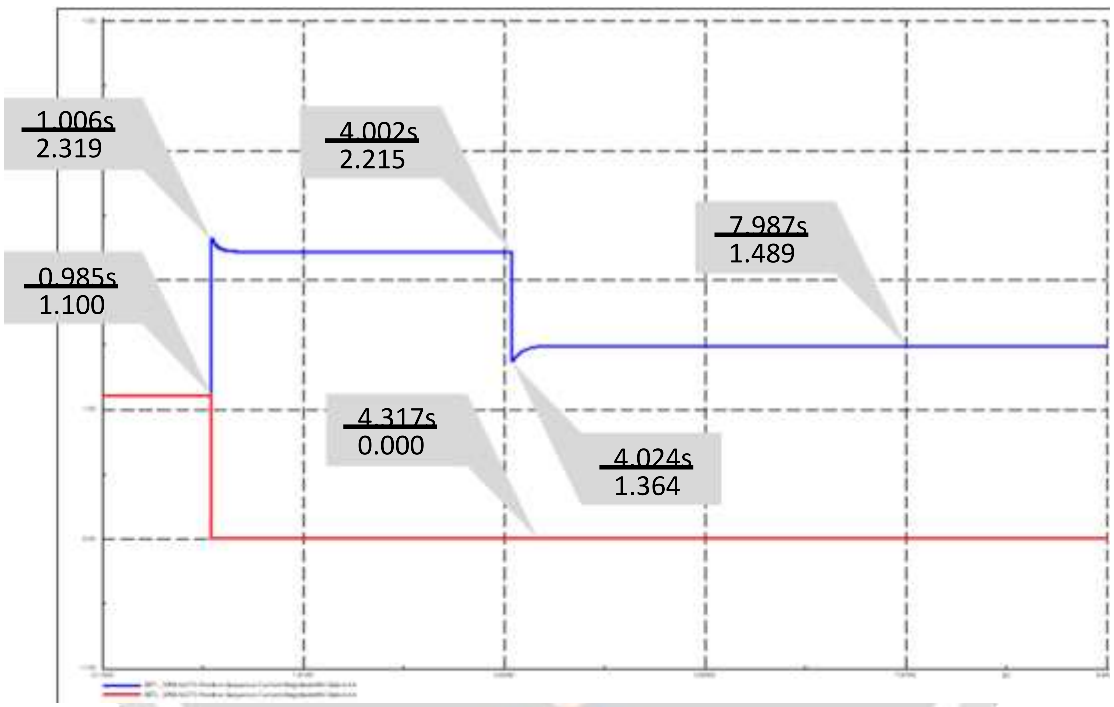

Chart - 1 IBT 1 and IBT 2 Pemalang Sub System before and after rele OLS work

6. REFERENCES

[1] F. Alvarado and S. Oren, "Transmission System Operation and Interconnection," *Natl. Transm. Grid Study*, pp. A1–A53, 2002.

[2] Kementrian ESDM, "Aturan Jaringan Sistem Tenaga Listrik (Grid Code)," *Menteri Energi dan Sumber Daya Miner. Republik Indones.*, no. 3, pp. 417–607, 2020, [Online]. Available: https://jdih.esdm.go.id/storage/document/PM ESDM No 20 Tahun 2020.pdf

[3] P. Proteksi, S. Udara, and T. Tinggi, "Pola Proteksi Gardu Induk," pp. 1–12.

[4] E. Dermawan and D. Nugroho, "Analisa Koordinasi Over Current Relay Dan Ground Fault Relay Di Sistem Proteksi Feeder Gardu Induk 20 kV Jababeka," *Elektum J. Tek. Elektro*, vol. 14, no. 2, pp. 43–48, 2017.

[5] H. Aji, A. Purwanto, E. Y. Pramono, M. Angga, and Taslim, "Island operation design in bali grid with RoCoF relay," *4th IEEE Conf. Power Eng. Renew. Energy, ICPERE 2018 - Proc.*, pp. 1–5, 2018, doi: 10.1109/ICPERE.2018.8739501.