



Analysis of Defense Scheme in OverLoad Shedding on 70kV Using DIgSILENT 15.1 for Enhancing the Reliability

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ABSTRACT

This research investigates the reliability of Kediri Subsystem 3,4, focusing on the impact of a Manisrejo-Nganjuk Transmission Line trip on Manisrejo-Caruban Transmission Line under normal and N-1 contingency conditions. Using Digsilent 15.1, load simulations were conducted revealing that under normal conditions, Manisrejo-Caruban Transmission Line operates at 88.92% capacity. A trip on Manisrejo-Nganjuk line could potentially overload Manisrejo-Caruban line, failing N-1 contingency requirements. To address this, Overload Shedding (OLS) was implemented on the Manisrejo-Caruban Transmission Line. Simulation results post-OLS implementation showed a reduction in line load to 64.99%, necessitating an OLS setting addition of 435.6 A. A two-stage OLS strategy was adopted: the first stage targeted OLS release at Nganjuk Substation Transformer 1, followed by the second stage at Caruban Substation Transformer 1. This effectively reduced the Manisrejo-Caruban Transmission Line load to 58.1% of its capacity. Economically, PT. PLN (Persero) benefited significantly from this implementation, saving Rp. 42,170,793 in costs. These findings underscore the efficacy of OLS strategies in enhancing system reliability and mitigating overloads, thereby optimizing operational efficiencies and cost savings for power utilities.

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1. INTRODUCTION

In the case of the 70kV Manisrejo-Nganjuk-Caruban SUTT, which is a *single phi* network in a non-metropolitan area, the *reclose* disturbance on April 1, 2024 shows the potential for overloading the 70kV Manisrejo-Caruban SUTT in the event of a trip on the 70kV Manisrejo-Nganjuk SUTT. This is not in accordance with the provisions of the Minister of Energy and Mineral Resources Regulation No. 20 of 2020

which requires that the current load in all transmission network equipment and GI remain within the normal rating limit for all *single contingency*. N-1 contingency refers to a situation in which one part of the electrical transmission system goes out due to interruption or maintenance. Therefore, the part of the transmission system that does not go out must be able to handle all existing electrical loads, so that the electricity supply is maintained and the system continues to operate reliably [1]. To prevent widespread blackouts, the addition of a *Defense Scheme Over Load Shedding* on the 70kV Manisrejo-Caruban SUTT is a solution to consider. This scheme aims to secure the operation of conveyors or transformers that are unable to accommodate the existing distribution load, by releasing part of the burden on consumers [2]. The implementation of this scheme is expected to maintain system reliability and prevent widespread disruptions that have the potential to cause losses to PLN and consumers. The research method used in this study is quantitative by taking data from the PLN UP2B East Java office and then calculating based on the data obtained. The data obtained was in the form of installation readiness data, conveyor peak load data, transformer loading data and supporting data.

In the previous study on the addition of the *defense scheme overload shedding* IBT 1 & 2 Pemalang, there was a potential overload with the conditions before the addition of OLS, which was 133%. The study shows that it is necessary to install OLS on IBT 1 & 2 Pemalang by setting OLS at 1900 A [3]. In another study on the addition of the *defense scheme of IBT 150/70kV Tasikmalaya* shedding because it did not meet the N-1 contingency, the OLS was added by releasing a load of 91.34 MW which made the voltage drop in the busbar overcame [4]. This study will analyze the reliability of the 70kV Manisrejo-Caruban SUTT in dealing with abnormal conditions due to trip disturbances on the 70kV Manisrejo-Nganjuk SUTT, as well as the impact of economic factors from the implementation of the *Defense Scheme Over Load Shedding* to minimize the risk of *overload* on the conductor.

2. RESEARCH METHOD

2.1 Research Flow Diagram

The procedure began by identifying the problems that existed in the 70kV Manisrejo-Caruban-Nganjuk SUTT, then data was collected in the form of installation readiness data, conveyor peak load data, transformer loading data and supporting data. After data collection, a reliability study was carried out on the 70kV Manisrejo-Caruban SUTT under normal conditions and during the N-1 condition before and after the addition of OLS. Then a calculation of the economic impact was carried out from before and after the addition of OLS to the 70kV Manisrejo-Caruban SUTT.

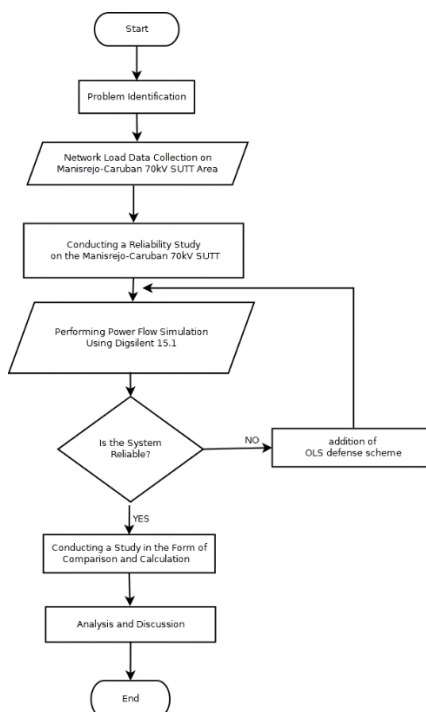


Figure 1. Research Flow Diagram

2.1 Research Flow Diagram

In this study, the creation of the OLS scenario requires installation readiness data, transmitter peak load data, transformer loading data located in the Kediri 3.4 SUTT 70kV Manisrejo-Caruban-Nganjuk Subsystem

in December 2023-April 2024, so that setting the OLS scheme at the peak load condition of the subsystem is considered to be able to represent the load condition of the subsystem at other times, and setting the OLS at the peak load time is considered to be able to work on other subsystem conditions.

Data PT. PLN (Persero) UP2B Java-Bali, SUTT 70kV Manisrejo-Caruban experienced the highest load in January 2024, while the largest transformer load occurred in February 2024. The load data that experienced peak conditions in December 2023-April 2024 at GI Caruban and GI Nganjuk was the load of distribution transformers. Modelling using DIgSILENT 15.1, installation readiness data, transmitter peak load data, transformer loading data are not changed in value to obtain conditions similar to peak load conditions in December 2023-April 2024, then the data is simulated using DIgSILENT 15.1.

1. Shipper Readiness Data

Table 1. Equipment Readiness Data

Conductor		Voltage	Type of conductor	Length of conductor	Nominal Current	Readiness of delivery	CT Ratio	TMS	TPAR	
From	To								Status	Time
Manisrejo	Caruban	70 kV	OCSR Ostrich	16,86 kms	396 A	100 %	400/5	0,3	Enable	2
Manisrejo	Nganjuk	70 kV	OCSR Ostrich	56,30 kms	396 A	100 %	400/5	0,3	Enable	2
Caruban	Nganjuk	70 kV	OCSR Ostrich	36,44 kms	396 A	100 %	400/5	0,3	Enable	2

2. Conveyor Loading Data

Table 2. Manisrejo-Caruban-Nganjuk 70kV SUTT Conveyor Loading Data

Month	transmission conductor	transmission readiness	highest load		
			A	MW	%In
Des 2023	Manisrejo-Caruban	396 A	332	38,6	84,06
	Manisrejo-Nganjuk		77	9	19,7
	Caruban-Nganjuk		32	3,5	8,1
Jan 2024	Manisrejo-Caruban	396 A	352	40,9	89
	Manisrejo-Nganjuk		80	9,4	20,67
	Caruban-Nganjuk		34	3,9	9
Feb 2024	Manisrejo-Caruban	396 A	349	40,5	88,27
	Manisrejo-Nganjuk		96	11,4	24,6
	Caruban-Nganjuk		12	1,1	2,7
March 2024	Manisrejo-Caruban	396 A	333	38,6	84,3
	Manisrejo-Nganjuk		92	10,9	23,64
	Caruban-Nganjuk		11	0,9	3,57
Apr 2024	Manisrejo-Caruban	396 A	319	37	80,7
	Manisrejo-Nganjuk		75	8,8	19,28
	Caruban-Nganjuk		28	3,2	7,51

3. Transformer Loading Data

Table 3. Data on Loading of GI Caruban and GI Nganjuk Transformers

Substation	Transformator	Monthly Loading Data (MW)					Average load (MW)
		Des	Jan	Feb	March	Apr	
70 kV Caruban	Trafo 1 – 20 MVA	13,39	16,91	11,33	12,29	13,33	13,45
	Trafo 2 – 30 MVA	37,56	26,69	29,19	26,24	25,91	27,12
70 kV Nganjuk	Tarfo 3 – 20 MVA	5,26	5,23	10,04	9,71	5,4	7,13

3. RESULTS AND DISCUSSION

3.1 Manisrejo-Caruban 70kV SUTT Reliability Analysis

The reliability analysis of the 70kV Manisrejo-Caruban SUTT was carried out using the system peak load realization data and load data per GI which was then entered into the Digsilent 15.1 application, after which observations were made to see the results of the study or study during normal conditions and N-1 conditions which can be seen as follows:

Table 4. Mitigation Results of Normal Conditions and N-1 SUTT 70kV Manisrejo-Caruban

Month	Mitigation	Conductor Manisrejo - Caruban			Information
		A	MW	%In	
Des 2023	normal condition	332	38,6	83,92	less safe, load above 50%
	Condition N-1 (manisrejo-nganjuk trip)	417	47,9	105,38	not safe, load above 100%
Jan 2024	normal condition	352	40,9	88,92	less safe, load above 50%
	Condition N-1 (manisrejo-nganjuk trip)	441	50,7	111,41	not safe, load above 100%
Feb 2024	normal condition	350	40,6	88,55	less safe, load above 50%
	Condition N-1 (manisrejo-nganjuk trip)	459	52,8	115,599	not safe, load above 100%
March 2024	normal condition	337	39	85,14	less safe, load above 50%
	Condition N-1 (manisrejo-nganjuk trip)	441	50,7	111,47	not safe, load above 100%
April 2024	normal condition	339	39,3	85,73	less safe, load above 50%
	Condition N-1 (manisrejo-nganjuk trip)	444	51	112,19	not safe, load above 100%

From the data in Table 4 above, it can be seen that the highest load SUTT is in February 2024 where during normal conditions the 70kV Manisrejo-Caruban SUTT is loaded at 88.55% of the equipment capacity and during the condition of the N-1 SUTT 70kV Manisrejo-Nganjuk trip, the 70kV Manisrejo-Caruban SUTT is loaded at 115.99% of the equipment capacity.

3.2 OCR and OLS calculations

From the results of the mitigation carried out, it is necessary to add OLS to reduce the potential for widespread blackouts.

1. Arus Setting OCR

$$I_{set\ OCR} = 1,2 \times \text{Arus Nominal (In)} \quad (1)$$

$$I_{set\ OCR} = 1,2 \times 396 \text{ A}$$

$$I_{set\ OCR} = 475,2 \text{ A}$$

2. Arus Setting OLS

$$I_{set\ OLS} = 1,1 \times \text{Arus Nominal (In)} \quad (2)$$

$$I_{set\ OLS} = 1,1 \times 396 \text{ A}$$

$$I_{set\ OLS} = 435,6 \text{ A}$$

3. OCR Delay Time

For OCR delay time, use the following *Standard Inverse* time characteristics:

$$t_{OCR} = TMS \times \frac{K}{\left(\frac{I}{I_s}\right)^A - 1} \text{ second} \quad (3)$$

where:

t OCR = OCR relay uptime(s)

TMS = Time setting on relay(s)

K = Constant with a value of 0.14 (standard value for Standard Inverse)

I = Relay working current (A)

I_s = Arus setting relay (A)

A = Exponential with a value of 0.02 (standard value for Standard Inverse)

so

$$t_{OCR} = 0,3 \times \frac{0,14}{\left(\frac{2 \times 396}{475,2}\right)^{0,02} - 1} \text{ second}$$

$$t_{OCR} = 4,09 \text{ second}$$

4. OLS Delay Time

To determine the delay time, the OLS here must coordinate with the OCR relay setting and the TPAR *dead time* that already exists in the installation readiness data. OLS is set a maximum of 1 second faster than the OCR setting at 2xIn and *TPAR dead time* is set faster than OLS [5]. It is known that the 70kV Manisrejo-Caruban SUTT TPAR is 2 seconds and the OCR delay time is 4.09 seconds, so the OLS delay time here is in the time range between 2 seconds to 4 seconds. So it is determined that the delay time for phase 1 OLS is 2.5 seconds and phase 2 is 3.5 seconds.

3.3 OLS Scheme

Furthermore, the loose load target for OLS phase 1 and phase 2 was determined by considering VIP customers in each transformer at GI Caruban and GI Nganjuk.

Table 5. Schema Trip OLS SUTT 70kV in Manisrejo-Caru

Scheme Trip OLS Conductor Manisrejo - Caruban		
OCR	In = 396 Iset = 475,2 I = 435,6 A	T OCR = 4 second
Step 1 OLS GI Nganjuk	PMT 20 kV Trafo 2 = 10,04 MW I = 435,5	2,5 second
Step 2 OLS GI Caruban	PMT 20kV Traf0 1 = 11,33 MW	3,5 second

In terms of the selection of this OLS target, the Phase 1 target is applied at Transformer 2 GI Nganjuk because the load on Transformer 2 GI Nganjuk is the smallest load of the three transformers in GI Caruban and in Phase 2 the target selection is carried out at Transformer 1 at GI Caruban because Transformer 1 GI Caruban is the transformer with the second smallest load of the three transformers in GI Caruban and GI Nganjuk. If Phase 1 still poses a risk of overload at the 70kV Manisrejo-Caruban SUTT, Phase 2 will work to free up the excess load in the Caruban GI so that it can avoid widespread blackouts. The following is the target trip scheme for the 70kV Manisrejo-Caruban SUTT,

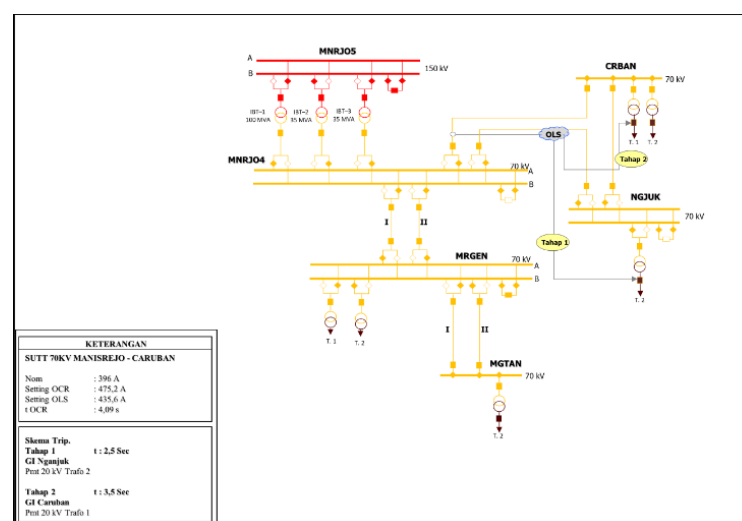


Figure 2. Phase 1 and Phase 2 OLS Trip Target Scheme

After the implementation of OLS phase 1 on the 70kV Manisrejo-Caruban SUTT which is still at voltage, the result of loading is 42.5 MW / 366 A / 92.29% of the equipment capacity. The load on the 70kV

Manisrejo-Caruban SUTT decreased from 111.41% to 92.29%. Then when OLS phase 2 was applied to the 70kV Manisrejo-Caruban SUTT which was still at voltage, the result of loading was obtained of 30.5 MW / 257 A / 64.99% of the equipment capacity.

3.4 ENS Calculation

After a simulation of the application of OLS on the 70kV Manisrejo-Caruban SUTT with results that are in accordance with the capabilities of the equipment, it is continued with the calculation of the efficiency of the resulting impact. To find out the losses incurred during the condition of N-1 SUTT 70kV Manisrejo-Caruban without OLS and during the condition of N-1 SUTT 70kV Manisrejo-Caruban with OLS using the following ENS calculations:

$$\text{ENS (kWh)} = \text{total load shedding} \times \text{Duration} \quad (4)$$

$$\text{ENS (Rp)} = \text{ENS (kWh)} \times \text{operating costs} \quad (5)$$

1. Condition of N-1 SUTT 70kV Manisrejo-Caruban without OLS

In this condition, it is known that the load goes out of 50.56 MW or 50,560 kW. Then the loss can be calculated assuming a 1-hour outage as follows:

$$\text{ENS (kWh)} = 50.560 \times 1 \text{ hour}$$

$$\text{ENS (kWh)} = 50.560 \text{ kWh}$$

$$\text{ENS (Rp)} = 50.560 \text{ kWh} \times 1.444,7$$

$$\text{ENS (Rp)} = \text{Rp } 73.044.032$$

2. Condition of N-1 SUTT 70kV Manisrejo-Caruban with OLS Phase 1

In this condition, it is known that the load went out of 10.04 MW or 10,040 kW. Then the loss can be calculated assuming a 1-hour outage as follows:

$$\text{ENS (kWh)} = 10.040 \times 1 \text{ hour}$$

$$\text{ENS (kWh)} = 10.040 \text{ kWh}$$

$$\text{ENS (Rp)} = 10.040 \text{ kWh} \times 1.444,7$$

$$\text{ENS (Rp)} = \text{Rp } 14.504.788$$

3. Condition of N-1 SUTT 70kV Manisrejo-Caruban with OLS Phase 2

In this condition, it is known that the load went out of 21.37 MW or 21,370 kW. Then the loss can be calculated assuming a 1-hour outage as follows:

$$\text{ENS (kWh)} = 21.370 \times 1 \text{ hour}$$

$$\text{ENS (kWh)} = 21.370 \text{ kWh}$$

$$\text{ENS (Rp)} = 21.370 \text{ kWh} \times 1.444,7$$

$$\text{ENS (Rp)} = \text{Rp } 30.874.683$$

From the three calculations above, there are potential costs that can be saved by the application of the overload shedding defense scheme on the 70kV Manisrejo-Caruban SUTT, the potential costs that can be saved can be calculated as follows:

$$\text{Beban selamat} = 50.560 - 21.370 \text{ kW}$$

$$\text{Beban selamat} = 29.190 \text{ kW}$$

$$\text{ENS (Rp)} = 29.190 \text{ kWh} \times 1.444,7$$

$$\text{ENS (Rp)} = \text{Rp } 42.170.793$$

It can be seen that the potential cost that can be saved for PT PLN (Persero) in the span of one hour when N-1 occurs on the 70kV Manisrejo-Caruban SUTT is Rp 42,170,793 which can increase the effectiveness and economy in the transmission of electricity at the 70kV Manisrejo-Caruban-Nganjuk SUTT and can increase the reliability of supply in the Kediri 3.4 Subsystem by reducing the risk of widespread blackouts.

4. CONCLUSION AND SUGGESTION

The conclusion obtained from this journal is that the reliability of the 70kV Manisrejo-Caruban SUTT under normal conditions has exceeded the limits of existing provisions. This condition is considered unsafe because if there is a disturbance in the 70kV Manisrejo-Nganjuk SUTT, there will be an overload or overload

on the 70kV Manisrejo-Caruban SUTT. The potential risk that occurs in the 70kV Manisrejo-Caruban SUTT during the 70kV Manisrejo-Nganjuk SUTT trip is that the load overflows so that the load exceeds the capacity of the equipment. With the addition of *the defense scheme, overload shedding* can increase the reliability of the 70kV Manisrejo-Caruban SUTT because the OLS can automatically cut off the load when detecting *overload conditions* by removing part of the load so that it does not cause widespread blackouts. From the results of the study, it is known that the losses experienced by PT. PLN (Persero) can be minimized so that it is not as large as the condition before the addition of *the defense scheme*. The suggestion for this study is that the addition of *a defense scheme over load shedding* on the 70kV Manisrejo-Caruban SUTT needs to be done, considering the growth of the load on the electric power sector in the Caruban area and its surroundings. This study requires further study if there is a change in the network configuration in the Kediri Subsystem 3,4 area. In addition to the addition of a defense scheme over load shedding on the 70kV Manisrejo-Caruban SUTT, the reliability of the Kediri 3.4 Subsystem can be increased by uprating the 70kV Manisrejo-Caruban-Nganjuk SUTT to the 150kV Manisrejo-Caruban-Nganjuk SUTT.

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