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Post Operational Optimization of Adaptive Overload Shedding Protection in the Bali Island Sub-system using the ADS Simulation

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Abstract: The Bali electrical network sub system is supported by the Java-Bali power transfer assisted by the Bali power generation. Most of these power plants are not economical, so the Java-Bali power transfer is prioritized. If an island operation occurs, the Bali sub system loses most of the power that supports its load. This loss of power can result in a black out. The Bali sub system must perform overload shedding equal to the loss of Java-Bali power transfer. However, because the magnitude of the Java-Bali power transfer is very dynamic, the amount of Over Load Shedding (OLS) is difficult to predict, so an optimization system is required that can calculate the amount of OLS according to the Java-Bali power transfer at any time. The optimization system can also determine OLS targets before Faults occur based on the Priority Scale. To ensure that the Optimization System has worked properly, an Adaptive Defense Scheme (ADS) simulation was created. In this simulation, the optimization system will be tested using the ADS simulation series. In this simulation, the optimization system will be tested using the ADS simulation series. This system is simulated so that it can work OLS target off contact. This system will be tested for the suitability of the load selection with the amount of Java-Bali power transfer. The load selection is compared with manual calculations using the same method to ensure the optimization system calculations are appropriate. Comparison between the selection of targets for the optimization system with calculations, and working contacts is made by making a suitability matrix. From the tests carried out, it was obtained that OLS System Optimization System target size was calculated with a maximum deviation of 5.5%, a minimum deviation of 0.037%, and an average deviation of 1.03%. The system is also capable of selecting targets with 100% accuracy and can also perform MTDS digital output according to 100% accuracy, that the operational system efficiency can be achieved very significantly.

Keyword: Bali Sub System, OLS, Priority Scale, Optimization System, ADS Simulation

INTRODUCTION

The Bali Electricity Sub System in its operations is supported by power transfer from Java, citing economic factors of operational costs. If the Bali Sub System uses its own power plant, it becomes uneconomical because the Bali Sub System has 3 power plants, two of which are PLTD (Diesel Power Center) and one PLTU (Steam Power Center). To support all its loads, the Bali Sub System must operate all its plants (Setiyawan et. al., 2019). Due to its heavy reliance on power transfer from the Java Electricity System, the Bali Sub System will experience system imbalance if the Java Bali Power Transfer is interrupted during island operation. The Bali Sub System needs an Over Load Shedding (OLS) Protection System to be able to remove the load in order to balance the system when Operation Island takes place in order to avoid this. (Mogaka et al. 2020) According to Hardoyo et. al. (2020) in its daily operation, the Java Bali Power transfer is quite dynamic because it depends on the condition of Java Electric Power which of course causes the load to be discharged when the Bali Island Sub System (Trip Quota) operation is also dynamic. A bad trip quota will likely result in a large difference between the target that should be wasted and the target that is actually wasted. Of course, this will be very uneconomical and detrimental to customers. According to Anugerah Akbar Setiyawan, Ontoseno Penangsang, (2019), Java Bali Power Transfer is dynamic because it depends on the condition of the Java Electric Power System. If the conditions of the Java Electric Power System allow, it will get surplus electricity that can be sent to the Bali Sub System. However, if not then it is certain that the Power Transfer received by the Bali Sub System changes. Because of this, Java Bali Power Transfer is dynamic. Figure 1 below illustrates the connection between the load on the Bali Sub System, power generated by the Sub System, and the transfer of Java Bali power.

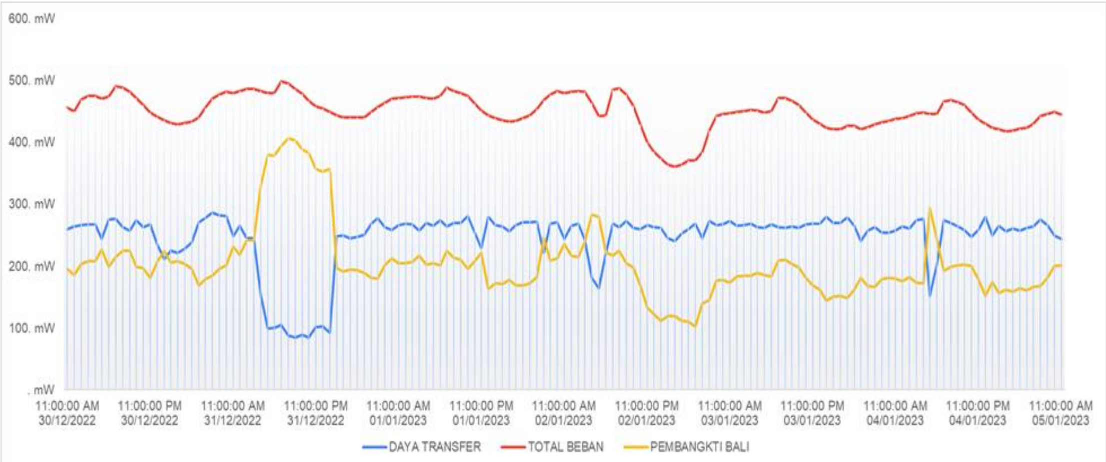

Figure 1. Graph of load magnitude relationship, Java Bali Power Transfer, Generated Bali Sub System

Figure 1 demonstrates that while the load on the Bali Sub System appears to follow a predictable pattern, the Java Bali Power Transfer does not, necessitating constant adjustment of the Bali Sub System's generation power. On the other side, the failure of Operation Island due to the loss of Java Bali Power Transfer will result in an imbalance in the Bali Sub System. However, because Java Bali Power Transfer is dynamic, the OLS must also be dynamic, so an Optimization System is needed that is able to calculate the load that must be off service (Trip Quota).

An optimization system that can determine the trip quota that will be disposed of according to the loss of power supply during island operations in real-time is required to ensure that Over Load Shedding (OLS) takes place as intended when the Bali Island Sub System operation occurs. On the other hand, because Bali is frequently the hub of international activity in a number of locations, the target location of OLS disposal cannot always be the same. As a result, the priority of the loads may change over time. To address this, the optimization system can also select the load based on the user-specified priority, allowing it to select the discharge target based on requirements (Elbaset, 2020). To ensure the Optimization System created works according to needs, the Optimization System is tested. Testing will limit to the following scopes: 1) The Optimization System is simulated close to the existence of the Bali Sub System; 2) Simulations are made by stringing software and hardware close to the situation in the field; 3) Simulation tests the accuracy of the Optimization System extinguishing the load seen on the Digital Output MTDS; 4) The OLS defense scheme trigger works the state of the fourth CB SKLT connected by AND gate and simulated with one artificial signal from MTDS 1; 5) The manufacture and testing of simulation circuits are carried out in the system protection sub-field laboratory at PT. PLN (PERSERO) UIP2B JAMALI; and 6) The load data used for ADS Simulation was taken from August to December 2022.

The operational sustainability of the electricity system in the Bali Sub System will benefit from this research. The variation of power that is extinguished and that would otherwise be extinguished becomes very minimal with this optimization method since optimization operates dynamically. A small deviation certainly increases the economic value in blackout actions when there is a disturbance because it will not turn off targets that do not actually need to be powered off.

The location of the off-powered target selection can also be more precisely targeted according to this optimization technique. Because users can classify various targets into different priority levels based on requirements, the optimization system is able to accomplish this. This improves system dependability since the optimization system can identify priority points, preventing it from being the optimization system's first choice when selecting blackout targets. System Optimization has other benefits that indirectly have an impact. With a dynamic optimization system, users do not need to make changes both in terms of installation and wiring series and in terms of device configuration. This will certainly save the operational costs of related work units.

For this research, literature references related to the technologies and theories used in this research are needed, especially regarding the Adaptive Defense Scheme (ADS) as a reference for making an adaptive Protection Scheme and about IEC-61850 as an adaptive defense supporting technology infrastructure (according to Maulana, 2021). For the basis of ADS, this study used several scientific journals. References are needed to ensure that this kind of technology has been implemented as in Instanbul according to a journal paper by Yavuz Atez, 2016 entitled Adaptive Protection Scheme for a Distribution System Considering Grid-Connected and Islanded Modes of Operation. The related paper entitled "IEC 61850 Communication Networks and Systems in Substations: An Overview for Users" on the application of IEC-61850 in substations was also referenced (Adamiak et al., 2009). These journals serve as a resource for understanding the operation of the optimization system and how to apply it to substations using ADS simulation. This study also uses the IEC-104 communication protocol for data gathering (Matouek, 2017).

METHODS

The research was carried out at the UIP2B JAMALI System Protection Laboratory from August to December 2022. The research was conducted by creating a software-based Optimization System which was further integrated to be tested with ADS Simulation. The research was carried out through the stages of work as in Figure 2 below.

Figure 2. Flow Chart Method

The desired defense strategy that would use this Optimization System must first be designed before establishing an Optimization System and testing it in ADS Simulation. The information gathered will serve a variety of purposes. The gathered information will be utilized to validate the necessity of this optimization system. The gathered information will also serve as a sample for testing. To evaluate the Optimization System under circumstances that are similar to those in the field, ADS simulations are made. Therefore, in order to test, you must first put the ADS Simulation's device setup as similar to actual field circumstances as possible. The Optimization System Algorithm is the foundation upon which the Optimization System will carry out optimization. It is an instruction calculation method. The Optimization System must be connected with ADS Simulation in order to test the Optimization System produced by ADS Simulation. The ADS Optimization and Simulation System must be set up on relevant devices in a certain way in order for it to be integrated.

The optimization system will be performed on a server PC that is connected to other devices, and ADS Simulation Modeling is done there, near to the conditions seen in the field. If interference occurs, the Optimization System will issue an Arming Signal in accordance with the findings of its calculations to prepare the target for outages. Digital signals from MTDS 1 will be used in the ADS Simulation circuit to simulate interference. Figure 5 presents an overview of the next series of ADS simulations.

Data collection was carried out to see the large characteristics of Java Bali transfers poured into Figure 3.

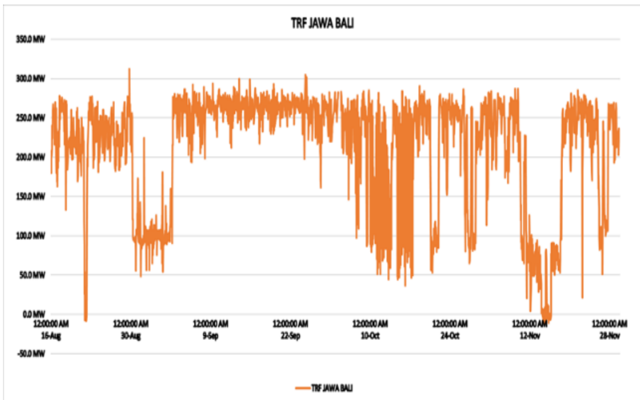

Figure 3. Java Bali Power Transfer Period August – November

A random and dynamic pattern was discovered based on the features of daily power transfer throughout the course of the four months, as well as over the course of one month and one day. Unrecognizable patterns make it challenging to develop suitable defense strategies and support the need for adaptive defense strategies. The daily power transfer amount can be divided into three categories based on the graph's average power amount, based on the graph's average power level, as follows: 1) Minimum Generation Conditions; 2) Conditions for Maximum Generation; and 3) Conditions for a Full Generation.

View Figure 4 to see the traits of each condition as shown below.

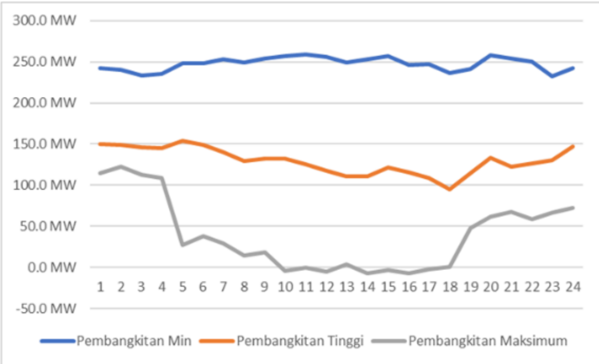

Figure 4. Average Power Transfer under 3 Conditions

Figure 4 shows Java Bali average power transfer graph in daily conditions 1, 2, and 3 that can be categorized into three conditions, based on the average power magnitude. The daily power transfer amount can be divided into three categories based on the graph's average power amount. Based on the graph's average power level, 1. Minimum Generation Conditions; 2) Conditions for Maximum Generation; and 3) Conditions for a Full Generation.

It is clear from the data's results that Java Bali power transfer requires a protection optimization system that can also determine dynamic protection needs because its characteristics indicate that it is dynamic. Figure 5 depicts the integration of the Optimization System to ADS Simulation. Figure 5 illustrates the integration of the Optimization System and ADS Simulation. Installation of a software-based optimization system on the server. The circuit from the ADS Simulation that will be tested is likewise shown in Figure 2.

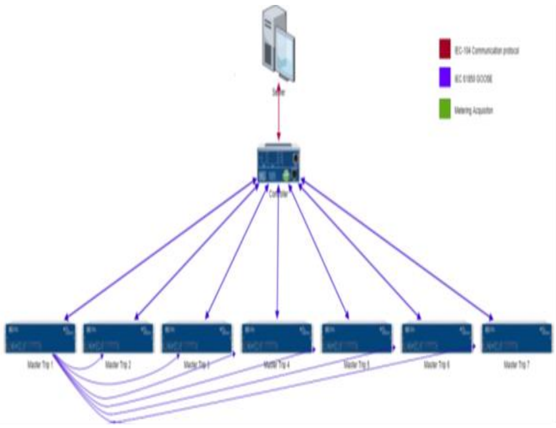

Figure 5. Simulation Topology Design

Figure 1 shows the Optimization System, a software-based system installed on a server PC. Data from databases built on the MySQL platform are used in the Optimization System's calculations. Manual data entry using preset data samples is used to enter values into the database. The database will obtain information from SCADA measurements in actual circumstances.

The Optimization System may dynamically determine the location of the outage prior to a disruption based on the Priority Scale and compute the load that needs to be extinguished based on the Trip Quota. Select targets can be sent out utilizing the Masterstrip Defense Scheme (MTDS) with ADS Simulation, as shown in Figure 5. The Optimization System chooses the target location based on two criteria: targets with the lowest to highest priority ratings and targets with the largest to smallest loads. Figure 6 is used by the Optimization System to determine which OLS Target is chosen with a large load. As seen in Figure 6, the Optimization System will sequentially sort OLS Targets according to the amount of the load from the first row to the last until all targets have been sorted. The load measurement data on the MySQL Database are the sorted data. Furthermore, Figure 6 translates into a script on the Optimization System as shown in Figure 7.

The Optimization System in choosing OLS Targets in addition to considering the load also considers the priority value. The Optimization System can choose targets based on their priority values shown in Figure 8. The Optimization System sorts OLS Targets using the Figure 8 approach, then chooses OLS Targets using the manner shown in Figure 8. Additionally, a script for the optimization system is created using the method from the flowchart in Figure 5 as shown in Figure 9.

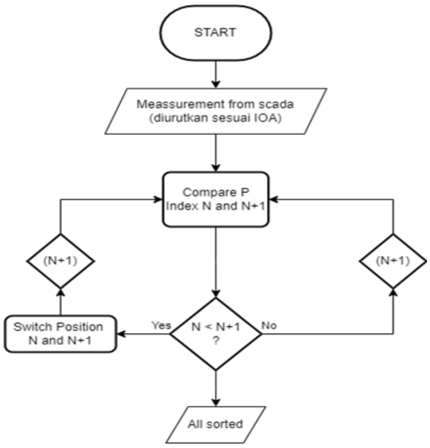

Figure 6. OLS Sorting Target Flowchart

```
Do
        flag_desc = False
        For x = 1 To n_target - 1
            y = x + 1
            If desc_mw(x) < desc_mw(y) Then
                id_temp = desc_id(x)
                mw_temp = desc_mw(x)
                desc_id(x) = desc_id(y)
                desc_mw(x) = desc_mw(y)
                desc_id(y) = id_temp
                desc_mw(y) = mw_temp
                flag_desc = True
            End If
        Next x
        If flag desc = False Then Exit Do
```

Figure 7. OLS Script Sorting Target

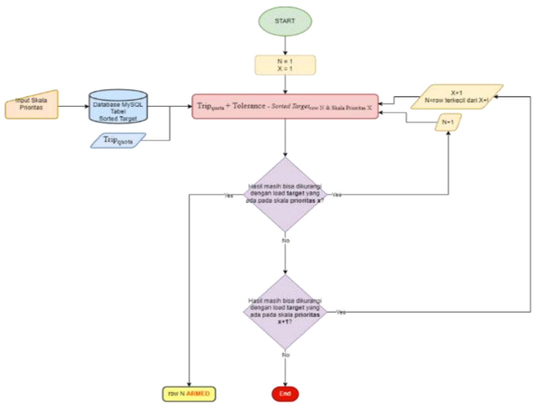

Figure 8. Flowchart for OLS Target Selection based on Priority Values

```
'===============================prioritas 1
sum_set = sum_set + tolerance
For x = 1 To n_target
        delta = sum_set - sum_arm
        If db_en(desc_id(x)) = "ON" And db_rd(desc_id(x)) = "ON" And db_pr(desc_id(x)) = 1 And desc_mw(x) > 0 And desc_mw(x) < delta Then
            sum_arm = sum_arm + desc_mw(x)
            arming(desc_id(x)) = 1
        End If
Next x
'===============================prioritas 2
For x = 1 To n_target
        delta = sum_set - sum_arm
        If db_en(desc_id(x)) = "ON" And db_rd(desc_id(x)) = "ON" And db_pr(desc_id(x)) = 2 And desc_mw(x) > 0 And desc_mw(x) < delta Then
            sum_arm = sum_arm + desc_mw(x)
            arming(desc_id(x)) = 1
        End If
Next x
'===============================prioritas 3
For x = 1 To n_target
        delta = sum_set - sum_arm
        If db_en(desc_id(x)) = "ON" And db_rd(desc_id(x)) = "ON" And db_pr(desc_id(x)) = 3 And desc_mw(x) > 0 And desc_mw(x) < delta Then
            sum_arm = sum_arm + desc_mw(x)
            arming(desc_id(x)) = 1
        End If
'===============================prioritas 4
For x = 1 To n_target
        delta = sum_set - sum_arm
        If db_en(desc_id(x)) = "ON" And db_rd(desc_id(x)) = "ON" And db_pr(desc_id(x)) = 4 And desc_mw(x) > 0 And desc_mw(x) < delta Then
            sum_arm = sum_arm + desc_mw(x)
            arming(desc_id(x)) = 1
        End If
Next x
'===============================prioritas 5
For x = 1 To n_target
        delta = sum_set - sum_arm
        If db_en(desc_id(x)) = "ON" And db_rd(desc_id(x)) = "ON" And db_pr(desc_id(x)) = 5 And desc_mw(x) > 0 And desc_mw(x) < delta Then
            sum_arm = sum_arm + desc_mw(x)
            arming(desc_id(x)) = 1
        End If
Next x

ThisWorkbook.Worksheets("MAIN").Cells(row_strategy, 5) = range
ThisWorkbook.Worksheets("MAIN").Cells(row_strategy, 6) = quota
ThisWorkbook.Worksheets("MAIN").Cells(row_strategy, 8) = sum_arm

For x = 1 To n_target
    ThisWorkbook.Worksheets("MATRIX").Cells(((ThisWorkbook.Worksheets("MAIN").Cells(row_strategy, 11) - 1) + x), 8) = arming(x)
Next x
```

Figure 9. OLS Target Selection Script Based on Priority Value

The Optimization System chooses an OLS Target to prepare for outages by taking the load size of the OLS Target starting from the largest and the Priority Value into account, as shown in Figures 8 and 9. Additionally, testing will be done to make sure the Optimization System's approaches are adequate. Tests are run utilizing samples of previously gathered data. Gathering data firstly before testing. In the period from August through December 2022, measurement data from SCADA were gathered at intervals of every hour. The data is also processed to reveal the features of the Bali Sub System.

The characteristics of Java Bali power transmission had previously been categorized into three categories. This categorization is done for testing purposes to demonstrate that the Optimization System can function properly in all scenarios indicated by modeling that separates the conditions of the Bali Sub System into three categories. There were a total of 15 test samples used for the tests on these 3 conditions, which were run using 5 data samples from each condition. Pre-collected data are used in the data sample. Table 1 displays the sample information of power transfer. To determine the accuracy or accuracy of the Optimization System, ADS Simulation is used. The correctness of the Optimization System is to be evaluated in three areas, specifically: 1) Calculation accuracy of the optimization system; 2) OLS Target Selection Optimization System Accuracy; and 3) OLS Target blackout accuracy during interference.

The accuracy of the Optimization System calculation is measured by finding the percentage deviation between the amount of power that should be extinguished (Trip Quota) and the amount of load selected by the Optimization System (Load ARM). The accuracy of selecting the OLS Target of the Optimization System (Arming Signal) is measured by comparing the Arming Signal generated by the Optimization System with the calculation carried out manually based on Figures 2 and 4. By contrasting the MTDS Digital Output that functions during interference signal simulation with the Arming Signal produced by the Optimization System, it is possible to assess the accuracy of OLS Target outages.

Table 1. Analysis of Power Transfer

Condition	Sample	Load Sample Time	Load	Transfer Sample Time	Transfer Power
(1) Minimum Bali Dedication	1	27 12 2022 15.51.40	401.5	17 08 2022 04.00.00	195.3 mW
	2	27 12 2022 15.51.40	401.5	22 08 2022 07.00.00	256.9 mW
	3	27 12 2022 15.51.40	401.5	22 09 2022 23.00.00	267.2 mW

	4	27 12 2022 15.51.40	401.5	16 10 2022 16.00.00	228.7 mW
	5	27 12 2022 15.51.40	401.5	25 11 2022 16.00.00	151.2 mW
(2) High Bali Dedication	1	27 12 2022 15.51.40	401.5	03 09 2022 07.00.00	137.4 mW
	2	27 12 2022 15.51.40	401.5	27 11 2022 05.00.00	100.4 mW
	3	27 12 2022 15.51.40	401.5	18 11 2022 16.00.00	85.0 mW
	4	27 12 2022 15.51.40	401.5	06 09 2022 07.00.00	85.6 mW
	5	27 12 2022 15.51.40	401.5	07 09 2022 07.00.00	142.4 mW
(3) Minimum Bali Dedication	1	27 12 2022 15.51.40	401.5	16 11 2022 14.00.00	0.2 mW
	2	27 12 2022 15.51.40	401.5	09 09 2022 07.00.00	7.2 mW
	3	27 12 2022 15.51.40	401.5	10 09 2022 23.00.00	25.9 mW
	4	27 12 2022 15.51.40	401.5	11 09 2022 07.00.00	2.6 mW
	5	27 12 2022 15.51.40	401.5	12 09 2022 07.00.00	8.4 mW

The test was carried out by simulating the Interference Signal on MTDS 1 according to Figure 1. The signal will be spread to each MTDS via ethernet media with IEC 61850 GOOSE. The signal will extinguish the target by working on the MTDS Digital Output in accordance with the Arming Signal received by MTDS.

RESULT AND DISCUSSION

The suitability of 'Load Arming' is measured to see the accuracy of the 'Load Arming' produced by the Optimization System with what should be extinguished according to the 'Trip Quota'. Suitability is measured by looking at the difference between the 'Load Arming' and 'Trip Quota' values in each test sample. From this difference, the deviation value can be seen in Table 2. Table 3 presents the accuracy outcomes of OLS Target Selection. Table 3 shows that, based on load size and priority value, all test samples under all three scenarios exhibit 100% accuracy. Because the sample condition does not call for the selection of an OLS Target, the rows highlighted in red are not counted.

Table 2. Accuracy of Test Results Optimization System

Condition	Sample	Trip Quota	Load Arming	Deviation	Deviation (%)
(1)	1	195.3	195.4	0.1	0.0512
	2	256.9	256.7	0.2	0.0779
	3	267.2	267.1	0.1	0.0374
	4	228.7	229.5	0.8	0.3498
	5	151.2	151.1	.0.1	0.0661
(2)	1	137.4	137.9	0.5	0.3639
	2	100.4	100.8	0.4	0.3984
	3	85	85.7	0.7	0.8235
	4	85.6	86.3	0.7	0.8178
	5	142.4	142.9	0.5	0.3511
(3)	1	0.2	0	0.2	
	2	7.2	6.8	0.4	5.5556
	3	25.9	25.7	0.2	0.7722
	4	2.6	2.5	.1	3.8462
	5	8.4	0	8.4	
MAX					5.5556
MIN					0.0374
AVG					1.0393

From comparison with the method previously described in all test samples, the average accuracy of Digital Output MTDS conformity is 100%. To show that the MTDS Digital Output is not working because 'Load Arming' is not 0 in Conditions 3 of Samples 1 and 5. Test result is depicted in Table 4.

From the measurement of three conformity parameters that have been carried out on all samples, the following results are obtained: 1) Trip Quota and Arming Load calculations get a maximum deviation value of 5.5%, a minimum of 0.037%, and an average of 1.03%; 2) The average deviation between the value of 'ARMING' of the Optimization System and the 'ARMING' value of the calculation is 0%; 3) When there is no P trans, the optimization system does not select any load; 4) The Optimization System will not select targets with higher priority values if targets with lower priority values still exist; and 4) The Optimization System can work on MTDS output contacts with 100% accuracy against Arming Signals.

Table 3. OLS Target Selection Accuracy Testing,

Condition	Sample	Number of Arming Signals	Suitability of manual calculations	Accuration (%)
(1)	1	29	29	100
	2	36	36	100
	3	37	37	100
	4	36	36	100
	5	29	29	100
(2)	1	25	25	100
	2	27	27	100
	3	19	19	100
	4	19	19	100
	5	26	26	100
(3)	1	0	0	100
	2	1	1	100
	3	2	2	100
	4	1	1	100
	5	0	0	100
MAX				100
MIN				100
AVG				100

From the results obtained above, it can be seen that the Optimization System can determine the total outage load with an average difference of 1.03%, which means that if implemented, the Bali Sub System OLS Protection System Post Operation can balance the load only by 1%. This greatly increases the economic value of previously existing Protection Schemes that were not dynamic.

Table 4. ADS Simulation Blackout Accuracy Test

Condition	Sample	Number of Arming Signals	DO MTDS compliance	Accuration (%)
(1)	1	29	29	100
	2	36	36	100
	3	37	37	100
	4	36	36	100
	5	29	29	100
(2)	1	25	25	100
	2	27	27	100
	3	19	19	100
	4	19	19	100
	5	26	26	100
(3)	1	0	0	100
	2	1	1	100
	3	2	2	100
	4	1	1	100
	5	0	0	100
MAX				100

MIN	100
AVG	100

CONCLUSION

Based on the result and discussion, there can be drawn several conclusions as follows:

1. The trip quota can be calculated by the optimization system with an average variance of 1.03%, which boosts efficiency.
2. In order to guarantee that the target that will be extinguished when there is a disruption can be set according to user needs and the level of importance of the target with 100% accuracy, the optimization system is capable of optimizing the target location according to the size of the OLS Trip Quota in accordance with the size of the load and the priority value.
3. With an accuracy of 100, the optimization system can extinguish the OLS target with MTDS in accordance with the place identified by the Arming Signal. Based on this method, it can display to users which extinguished targets in a very substantial way if there is user interference.

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