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Implementation of Monitoring Device for Fault Location, Isolation, and Service Restoration (FLISR) in Jakarta Area Distribution Network

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Abstract— **Fault Location, Isolation, and Service Restoration (FLISR) is one of the Distribution Automation (DA) tools that optimize operators to identify faults and power switch automation. It aims to mitigate the number of customers interrupted by the outage. The implementation of FLISR generates a distribution automation system that coordinates the operation of tools, software, and special communication network. It automatically locates faults and quickly reconfigures power flow to reduce the outage duration and the numbers of customers interrupted by the outage. FLISR depends on rerouting ability. Thus, it needs data associated with accurate network configuration, real-time network operation mode, optimization algorithm in restoration system, and environment to enable remote switching. In accordance with Standard guidelines for electricity distribution, the reliability index is used as the standard to examine the service quality of electrical distribution. Two parameters used in the evaluation of FLISR operation are the number of customers interrupted (CI) and customer minutes of interruption (CMI). Both parameters are equation components used to calculate SAIFI and SAIDI. FLISR cannot prevent outages but can mitigate the impact of faults on customers.**

Keywords - Distribution, Faults, FLISR (Fault Location, Isolation, and Service Restoration), SAIDI (System Average Interruption Duration Index), SAIFI (System Average Interruption Frequency Index)

I. INTRODUCTION

As the world has been technologically advanced, electric power system becomes the main part of modern society. Electricity demand is expected to grow 11-12% in 2015 dominated by household sector, industrial sector, and commercial sector. [1]. The increasing demand of electricity require electrical provider to improve the reliability of networks. One way to improve the reliability system is implementing a smart grid technologies in distribution networks[2]. There are seven key functionalities that critical in deployments of smart grid technologies: 1) Demand response and consumer 2) wide area situational awareness 3) distributed energy resource 4) energy storage 5) electrical transportation 6) network communications 7) advanced metering infrastructure (AMI) 8) distribution grid management [3]. Fault Location, isolation, and service restoration are important keys in implementing smart distribution grid management [4].

FLISR is one of distribution automation tools consists of protection and switching devices to locate faults and isolate faulted area. This allows fast recovery for uninterrupted feeders[5]. The implementation of FLISR can improve the reliability by reducing the durations of outages. [6]. One of important aspects when applying FLISR in distribution networks is the selection of technology and algorithm to locate the interruption points and perform the restoration.

Dlab is an application developer company that offers digitalized, efficient, and reliable smart grid technology[7, 8]. Application developed by dLab includes visualization of network conditions, analysis and contextualization of incidents, and measure of power quality[7]. In this research dlab technologies is applied in Jakarta distribution network to observe its effectiveness for FLISR application. The main contribution of this research are:

- The pilot project of the distribution grid management implementation in Jakarta distribution area using dLab.
- Prototype of FLISR implementation in PLN networks in Indonesia
- Enable electricity distribution system to have better standard.

The remainder of this paper is arranged as follow: in section 2, we discuss about literature review related to FLISR implementation in distribution network. Section 3 describing existing condition of electrical distribution, which followed by FLISR fault simulation using dLab data in section 3. Section 4 describe result and discussion related to this research.

II. Literature Review

A novel FLISR algorithm based on Multi-Agent system (MAS) concept demonstrate a successful identification and isolation of the faulty zone [2]. The MAS architecture are configured to support the IEC 61850 Generic Object-Oriented Substation Event (GOOSE) protocol and implemented after distribution grid in Brescia. In order to resolve the restoration part of FLISR, [5] implement multiagent-based distribution automation solution which reduce grid topology to an undirected weighted graph. This solution is tested in physical dc grid model and several Arduino microcontrollers and raspberry pi algorithm. The result shows that it complied to state-of-the-art standard including IEC 61850.

FLISR operation in 5 utilities in North America involving 10 operating companies under different technologies and system operation is analyzed in [9]. Between the observed time, FLISR application is able to reduce number of customer interruption up to 45% compared to non-FLISR application. It also reduced the interruption time to each customer by 51% during outage event. Self-healing schemes using FLISR technology impact to system reliability can be estimated via predictive reliability model [6]. The research shows that implementation of FLISR leads to reliability improvement. These results can be employed to determine cost-benefit ratios of several FLISR schemes implementation.

III. Existing Condition of Electrical Distribution

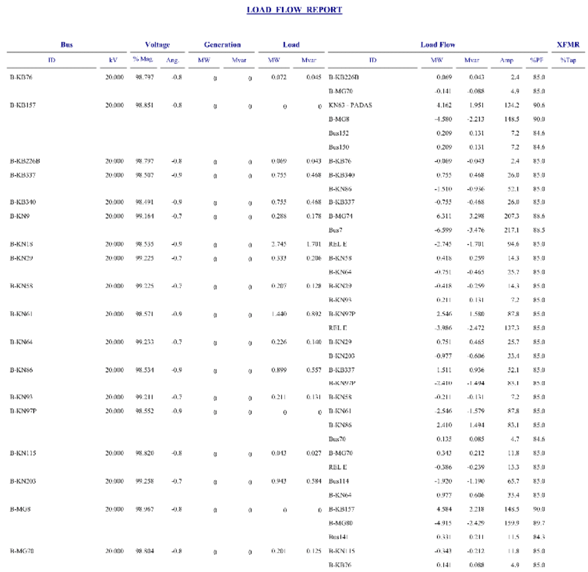
Distribution area in Jakarta serves power loads of 4.680 MW [10] with area of service of West Jakarta, South Jakarta, Central Jakarta, East Jakarta, North Jakarta, and nearby area. Setiabudi substation is one of the substations managed by Disjaya that serves premium costumers as it is located in the business center of Jakarta. Feeders in Setiabudi substation taken as the objects of this research are Plaza Danamon, Split, Umpan, Wallpaper, Talempong, Koral, Siter, Padas, Harpa, Gamelan.

Profile of existing conditions of feeders taken as the object of the research was observed using Power Flow simulation. The observed parameters consist of power flow, voltage drop, and short circuit.

A. Power Flow

Power flow simulation aims to examine the system condition and power flow in existing networks described in the single-line diagram [11]. Power flow simulation is a study that is used as the foundation for the preliminary condition and reference in the subsequent studies, such as short circuit, and fault location, isolation and service restoration (FLISR) [12].

ETAP report shows results of power flow in the form of parameters that are measured in single-line diagram at Setiabudi substation. Figure 1 displays the results of the report from the ETAP power flow simulation. The table shows the highest active power which is calculated from the power flow report based on the voltage of 20V is 6.3 MW.



LOAD FLOW REPORT

Bus ID	Bus kV	Voltage % Mag.	Voltage Ang.	Generation MW	Generation Mvar	Load MW	Load Mvar	Load Flow ID	Load Flow MW	Load Flow Mvar	Load Flow Amp	Load Flow %PF	XFMR %Tap
B-KB76	20.000	98.797	-0.8	0	0	0.072	0.045	B-KB226B	0.069	0.043	2.4	85.0	
								B-MG70	-0.141	-0.088	4.9	85.0	
B-KB157	20.000	98.851	-0.8	0	0	0	0	KN63 - PADAS	4.162	1.951	134.2	90.6	
								B-MG8	-4.580	-2.213	148.5	90.0	
								Bus152	0.209	0.131	7.2	84.6	
								Bus150	0.209	0.131	7.2	84.6	
B-KB226B	20.000	98.797	-0.8	0	0	0.069	0.043	B-KB76	-0.069	-0.043	2.4	85.0	
B-KB337	20.000	98.507	-0.9	0	0	0.755	0.468	B-KB340	0.755	0.468	26.0	85.0	
								B-KN86	-1.510	-0.936	52.1	85.0	
B-KB340	20.000	98.491	-0.9	0	0	0.755	0.468	B-KB337	-0.755	-0.468	26.0	85.0	
B-KN9	20.000	99.164	-0.7	0	0	0.288	0.178	B-MG74	6.311	3.298	207.3	88.6	
								Bus7	-6.599	-3.476	217.1	88.5	
B-KN18	20.000	98.535	-0.9	0	0	2.745	1.701	REL E	-2.745	-1.701	94.6	85.0	
B-KN29	20.000	99.225	-0.7	0	0	0.333	0.206	B-KN58	0.418	0.259	14.3	85.0	
								B-KN64	-0.751	-0.465	25.7	85.0	
B-KN58	20.000	99.225	-0.7	0	0	0.207	0.128	B-KN29	-0.418	-0.259	14.3	85.0	
								B-KN93	0.211	0.131	7.2	85.0	
B-KN61	20.000	98.571	-0.9	0	0	1.440	0.892	B-KN97P	2.546	1.580	87.8	85.0	
								REL E	-3.986	-2.472	137.3	85.0	
B-KN64	20.000	99.233	-0.7	0	0	0.226	0.140	B-KN29	0.751	0.465	25.7	85.0	
								B-KN203	-0.977	-0.606	33.4	85.0	
B-KN86	20.000	98.534	-0.9	0	0	0.899	0.557	B-KB337	1.511	0.936	52.1	85.0	
								B-KN97P	-2.410	-1.494	83.1	85.0	
B-KN93	20.000	99.211	-0.7	0	0	0.211	0.131	B-KN58	-0.211	-0.131	7.2	85.0	
B-KN97P	20.000	98.552	-0.9	0	0	0	0	B-KN61	-2.546	-1.579	87.8	85.0	
								B-KN86	2.410	1.494	83.1	85.0	
								Bus70	0.135	0.085	4.7	84.6	
B-KN115	20.000	98.820	-0.8	0	0	0.043	0.027	B-MG70	0.343	0.212	11.8	85.0	
								REL E	-0.386	-0.239	13.3	85.0	
B-KN203	20.000	99.258	-0.7	0	0	0.943	0.584	Bus114	-1.920	-1.190	65.7	85.0	
								B-KN64	0.977	0.606	33.4	85.0	
B-MG8	20.000	98.967	-0.8	0	0	0	0	B-KB157	4.584	2.218	148.5	90.0	
								B-MG80	-4.915	-2.429	159.9	89.7	
								Bus141	0.331	0.211	11.5	84.3	
B-MG70	20.000	98.804	-0.8	0	0	0.201	0.125	B-KN115	-0.343	-0.212	11.8	85.0	
								B-KB76	0.141	0.088	4.9	85.0	

Figure 1 Result of Power Flow Simulation in Existing Condition

B. Voltage Drop

Voltage drop is a measure of change between sending-end voltage and receiving-end voltage. As shown in the Table 1, in existing condition, distribution area of Setiabudi substation has the lowest voltage value, which occurred in Split end Feeder(19.64 kV). However, the voltage value is between the Standard of PLN (SPLN) No. 72 of 1987.

C. Short Circuit Simulation

Short circuit occurs when electric current makes direct connection to ground or live network which of the impedance is relatively low The event generates an excessive flow of current compared to the normal condition [13]. The simulation aims to identify the highest fault current in the system, investigate the operation of protection devices, and verify the fault current with data available from dLab laboratory portal.

The results of the simulation are summarized in the report which includes information on important parameters, such as initial symmetrical short-circuit current (I"k), maximum current/ first peak of the fault current (Ip), short-circuit breaking current (Ib), and steady-state short-circuit current (Ik) as shown in Figure 2. Table 1 shows the results of short circuit analysis reported from ETAP simulation. The peak current of 3-phase fault is103,7 A and 1-phase-to-earth fault current is 2,271 A.

Table 1 Voltage Drop of Observed Branch

Branch	*Voltage*	*Percentage of Volatge Drop*
Plaza Danamon	19,65 kV	1,74 %
Split	19,64 kV	1,78 %
Umpan	19,71 kV	1,44 %
Wallpaper	19,7 kV	1,48 %
Talempong	19,65 kV	1,74 %
Koral	19,71 kV	1,45 %
Siter	19,88 kV	0,6 %
Padas	19,76 kV	1,19 %
Harpa	19,88 kV	0,6 %
Gamelan	19,87 kV	0,67 %

Bus		3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				*Line-to-Line-to-Ground			
ID	kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
Bus14	20.000	34.495	88.914	34.495	0.881	2.271	0.881	0.881	11.383	29.340	11.383	11.383	30.090	77.561	30.090	30.090
Bus16	20.000	34.495	88.914	34.495	0.881	2.271	0.881	0.881	11.383	29.340	11.383	11.383	30.090	77.561	30.090	30.090
Bus18	20.000	27.470	63.333	27.470	0.876	2.019	0.876	0.876	10.273	23.685	10.273	10.273	23.999	55.331	23.999	23.999
Bus70	0.400	15.230	24.883	15.230	0.187	0.306	0.187	0.187	0.320	0.523	0.320	0.320	13.194	21.557	13.194	13.194
Bus86	0.400	15.286	24.966	15.286	0.187	0.306	0.187	0.187	0.320	0.523	0.320	0.320	13.242	21.628	13.242	13.242
Bus87	0.400	15.265	24.928	15.265	0.187	0.305	0.187	0.187	0.320	0.523	0.320	0.320	13.224	21.595	13.224	13.224
Bus88	0.400	15.251	24.903	15.251	0.187	0.305	0.187	0.187	0.320	0.523	0.320	0.320	13.212	21.574	13.212	13.212
Bus89	0.400	23.784	38.873	23.784	0.188	0.307	0.188	0.188	0.323	0.528	0.323	0.323	20.602	33.672	20.602	20.602
Bus90	0.400	23.784	38.873	23.784	0.188	0.307	0.188	0.188	0.323	0.528	0.323	0.323	20.602	33.672	20.602	20.602
Bus91	0.400	15.191	24.795	15.191	0.187	0.305	0.187	0.187	0.320	0.522	0.320	0.320	13.160	21.480	13.160	13.160
Bus93	0.400	30.012	60.517	30.012	0.188	0.380	0.188	0.188	0.324	0.654	0.324	0.324	26.009	52.446	26.009	26.009
Bus101	0.400	23.944	39.156	23.944	0.188	0.307	0.188	0.188	0.323	0.528	0.323	0.323	20.741	33.917	20.741	20.741
Bus114	20.000	34.495	88.914	34.495	0.881	2.271	0.881	0.881	11.383	29.340	11.383	11.383	30.090	77.561	30.090	30.090
Bus139	0.400	23.967	39.200	23.967	0.188	0.307	0.188	0.188	0.323	0.528	0.323	0.323	20.760	33.956	20.760	20.760
Bus141	0.400	30.546	62.102	30.546	0.188	0.383	0.188	0.188	0.324	0.659	0.324	0.324	26.472	53.819	26.472	26.472
Bus150	0.400	23.973	39.205	23.973	0.188	0.307	0.188	0.188	0.323	0.528	0.323	0.323	20.766	33.960	20.766	20.766
Bus152	0.400	23.973	39.205	23.973	0.188	0.307	0.188	0.188	0.323	0.528	0.323	0.323	20.766	33.960	20.766	20.766
KN63 - KORAL	20.000	26.246	55.499	26.246	0.874	1.847	0.874	0.874	10.008	21.163	10.008	10.008	22.935	48.497	22.935	22.935
KN63 - PADAS	20.000	26.246	55.499	26.246	0.874	1.847	0.874	0.874	10.008	21.163	10.008	10.008	22.935	48.497	22.935	22.935
REL A	20.000	34.495	88.914	34.495	0.881	2.271	0.881	0.881	11.383	29.340	11.383	11.383	30.090	77.561	30.090	30.090
REL B	20.000	34.495	88.914	34.495	0.881	2.271	0.881	0.881	11.383	29.340	11.383	11.383	30.090	77.561	30.090	30.090
REL C	20.000	27.470	63.333	27.470	0.876	2.019	0.876	0.876	10.273	23.685	10.273	10.273	23.999	55.331	23.999	23.999
REL D	20.000	34.495	88.914	34.495	0.881	2.271	0.881	0.881	11.383	29.340	11.383	11.383	30.090	77.561	30.090	30.090
REL E	20.000	27.470	63.333	27.470	0.876	2.019	0.876	0.876	10.273	23.685	10.273	10.273	23.999	55.331	23.999	23.999
REL F	20.000	34.495	88.914	34.495	0.881	2.271	0.881	0.881	11.383	29.340	11.383	11.383	30.090	77.561	30.090	30.090
TB5 - SITER	20.000	25.087	51.666	25.087	0.872	1.797	0.872	0.872	9.795	20.172	9.795	9.795	21.929	45.162	21.929	21.929
TB5 - TALEMPONG	20.000	25.087	51.666	25.087	0.872	1.797	0.872	0.872	9.795	20.172	9.795	9.795	21.929	45.162	21.929	21.929

All fault currents are in rms kA. Current ip is calculated using Method C.

* LLG fault current is the larger of the two faulted line currents.

Figure 2 Result of Short Circuit Simulation

IV. FLISR SIMULATION DATA OF FAULT FROM DLAB

Fault verification was conducted after power flow simulation and short circuit simulation. The fault verification data recorded in dLab portal and SCADA were compared to the results of simulation from ETAP software.

A. 3-Phase-Fault

Data taken from dLab shows that 3-phase short circuit fault was occured at Wallpaper feeder on 11 December 2021 with the electric current of 9456,6 A. Meanwhile, data from SCADA shows fault current on the feeder is 8397 A that activate the overcurrent relay. The simulation in ETAP proved that fault current has occurred in Wallpaper feeder, precisely in segment KN115 – MG7 as shown in Figure 3. Fault current at substation MG70 is 10.344 kA, which verified the fault as recorded in dLab. The difference fault current occurs due to impedance different between simulation data and existing condition.

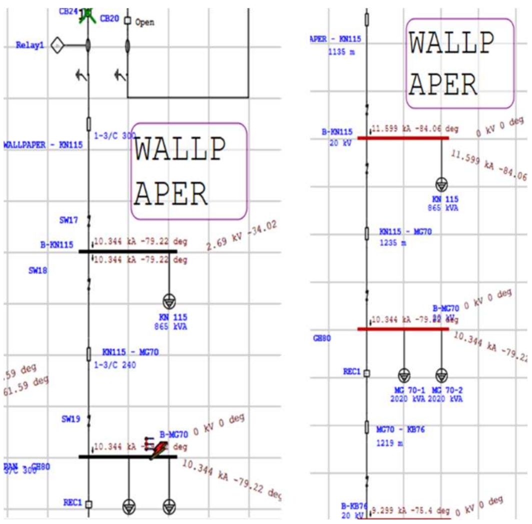


Figure 3 Results of 3-Phase Short Circuit Simulation Using ETAP 16.0.0

B. Phase-to-earth fault (Ground fault)

The data from dLab above shows a single-phase-to-earth on Wallpaper feeder occurred on 19 October 2021 with the electric current of 854,59 A. Meanwhile, data from SCADA shows the fault current of 898 A on the feeder that operated ground fault relay. The single phase to ground fault simulation in ETAP as depicted in Figure 4, shows that the fault in Wallpaper feeder between segment KN115 – MG7 is 0,859 kA, which verified the fault current as recorded in dLab and existing SCADA.

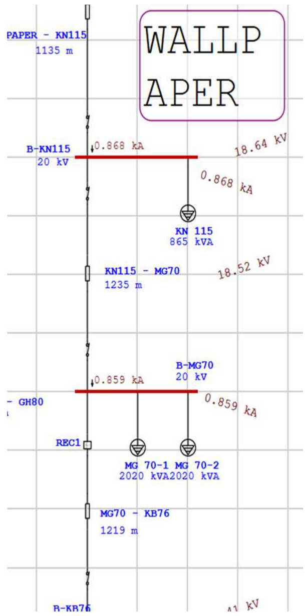


Figure 4 Simulation result of a single-phase-to-earth fault

C. The implementation of FLISR in Existing Condition at Setia Budi substation Based on dLab data

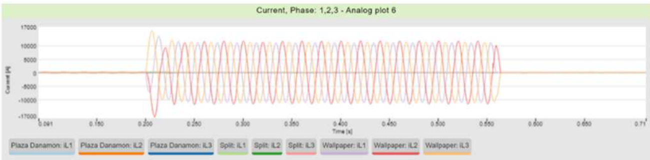
The Implementation FLISR using dLab application is examined to seek its fitness. dAnalyzer is one of the dLab feature which able to monitor, identify, and record the 3-phase fault happened on 11 December 2021. The event was described in its display: 11 December 2021 at 12:17:41 with the short circuit current of 9456,6 A on Wallpaper feeder.

The measurement data as stored in dLab shows the amount of current flowing in short circuit condition that occurred on 11 December 2021 at 12:17:41. The amount of zero sequence current is 1826,1 A for RMS value and 6775,0761 A for peak value. In fault condition, the value of short circuit current in phase R(L1) is 8485,1 A, phase S(L2) is 9456,6 A, and phase T(L3) is 9409,3 A.

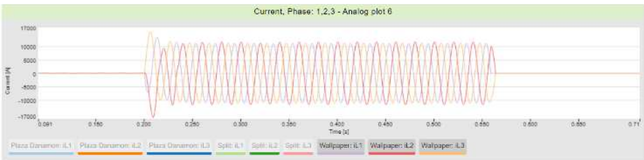
Results of event monitoring on several feeders in one analog plot (analog 7) are depicted in Figure 5 (a). Whereas Figure 5 (b) depicts Wallpaper feeder that is faulted and its monitoring results have been separated from the rest of feeders. The graphic shows that the fault duration between 0,25 seconds and 0,58 seconds (occurred around 0,33 seconds).

Based on the record, dAnalyzer only identified the amount of fault current on faulted feeders and has not embedded with tools to locate the exact point (fault location), isolate, and restore the fault (Isolation and Service Restoration). Further analysis is needed to detect the location, isolation, and restoration of faults using supported software like ETAP (Electrical Transient Analyzer Program). Data obtained from dAnalyzer can be taken as the reference to locate faults and used in the subsequent steps. This simulation represents the implementation of FLISR in Setiabudi substation when interruption occurred.

Based on the recorded data from dAnalyzer, the amount of current flowing in 3-phase fault is 9456,6 A. Simulation performed using ETAP application in 3-phase fault condition occurred on Wallpaper is depicted in Figure 6. The figure shows the condition when short circuit occur for each substation on Wallpaper feeder. The amount of short circuit current in substation MG70 is 10,344 kA, which is higher than the short circuit current recorded in dAnalyzer. Whereas the amount of short circuit current in substation KB76 is 9,299 kA or 9.299 A, which is lower than the short circuit current recorded in dAnalyzer. Hence, the fault location is identified between both substations or in segment MG70 – KB76.



(a)



(b)

Figure 5 Monitoring Results of (a) Feeders in Analog Plot (b) Wallpaper feeder in short circuit condition

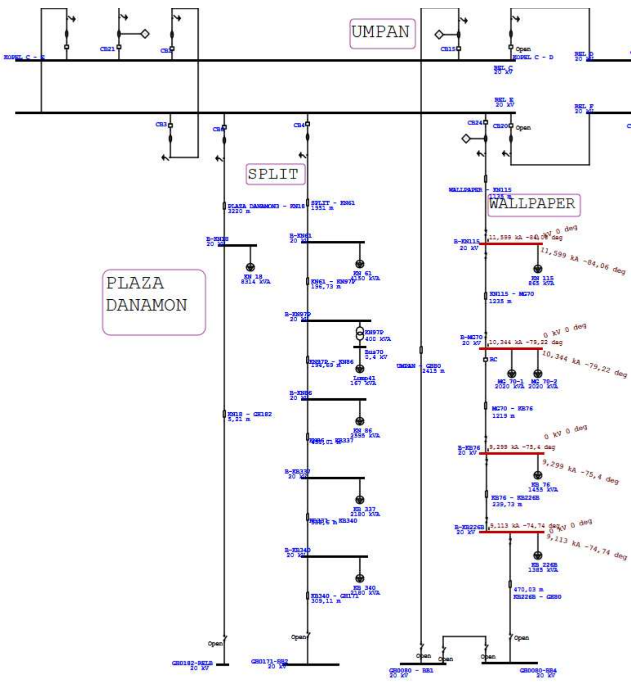


Figure 6 Phase Short Circuit Simulation on Wallpaper Feeder at Setiabudi Main Substation

D. Simulation of Protective Coordination of Overcurrent Relay for Fault Restoration on Sampling Feeder

Simulation is performed due to the unavailability of component to support FLISR implementation. In order to applying FLISR, several equipment need to be prepared to enable to automatic switching during fault. dLab equipment mostly focus on monitoring the current condition of electrical network and unable to do the fault locator and restoration. To overcome this issue, fault simulation is implemented in ETAP as shown in Figure 7. The calculation of short circuit current at 1% is 8.768 A.

Protection coordination graphic in Figure 8 shows that no overlapping relay in star protection because the coordination has been made adjustable for its distance and current. However, there are several adjustments in relay setting due to the low current loads on feeder (2A), so adjustment in coordination is necessary before obtaining the results as shown in the graphic above. The setting is adjusted by calculating the protections or summarizing main protection and backup protection between segments until relay 1. The short circuit was obtained from bus GH 00080-BB04 until bus MG 70.

V. Result and Discussion

Based on evaluation of fault location, isolation, and service restoration (FLISR) in existing distribution networks at PLN main distribution unit of Greater Jakarta from Setiabudi substation, the research concludes several points:

A. Power Quality

Report of power quality displayed on dLab is referred to the standard of EN50160 about power quality condition in the observed system per week to check the system condition. If the measure does not meet the standard, the red indicator will appear whilst green indicator will appear when it meets the standard.

Figure 7 Protective Coordination on Wallpaper Feeder

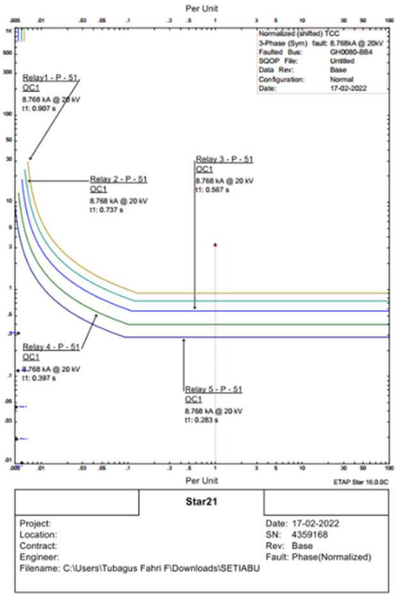


Figure 8 Protection Coordination

The report form monitoring and power quality value recorded in dLab for the parameters (Slow voltage variations (SVV), Voltage Harmonics (VH), Voltage unbalance (VUB), Voltage dips/swells (VDS), and Frequency stability (FS)) show a good condition. On the contrary, Rapid voltage changes and Flicker (RVCF) have been in a bad condition and do not comply with the standard of EN50160 for several weeks. Report of power quality from dLab also provides current and total value of Total Harmonic Distortion (THD) in feeder group.

B. Verification and Fault Simulation

Fault verification was conducted by ETAP software to easily evaluate the existing condition of electricity networks, analysis of power flow, and the system of FLISR (Fault, Location, Isolation, and Service Restoration) [14]. One of the feeders taken as sampling feeder to verify and simulate fault is wallpaper feeder. Wallpaper feeder was selected as recurring fault occurred in it. Fault simulation was conducted in bus bar MG 70. Fault verification was conducted based on data recorded on dLab and SCADA.

1. Voltage Profile.

Voltage in Electric energy system must be steadily maintained especially in distribution area. As stipulated in SPLN No. 1 of 1995 about voltage variations permitted for the impact of voltage loss is maximum +5% and minimum -10% in terms of service [11]. The result of the simulation shows voltage condition in busbar MG70 is 0,387 kV or 1,47%. The simulation also shows that voltage drop is still in the limit of established standard.

2. Analysis of short circuit

The main purpose of short circuit analysis in ETAP simulation is to verify fault in Setiabudi feeders. Sampling for this research was taken from faulted point that is Wallpaper feeder. Fault was sent to switching substation bus GH0080-BB4, which was recorded by dAnalyzer as 3-phase short circuit of 9456,6 A.

ETAP simulation obtained from busbar MG70 that was short circuited at 10,344 has 9% difference from dLab measure. However, the value difference can be tolerated and is considered close to dLab measure.

C. The implementation of FLISR

As dLab is only able to monitor, identify, and record an event without recognizing the fault location, the implementation of FLISR using dLab needs more additional tools and application. One of the example is to obtain the information of fault current, further analysis shall be conducted using other supported software like ETAP, Digsilent, and other software.

The implementation of FLISR on Wallpaper feeder as sampling feeder with fault current of 9456,6 A locates fault in segment MG70 – KB76, isolates faulted segment MG70 – KB76 in both upper course and lower course, and restores the uninterrupted parts in wallpaper feeder that was affected by the outage. The outage caused by fault isolation is restored using maneuver through express feeder located in Setiabudi main distribution unit and energized by the same transformer of Wallpaper feeder to mitigate overload in the transformer and transmission line, to maintain the voltage quality, and to reduce loss.

The implementation of FLISR reduces outage duration because fault location can be detected and costumers interrupted by the outage can have the electricity back after feeder protection is operated, and thus improves index value of SAIDI [15].

CONCLUSION

Equipment evaluation and simulation of fault location, isolation, and service restoration (FLISR) in existing distribution networks at PLN main distribution unit of Greater Jakarta generate several conclusions:

1. There should be further development or additional features in dLab to support FLISR system since the currently installed tools have not been able to implement “Location, Isolation, and Service Restoration” when interruption occurred. Thus, reconfiguration to enhance the reliability networks (SAIDI/SAIFI) is hardly fulfilled. Moreover, the tools are not equipped with algorithm to predict faults that can be used as early warning system and future networks planning.
2. As dLab is able to monitor, identify, and record an event without recognizing the fault location, the implementation of FLISR can work by obtaining information of fault current such as 3-phase fault or any other faults. Then, further analysis is conducted using other supported software like ETAP, Digsilent, and other software
3. These dLab tools are recommended for areas with poor power quality condition caused by the installation of renewable energy, such as networks that have been connected to solar power or rural area.
4. Lifetime prediction has not yet supported by dLab and the data obtained only showed data harmonization and faults. Finally, dLab is suggested to provide additional features to support these needs.

For future work, dLab implementation should not consider FLISR benefit due to the limitation of its function. dLab would be worked well to monitor impact of distributed renewable energy injection to distribution system. The deployment of power electronic devices and renewable energy intermittency might have a severe problem to distribution system power quality.

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