DISTRIBUTION AUTOMATION SYSTEM FIELD TEST IN JAKARTA MV NETWORK

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ABSTRACT

In order to meet the requirements of providing reliable electrical power service in metropolitan areas, it is imperative to undertake continuous development efforts, particularly in terms of enhancing system reliability. One key strategy for achieving this objective is the implementation of automation in the distribution system, specifically through the deployment of self-healing grid technology. Given the existence of multiple alternative approaches to self-healing grid implementation, it is critical for electric utility companies to possess a thorough understanding of the unique characteristics of each method and their suitability with respect to the specific distribution network being managed. Failure to appropriately match a given method to the characteristics of a distribution network can lead to significant inefficiencies in the future and potentially impede the successful implementation of self-healing grid technology. This paper will discuss the field testing results of both DAS methods, covering some of the issues e.g., ease of implementation, recovery time, and interoperability.

INTRODUCTION

PLN Indonesia has implemented the spindle topology in the electrical distribution network in the Jakarta region. This topology is an advancement of the radial topology, comprising of several load-bearing feeders and express feeders, the ends of which are connected at the switching substation. The express feeders must be constantly energized and prepared to serve as backup supply for feeder segments that encounter a disturbance or are undergoing maintenance. In normal operating conditions, the load-bearing feeders operate radially, since the endpoints of the feeders are NOP (normally open points) at the switching substation as shown in Figure 1.

In the secondary substation, there are generally three types of medium voltage cell (MV cell): load break switch (LBS), circuit breaker (CB), and transformer protection (TP) cells. The CB type of MV Cell is equipped with a protection relay, unlike the LBS type. In the LBS type, the ground fault detector (GFD) is utilized as a tool to identify the network segment that caused a fault.

Currently, the medium voltage network fault recovery procedure using supervisory control and data acquisition (SCADA) infrastructure is as follows:

- Detection: Protection relays located in primary or secondary substations detect faults, which then trigger an alarm in the Distribution Control Centre (DCC).
- Isolation: The dispatcher examines the fault current's type and magnitude while paying attention on the Single Line Diagram. The information is compared to the GFD indication on the secondary substation. The dispatcher isolates the faulted segment after summarizing this data by operating SCADA-ready MV Cell remotely from DCC.
- Service Restoration: The dispatcher will use the SCADA-ready MV Cell on the primary substation, secondary substation, and switching substation to restore the load through express feeder, excluding the faulted segment. Inherently, this is accomplished by taking into account on the feeder's load. Lastly, recovery efforts for segments lacking SCADA facilities are achieved by dispatching field officers to the secondary substation, where they will observe fault indicator to assess the situation.

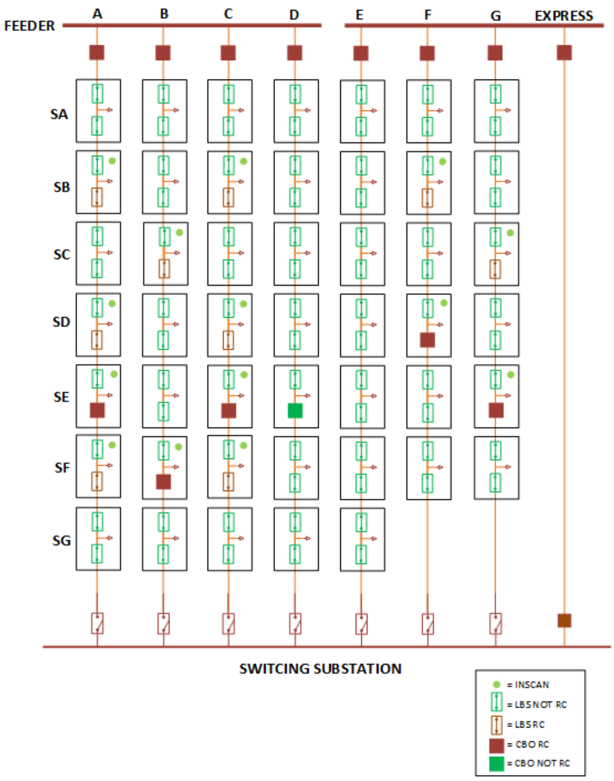

Figure 1. Typical medium voltage spindle topology

Based on the previously described fault recovery procedure, it is evident that the SCADA master station and IEDs in the distribution system plays a significant role in determining the duration of recovery. This aligns with the findings of studies presented in [1] [2].

Hence, PLN Indonesia has made efforts to increase the

penetration of SCADA infrastructure in its distribution network over the past five years. In the Jakarta Region, SCADA infrastructure mainly utilizes three types of telecommunications links, i.e., fibre optic, radio data, and GSM networks. Currently, all of the primary and switching substation are SCADA-ready. In secondary substations, 24% are equipped with SCADA systems with the aim of achieving a penetration rate of 25%-30%. Of the telecommunications links utilized on secondary substations, GSM networks are the most widely used, comprising 81% of the total. Radio data and fibre optic networks account for 10% and 9% of usage, respectively.
In primary substation, all the MV Cell are equipped with protection relay and SCADA-ready. On the other hand, MV Cell installed in switching substation are SCADA-ready Load Break Switch, without fault interruption capability.

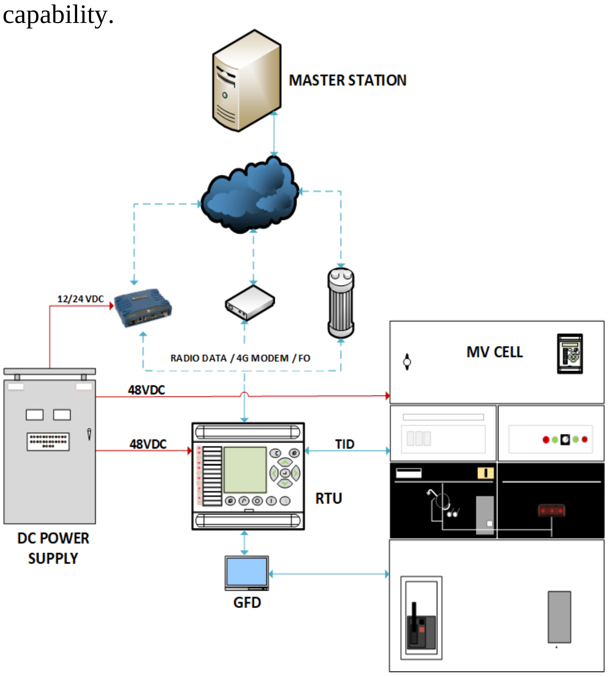

Figure 2. SCADA infrastructure topology in secondary substation

Typical SCADA configuration in the secondary substation is as illustrated in Figure 2. The primary functions of SCADA devices in secondary substations are to remotely open and close MV Cell and to acquire both telesignal and telemetry from relay / fault indicators. A device to detect MV faults such as ground fault detector or the more advanced fault indicator is installed in the same MV Cell within the substation. The data collected by the Remote Terminal Unit (RTU) is transmitted to the Master station using Fiber Optic, Radio Data, or 4G Modem. SCADA equipment at the secondary substation is powered by a direct current (DC) power supply from a rectifier with a battery backup. The power supply level typically used is 48 VDC for RTUs and Intelligent Electronic Devices (IEDs), and 12 VDC for telecommunications equipment.
The average recovery time for MV disturbances under the current network condition is 40.3 minutes. The figure is fairly consistent with the typical utility response time reported in [3], which is 45 minutes. Aiming for recovery time less than 15 minutes, a significant improvement is required, including the implementation of distribution automation.

DISTRIBUTION AUTOMATION

Distribution automation refers to the use of advanced technologies, such as telecommunication infrastructures, smart meters and sensor systems, to improve the efficiency and reliability of electrical power distribution networks. It will incorporate fundamental automation features such as SCADA with all communication requirements, automating the protection system to outage management systems, including customer information systems. In a distribution utility there are three areas where automation can be implemented: first at the customer location, second on the feeders, and finally in the substation [4].
There are several issues that can arise in distribution network automation:

- Complexity: Electric distribution networks can be complex, with a large number of interconnected components and devices. Automating such a network can be challenging, as it requires the integration of multiple systems and the coordination of various functions.
- Reliability and availability: Automation systems must be reliable and available to ensure the continuous operation of the distribution network. Any failure or downtime can have serious consequences, including power outages and disruptions to critical services.
- Security: Automation systems must be secure to protect against cyber threats and unauthorized access. This requires robust security measures such as encryption, authentication, and access control.
- Interoperability: Different automation systems may use different protocols and communication standards, making it difficult to integrate them into a cohesive network. Ensuring interoperability among different systems is critical to the success of an automated distribution network.
- Maintenance and upgrades: Automation systems require regular maintenance and upgrades to ensure their continued operation and to incorporate new features and capabilities. This can be a significant burden for utilities, as it requires resources and planning.
- Cost: Automating a distribution network can be expensive, as it requires the deployment of advanced technologies and the integration of multiple systems. This can be a significant barrier for utilities, particularly in developing countries.

One of the main objectives of distribution network automation is to reduce the SAIDI (System Average Interruption Duration Index) metric, which measures the amount of time customers are without power due to

outages or other disruptions. By automating key processes and enabling real-time monitoring and control of the distribution network, utilities can reduce the frequency and duration of power outages, resulting in improved customer satisfaction and cost saving. Overall, the adoption of distribution network automation technologies is an important step towards modernizing and improving the reliability of electricity distribution systems.
The purpose of this paper is to examine the use of feeder automation for Fault Location Isolation and System Restoration (FLISR), also referred to in some research as self-healing grid. Self-healing is important for a distribution system, meaning that faulty components are isolated from the grid, and the system can return to normal operation without human intervention [5]. Self-healing problems, different approaches, integration of distributed generation, and cost issues are thoroughly discussed in [6].
The objective of self-healing mechanism include:

- Maximization of restored load
- Minimization of restored time
- Minimization of restoration/recovery time
- Maximization of restored reliability

Note that while the resilience of the distribution network is not part of the discussion in this paper, it has strong correlations with the amount of restored load and restoration time.
There are several methods to implement self-healing in the distribution network which has been the subject of research in [7] and [8], namely:

a. Distributed

In this technique, the automation logic is located in the RTUs. This automation is based on peer-to-peer communication, meaning that field devices are able to perform necessary grid automation tasks without the need for intervention from the SCADA Master Station. Provide by ring main units or pole top installations. The RTU react automatically to reconfigure the network and informs the SCADA

b. Semi-distributed

The automation logic is implemented in one of the RTUs at a substation on the feeder. This central RTU then sends control commands to other RTUs on the feeder during the reconfiguration process. To facilitate this technique, the grid is divided into different clusters based on factors such as size, load criticality, and network topology, with a central RTU assigned to each cluster. In this technique, the SCADA Master Station can only monitor the reconfiguration procedure and turn on or off the automation logic in the RTU.

c. Centralized

In contrast to the previous approaches, the centralized self-healing architecture assigns all of the automation logic to the SCADA Master Station, allowing for the complete implementation of the grid. In this method, RTUs at each substation are passive and do not contain any automation logic. They only provide status and alarm signals as inputs for decision-making and action-related outputs. The master station collects and processes this input data, and the output of the master station's calculations is executed by the RTUs.

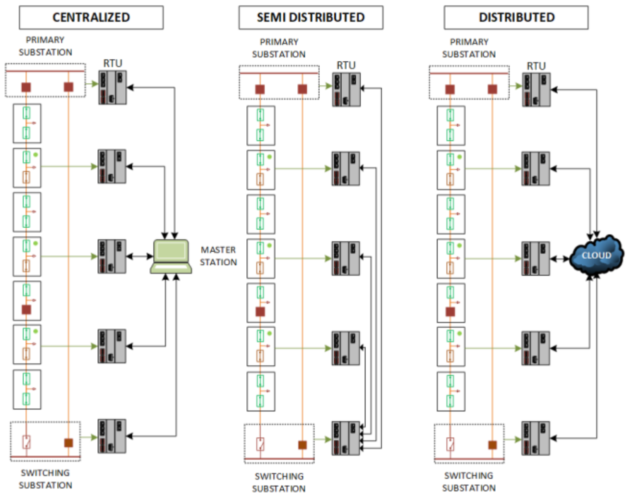

Figure 3. Self-healing grid methods

CASE STUDY

In this section, field testing result of centralized and semi-distributed self-healing methods is discussed. Each technique is implemented within distinct distribution networks within the Jakarta metropolitan region.

Centralized

The first test case is using centralized self-healing technique that is implemented in the feeder illustrated in Figure 4.

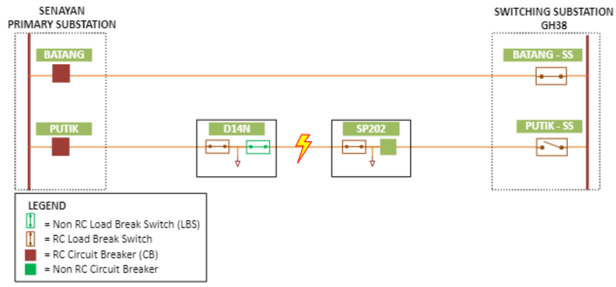

Figure 4. Centralized self-healing feeder

The single line diagram is simplified for clarity, showing only one load-bearing feeder Putik with the express feeder Batang. As depicted in Figure 4, the secondary substations D14N and SP202 are prepared with SCADA infrastructure. Each of the substations is equipped with a single LBS remote control (RC) unit. Substations without SCADA facilities are not shown for simplicity.
When the fault occurs, master station run topology check to ensure switch position circuit breaker position in the primary, secondary, and switching substation are in normal / default operation condition as shown in Figure 4. The fault will trip circuit breaker Putik, and the fault indicator in D14N will send a fault alarm to the master

station. Master station determines the fault location in segment D14N – SP202 based on the events occur in Putik and D14N. After ensuring self-healing status is in "enable" state, master station construct fault isolation and restoration scenarios taking into account known fault location. The scenario is subsequently evaluated by comparing it to the express feeder load. The procedure will proceed to the restoration phase if the express feeder load does not exceed 100A; otherwise, the procedure will stop at the isolation phase. Once the scenario has been validated, RC commands are sent to the substations, which in this case are **open** D14N and SP202 to isolate the faulted segment then **close** Putik and Putik-SS to restore power to the healthy segments.

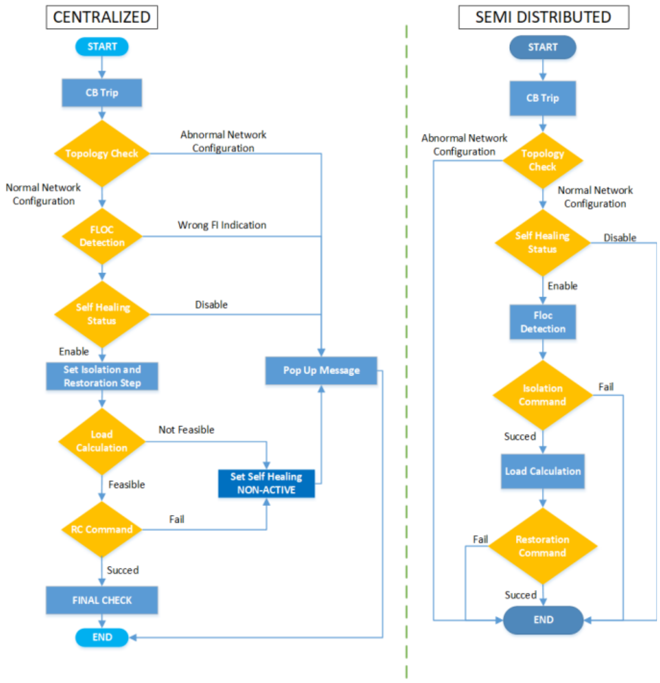

Figure 5. Self-healing flowchart of centralized and semi-distributed method

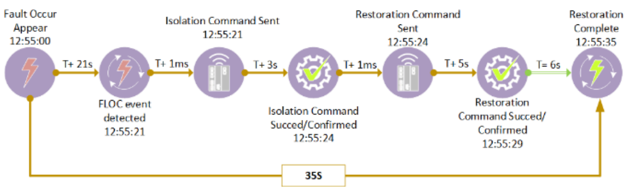

Figure 6. Centralized self-healing recovery sequence

As shown in Figure 6, centralized self-healing method detects the fault location, isolates the faulty segment, and restores the healthy segment in 35 seconds. During the implementation phase, centralized self-healing is quite simple because it does not necessitate any additional infrastructure beyond the basic SCADA functions that are already available.

Semi-Distributed

The second case is utilizing semi-distributed self-healing method, which implemented in feeder GShock and Seiko as shown in Figure 7. In this case, there are 3 SCADA-ready secondary substation KL234, KB285A, and KL221 in between primary substation New Senayan and switching substation GH151. As the previous case, the non-SCADA substations are not shown for simplicity.

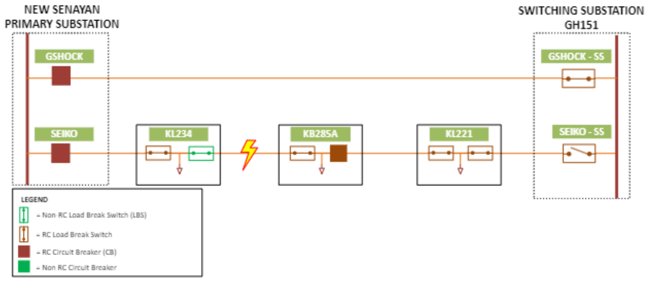

Figure 7. Semi distributed self-healing feeder

In contrast to the previous method, the automation logic in the semi-distributed method is embedded in the switching substation's RTU that serves as a gateway. This necessitates the other RTUs in the system to send data to the gateway as well as the master station. Figure 8 depicts the communication topology implemented to enable this automation method. Note that the master station function as a slave to the gateway in order to transmit required data from the primary substation.

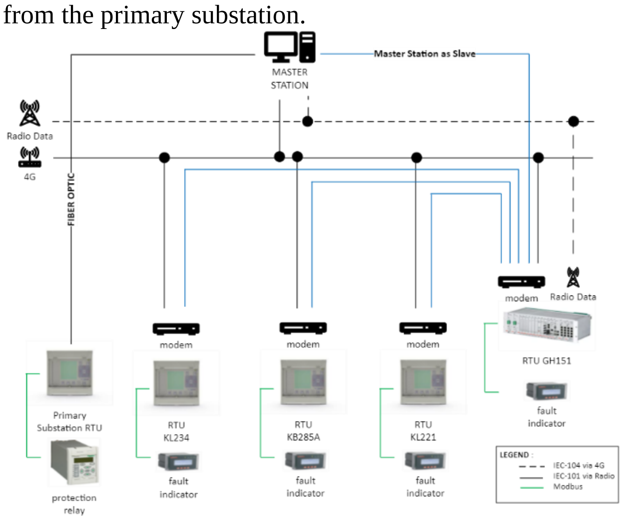

Figure 8.Semi-distributed method communication topology

In the event of a fault, the RTU in GH151 conduct a verification upon obtaining a trip signal from the master station to confirm that the switch positions at substations KL234, KB285A, KL221, Seiko-SS, GShock-SS, and GShock are in their normal operating conditions as shown in Figure 7. The automation procedure will not proceed if the switch positions are not in their normal operating conditions. If the self-healing status is enabled, the procedure will proceed to the next step, which is to determine the faulted segment by scanning the fault indicator status at KL234, KB285A, and KL221. In this case, the fault trips the breaker by activating the protection relay in Seiko. On the other hand, fault indicator in KL234 sends an alarm signal to the RTU in GH151. Based on the information received, RTU in GH151 determines that the fault is located in KL234 - KB285A segment. Afterward, the gateway sends RC commands to the RTU at KL234 and KB285A to **open** the LBS as an isolation procedure. The restoration procedure is initiated with a load calculation, which compares the current flow through substation KB285A prior to the disturbance to the reserve capacity of express feeder GShock. If the load calculation results indicate that the express feeder is capable of supplying the load of KB285A – GH151 segment, the gateway will send RC command which in this case is to **close** CB Seiko and LBS Seiko-SS.

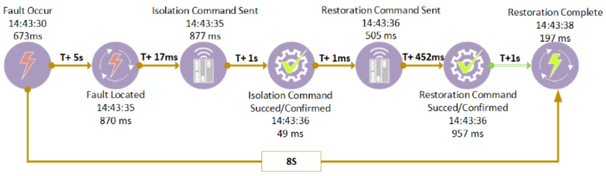

Figure 9. Semi distributed self-healing recovery sequence

Figure 9 shows that the semi-distributed method exhibits a notably faster recovery time in comparison to the centralized self-healing approach. However, during the implementation phase of this method, several challenges were encountered such as the need for specific configuration on each RTU involved in the self-healing scheme. This may present a significant obstacle during the deployment of the self-healing method in other locations, specifically in cases where the RTUs within the feeder/spindle system are unable to establish effective communication with one another due to differences in communication protocol, for instance. Therefore, it is essential to ensure that the communication protocols and infrastructure are appropriately designed and implemented to facilitate seamless inter-RTU communication in order to ensure the successful deployment of semi-distributed self-healing method. Another limitation of this method is that resetting of each RTU will be required when there is a reconfiguration on the feeder that is the subject of self-healing.

CONCLUDING REMARKS

Field testing result of both centralized and semi-distributed methods within two distinct spindle MV network is presented in this paper. Results from field testing indicate that the centralized method is more straightforward to implement, requiring no specific configuration settings on the RTU side or communication links, as the automation logic is fully embedded within the master station SCADA. However, the centralized method does exhibit longer execution times compared to other methods, though this is not a significant concern as the time achieved is still far superior to the absence of automation. On the other hand, the semi-distributed method requires shorter periods of time from the occurrence of a fault to the completion of recovery of the healthy segments on the affected feeder. The main disadvantage of this approach is the need for specific configuration settings on the RTU side and its communication links, which can prove challenging during reconfigurations or the addition of new substations equipped with SCADA facilities on the feeder.

In conclusion, based on the characteristics outlined above, it can be determined that the centralized method is more suitable for wide area distribution network, while the semi-distributed method is better suited for specific areas requiring high service levels with relatively minimal changes to the underlying electrical network infrastructure.

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