SEMI-DISTRIBUTED AUTOMATIC SCHEME FOR SELF-HEALING IMPLEMENTATION IN DISTRIBUTION SYSTEM

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ABSTRACT

The modernization of the Distribution Grid aims to enhance the functionality of feeder monitoring, outage management, fault detection, and restoration as main features for improving reliability and stability. To fulfil the expectation so as the services agreement of the premium customers (i.e., data centre, bank, hospital, business centre, and others) in Jakarta, the Distribution Control Centre should deal with high reliability, resiliency, and efficiency. A semi-distributed Automatic scheme that provides reliably self-healing restoration roles that comply with IEC standards was designed and complemented with the existing SCADA system. In this paper, the self-healing algorithm identifies the fault location, isolation, and restoration services of the damaged section in the real feeders. The recovery scenarios are designed for each line segment. The improvement settings regarding interoperability between Intelligent Electronic Devices (IEDs) among the feeders were conducted to accelerate fault detection and clearance decision. Furthermore, Early Warning System (EWS) indicators through the distribution substation were also carried out (i.e., Trip Circuit Supervision (TCS), Motor Supply Fault (MSF) of the circuit breaker, Protection Supply Fault (PSF), and Earthing Leakage Current detection) delivers as a function to the Fault Location Isolation Service Restoration (FLISR) system. Finally, the obtained parameters resulting during the fault at the damage section are considered for the localization and restoration scenarios of the SCADA system automatically to improve the System Average Interruption Duration Index (SAIDI) and Energy Not Served (ENS) performance.

***Keywords**— self-healing, semi-distributed, FLISR, SAIDI*

1. INTRODUCTION

The power distribution grid nowadays strongly deals with various challenges due to higher customer requirements of supply and quality, Distributed Energy Resources (DER) penetration, development of the Electric Vehicle (EV) population, etc. To counteract this trend, the distribution automation system enhances the reliability, resiliency, and efficiency of the distribution network by combining feeder monitoring until fault restoration.

The supervisory Control and Data Acquisition (SCADA) system have a combined function of Remote Terminal Unit (RTU), Telecommunication Protocol, and master station as the main equipment to collect data from the field. The information will be integrated into the DMS (Distribution Management System) to make correct decisions.

Implementation of DMS, which the Fault Location, Isolation, and Service Restoration (FLISR) as a main feature, was delivered to determine fault location fast and accurately [1]. This system was more than a monitor and remotely control of the device, but also identified the fault section, and determined switching operations to isolate areas and restore supply to customers. The total reactance from digital relays to the fault location was calculated by the measurement of current and voltage records as input parameters. As a part of automated fault identification, FLISR provides information within seconds to normalize the fault section, therefore minimizing outage duration and frequency [2].

The improvement setting regarding interoperability between Intelligent Electronic Devices (IEDs) among the feeders was implemented to accelerate fault detection, and clearance decisions will deliver in this paper. The Early Warning System (EWS) indicators through the distribution substation were also taking account to provide information to SCADA system.

This paper is organized as follows. Section II will introduce the architecture of semi-distributed system. Self-healing and early warning system will perform in section III. Self-healing implementation in real feeder and the result presented in Section IV. Section V provide the results, and concluding remarks are provided in section IV.

2. SEMI - DISTRIBUTED AUTOMATIC ARCHITECTURE

Automatic Distribution System (ADS) in the power distribution grid is designed to improve the functionality of SCADA applications, which has the main function of real-time monitoring and control of electricity distribution equipment within substation and feeder, measurement data acquisition, and network route.

The self-healing implementation toward enhancing the SCADA function has been defined as three categories, which are centralized, semi-distributed and distributed [3][4]. A centralized architecture implements all the logic controlled programmed in the master station so that every scenario function within the primary substation and feeder is stated in master station; then, the switching decision is chosen by the fastest operation. The semi-distributed architecture as shown in Figure 1 has relatively faster operation time than the centralized scheme. This automatic system is proposed at the primary substation and feeder or regional control that has one concentrator function in each region. At the same time, the distributed scheme was implemented in a secondary substation, which has the local capability to execute logic commands over the protection scenarios.

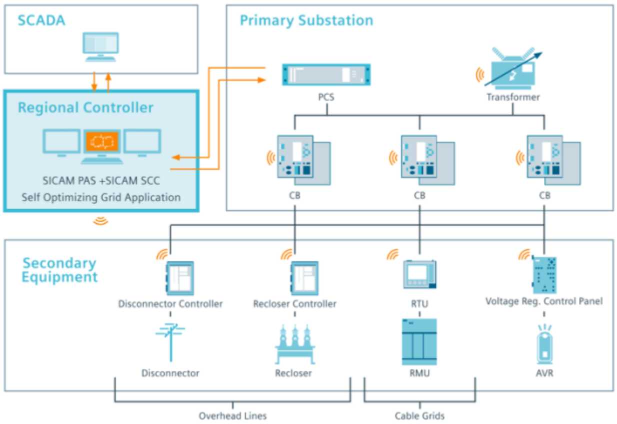

Figure 1 Semi-Distributed Architecture [3]

Over the implementation of an automatic system, FLISR function allows the utilization of all accessible data in the distribution grid to determine possible fault scenarios and specify the restoration scheme. The operation of FLISR is described as follows [5]:

a) Identification of fault location: The electronic equipment in the field captured the damaged section as current and voltage parameters and informed the condition regional controller.
b) The Regional controller sends the signal to the closest equipment to open the breaker, localized the fault section. And confirm back to the regional controller that the breaker status is open.
c) At the same period, the regional controller sends a command to activate another source to supply the healthy section.
d) The normal configuration will return as before the fault condition when the damaged section has been normalized.

3. SELF-HEALING AND EARLY WARNING SYSTEM

The electronic devices identified in the substations for supporting to assist the grid control centre in determining parameters result during the fault, there are Fault Detector (FD) and controller or protection with functionally as RTU. The Fault detector is necessary to recognize the direction of the disturbed area and then notify the RTU, while the RTU capture the information and communicates it to the control centre or other devices.

The self-healing scheme was designed by improves some logic data for each RTU. The logic has unique command between RTU, regarding the numbers of distribution substations. RTU play an important role in collecting and communicating data through the master station and other devices. Moreover, the communication protocol also needs to deliver the information within command centre and RTU among feeders. The equipment connection adopts the combination of IEC 60870-5-101 and IEC 60870-5-104. IEC 101 is a standard protocol for electric power system activities, i.e., monitoring, communications for control, tele-protection, and telemetering[6]. However, the IEC 104 has the same format data, but it is suitable for data transfer over ethernet, in this case by 4G connection.

To provide reliability and prevent malfunctions of each component, every mechanical function or environmental condition should be ensured to be in proper condition. In the substation building, thermal sensors, humidity, flooding and a smoke detector were installed, while Trip Circuit Supervision (TCS), Motor Supply Fault (MSF) of the circuit breaker, Protection Supply Fault (PSF), and Earthing Leakage Current detection parameters become the consideration the readiness of the mechanical electrical system. Moreover, each status was supervised at any time by the SCADA system.

4. IMPLEMENTATION AND RESULT

This paper performs two feeders for the self-healing scheme, named SEIKO (A) and GSHOCK (B), as an expression of the New Senayan Substation in Jakarta.

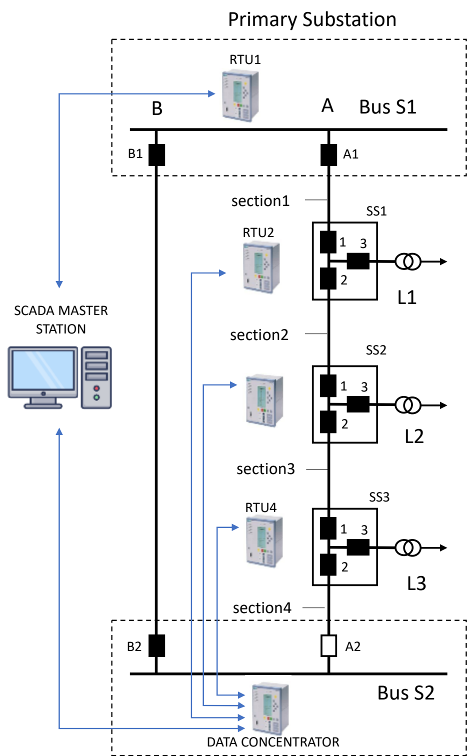

Figure 2 Feeder Architecture

The spindle configuration has 2,5 MW load and divides into four sections. This feeder supplies public services offices and dominantly business centres or retail customers. Remote Terminal Unit (RTU) controller as RTU1 to RTU4 was installed as a secondary substation (SS1 to SS3), and one data concentrator as the regional controller in bus S2, as shown Figure *2*.

The equipment controller is connected by a combination of IEC 104 communication protocols via 4G and IEC 101. Every secondary substation consists of three circuit breakers, one as an incoming SS, two as an outgoing SS and three as a load breaker.

The self-healing mechanism with a semi-distributed automatic scheme principally is implementing the FLISR system. Before this method is implemented, firstly, the loop automation features of RTU in S2 should be activated. That device is functioning as a data concentrator that will capture all the loop activities and take into consideration changing line configuration during a fault occurs.

Secondly, it improves the RTU logic for many scenarios of fault conditions in each line section. The fault detector will deliver a signal to RTU if any disturbance occurs close to them, and the RTU also receives the breaker status of the involved section. Now RTU has all information about the possible location of the fault and which breaker will do their action to open or close to localized damaged section as a consequence of continuous customer supply.

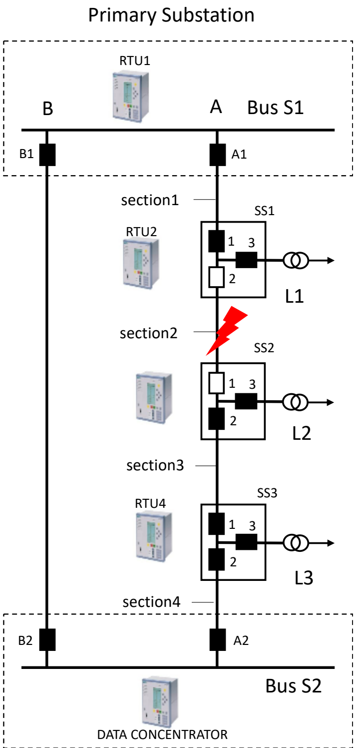

Figure 3. Fault Occur in Section2

In the case fault occurs in section2, the isolation stage begins when the fault current flows over the detector SS1, and the protection relay of A1 is picked up, so open the breaker. RTU1 transmits the fault signal data concentrator at bus S2 so that the loop automation status is active. The concentrator sends an open signal to SS1 to open breaker two and SS2 to open breaker one via RTU2 and RTU1, respectively. Open breaker status of SS1 and SS2 confirm to data concentrator. Regarding the open status, the data contractor sends a close signal to breakers A1 and A2 to close, so the load keeps in supply and the damaged section is isolated. Before the FLISR system was implemented, the restoration process took 38 minutes on average, but after the FLISR system was implemented, is approximately 8 seconds, as logger data report below:

Table 1. Data Logger of RTU

No	Time	Action
1	14.43.30	Fault detection
2	14.43.35	Confirm fault in section 2
3	14.43.35	Command CB 1 SS2 open
4	14.43.36	Command CB 2 SS1 open
5	14.43.36	Confirm CB 1 SS2 open
6	14.43.36	Confirm CB 2 SS1 open
7	14.43.36	Command close A1
8	14.43.36	Confirm isolation success
9	14.43.36	Command close A2
10	14.43.36	Confirm A1 close
11	14.43.38	Confirm restoration success

5. CONCLUSION

The real feeder implemented a self-healing method by a semi-distributed automatic scheme; it needed improvement of the RTU's logic of the existing SCADA system. There is a minimum attempt for deployment to avoid complicated processes and high-cost equipment. By significantly reducing the recovery duration, this scheme has contributed to reducing SAIDI, Energy Not Served (ENS), and increasing the network's reliability. It also means increased revenue for the utilities and services for the customers.

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