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Fuzzy Logic Method in SCADA to Optimize Network Electric Power Smart Grid

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Abstract: Smart grid is one of the solutions in terms of distribution of electricity to make it more effective and reliable. One of the main functions of the smart grid is to provide an important role in maintaining the reliability of electricity supply. Some sections in the smart grid include existing equipment at the site and the central computer. In order to convey the data from the site plant to the central computer, it needs a smart grid instrument controllers like SCADA. SCADA has a role to monitor, control, and communicate in two-ways between equipment on the site plant and the central computer. In SCADA systems, we often experience difficulty in obtaining data such as uncertainty of data and non-precision data. Then a method to overcome it is needed. In this study, Fuzzy Logic is used to detect network conditions toward the aspects of loading and the interference of overcurrent. Using four input variables with three and four linguistic value and four output variable with two linguistic value has resulted in eighty one rule base. Identification of faults was conducted by how big the DC voltage and the current. Once validated by SCADA systems and the use of Fuzzy Logic, we obtained 97.53% of the perfection of the system.
Keywords: Fault, Fuzzy Logic, SCADA, Smart grid

I. INTRODUCTION

The needs of electricity in Indonesia has increased every year. It was proved by the increase in the average growth of 8.6% from 216.8 TWh (Tera Watt Hour) to 457.0 TWh throughout 2016 and 2025. To meet it, the Indonesian government has tried to build and renew generation facilities, rearrange the transmission network, and rearrange the distribution network. The obstacle of the government's efforts includes limited electricity supply due to differences in geographic location so that the electricity weren't fulfilled. The power supply in Indonesia is currently using interconnection system that is used by all major islands, while small islands are still using the isolated system and has reached the electrification ratio up to 88.3% [1].

In recent years, Indonesia is building an interconnection system. It is proven by the efforts of the government to operate a new power plant, add plant reliability, improve the reliability of the transmission system, strengthen the transformer in the substation, increase the recovery of electricity supply during faults and open up the possibility of a hybrid solar power and hybrid thermal power station. The Government's efforts are aimed to anticipate growth in customer demand, maintain continuity of power supply and maintain, steady voltage in accordance with the needs and automation of network operation of electricity[2].

Based on the above elaboration, in 2011 Gao and Redfern tried to provide solution by creating a more effective and reliable electrical distribution. In that study, smart grid system was used. This system had used smart devices, modern communication systems and reliable management system[3]. Other advantages of this system were to have a large capacity in monitoring data generated by an integrated, data analysis for supporting decision, increased security, effectiveness in communication, to meet customer demand and reduce energy consumption and costs.

Based on the research conducted by Gao and Redfern, Borlase (2013) tried to provide a solution by creating a control instrument in the smart grid. The instrument was a Supervisory Control and Data Acquisition (SCADA) [4]. This system referred to a system or combination of systems that and collect data from various sensors which were located in the site plant. Then they sent the data to a central computer which was then used to view, manage and control devices in the site plant. Broadly speaking, SCADA installed in the central computer with SCADA software in it, the appearance of the Graphical User Interface (GUI), front-end data acquisition equipment, presenting data and information in real-time, intelligent alarm processing, can use thin clients and web-based clients, using one or more Remote Terminal Unit (RTU) and using a communication system. Utilization of SCADA systems in the power network aims to obtain data in real-time on the site plant as it is in the power plants, substations transmission and distribution, feeder distribution, and other devices, giving orders to the equipment located at the site of the plant with response time ranges between 1-5 seconds.

When we pay attention on its components, SCADA consists of two components, field devices such as RTU, and central computer. RTU is a microprocessor device which transfers the telemetry data to the central computer. RTU is located in the plant site. The main functions of RTU are interfacing input/output, collecting data, presenting data to a central computer, and manipulating the data before it is sent to the central computer.

Meanwhile, the central computer is a computer system that is responsive to the circumstances which occur in the RTU. In large SCADA system, central computer serves to reduce double data, distribute software, and record events which occur on each device.

According to the research conducted by Gouzhen et al in 2009, SCADA systems were used for monitoring, controlling, and two-way communication between the central computer and the photovoltaic power plant. There were two basic studies in this research. They were a match between the conditions at the plant site in the central computer and a server configuration SCADA[5].

Every complex system definitely will have some risks. Some risks that occur in the SCADA are the breakdown of communication between the central computer and the device at the site plant, the unstable data transmission, and the damage to system which causes faults[6].

SCADA systems often have difficulty in obtaining data from the RTU. Some of the difficulties are the amount of noise, the uncertainty of data, and the ambiguous data obtained in the SCADA system. To overcome this, Kumar et al are using Fuzzy Logic. Because Fuzzy Logic is able to cope with the uncertainty and non-precision data received from the RTU to the central computer. In this methods there is membership function and rule base that can be adapted to the needs [7]-[8].

Based on the explanation above, this research focuses on the use of Fuzzy Logic in SCADA which is used to detect faults that occur on the network due to fault of overcurrent and load.

II. MATERIALS

In the SCADA system, the quality of the measurement depends on the transducer and converter, telemetered to control systems via communication links. One of the components in SCADA located at the site of plant is RTU in which there are inputs and outputs such as analogue-to-digital converters, digital-to-analogue converters, analog inputs, digital inputs and digital outputs and communication ports in it.

The data used in this research is data types such as voltages and currents generated by the devices on site plant and the voltage and current received by the central computer, fault, response time which occurs during and after faults as well as length of transmission media used.

III. METHOD

3.1. Measurement

For measurement, the data was obtained from the following ways: First, by using the data changes to large voltages and currents generated by the devices on site plant so that voltage and current received central computer will adjust magnitude. Second, by using multiple nodes as a source of voltage and current and form a network, then between the node, a fault was created. It will affect the delivery of data and information to the central computer. Third, doing the analysis using fuzzy logic by doing data collection first and then process them to obtain the rule for any condition of input results. Then the data will be saved and will be used by Fuzzy Logic in determining the output to obtain optimum use of resources and load usage.

3.2. System Scheme

In this study, a scheme of the system as shown in Figure 1 is used.

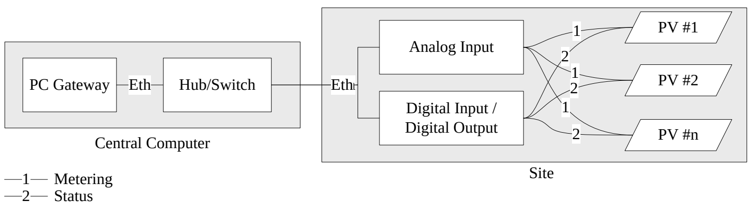

Figure 1. System Scheme

Based on Figure 1, it was concluded that: First, PC Gateway is a unit which displays and stores data generated by the site plant section. Second, PC Gateway will provide data and information in the SCADA system. Third, status and control of existing equipment at the site plant will be read by a sensor device that has a digital input and digital output. Fourth, the measurement will be addressed by tools which have inputs analog sensor. Fifth, the source voltage and current are generated by photovoltaic (VP).

3.3. Fuzzy Logic

In this study, the method of Fuzzy Logic used can be seen in Figure 2.

Figure 2. Structure of Fuzzy Logic

In fuzification in taking input and has been predetermined the degree of membership. In this study, four input variables, namely volt1, volt2, volt3 and volt4 are taken. It generates four output variables which are relay1, relay2, relay3 and relay4. The value of all the linguistic input variables is divided into three: low, normal and high, while the linguistic value of the output is divided into two: open and close.

Each input variables have low membership function with a voltage range between 0V up to 2V, normal to the voltage range between 2V up to 9V and high voltage range between 9V up to 10V. Meanwhile, the output variable has an open membership functions which have a normal stress, and has covered the low and high voltage.

From the results of fuzification input, eighty one rule base was obtained. This rule base was implemented on Analog Input tool and displayed in the form of SCADA systems on the PC Gateway. Here are two of the eighty one rule base obtained: First, when volt1 is low, and volt2 is low, and volt3 is low and volt4 is low, then relay1 is opened, and relay2 is opened, and relay3 is opened, and relay4 is opened. Secondly, when volt1 is normal, and volt2 is normal, and volt3 is *high*, and *volt4* is *high*, then *relay1* is *opened*, and *relay2* is *opened*, and *relay3* is *closed*, and *relay4* is *closed*.

3.4. SCADA System

In this study, SCADA systems are used to display data and information such as status, control and measurement of the devices that exist in the plant site and then the data will be sent to the PC Gateway. Then the data will be stored in the existing database on a PC Gateway that will serve as a log.

Globally, the display of SCADA can be seen in Figure 3.

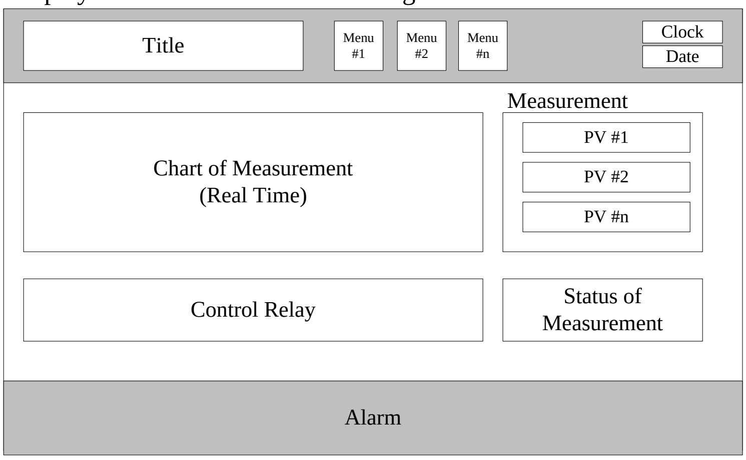

Figure 3. SCADA Layout

In this study, the SCADA system layout is divided into three sections: *Header*, *Body* and *Footer*. The *Header* section is used for the placement of titles, multiple menus which are used, the time and date information. Meanwhile, the *Body* section is used to display features such as charts and bar voltage measurements in real-time generated by PV. In the control relay, it is used to control relays manually or automatically and on the status of measurement, it is used as a condition of the relay and PV connected/on or disconnected/off on SCADA systems. Finally, on the *Footer* it is used to display event and alarm which occur in real-time.

IV. EXPERIMENT AND RESULTS

4.1. Measurement

In this study, four measurements of solar panel modules are used. This solar panel module serves to transform solar energy into DC power. These solar panels have each specification Maximum Power (Pmax) of 100W. Figure 4 is voltage measurements which have ever been done. The voltage values measured is up to 10V, and the smallest time used is milliseconds (ms).

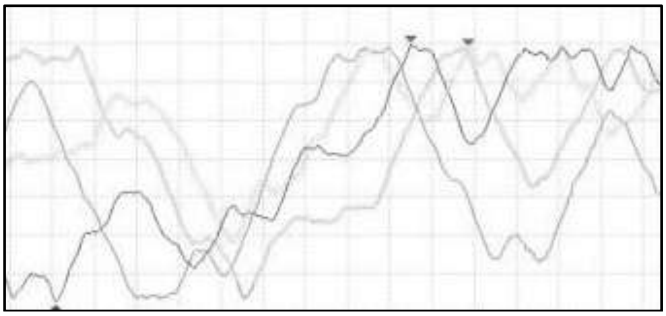

Figure 4. Voltage measurements

In this measurement, it has also been implemented with fuzzy logic membership functions numbers 1-2 which mean *low*, the rate of ≥ 2 - ≤ 18 which means*normal* and the number >18 which means*high*. In the measurement of value of <2 and >18, the graph shown is red. Still in the graph, the triangle mark above illustrates the highest voltage and the triangle below illustrates the lowest voltage during the measurement taken.

4.2. SCADA System

Tests conducted on the SCADA system aims to determine whether the design results system has functioned properly and in accordance with the recommended specifications. Tests performed include First, making sure all devices on the central computer and the site plant have been connected in accordance with the procedure. Second, making sure that application of SCADA system can be operated in line with expectations. Third, testing the SCADA system which serves to communicate between devices on the site plant, central computer and user.

The display of this test is shown in Figure 5.

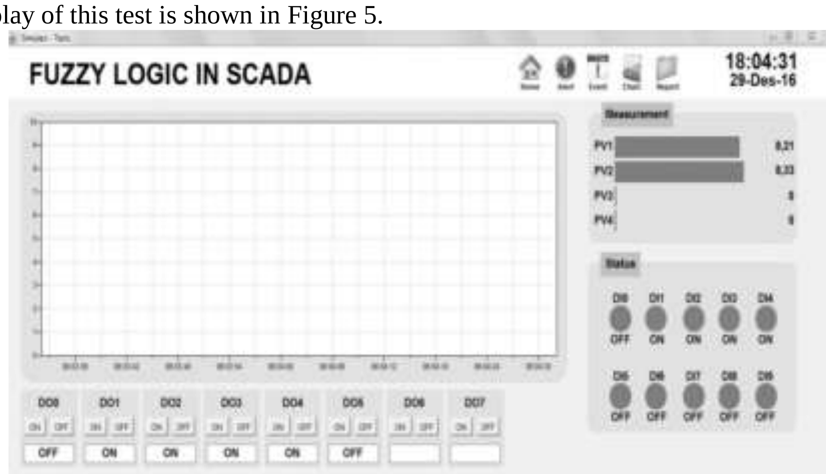

Figure 5. Display SCADA System Testing

Figure 5 has included some details of which are measurements that have been done in real-time which amounted PV1 and PV2 of 8,33V and 8,21V, relay status is shown in DI1 to DI4 is ON.

4.3. Scenario of Fault

Scenario of fault in this study is used to test and measure the robustness of the system that has been created. Several scenarios of faults that have been made can be seen in Figure 6 and Table 1.

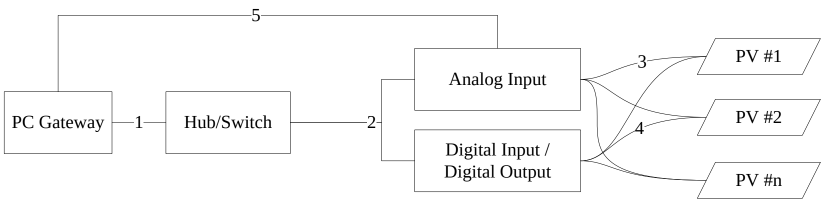

Figure 6. Scenario of fault

Table 1. Scenario of fault

No	Description	Cable Length	Response Time
1	UTP cable is disconnected between the Gateway PC and Hub / Switch	1m	0,1ms
2	UTP cable is disconnected between Hub/Switch with Analog Input module and Digital Input module.	2m	0,2ms
3	Negative cable is disconnected between Analog Input module and PV #1	5m	0,5ms
4	Cable is disconnected between Digital Input module and the PV #2	5m	0,4ms
5	UTP cable is disconnected between the PC Gateway and Analog Input module which is connected directly	3m	0,2ms

V. CONCLUSION

The use of Fuzzy Logic was conducted to determine the membership functions of the four input and four output voltage magnitude condition of the relay. Membership function has obtained eighty-one rule base. The calculation of Fuzzy Logic has been implemented in Analog Input module and into the SCADA system. Once validated between SCADA systems and the use of Fuzzy Logic, then we obtained 97.53% of the perfection of the system or two of the 81 rule base to be evaluated.

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