Simulation Design of Ungaran 500kv Substation Operation System Using Microcontroller

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Abstract. Extra High Voltage Substation 500 kV is one part of the backbone of the electrical system in Indonesia, this happens because it supplies so many areas. In terms of these benefits it can be seen that the equipment in the substation must have high reliability so that the quality of electric power reaches the consumer optimally and consumers will not feel disadvantaged. Operation of a switching device at the substation to make changes to the system is called maneuvering. In the implementation of the substation maneuver, it must be in accordance with the Standing Operating Procedure (SOP), if a switching error occurs when the maneuver will be fatal for the electric power system and can cause harm to the company and consumers. Therefore we need a safety in the substation maneuvering process called interlock. In this final project, a simulation tool is made to apply the working principle of the interlock system to CB and DS in maneuvering voltage relief, voltage delivery maneuvers and load-based maneuvers based on the Arduino Mega 2560 as the central controller for the entire system circuit. This simulator tool has a fairly high level of work accuracy in accordance with SOP (Standing Operating Procedure). It is hoped that this tool can provide knowledge to the general public about the existing maneuvering system in the GI in maintaining electric power transmission systems well and easily understood.

1. Introduction
Main substation is part of a power system that is centralized in a place containing transmission and distribution lines, safety equipment and control equipment. The main function of the substation is to regulate the flow of electric power from one transmission line channel transmission to another, distribute it to consumers, as a place to reduce the transmission voltage to the distribution voltage, as a control and safety system operation [1]. Maneuvering (Switching) is an activity before and after installation work, both on the installation and distribution installation. In the form of opening / closing activities of Electric Power System components such as CB and DS. In this activity a good coordination is needed between the parties involved, so that the work can run well, properly and safely [2]. In the implementation of the substation maneuver, it must be in accordance with the Standing Operating Procedure (SOP), if there any switching error when the maneuvering process, it will be fatal for the electric power system and can cause harm to the company and consumers. Because of that, we need to watch for the safety in the substation maneuvering process which called interlock [3]. The interlock system must be equipped to prevent possible errors or omissions in operation of the equipment and to ensure operator safety. Interlocking devices must be of a mechanical type with high manufacturing standards, cannot be contested and the mechanical strength should be...
stronger than mechanical controls.

2. Designing

In this final assignment, the author makes a tool that is used as a simulator to explain the core material about the operating system and PMT and DS interlock in the 500 kV substation Ungaran during voltage release maneuvers, voltage maneuvers and load transfer maneuvers. The equipment used in the simulator is equipment that functions as a substitute for actual system equipment. The components in the electric power system that are actually replaced by electronic components as hardware, such as circuit breakers (CB) or power breakers (PMT) are replaced by rotary switches, disconnecting switches (DS) or separators (DS) are replaced by toggle switches, and The Arduino ATmega 2560 microcontroller is used here to retrieve, condition and process data to match the equipment so that it can be processed and analyzed in software. The block diagram shown in Figure 1 below is designed to facilitate understanding of the simulator tool.

2.1. Hardware Designing

Figure 1 is a block diagram of the whole system from the prototype Designing a 500 kV substation operating system simulation using a microcontroller. The following are the parts of the block diagram include. Block 1 is a series of power supplies that serves to supply voltage to the microcontroller and other components. 220 VAC PLN voltage source entered into the adapter which is then the voltage is lowered and rectified to 12 VDC. Then the adapter is connected to the dc-dc converter circuit to lower and stabilize the voltage to 5 VDC for supply to the microcontroller [14–24]. Block 2 is a series of simulator inputs consisting of rotary switches and toggle switches that function to give the simulator ON/OFF commands.

Figure 2: Panel Input Simulator
Block 3 is a simulator output series consisting of an indicator LED and an LCD display that serves to display the command output from the input set.

2.2. Software Designing
After the hardware design is complete, the next step is to create a program for the simulator. Making a program for Arduino Mega 2560 requires an application to send programs from a PC to the Arduino Mega 2560 module. Writing programs is done using the Arduino IDE application. To facilitate the understanding of program design in the simulator, a flowchart is made as follows.

3. Result and Analysis
After the design and manufacture of tools is carried out, a discussion and analysis of the overall tool testing is carried out. The purpose of the overall tool testing is to find out whether the simulator’s performance is functioning as expected. After all the series of devices are installed properly and the program is finished being uploaded to the Arduino ATMega 2560 microcontroller, the next step is testing the whole system by combining the whole series and then testing the overall system performance.

In Figure 5 (a) is the input panel as the operation panel CB and DS in the substation, while in Figure 7 (b) is output in the form of a single line from the 500KV substation, and for operating
guidelines or conditions when operating can be seen on the LCD. Initial conditions when testing simulators under normal conditions or lack of maintenance. Following are the steps in testing:

Connect the simulator with a voltage of 220 VAC. Then press the switch on the Ungaran Substation panel box so that the LEDs on the 500KV Substation are lit except the LED as follows:

(i) IBT 3
(ii) Ngimbang
(iii) Mandirancan 2
(iv) Tanjung Jati 2
(v) Busbar A
(vi) Busbar B
(vii) ES IBT 3
(viii) ES Ngimbang
(ix) ES Mandirancan 2
(x) ES Tanjung Jati 2
(xi) ES Busbar A
(xii) ES Busbar B

The current state of the simulator when maintaining and normalizing the output. Maintenance in this simulator as follows:

3.1. Diameter 1
In diameter 1, it is divided into 2 parts, namely bay Ngimbang and bay IBT 3. This test is carried out one by one in accordance with the direction of maintenance to be performed on the system. The following is an example of a simulation test of CB and DS operating systems when maintenance occurs at diameter 1 on the bay Ngimbang. Maintenance on the substation simulator for bay Ngimbang Load by pressing the 'Ngimbang' button on the panel box, the yellow LED on bay Ngimbang on the single line output will light up and provides instruction to immediately release the voltage on bay Ngimbang in the order maneuver as follows:

(i) CB AB1 open
(ii) DS A5 & DS A6 open
(iii) CB A1 open
(iv) DS A1 & DS A2 open
(v) DS A3 open
(vi) ES A4 close
In Figure 7 it can be seen that on bay Ngimbang the voltage has relief, where DS and CB are die out or in open condition and ES Ground is lit or in close condition. After the maintenance of bay Ngimbang, the normalization of the bay is immediately carried out, with the following normalization sequence.

(i) ES A4 *open*
(ii) DS A3 *close*
(iii) DS A1 & DS A2 *close*
(iv) CB A1 *close*
(v) DS A5 & DS A6 *close*
(vi) CB AB1 *close*
In Figure 8 is the output of the process of normalizing the voltage at the bay Ngimbang, where CB and DS have been operated closed or lit, except for ES the ground is operated open or in a state of outages. This proves that the system has returned to normal after maintenance of the bay Ngimbang.

3.2. Diameter 2
In diameter 2, it is divided into 2 parts, namely bay Mandirancan 2 and bay Tanjung Jati 2. This test is carried out one by one in accordance with the direction of maintenance to be performed on the system. The following is an example of a simulation test of CB and DS operating systems when maintenance occurs at diameter 2 on the bay Mandirancan 2.

![Figure 9: Indicator of maintenance demand (Yellow LED) on bay Mandirancan 2](image)

Maintenance on the substation simulator for bay Mandirancan 2 Load by pressing the 'Mandirancan 2' button on the panel box, the yellow LED on bay Mandirancan 2 on the single line output will light up and provides instruction to immediately release the voltage on bay Mandirancan 2 in the order maneuver as follows:

- CB AB2 open
- DS B5 & DS B6 open
- CB A2 open
- DS B1 & DS B2 open
- DS B3 open
- ES B4 close

![Figure 10: Condition voltage release bay Mandirancan 2](image)

In Figure 10 it can be seen that on bay Mandirancan 2 the voltage has relief, where DS and CB are die out or in open condition and ES Ground is lit or in close condition. After the maintenance of bay Mandirancan 2, the normalization of the bay is immediately carried out, with the following normalization sequence.
In Figure 11 is the output of the process of normalizing the voltage at the bay Mandirancan 2, where CB and DS have been operated closed or lit, except for ES the ground is operated open or in a state of outages. This proves that the system has returned to normal after maintenance of the bay Mandirancan 2.

3.3. Busbar
Ungaran’s 500 kV substation has a double busbar configuration that is connected to 3 CB arranged in series or can be called a 1.5 CB system. Under normal conditions, busbar A and busbar B are connected to each other so that it is easier to maneuver overloading during maintenance at the busbar direction. This test is carried out one by one in accordance with the direction of maintenance to be carried out on the system. The following is an example of a simulation test of CB and DS operating systems when there is maintenance on Busbar A.

Maintenance on the substation simulator for busbar A Load by pressing the 'busbar A' button on the panel box, the yellow LED on busbar A on the single line output will light up and provides instruction to immediately release the voltage on busbar A in the order maneuver as follows:

- CB A1 open
- DS A1 & DS A2 open
- CB A2 open
- DS B1 & DS B2 open
- ES busbar A close

In Figure 13 it can be seen that on busbar A the voltage has relief, where DS and CB are die out or in open condition and ES Ground is lit or in close condition. After the maintenance of busbar A, the normalization of the bay is immediately carried out, with the following normalization sequence.

- ES busbar A open
Figure 12: Indicator of maintenance demand (Blue LED) on busbar A

Figure 13: Condition voltage release busbar A

- DS B1 & DS B2 close
- CB A2 close
- DS A1 & DS A2 close
- CB A1 close
- CB AB2 close

Figure 14: Condition normalization busbar A

In Figure 14 is the output of the process of normalizing the voltage at the busbar A, where CB and DS have been operated closed or lit, except for ES the ground is operated open or in a state of outages. This proves that the system has returned to normal after maintenance of the busbar A.
4. Conclusion

The conclusion obtained from this research is Testing the simulation of the 500 kV GI operating system at Ungaran Substation carried out manually by performing ON / OFF operation on the control panel, running well in accordance with the operation manual of the Ungaran 500 kV Substation, APP Semarang No. P3B / PET / APPSMG / 15 / OPGI, which is currently in force. This simulator can only be operated in accordance with the Standing Operating Procedures (SOP) in the Ungaran Substation operation booklet. If the operation is not in accordance with the applicable SOP, the system cannot run properly or an error occurs.

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