Integration of MicroSCADA SYS600 9.4 into Distribution Automation System

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***Abstract*— In this paper, the Distribution Automatic System (DAS) is introduced and analyzed to improve the operation of power systems in Quang Nam province, Vietnam. The application of DAS contributes to quickly detect and isolate incidents, immediately restore the normal operation of the system and improve the power system reliability. The DAS is an effective support tool for the dispatchers in the remote operation, control and management of power systems. Previous publishes have done the research and application of DAS technology to the distribution grid but did not analyze of busbar segment problem and the programming for the DAS. This paper investigates the application of DAS using MicroSCADA SYS600 9.4 Pro software in the construction of smart grids in Quang Nam province and examines specific cases of faults on two Quang Nam feeders. Also, a program to implement the simulation of DAS is processed.**

Keywords— Distribution Automatic System, distribution grids, MicroSCADA SYS600 9.4 Pro, SCADA systems, Smart grid.

I. Introduction

The economy of Quang Nam province, Vietnam has been making particularly important changes, especially the industry, tourisms and services are developing rapidly. Therefore, the demand to meet power capacity, uninterruptible power supply and quality of electricity for the production processes and daily-life activities are increasing day by day. In addition, the development of renewable energy sources in Quang Nam, especially photovoltaic rooftop systems, poses challenges affecting the utility grid when these sources are grid-connected. The connection of these systems to the distribution grid in random order (depending on the location of the installed household) will cause phase imbalance and large difference in transmitted power if rooftop systems only focus on connecting to a single phase. Thus, the integration of automatic monitoring and operation technologies is one of the optimal solutions to meet the strict requirements in the energy development context of Quang Nam province.

The emergence of Distribution Automatic System (DAS) technology to the distribution grid based on the monitoring, management, control and data acquisition system of Supervisory Control and Data Acquisition (SCADA) will contribute greatly to quickly detecting reliability of power supply to customers and strengthen power quality.

The Distribution Automatic System – DAS, is a system that automatically controls the operation mode of the distribution grid to detect faulty elements and detach them from the system. The corrupted segment will be quickly isolated fragmented, and the power supply of the other elements will be restored in order to avoid power outage over a wide area.

The combination of DAS technology and SCADA system platform will bring positive effects to the Vietnamese power system and it will support the dispatchers in the process of system operation and management.

Despite of the previous studies about the application of the DAS, the relevant issues of the experimental DAS still have not been explored, such as the analysis of incidents on the grid or processes to build the DAS. Therefore, this paper will present the technology of the DAS on SCADA monitoring, control and data collection system applied to the distribution grid of Quang Nam province, Vietnam. Incident cases tested on the DAS, particularly two feeders of the 110kV Hoi An substation in Quang Nam province, will be highlighted on the analysis and research to provide appropriate solutions to detect and eliminate the incidents. In addition, the research will build database and control program for the system to execute system operation using MicroSCADA SYS600 9.4 Pro software and make recommendations to complete an applicable DAS for the Vietnamese power system.

II. SCADA Systems

A. *Introduction to SCADA systems*

SCADA (Supervisory Control and Data Acquisition) is an industrial automation management system with the function of controlling, monitoring and collecting data of the system. Thanks to the SCADA system, operators can identify and control the operation of electrical equipment through computers and communication networks. In the management and operation of the power system, the SCADA system plays a very important role in assisting operators in accurately tracking, monitoring and processing data in the power system [1].

The advantage of SCADA systems is to provide accurate and timely data that allows to optimize the operation of the system and process. Moreover, the power system using SCADA is always more efficient, reliable and safer.

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The main components of a basic SCADA system are supervisory computers (also called supervisory center), remote terminal units (RTUs) and communication infrastructure. The RTUs are located at the substation to collect data as well as to monitor and send control signals to the central SCADA system via communication infrastructure (fiber-optic cable or 3G). The switchgears such as reclosers, load break switches (LBS) or ring main unit (RMU) have control panels that are connected to the SCADA system using 3G technology or fiber-optic cable channels, usually via 3G transmission lines using 3G modems [1-2].

B. Principle and function of SCADA systems

- Principle of SCADA systems:

According to the predetermined period (about a few seconds), the host computer of the SCADA system at the supervisory center will perform the signal transmission for sequential scanning of substations, reclosers and LBS. These elements are equipped with RTUs or Gateway devices that allow the supervisory center to control devices through them [3].

- Function of SCADA systems:

The SCADA system has three main functions: monitoring, control and data collecting. In addition, the SCADA system also has the function of analyzing, processing and storing data; power flow calculation; short-circuit and reliability calculation; load demand management and providing database for other purposes [4-5].

III. Distribution Automatic System

A. Implementation of Distribution Automatic System

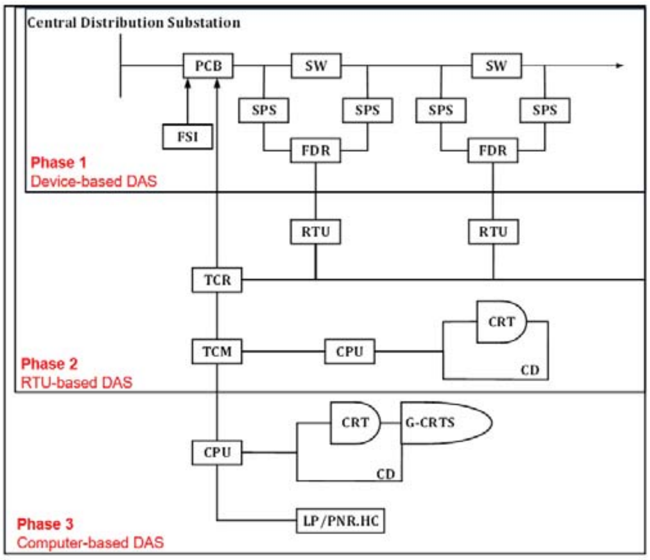

Fig. 1. Implementation phases of the DAS

According to Figure 1 the implementation of the DAS usually goes through 3 phases as follows:

- Phase 1: Installation of automatic circuit breakers (CB) and fault detecting relays (FDR) on medium voltage power lines. In phase 1, the incident area is automatically isolated from the system by devices on the medium voltage power line without activating devices at the supervisory center.
- Phase 2: Additional installation of RTUs and communication lines to receive information at the position of automatic CB in medium voltage power lines. At the supervisory center, remote control units and computer systems are installed to display the medium voltage grid in a simple form. Based on the information remotely obtained from the grid, the operators at the supervisory center will control automatic CB to isolate the faulty part by using the computers.
- Phase 3: Upgrading the functions of phase 2. At the supervisory center, supercomputers are used to manage the operation of the medium voltage distribution grid displayed according to the geographical map and adjust the process calculation automatically. After the completion of the above 3 phases, the distribution grid is completely remote-monitored [6-7].

B. Communication protocols

Currently, most SCADA systems of the Vietnamese power system use IEC 60870-5-101 protocol for communication from control points to the SCADA system. Basically, IEC 60870-5-101 protocol meets the requirements of real-time measurement and control signals for control objects. However, with the characteristics of connection by serial communication interface, IEC 60870-5-101 protocol has many limitations in establishing physical communication channels, and it is difficult to expand the connection points on the system. With the development of communication protocols based on TCP/IP communication protocol, IEC 60870-5-104 protocol was appeared to become a communication solution for SCADA systems, creating many advantages in implementation as well as high stability in communication [8-9].

The IEC 60870-5-104 protocol was released by the International Electrotechnical Commission in 2000. The IEC 60870-5-104 protocol creates physical connections based on TCP/IP protocol so the implementation of communication on physical layers becomes simpler and is easily compatible with Gateway devices and RTUs of different companies.

Communication signal of IEC 60870-5-104 connecting from RTUs to SCADA system is carried out on Fast Ethernet (FE) physical layers of communication devices, or through E1/FE converters (main line). Backup line is also proposed to be made via low-cost Internet connections (3G/GPRS or ADSL) [10-11].

Some basic advantages of IEC 60870-5-104 communication protocol evaluated through the testing process are listed as follows:

- The IEC 60870-5-104 protocol is obviously compatible with the IEC 60870-5-101 protocol for the link layer and the application layer. Therefore, the database construction for control objects on the MicroSCADA system does not change.
- The IEC 60870-5-104 supports an interface connection using Ethernet (FE ports), so the expense of communication devices is relatively low, or it is easy to hire FE ports of other network providers with the reasonable cost.

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- With the basic speed of FE connection from 128kb/s to 2Mb/s, the signal response speed of the IEC 60870-5-104 protocol is better than the IEC 60870-5-101 protocol. Moreover, it also supports 32-bit measurement (CP56Time2a).

Thus, the application of IEC 60870-5-104 communication protocol for SCADA systems of the distribution grid will basically overcome the limitations that the IEC 60870-5-101 were encountered. Based on TCP/IP network protocol, the IEC 60870-5-104 allows simple, low-cost communications, and easily exploits the telecommunications infrastructure of network service providers. However, the security in communication solutions must be specially prioritized when using public communication infrastructure [10-11].

IV. Simulation of DAS on the Distribution Grid

A. System diagram

In this paper, Feeder 471 and Feeder 476 of the 110kV Hoi An substation, presented in Figure 2, will be analyzed to simulate the DAS. The reason for choosing these feeders is the high penetration of photovoltaic rooftop systems around this area, which require timely supervision and control in order to ensure power quality and stability.

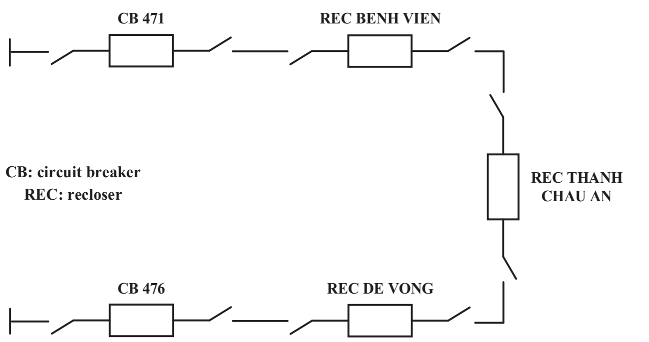

Fig. 2. Diagram of the simulation of the DAS tested on Feeder 471 and 476.

Initially, the communication signals of the control panels at Feeder 471, Feeder 476, Benh Vien, De Vong, Thanh Chau An and devices connected to the supervisory center are supposed to be normally operating, ensuring the backup power supply. Then, the incident cases will be assumed to evaluate the system. Possible incidents on Feeder 471 and Feeder 476 include: the incident on the segment from CB 471 to REC Benh Vien on Feeder 471 (case 1), the incident on the segment from REC Benh Vien to REC Thanh Chau An (case 2), the incident on the segment from CB 476 to REC De Vong on Feeder 476 (case 3) and the incident on the segment from REC De Vong to REC Thanh Chau An (case 4).

For example, the incident in case 1 is selected to analyze and build algorithm flowcharts, illustrated in Figure 3, to evaluate the system response. After identifying the incident location in the segment from CB 471 to REC Benh Vien, the protective relay will send the signal to switch off the CB at the beginning of Feeder 471. If the backup power source of Feeder 476 is available, the system confirms eligibility for the DAS program implementation. After that, the system will execute commands to switch off REC Benh Vien and switch on REC Thanh Chau An to continue supplying power for the segment that is not faulty. The automation of the distribution grid is done by FDR and sectionalizers installed on the distribution power lines of the distribution grid combined with reclosing function (F79) of the CB equipped at the beginning of the feeder. In the system, the commonly used relays are: Instantaneous/AC Time Overcurrent (F50/F51), Neutral Instantaneous/Neutral Time Overcurrent (F50N/F51N), Reverse-Phase Overcurrent (F46). When an incident occurs on one of the two feeders (471 or 476), the system detects

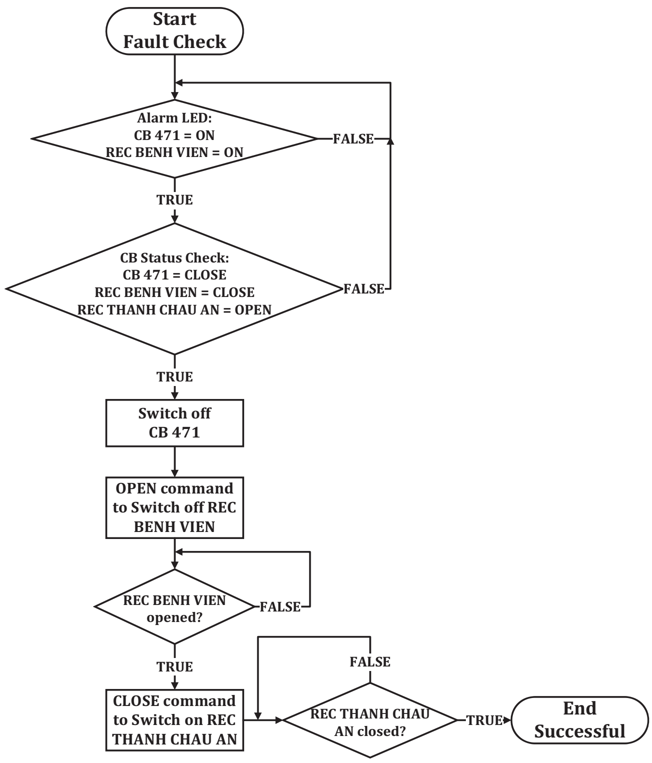

Fig. 3. Flowchart of problem-solving algorithms for incident case 1.

incidents thanks to information retrieved from the substation (breakers, relays, etc.), then execute commands to switch on/off CB to eliminate the incident and restore the normal operation of the grid. During this period, the faulty area is automatically isolated by existing devices on the two feeders of the distribution grid lines without the need of management and monitoring devices of the Regional Dispatch Center [11].

The protective time setting for overcurrent relay (standard inverse) in the program can be approximated by the following equation (based on the IEC 60255 standard):

$$t_{relay} = TMS\left(\frac{k}{\left(\frac{I}{I_s}\right)^{\alpha} - 1}\right) \tag{1}$$

where: t_{relay} is the tripping time (seconds), I is the fault secondary current (A), I_s is the relay pick-up current setting and TMS is the time multiplier setting. For standard inverse, $k = 0.14$ and $\alpha = 0.02$.

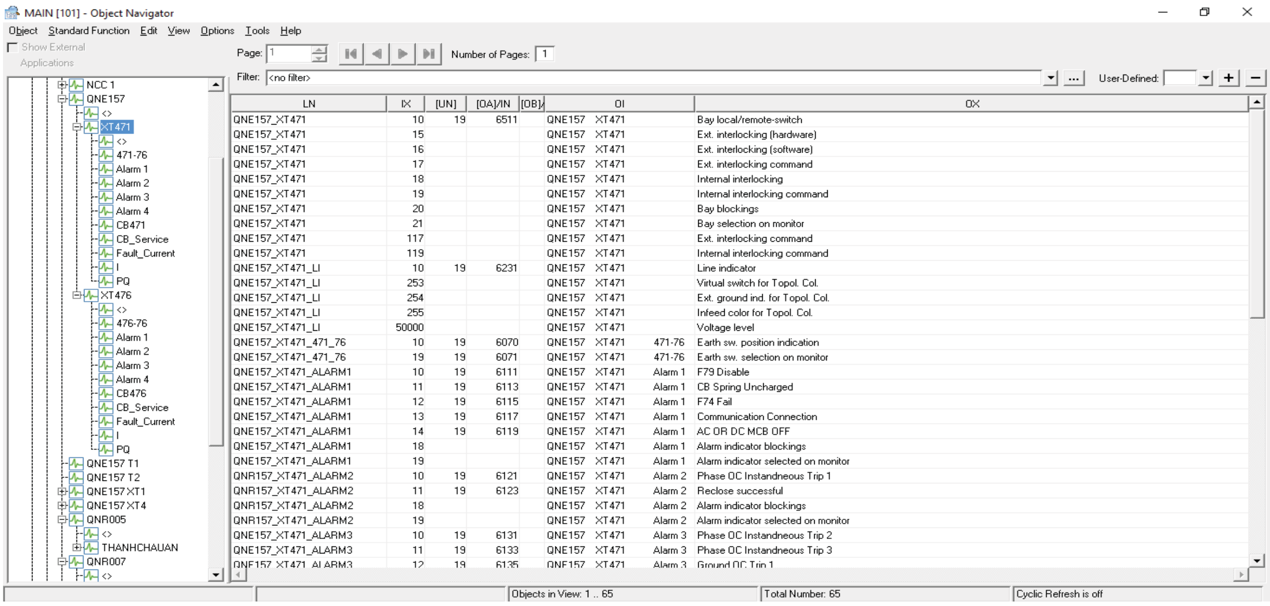

Fig. 4. Database of the entire system.

In addition, the automation of the distribution grid also comes with the functions of monitoring and remote control of sectionalizers. In order to fulfill this function, it is necessary to install RTUs and communication lines to receive information of sectionalizers located on the distribution lines. Based on the obtained information, the operators at the Dispatch Center will switch on/off the automatic CB to isolate the faulty element on the computer. At the supervisory center, it is necessary to install supercomputers to manage the operation of the distribution grid according to the geographical map and adjust the calculation automatically.

B. Building database

In the SCADA system, every change of elements and devices in the system is monitored as updated data from time to time. The data constitutes the database system with the main purpose of communicating with devices connected to the system and updating information to the supervisory technician after receiving notification of changes in the system.

Dynamic information are called Variables or Tags, which are real-time units. The data is associated with the variables defined in the Variable List or Data List [12-13].

The order of database construction in SCADA systems is presented as follows [14-15]:

- Receiving update notifications: The SCADA system receives notifications that there is a change in the control objects.
- Querying the changes: The system displays the changes and system responses to the changes. For each affected object, information from the application model and the SCADA topology model for the device is retrieved. The application model system provides a to-do list (add, delete, modify) then apply to topology model.
- Updating topology model: The changes from devices and connections from the database to the SCADA topology model are compared, then the database to make changes validated are edited.
- Updating SCADA database: Updating device information to link status or field values.
- Operational control in testing mode.
- Providing online display of information and specifications for technicians.

Building database of the SCADA system is carried out thanks to the powerful support of MicroSCADA SYS600 9.4 Pro software provided by ABB Group.

To build the database, the "Object Navigator/Standard Function" tool is used by manually creating each data object or using Excel files to batch import all data of the substation into SYS600 software, as illustrated in Figure 4.

The software allows to initialize 8 signals corresponding to 8 addresses at a time. All processing objects are connected according to these following fields: Unit Number (UN), Object Address (OA), Object Bit Address (OB) [16].

C. Developing program for the DAS

To build a control program for the DAS, it is first necessary to build a scheme of the two feeders 471 and 476 of 110kV substation. The "Display Builder" tool supports the construction of two feeders 471 and 476, which is illustrated in Figure 5. Based on the built-in database, the system diagram is designed using the "Actions/Objects Browser" tool.

The system control is simulated, using the control buttons: Fault simulation, Switching operations, Restore the system. The incident simulation program is implemented for the 4 cases mentioned in the previous section.

The SYS600 software uses the SCIL (Supervisory Control Implementation Language) programming language, illustrated in Figure 6, which is a high-level programming language specifically designed for the application of system monitor and control. All SYS600 application programs as well as most system configurations are built by SCIL [16-17].

After the implementation of the DAS, the response of the system is shown in Fig. 7.

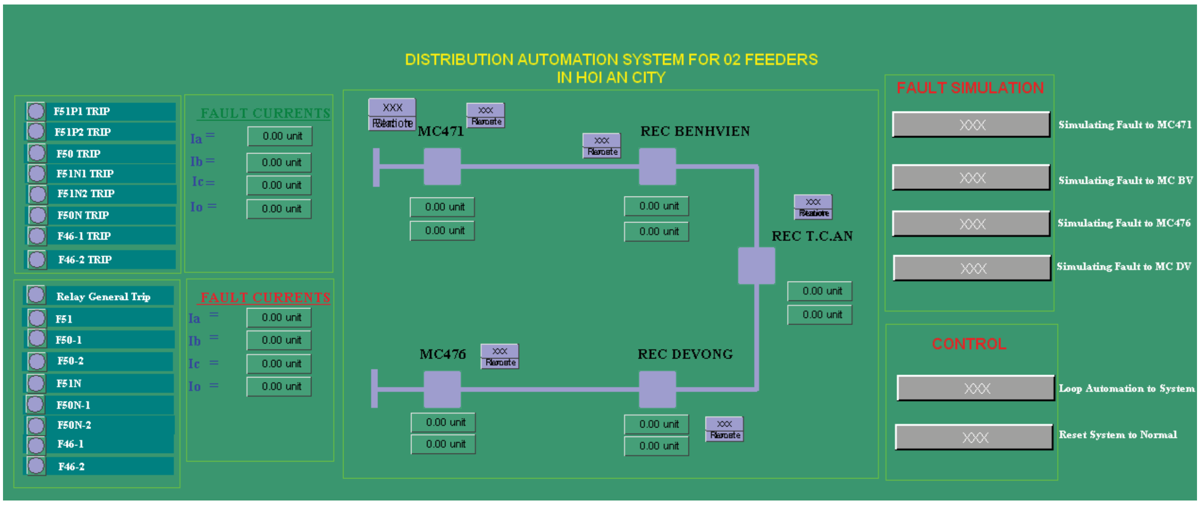

Fig. 5. Diagram of the DAS on Feeder 471 and Feeder 476.

```
|;[CODE SCIL]
;=====================================================================================================================
#local x_cot
      x_cot=console_output("DAS thong bao::: Bat dau thuc hien LOOP AUTOMATION cho XT471E157 & XT476E157")
      x_cot=console_output("DAS thong bao::: Step1: DAS kiem tra xac nhan vi tri su co.....")
#IF   QNE157_XT471_CB471:P10==2     AND -
      QNE157_XT471_ALARM3:P11==1    AND -
      QNR007_CB:P10==1                  -
#THEN #BLOCK
      x_cot=console_output("DAS thong bao::: Step2: Xac nhan vi tri su co nam trong phan doan [MC471E157 va MC Benh Vien]!")
      x_cot=console_output("DAS thong bao::: Step3: DAS kiem tra nguon du phong tu XT476E157 dam bao....")

      #IF   QNR005_CB:P10==2           AND   -
            QNE157_XT476_CB476:P10==1        -
      #THEN #BLOCK
            x_cot=console_output("DAS thong bao::: Step4: Xac nhan nguon du phong tu XT476E157 dam bao!")
            x_cot=console_output("DAS thong bao::: Step5: Xac nhan du dieu kien de thuc hien Loop Automation!")
            x_cot=console_output("DAS thong bao::: Step6: DAS thuc hien lenh [OPEN] [QNR007_MC Benh Vien]....")
                #set QNR007_CB:pss10 = 1
                #set QNR007_CB:P10 = 2

            #IF  QNR007_CB:P10 == 2 -
            #THEN #BLOCK
                  x_cot=console_output("DAS thong bao::: Step7: Xac nhan da [OPEN] [QNR007_MC Benh Vien] thanh cong!")
                  x_cot=console_output("DAS thong bao::: Step8: DAS thuc hien lenh [CLOSE] [QNR005_MC Thanh Chau An]....")
                        #SET QNR005_CB:PSS10=1
                        #SET QNR005_CB:P10=1
            #BLOCK_END
            #ELSE x_cot=console_output("DAS thong bao: khong [OPEN] duoc [QNR007_MC Benh Vien], DAS khong thanh cong ! Ket thuc

            #IF QNR005_CB:P10==1 -
            #THEN #BLOCK
```

Fig. 6. Part of control program for the DAS.

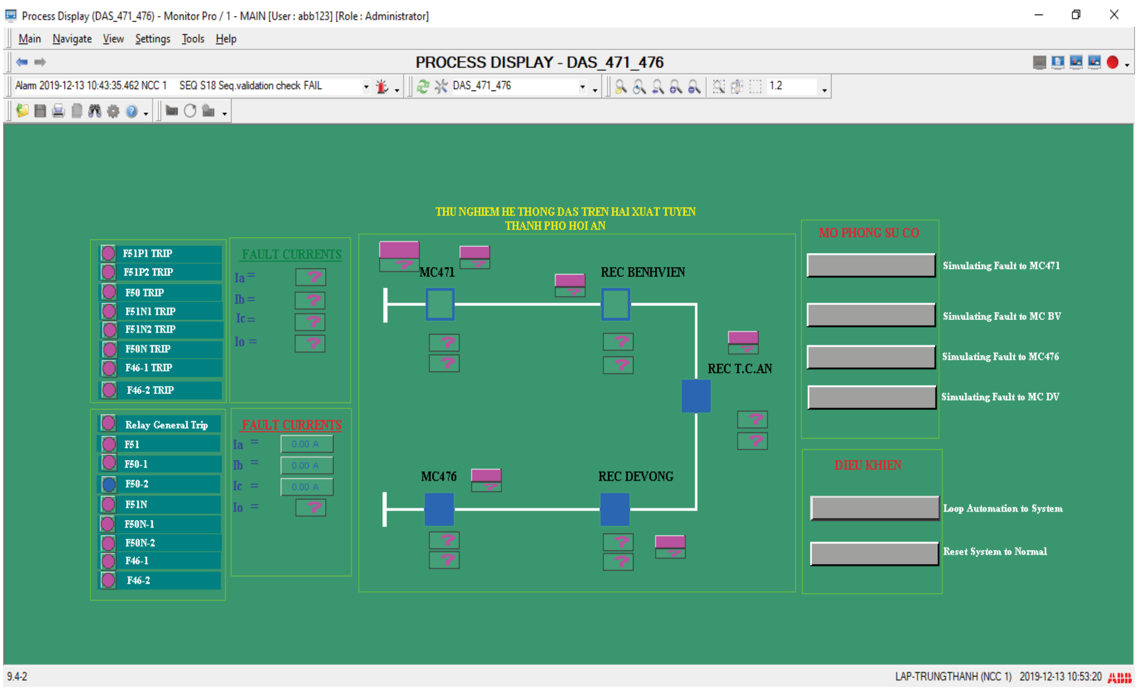

Fig. 7. The DAS performs automatic processing.

D. Assessment of the results

In the simulation, the system shows the ability to handle incidents quickly, accurately, independently and automatically, ensuring a safe isolation in different cases. The DAS contributes to solve power problems by limiting the area affected by power outages during power line incidents. Therefore, the application of DAS in the Vietnamese distribution grid in the future is necessary for the operation and management of the power system. In the near future, the proposed program will be tested and expected to put into operation. In addition, two indices System Average Interuption Duration Index (SAIDI) and System Average Interuption Frequency Index (SAIFI), which are used for the power system reliability assessment, must be considered in the upcoming research of the DAS. SAIDI and SAIFI are calculated based on (2) and (3).

$$SAIDI = \frac{\sum U_i N_i}{N_T} \quad (2)$$

$$SAIFI = \frac{\sum \lambda_i N_i}{N_i} \quad (3)$$

where: N_i is the number of power consumers and U_i is the annual outage time for location i, N_T is the total number of consumers and λ_i is the failure rate.

Thanks to the application of the DAS, the power system reliability might be significantly improved, with SAIDI and SAIFI indices are expected to reduced by 20-25%.

V. Conclusion

In this paper, the authors have built the corresponding algorithm for the incidents that can occur in the Distribution Automatic System and have presented the application of MicroSCADA SYS600 9.4 Pro software in the construction of an actual DAS. The simulation case studies show that the DAS must perform the process of checking the signals of the devices to ensure stable connections before implementing the program. Therefore, the communication channel connecting the devices and the SCADA Supervisory center plays a very important role in the accuracy and safety of the DAS. Moreover, the system should use fiber-optic cable and have backup lines, network port monitoring equipment. Communication protocols must be selected consistently according to the National standards. The DAS must be programmed carefully, safely as well as calculated based on the conditions of various constraints: short-circuit current, number of switches of CB, types of short-circuit incidents (transient, steady state, etc.).

Lastly, the SCADA system at the Supervisory center should be evaluated and verified periodically, especially for communication devices connected to the system. All incidents due to SCADA software failures will lead to the interruption of the DAS program and the whole system. Thus, the study of automation technology in the substation and the DAS aims to thoroughly implement the automation of distribution grid operation, bringing high efficiency in the operation of the Vietnamese power system in the future.

Acknowledgment

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