SCADA System for Monitoring and Reconfiguring an Electrical Distribution Network After a Fault

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Abstract. The main goals of any power system are represented by the continuity of electricity delivery and by maintaining voltage and frequency parameters in an acceptable disturbances range. If, during operation, the parameters of the power lines are different from normal due to defects, then the power line is in an abnormal operating mode, in which malfunctions or damage to electrical installations may occur. Then the problem of defect analysis appears in order to manage them quickly. The present paper aims to present a SCADA system that includes the defect analysis in a distribution network by analyzing the signals in several different points of the electrical network.

Keywords: Current control · Power system faults · Power system protection · SCADA systems

1 Introduction

In case of defects, the power lines have an abnormal operation regime. The effect of abnormal power lines regimes is more unfavorable as the operating time in these regimes is higher.

Determination and elimination of defects depends on the structure of the electrical networks in the respective area, on the functioning scheme at the moment of fault occurrence of and on the existing automation in the stations involved in the fault regime [1, 2]. In an electric power distribution system, detecting High Impedance Faults (HIFs) are generally a difficult problem [3]. Each fault type needs to be analyzed individually [4].

2 Aim of Paper

The main objective of the paper is the research and implementation of new facilities in SCADA (Supervisory Control and Data Acquisition) systems for power distribution networks, facilities which will provide to the operators of SCADA systems operational

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safety, time reducing between received information about an incident which took place in the energy system monitored by the SCADA system and its signaling and the possibility of taking the best decisions in supplying consumers after a damage in the energy system.

Different studies conducted on various SCADA systems, showed that in frequent cases when either HMI (Human Machine Interface) displayed incomplete or too much information, the SCADA operator was determined to take wrong decisions when consumer's path of power supply had to be restored. It was also noticed that an inappropriate decision of the SCADA system operator could lead to worsening of the event that took place and, instead of feeding as quickly as possible the consumers, generated new damages. Thus, instead of supplying electricity to the consumer, the operator could operate or supply damaged equipment's through good equipment's, which may lead to an increased fault area and damages to other equipment's. It is thus necessary to develop SCADA systems as safe as possible to provide clear and precise information.

Traditionally, measurements used for power system monitoring are collected by low updating rate SCADA systems via Remote Terminal Units (RTUs). Estimations based on those measurements could not be accurate enough in capturing how the system states evolve in time [5].

An efficient way to increase information accuracy is to interconnect SCADA systems with specialized devices and equipment's that monitor power equipment's in an electrical transformer station. Interconnection with these devices requires new facilities in SCADA systems, facilities that can provide to SCADA system operators the possibility of reducing consumers feed times and operational safety.

By introducing these new facilities, SCADA systems will become much more reliable and safer in operation, reducing the risk of a fault spreading if the operator takes the wrong decisions.

Control Center operators possess knowledge about the network's dynamic behavior, namely its physical laws, its protection devices and their operation and how to combine their knowledge with incoming SCADA information (alarms) to assess the Electrical Network's state, in order to perform fault diagnosis and to plan and execute power supply restoration [6–8].

3 Case Study in Different Fault Situations

The case study refers to an 110 kV electric power grid consisting of the power lines and power stations to which these lines are connected.

The analysis was performed on two operating cases, which are monitored by the same SCADA system.

The studied electrical network consists of 110 kV overhead power lines, which interconnect five power stations A, B, C, D, E.

Stations C, D, E are system stations and can be considered sources for the analyzed network, each of them being capable of delivering electricity to the national power system, and therefore across the network on which the study is conducted.

The network on which the case study is performed is illustrated in Fig. 1 where a configuration of 110 kV power lines and power stations is presented, with the possibility of receiving the voltage from three power sources, namely from station E, from station C and station D. High voltage lines have the same construction type and the same electrical characteristics, depending on the length of each line.

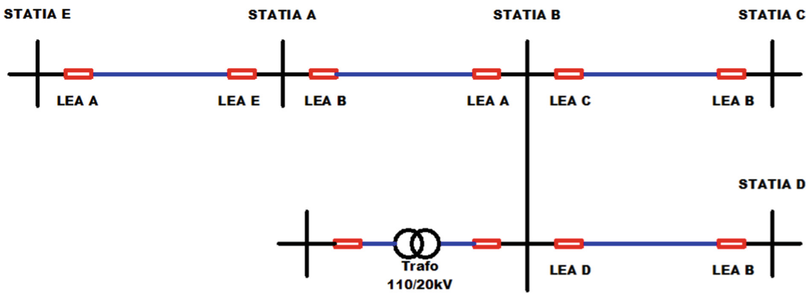

Fig. 1. Network configuration for the study case.

On all overhead power lines, independent protection and automation devices are installed, including five-stage distance protection, four of them directed and one not, as well as two-stage directed homopolar protection.

On these lines were implemented a series of automations, included in the SCADA system for LRP (Line Reconnecting Process) automation on all power lines, and in power station B, on LEA A, the AROL (Automatic Open Loop Reconnecting) automation was implemented, so it could function with an open loop.

The first case study was made when the loop is open, the breaker in power station B on LEA A is disconnected and the AROL automation is in operation.

The role of this automation is to reconfigure the normal scheme when one of the energy sources becomes unavailable.

In this case, the defect is initially fed from one end, but during the event, the power flow changes, as well as the power supply of the fault.

The second case study was made on the same network, but when all the circuit breakers are connected, the network is running loose and the fault is fed by several parts. The SCADA system will receive information from the main power stations that are supplying the fault and the information regarding the proper or improper operation of the protection and automation will be analyzed and transmitted to the operator together with the state of consumers (properly/improperly fed) correlated with the network situation at the end of the event.

The SCADA system will receive information from distance protection, homopolar directed protection, maximum current reserve protection and LRP automation. The HMI will display this information based on special integration features able to synthesize the displayed information.

4 SCADA System

The SCADA application receives digital and analogue information from five power stations, compares them to each other and informs the SCADA system operator by displaying on the screen if the operations of the protection, automation and circuit breakers positions are appropriate at the end of an event.

The SCADA system verifies each time the confirmation of the connected position of the high voltage circuit breakers after an automation operation, LRP. If, after the operation of these automations, the disconnected position of the circuit breaker is not displayed, the fault is signaled and the system operator is informed about the event.

The SCADA system integrates the startup information from the numerical protection terminals. Based on this information, the functioning of the system is assessed and it is possible to check the startup currents on the phases at which the fault occurs.

The SCADA system compares the startup current signals on defect phases from the source to the fault location. The system checks the startup of the same phase in at least two or three places. When on the fault supply path, it cannot be found the same startup phase or zero currents, the SCADA system will signal an error, and the system operator will be informed of the event.

The SCADA system performs a comparison of defect distances resulting from calculations with the defect distances determined by protection relays and displays them on HMI (Human Machine Interface) (Fig. 2).

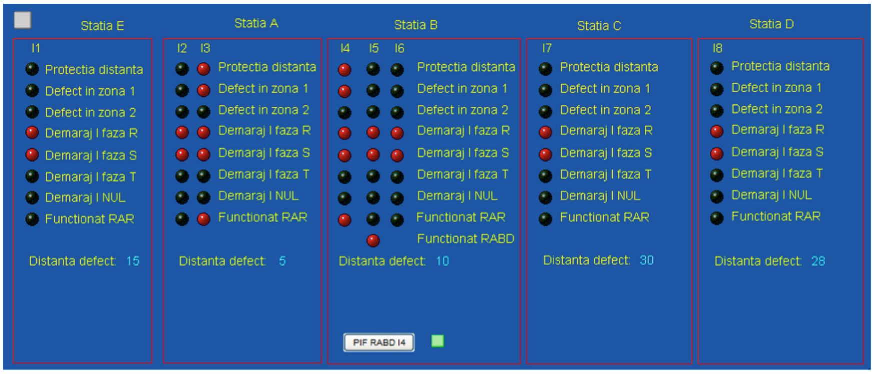

Fig. 2. HMI SCADA.

The distance to the fault site calculation is performed by the localization defect tool of each numerical protection terminal which is a component of each power line cell and the length to the defect is transmitted by the numerical protection terminal to the SCADA system.

The fault locator function is included in the line protection terminal and provides high precision measurements and indications with an error of $<\pm 3\%$ of the distance to the fault location.

The used algorithm eliminates the influence of the load current on the overcharging from the opposite end and reduces the influence of the pass-through resistance at the fault site. The distance to the fault location can be indicated as a percentage of the line length or in kilometers.

The fault locator algorithm is based on the values of measured voltages and currents at the mounting location of the numeric protection terminal.

The length to the fault location is calculated at each station that is on the fault current supply path by summing the section length to the fault of the affected line and the lines interposed on the fault current circuit lengths.

The SCADA system displays the length to the fault location and reconfigures the network to isolate the fault.

Figure 3 shows the distance to the fault and isolation of the affected network by opening the circuit breakers I3 and I4.

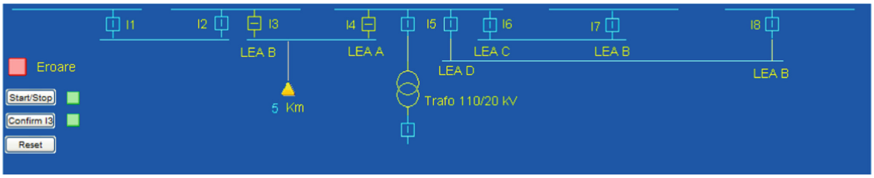

Fig. 3. Network reconfiguration after fault.

The comparison lengths checking to the point of defect can only be done on one section of the network. The lengths checking can't be done on two sections because countless defects occurring in the power networks are not net short-circuits and the fault circuit often interferes with the internal resistance of the electric arc produced at place of defect. In this situation, the length calculated by the fault locator to the defect location is greater than the true length of the line.

A new comparison of the occurred signals is performed by the SCADA system by comparing the missing voltage signal from a line with the triggered position of all the circuit breakers on that line. If, following the event that occurred, the line breakers remain triggered, with an unsuccessful LRP occurring, the SCADA system waits for line voltage signaling at both stations and if it fails to function, an error will be signaled, and the system operator will be informed of the event.

The SCADA system uses information from the 5 power stations, information that are gathered from the numerical protection terminals mounted on the lines in the power stations.

5 Conclusions

The paper proposed a SCADA system development for displaying signaling and protection monitoring in five power stations of a power system. In addition to monitoring, command and data acquisition, the system also analyzes the information received from independent protection and automation systems. The SCADA system analyzes the signals occurred starting from a trigger on one of the lines, compares the onset of all lines along the fault line, verifies the display of the circuit breakers connected position after a LRP cycle or after an AROL (Automatic Reconnection in Open Loop) operation, and, if identifies wrong signaling, displays the error signal and communicates the incorrect signals to the SCADA system operator.

In the proposed SCADA system new features were introduced that allow the calculation of the parameters required for the distance protection settings by taking into consideration the line specific values. Thus, by considering the values of resistances and reactance, the control impedances for each stage of the distance protection are calculated.

Based on studies and analyzes performed, it can be concluded that there is a strong dependence between the power distribution network and the data transmission networks used by SCADA systems. The two cases presented lead to the conclusion that the existence of several distribution power lines leads to the need of developing a complex data transmission network for SCADA systems.

Through studies based on the simulation of the interconnected operation different power systems, optimal operation can be achieved, with as few as possible damage to the interconnected systems, a low degree of danger and smaller fault times.

If a fault situation occurs, by using the new facilities included in the SCADA systems, the weaknesses in the electrical power systems can be identified.

Based on the risk assessment models, short-term forecasts can be performed, regarding the quality of the services provided by a SCADA operator compared to the quality of the electricity supplied to the customers.

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