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IMPLEMENTATION OF SYSTEM THAT EXECUTS THE FLISR FUNCTION (FAULT LOCATION, ISOLATION, SYSTEM RESTORATION) IN THE NEOENERGY GROUP

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SUMMARY

This article describes the planning criteria and the deployment steps for a system that runs the FLISR function on power distribution networks. This function consists of the location and isolation of a fault, besides the reconfiguration of the network to restore the service, by obtaining data and sending commands to the field equipment. The criteria and steps presented below were considered for the application of the ActionWise system, developed by the companies Sinapsis and Spin, in the distribution circuits of CELPE and COSERN, companies that are part of the Neoenergia group.
ActionWise has been integrated into the SCADA system of the Control Center of each utility, where SCADA interfaces with the field equipment and the operating stations, and the ActionWise FLISR function works as an algorithm integrated with this SCADA. To determine the maneuvers to be executed in the network, we used state estimation and optimization algorithms. ActionWise has a graphical interface for operators to monitor, in real time, events on the network, as well as to generate alarms, events and reports of treated faults. A simulator is also available that allows to test all the functionalities of the system, in laboratory environment, greatly reducing the cost of implantation.
This solution was installed in 62 circuits of two concessionaires of the group Neoenergia (about 260 switches / breakers) where significant gains are expected in the indicators of continuity and quality of service due to this deployment.

KEY WORDS

Distribution System Recomposition, FLISR, Self-healing, Distribution Automation, ADMS

1.0 - INTRODUCTION

In the distribution circuits, the radial configuration is adopted to the detriment of the mesh configuration to reduce investment costs and operating costs, but results in a loss of system reliability [1]. With the installation of automatic switches in the network, in addition to other systems and equipment that perform the supervision and execution of maneuvers remotely, it is possible to mitigate this loss of reliability, besides allowing the application of automation functionalities such as the FLISR (Fault Location, Isolation and Service Restoration), which performs the location and isolation of a fault in the network, as well as restoring the power service to passages not directly affected by the fault.
As shown in Figure 1, without the FLISR function, there would only be a power recovery after the steps of identifying the occurrence in the network, preparing and moving the field teams, locating the fault and executing maneuvers in the network, which can lead to some hours to complete in some situations. With the application of the FLISR function, it is possible to perform the restoration of energy to certain areas of the network in a few minutes, contributing to the reduction of network continuity indicators.

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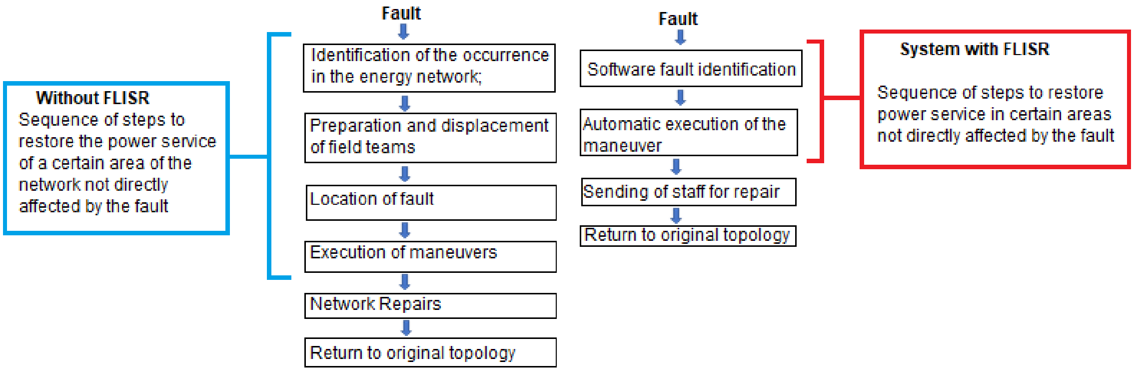

Figure 1 - Comparison of the power recovery steps after a fault

This paper presents the planning criteria and the steps for implementing a system that performs the FLISR function, applied in the distribution circuits of the companies CELPE and COSERN, which are part of the Neoenergia group. The system in question, called ActionWise, has integration with the companies' SCADA system, as well as executing state estimation and optimization algorithms to determine the most appropriate sequence of maneuvers to be performed in the network. The ActionWise system is commercialized by Spin Canada.

2.0 - DEVELOPMENT

2.1 Steps to Execute the FLISR Function

The execution of the FLISR function can be divided into the following steps:

1. Identification of the fault in the network;
2. Determination of the location of the fault;
3. Identification of the block to be isolated and execution of maneuver to isolate the fault;
4. Planning and execution of maneuvers to reestablish the supply of energy to healthy parts of the network;
5. Return to normal state after repairing the network.

With the automation of distribution networks and the installation of automatic equipment such as reclosers and fault identifiers, in addition to communication systems to transmit the information obtained by such equipment to convenient locations, it is possible to perform the steps of the FLISR function automatically, with greater speed and efficiency. As an example, an arrangement with two circuits operating in radial configuration, both with an output circuit breaker (CB1 and CB2) and a normally closed automatic recloser installed along the main trunk (RA1 and RA2) will be used. In addition, there is a normally open recloser (RA3) in the interconnection between the two circuits. This arrangement is shown in Figure 2.

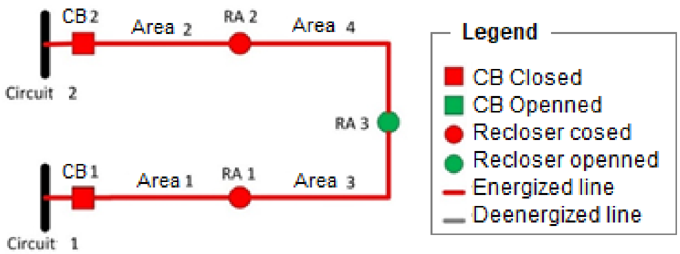

Figure 2 – Topology with two circuits interconnected by a normally open recloser

2.1.1 **Network Fault Identification**

If there is a permanent fault in area 1, the CB1 circuit breaker open due to the overcurrent protection trip. After the reclosing attempts, the CB1 will open definitively, interrupting the power supply to all the consumers connected to circuit 1, as shown in Figure 3. Using a communication system to send the information about this occurrence to the operator in the center the fault identification step becomes fully automatic. For the cases where a fuse switch actuates and the disconnection of a branch of the network, fault identification is still predominantly made through telephone calls from consumers.

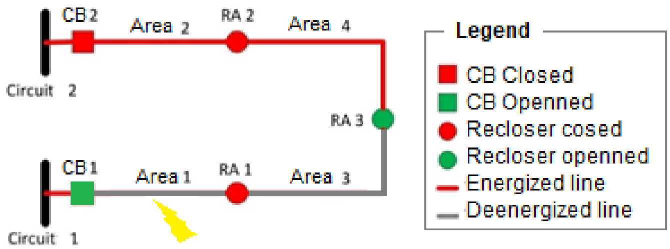

Figure 3 - Fault in area 1 and opening of the circuit breaker CB1

2.1.2 **Determination of the fault location**

After identifying the fault in the network, assuming adequate coordination of the protection settings of the CB1 and RA1 equipment, it is possible to state that the fault in the network occurred in area 1. In this way, the system operator can dispatch the field teams to locate the exact point of the fault in that section and perform the necessary repairs on the network. For cases where a fuse switch is actuated, a possible alternative to reduce fault location time is to install fault identifiers along the circuit, which detect the passage of a fault current through its terminals. Information about the fault can be transmitted only locally, with a light signal being emitted by the equipment, or remotely, with the sending of information through a communication system.

2.1.3 **Identification of the Block to be Isolated and Execution of Maneuver to Isolate the Fault**

After opening the circuit breaker CB1, if a system is implemented in the circuits that execute the FLISR function, the opening of the recloser RA1 will be executed to isolate the fault in the shortest possible distance from the network. Without the FLISR function, the block where the fault occurred will only be isolated after the dispatch of the field team and the location of the fault by this team.

2.1.4 **Planning and Execution of Maneuvers to Restore Service to Healthy area of the Network**

To perform the automatic reconfiguration after the occurrence, the closing of the key RA3 occurs, restoring the power supply to the area 3. The switch RA3 will be closed only if the circuit 2 has sufficient capacity to support its original load and the loads transferred from the area 3. The Figure 4 illustrates the execution of the two maneuvers mentioned above and the section reestablished. The consumers connected to area 3 will have the energy restored in a much shorter time in relation to the case in which it would be necessary to wait for the system operators to locate the fault and to execute the maneuvers in the network manually, being thus possible to notice the gains in the indicators due to the employed automation distribution networks. If the entire reconfiguration procedure of the network is completed in a time interval of less than three minutes, according to the methodology established by regulatory agency (ANEEL), the interruption of the power supply to the consumers of section 3 will not be considered in the calculations of the indicators of continuity of this circuit.

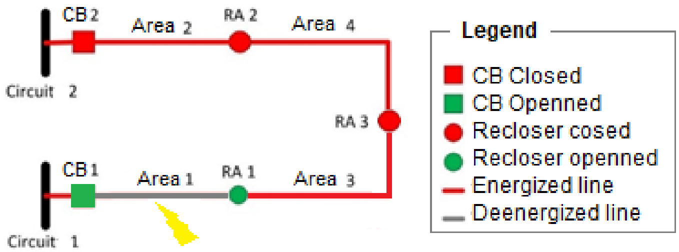

Figure 4 – Fault isolation (Open RA1) and restoration of the service (close RA3) to area 3

In the example used, complex logic is not required to determine the maneuvers to be performed to restore service to healthy parts of the network. However, in networks with more complex topologies, with more possibilities of maneuvering between circuits, it is interesting to use a system that analyzes the various possibilities and provides the sequence of maneuvers more suitable for the reestablishment of the service.

In order to solve the problem of reconfiguration of the network after a contingency, multi-criteria optimization methods are usually used, among them: methods based on fuzzy logic [2] [3], evolutionary algorithms like genetic algorithms [3] - [7] and simulated annealing [4] [5], among others.

The papers mentioned have in common the fact that they perform the analysis of the complete network to solve the problem, that is, they concentrate all the data of the network at a certain point to carry out this analysis. In practice, this means collecting data from the field equipment through a data acquisition and supervision system (SCADA), making it available to the system where the developed algorithm will be installed. This system can be installed at the substation level, monitoring by controlling the equipment and circuits corresponding to that station, or directly in the distribution operation center (COD), which allows controlling multiple substations and circuits.

As an alternative to the systems that concentrate all the information in a certain point of the network, in the following year's algorithms and systems with distributed intelligence among the several equipment in the network were developed, emphasizing the concept of multi agent systems [11]. In addition, with the increasing penetration of renewable energy sources in the network, the reconfiguration algorithms now consider the existence of distributed generation in the network [8] - [10].

As the system presented in this article, works [12] and [13] present systems deployed by distributors that use algorithms with intelligence concentrated at a certain point in the network, using metaheuristic and multicriteria optimization.

2.1.5 **Return to Normal State after Network Repair**

After the fault repair services, the maneuvers to perform the return of the network to the normal state can be done manually by the operator in the field, or automatically, with the sending of maneuvering commands. The system with the FLISR function generates the sequence of maneuvers to be performed, being able to execute them automatically or after the authorization of the system operator.

2.2 Planning Criteria for System Deployment with the FLISR Function

The first planning step for implementing the FLISR function is to define the level of system automation that will accommodate this function. The following options can be used [14]

- Automation at the local level, with distributed intelligence between the field equipment and optional use of a communication system to exchange information between equipment.
- Centralized level automation with communication. A centralized system receives the information from field equipment, analyzes this data and sends commands to perform the necessary maneuvers in the network. This type of system can control the equipment of a substation or multiple substations.
- Automation at a centralized level with communication and integration with management features. In this case, in addition to performing the FLISR function, the centralized system described in the previous item is integrated with an advanced distribution management system (ADMS), providing important information for planning and operating the electrical system.

In order to define the strategy to be used in a given network, the expected gains can be compared with the reduction of the indicators of continuity and reduction of operational expenses (OPEX) with the necessary investments for development and deployment of the system with the FLISR function.

The solutions belonging to the first group are highly reliable because they do not centralize the information at a given point. However, some solutions require the exchange or adaptation of existing equipment in the field, which represents a high cost of implementation.

Centralized communication automation solutions usually have lower implementation costs than those of the first group, as they do not require major changes in field equipment.

Third party solutions are generally integrated with the ADMS system used by the distributor.

Generally, in an electrical system that already has equipment and communication network implanted, using a solution that allows integrating the pre-existing infrastructure in the network is the most viable solution. As a complement, less drastic strategies such as reallocation of existing reclosers in the network can provide significant gains in low cost system continuity indicators.

2.3 Stages of System Deployment with the FLISR Function

Using as an example a centralized system connected to the SCADA system (supervision and data acquisition system), the first stage of deployment consists of the installation and commissioning of new equipment and the associated communication system. Then, the integration of this equipment with the

SCADA system is done, with the configuration of the analog and digital points that will be transmitted between the systems. The system interfaces that will be used by the operators in the control center must also be configured.

Before the final deployment in the field, it is interesting to perform a test step for system validation and integrations, called "listening mode" deployment. At this stage, the system normally collects all the information and executes the algorithms to obtain the maneuvers to be executed in the network, but does not send maneuvers commands to the field equipment. After performing all the tests and adjustments during the "listening mode" deployment, the final mode implementation is performed with the collection and analysis of the results, which can be used later not only to evaluate the solution itself, but also to determine a methodology for the application of this technology throughout the concession area of a distribution company.

2.4 Case Study

As a case study, the ActionWise system will be presented with the FLISR function, implemented in the distribution circuits of CELPE and COSERN.

2.4.1 **System Deployment Strategy**

For CELPE and COSERN, the strategy adopted was centralized automation with communication, with the integration of the ActionWise system with the centralized SCADA system used by these companies. Figure 5 shows the architecture described for the solution. Reclosers, circuit breakers and communication systems were already used previously in the circuits to be integrated into the ActionWise system. In this way, it was possible to implement a system with a reduced cost, due to the use of existing infrastructure in the network, with significant gains expected in the continuity indicators of the electric network.

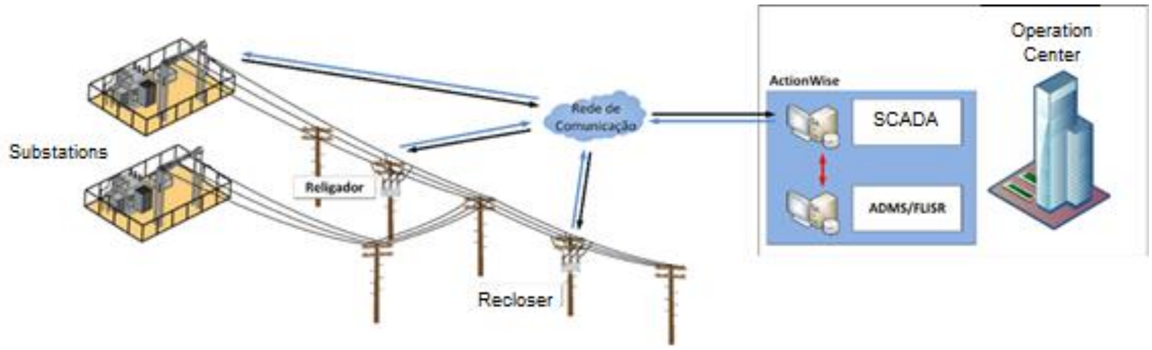

Figure 5 – Overview of the implementation of the ActionWise system in the distribution system of CELPE

2.4.2 **Architecture and Functioning of the Platform ADMS/FLISR**

The ActionWise system consists of two main modules:

- SCADA module, which integrates with the SCADA system used by the distributor. If it is of interest, the system can be integrated directly to the field equipment, functioning as a SCADA system.
- ADMS / FLISR module, detailed below.

The ADMS / FLISR platform is composed of concurrently executed processes that communicate by sending and receiving messages as shown in Figure 6. A message contains the information necessary for the destination process to perform an operation.

Network assembly can be done in two ways: by importing data from a geographic information system (GIS or BDGD), or by manually mounting the topology. In the case studied, the topology assembly was performed manually.

From the information received from the field equipment through the SCADA system, the estimation of network states is carried out periodically. Thus, when a contingency occurs, an estimate is used immediately prior to the moment of the fault. The algorithm that performs the contingency analysis considers in its objective function to minimize the number of customers disconnected by the fault, to minimize the number of maneuvers performed in the network and, finally, to maximize the current reserve in the neighboring circuits. Once the sequence of maneuvers in the network has been determined, the commands are sent to the field devices via the SCADA module.

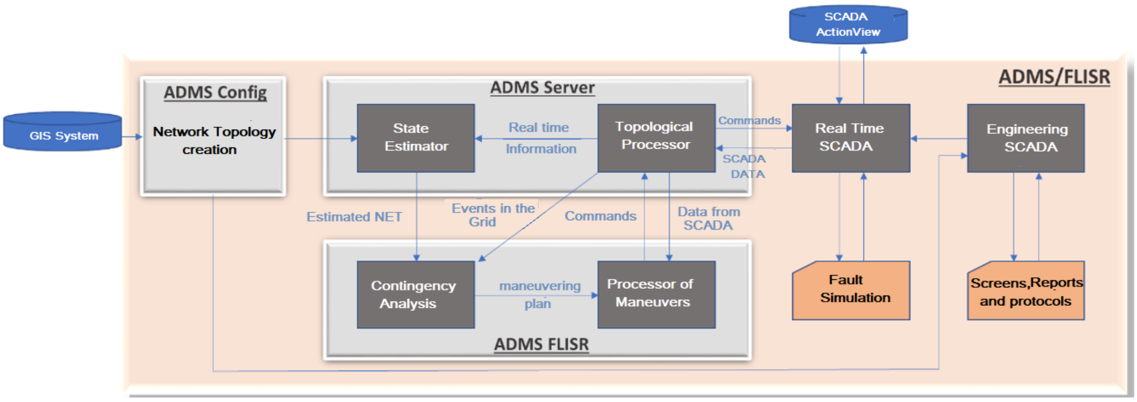

Figure 6 - Flow chart of the ADMS / FLISR platform

2.4.3 **Operation of ActionWise System and Used Screens for Operation Grid**

Figure 7 shows the screen of the ActionWise system used for the operation of the power grid. The grouping represented on the screen consists of 10 feeders and 57 automatic switches (circuit breakers or reclosers).

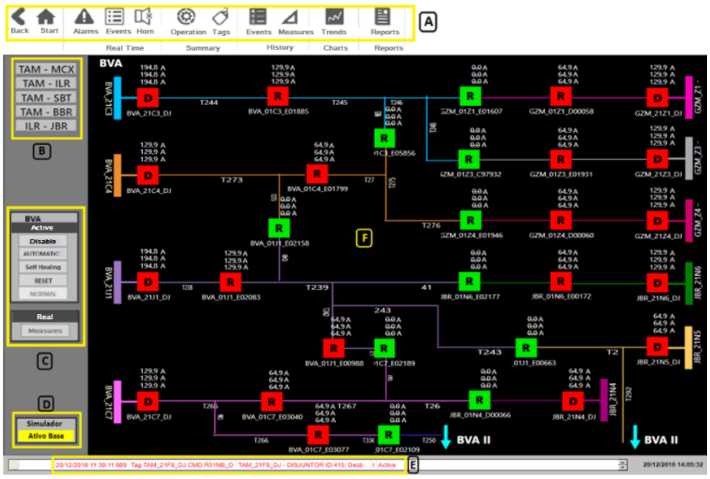

Figure 7 – One ActionWise screen used for network operation

In the menu at left side of screen, you can individually activate or deactivate the FLISR loops (B), select to perform the maneuvers manually (required the operator confirmation) or automatic; and activate or deactivate the listening mode, in which the system obtains data and executes the algorithms, but does not send commands to the equipment. Figure 8 highlights the window with the list of maneuvers obtained by the system considering the manual operation, that is, depends on the acceptance of the operator for the execution of the maneuvers.

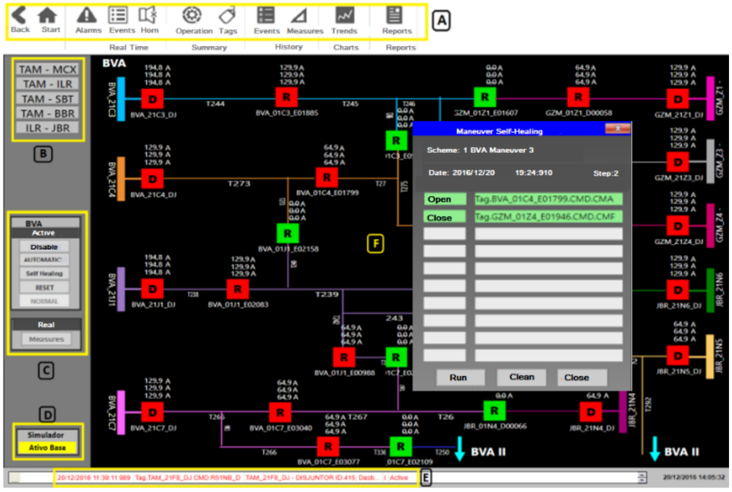

Figure 8 – Window with the list of maneuvers to be executed in the network if authorized

Figure 9 shows two windows: the first one diagnoses the abnormality in a given switch, and the second, with options to enable or disable certain switch commands (live line, reclosing, etc.).

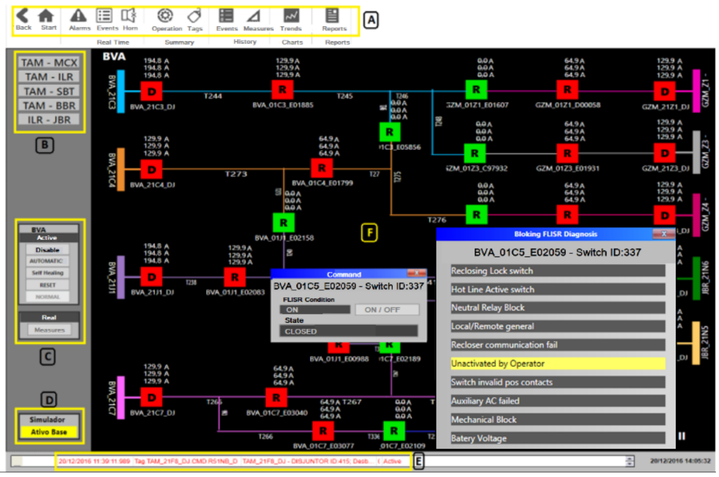

Figure 9 – Operation screen and window with a list of manoeuvres to be executed in the network

Finally, the ActionWise integrated with a network simulator that performs state estimation algorithm and power flow to obtain measurements along the network, and sends these values to the ActionWise, in addition to digital values referring to the state of equipment, alarms and permanent faults in the network. In this way, it is possible to simulate faults in the electrical system and to verify the sequences of maneuvers obtained by the solution in each case. This tool is important for the testing steps before the complete implementation of the system and for trainings performed with system operators.

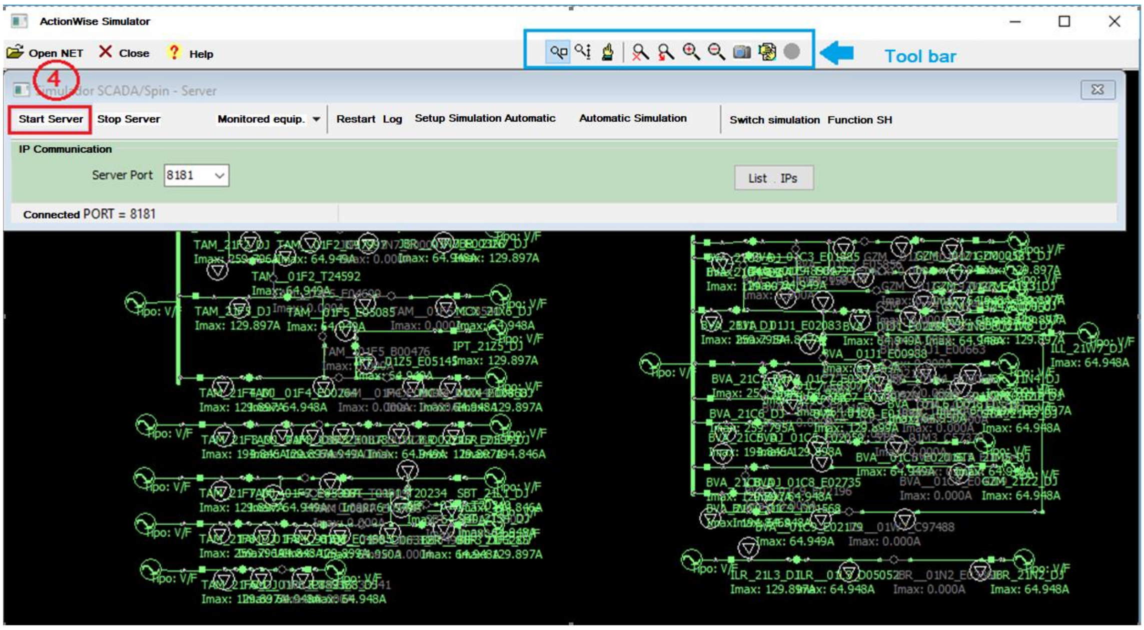

Figure 10 – Network simulator screen integrated with the ActionWise

3.0 - CONCLUSIONS

The present work presented a methodology with planning criteria and steps for the implementation of a system that performs the FLISR function, identifying and, automatically, isolating the fault in the network, besides performing maneuvers remotely to reestablish the energy supply to healthy parts of the network.

It was used as a case study the implementation of the ActionWise system in the distribution circuits of the companies CELPE and COSERN, which are part of the Neoenergia group. Already having automatic switches and a communication system installed in its network, it was interesting for the companies to adopt a solution that could use the existing infrastructure, without high expenses with the purchase of new equipment or the renovation of existing ones. Another advantage of the adopted strategy was the integration with the utility's SCADA system, so it is not necessary to perform the direct configuration of the field equipment with the system that performs the FLISR function.

The implementation of the ActionWise system in companies has been finalized and is currently being operated in listening mode, receiving information and executing algorithms, but without sending commands to the field equipment. This mode is used to test the logics and the integrations developed, before the definitive implementation of the system. Significant gains are expected in the continuity indicators of the electric grid with the automatic maneuvers performed by the ActionWise system. With the implementation of the solution for a significant period, it will be possible to evaluate quantitatively the gains obtained.

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5.0 - BIOGRAPHICAL DATA

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