Planning and Implementation of a System that Executes the FLISR Function in Distribution Networks

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***Abstract* – this article describes the planning criteria and the steps for implantation of a system that executes the FLISR function in energy distribution networks. This function consists of locating e isolating a fault, besides the reconfiguration of the network to restore the service to clients situated in health stretches of the network. The criteria and the steps described were considered to the application of the system ActionWise, developed by the companies Sinapsis and Spin, in the distribution circuits of the Companhia Energética de Pernambuco (CELPE), part of the Neoenergia group.**

***words* – Energy distribution, automation, intelligent networks, auto reconfiguration of network, FLISR.**

I. INTRODUCTION

The energy distribution system represents the last step of the electrical energy supply for consumers. After the generation step that, due to the energy matrix in Brazil being predominantly hydraulic, it is usually made far from the urban centres, the transportation of the generated energy is made through long transmission lines to the substations of sub transmission, that represent the beginning of the distribution system. Usually operating with tensions between 69kV and 138kV, the sub transmission system transports the energy to the distribution substations, in addition to providing energy to consumers fed in high tension. The focus of this work, the primary distribution system starts in the distribution substations, that are usually located inside cities, ant its circuits follow streets until they arrive to the final consumer.

In the distribution circuits the radial configuration is adopted instead of the mesh configuration to reduce investment costs and operational costs, however the result is a loss of system reliability [1]. With the installation of automatic switches in the network, besides other systems and equipment that supervise and execute the manoeuvres remotely, it is possible to mitigate this reliability loss, as well as allow the application of automation functionalities as FLISR (Fault Location, Isolation and Service Restoration), that execute the location and isolation of a fault in the network in addition to restore the energy service of stretches not affected by defect.

As illustrated in Figure 1, without the FLISR function, there would only be restoration of the energy after the following steps elapsed: identification of the occurrence in the network, preparation and displacement of the field teams, location of the fault and execution of the network manoeuvres. This can take a few hours to complete in some situations. With the application of the FLISR function, it is possible to execute the re-establishment of the energy in some stretches of the network in a few minutes, contributing to the decrease of the indicators of network continuity.

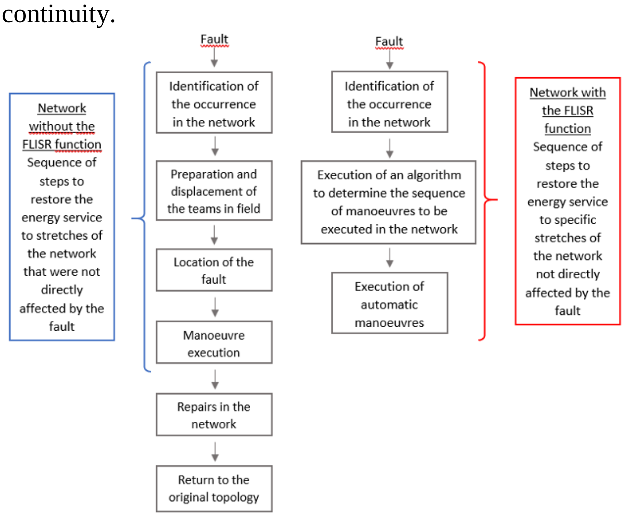

Figure 1 – Comparison of the steps executed after a fault with and without the FLISR function [2]

Are introduced in this work the planning criteria and the steps for implementation of a system that executes the FLISR function, applying in the distribution circuits of the Companhia Energética de Pernambuco (CELPE), that is part of the Neoenergia group. The system in question, named ActionWise, has integration with the SCADA system of the company, in addition to executing status estimation and optimization algorithms to determine the sequence of manoeuvres best suited to be done in the network.

This article is organized in the following way: in item II are presented all the steps to execute the FLISR function. In items III and IV are presented the planning criteria and the steps to implement the system that executes the FLISR function, respectively. In item V, the ActionWise system is introduced with more details. Finally, in items VI and VII, are introduced the work conclusions and the references.

II. STEPS FOR EXECUTING THE FLISR FUNCTION

The execution of the FLISR function can be dived in the following steps:

1. Identification of the fault in the network;
2. Identification of the location of the fault;
3. Identification of the block to be isolated and execution of the manoeuvre to isolate the fault;
4. Planning and execution of manoeuvres to restore the energy supply to healthy stretches of the network;
5. Return to original state after the repair of the network.

Traditionally, the tasks of detection and location of a fault in the electric network starts with phone calls from consumers, which allows the determination of the approximated location of the occurrence and then the distributor sends the field teams. After arriving to the location and determining the exact point of the defect, the team executes the manoeuvres to isolate it and, if possible, restores the supply to health parts of the network by closing a normally open key. Next, some repairs are done in the network and, finally, the network can return to its normal state.

With the automation of the distribution networks and the installation of automatic equipment, like reclosers and fault identifiers, in addition to communication systems to transmit information obtained by that equipment to convenient locations, it is possible to execute the steps of the FLISR function automatically, faster e more efficiently. As example, will be used an arrangement with two circuits operating in radial configuration, both with an output circuit breaker (DJ1 and DJ2) and an automatic recloser normally closed installed along the main trunk (RA1 and RA2). Besides that, there is a recloser normally open (RA3) in the interconnection between the two circuits. This arrangement if presented in Figure 2.

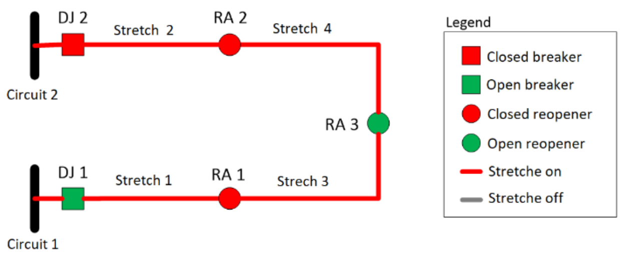

Figure 2 – Arrangement with two circuits interconnected by a recloser normally open.

1) *Identification of fault in the network*: in the event of a permanent fault in the stretch 1, the circuit breaker DJ1 will act due to an overcurrent caused by the defect. After the attempts of reclosing, the DJ1 will open permanently, interrupting the energy supply to all consumers connected to circuit 1, as shown in Figure 3. Using one communication system that allows sending information about this occurrence to the control centre operator, the identification step becomes totally automatic. For the cases in which occurs an actuation through a fuse switch and the shutdown of a branch line, the identification of the failure is still predominantly made through costumer's phone calls.

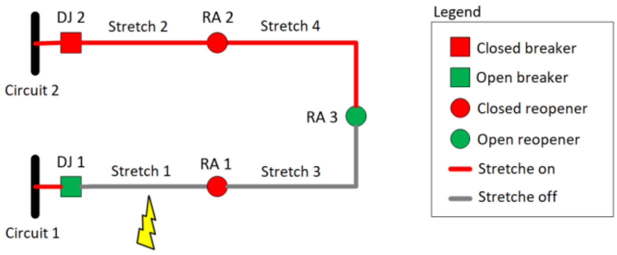

Figure 3 – Fault on stretch 1 and opening of the breaker DJ1.

2) *Identification of the location of the fault*: after the identification of the fault on the network, supposing the adequate coordination of the protection adjustments of the equipment DJ1 and RA1, it is possible to say that the fault in the network happened in stretch 1. This way, the system operator can send the field teams to locate the exact point where the fault occurred in this stretch and then repair what's necessary in the network. For the cases in which occurs an actuation of a fuse switch, a possible alternative to reduce the time of fault location is to install fault identifiers alongside the circuit, that detect the passage of a fault current through its terminals. The identification of the fault can be transmitted locally, as light signal being emitted by the equipment, or remotely, by sending information through a communication system.
3) *Identification of the block to be isolated and execution of manoeuvres to isolate the fault*: after the opening of the circuit breaker DJ1, if it is installed in the circuits of a system that executes the FLISR function, this system will know that the stretch 1 must be turned off, then will be executed the opening of the recloser RA1 to isolate the fault in the smallest section of the network possible. Without the FLISR function, the block where occurred the fault will only be isolated after the arrival of the field team and the location of the fault by this team.
4) *Planning and execution of manoeuvres to restore the service to health parts of the network*: to do the reconfiguration automatically after the occurrence, the switch RA3 is closed, restoring the energy supply to stretch 3. The switch RA3 will be closed only if the circuit 2 has enough capability to support its initial load plus the load transferred from the stretch 3.

In the example used, there is no need for a complex logic to determine the manoeuvres to be executed to restore the service to healthy stretches of the network. However, in networks with a more complex topology, with a bigger number of possibilities of manoeuvres between circuits, can be interesting to use a system that analyses the many possibilities and gives the sequence of manoeuvres most suitable to restore the service.

To solve the problem of reconfiguration of the network after a contingency, usually are used methods of multicriterial optimization, such as: methods based in fuzzy logic [3] [4], evolutionary algorithms as genetic algorithms [4]-[9] and simulated annealing [5] [6], among others.

The works cited have in common the fact that they do the complete analysis of the network to solve the problem, that is, they concentrate all the data of the network in one specific point to do this analysis. In practice, it means to collect all the data from the field equipment through a supervisory and data acquisition system (SCADA), making them available to the system where will be installed the developed algorithm. This system can be installed both on the substation level, monitoring and controlling the equipment and circuits corresponding to that station, or directly on the distribution operation centre (DOC), that allows to control multiple substations and circuits.

As an alternative to systems that concentrate all the information in one specific point in the network, in the following years were developed algorithms and systems with intelligence distributed between several equipment in the network, highlighting the use of the multiagent concept. In addition to that, with the growing penetration of renewable energy sources, the reconfiguration algorithms started to consider the existence of the distributed generation in the network [10]-[12].

Regarding the applications done in distribution companies in Brazil, an example of a system with distributed intelligence can be found in [13], which uses the multiagent systems concept.

Like the system presented in this article, the works [14] and [15] both present systems implemented by distributors that use a specific point in the network, using metaheuristic methods and multicriterial optimization.

In the event that all the reconfiguration procedure of the network is concluded in a time interval smaller than three minutes, according to me methodology stablished by ANEEL, the interruption of the energy supply to costumers of stretch 3 will not be considered in the calculations of the continuity indicators for this circuit, which represents improvement over the case where there is not an automatic reconfiguration system installed in the network.

The Figure 4 illustrates the execution of both manoeuvres cited above and the restored stretch.

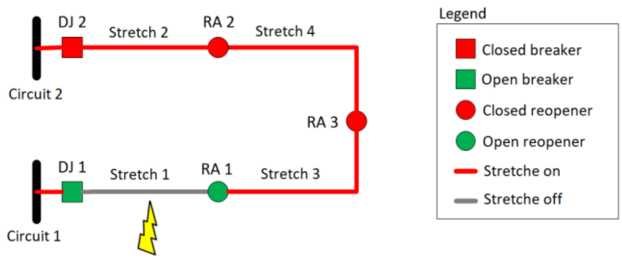

Figure 4 – Isolation of the defect (opening the recloser RA1) and restore of the service (closing the switch RA3) to the stretch 3.

This way it is possible to notice possible gains in the indicators resulting from the automation used in the distribution network. The costumers connected to the stretch 3 will have the energy restored in a much smaller time span if compared to the case where it would be necessary to wait for the system operators locate the fault and execute the manoeuvres in the network manually.

5) *Return to the normal status after repairing the network*: after the repair services in the stretch with the fault, the manoeuvres to return the network to its normal status can be done manually by the operator in field or automatically, by sending the manoeuvre commands. The system with the FLISR function generates the sequence of manoeuvres to be done, being able to execute them automatically or after authorization of the system operator.

III. PLANNING CRITERIA FOR IMPLEMENTING THE SYSTEM WITH THE FLISR FUNCTION

The first planning step for implementing the FLISR function consists of defining which level of automation of the system will shelter this function. The following options can be used [16]:

- Automation in local level, with distributed intelligence between the field equipment and optional use of a communication system to exchange information between the equipment.
- Automation in centralized level with communication. A centralized system receives the information from the field equipment, analyses the data and sends commands to execute the necessary manoeuvres in the network.
- Automation in centralized level with communication and integrated with management functionalities. The centralized system described in the previous item, in addition to executing the FLISR function, is integrated to an advanced management system for managing the distribution (ADMS), supplying important information for planning and operating the electrical system.

To decide which strategy is going to be used in a specific network, the expected gains in the continuity indicators can be compared to the operational expenses (OPEX) with the investments needed to develop and implement the system with the FLISR function. For example, a strategy that needs the installation of new equipment and a new communication system in the networks, that will bring bigger gains in the system indicators, may not be the most adequate strategy, in case the value invested is too high.

This way, in a network that already has equipment and a communication system, using a system that allows to integrate the existing infrastructure in the network may be the most viable solution. As a complement, less drastic strategies as reallocating the existing reclosers may grant expressive gains in the continuity indicators of the system with reduced cost.

IV. STEPS FOR IMPLEMENTING THE SYSTEM WITH THE FLISR FUNCITON

Using as an example a centralized system connected to the SCADA system and to the ADMS, the first step of the implementation consists of the installation and commissioning of new equipment and the associated communication system. Then, the integration of those equipment with the SCADA system is made.

The next step is the integration of the system with the FLISR function to the SCADA system and to the ADMS management systems, with the configuration of the analogical and digital points to be transmitted between the two systems. Also, the interfaces of the system must be configurated, because they will be used by the operators in the control centre.

Before the definitive implantation in field, it is interesting to do a test step to validate the system and the integrations made, called implantation in “listening mode”. At this stage, the system collects normally all the information and executes the algorithms to obtain the manoeuvres to be executed in the network, however it does not send the manoeuvre commands to the field equipment.

After all the tests and adjustments are done during the implantation of the “listening mode”, the implantation in final mode is made, with the collection and analysis of the results, that can be used after not only to evaluate the solution itself, but also to determine a methodology for application of this technology in all the concession area of a distribution company.

V. CASE STUDY

As a case study, will be introduced the ActionWise system with the FLISR function, implanted in the CELPE distribution circuits.

Developed by Spin, the ActionWise came up from the integration of the SCADA system Action.NET with the platform named here as ADMS/FLISR, to execute in real time advanced functions such as FLISR, Volt-Var control, load relief in substations, among others.

1) *Strategy for implantation of the system:* with the SCADA already installed in the CELPE´s Centre of Control, the chosen strategy for implanting the FLISR function was to integrate the SCADA/ADMS/FLISR ActionWise to the SCADA of the Centre of Control. The integration was made through the protocol IEC-60870-5-104. The Figure 5 presents the architecture described for the solution.

   Were also used the reclosers, circuit breakers and communication systems that were already implanted previously to be integrated to the ActionWise system. This way, it was possible to implant a system with reduced cost, due to the already existing infrastructure in the network that was used, with expressive expected gains in the continuity indicators of the electrical network.

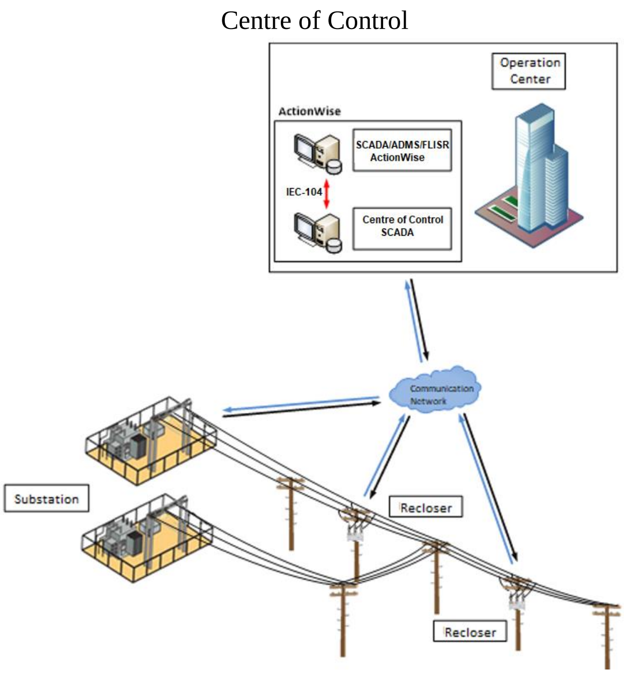

Figure 5 – General vision of the ActionWise system in the CELPE network.

2) *Architecture and operation of the SCADA/ADMS/FLISR platform:* the platform is composed by processes that are executed in a concomitant way, that communicate among them through sending and receiving messages, according what is shown in Figure 6. A message contains the necessary information for the recipient process to operate.

The assembly of the network can be done in two ways: through the importation of data from a geographical information system (GIS), or assembling the topology manually.

Starting from the information received from the field equipment through the SCADA system, the estimation of the network status is done periodically. This way, when a contingency happens, is used an estimation from immediately before the fault.

The algorithm that makes the contingencies searches to minimize the number of clients disconnected because of the defect. If there are more than one solution that meets the criteria, the chosen solution is the one that makes the smaller number of manoeuvres in the network. If there are still more than one option, is chosen the manoeuvre that transfer load to the help circuit that has the biggest current reserve (difference between the capacity and the current measurement in a specific moment).

Once the sequence of manoeuvres in the network is settled, the commands are sent to the SCADA of the Centre of Control (ActionView), that transmits them to the field equipment.

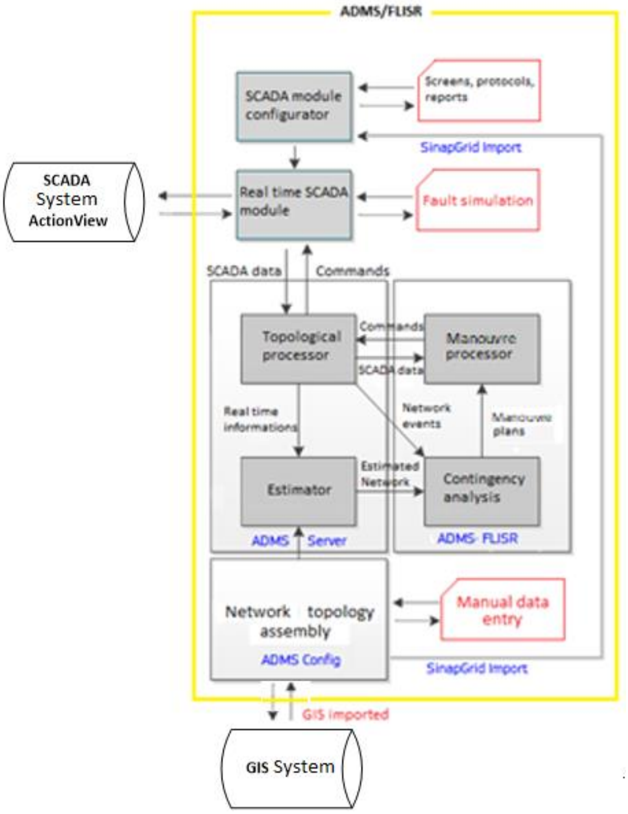

Figure 6 – Operation flow chart of the ADMS/FLISR platform.

3) *Operation of the ActionView system and the screens used to operate the electrical network:* the Figure 7 represents the screen from the ActionWise system used to operate the electrical network. The group represented in the screed is made by 10 feeders and 57 automatic switches (reopeners and circuit breakers).

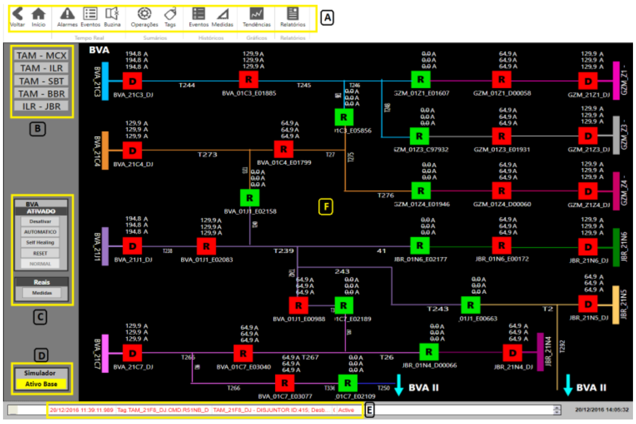

Figure 7 – Screen from the ActionWise system for network operation.

Through the menu located in the left corner of the screen, it is possible to activate or deactivate the FLISR function in the circuits, do the manoeuvres manually (the operator authorization is necessary to manoeuvre the switches) or automatically (without the operator authorization) and, finally, activate or deactivate the listening mode, in which the system obtains data and executes the algorithms, however does not send commands to the equipment.

In Figure 8, appears highlighted a window with a list of manoeuvres to be done in the network. The operator can accept or reject the manoeuvre plan.

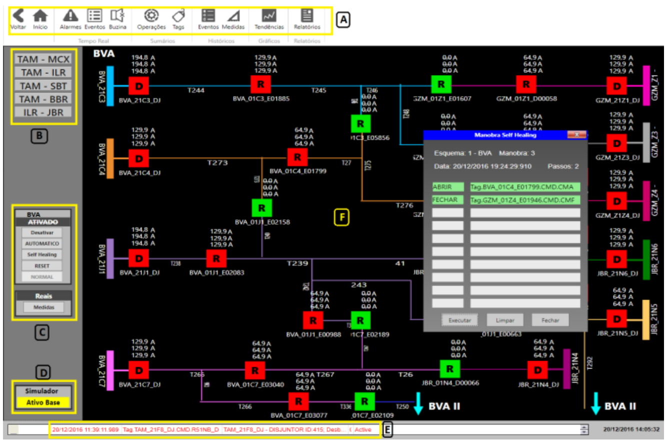

Figure 8 – Operation screen and the window with the manoeuvre to be executed in the network.

Finally, in Figure 9 are shown two windows: the first with the diagnosis of the existing abnormality in a specific switch, the second with options to enable or disable certain commands of the switch (energized line, recloser, telecommand, etc). See an example running in the youtube.

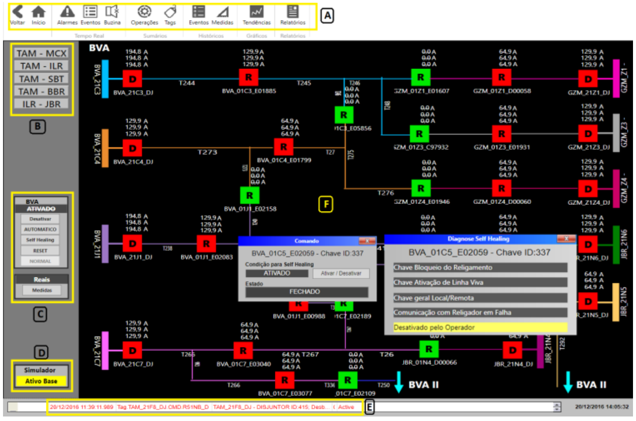

Figure 9 – Operation screen, switch command window and window with diagnosis of the abnormal status in the switch.

VI. FINAL OBSERVATIONS

The present work introduced a methodology with the planning criteria and steps for implementation of a system that executes the FLISR function, to identify and locate automatically a defect in the network, in addition to make manoeuvres remotely to restore the energy supply to healthy stretches of the network.

Was used as a case study the implantation of the ActionWise system in the distribution circuits of the CELPE utility that is part of the Neoenergia group. Already having automatic switches (circuit breakers and reclosers) and a communication system installed in its network, it was interesting for the company to adopt a solution that could use the existing infrastructure, without elevated costs that come with buying new equipment or renewing the existing ones.

Another advantage of the strategy adopted by CELPE was the integration with the SCADA system ActionView, that was it was not necessary to do the direct configuration of the field equipment with the system that executes the FLISR function. Was done only an integration of this system with the SCADA of the Centre of Control (ActionView).

The ActionWise system was implanted in the CELPE network and in the moment it is operational receiving information and executing algorithms, and sending commands to the field equipment.

Expressive gains are expected in the continuity indicators of the electrical network with the automatic manoeuvres done by the ActionWise system. With the implantation of the solution for a significative period of time, soon will be possible to evaluate quantitatively the gains obtained.

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