# A Fault-Indicator-Based Methodology for Distribution Power Systems Fault Location

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***Abstract*— This paper presents a methodology for fault location in distribution systems of electric energy through remote management of fault indicators in a distribution circuit of CODENSA. The selection of the circuit was made from a methodology that is described in detail and includes features such as quality indicators (ITAD, SAIDI and SAIFI), circuit topology, and others. The placement of the fault indicators was made based on criteria defined in the references consulted. These devices are automated and they send the information of its status to CODENSA Control Center, which processes these signals. Also it is presented a fault location model-based on Petri Nets, which is fed with the signals sent by the fault indicators. Finally, it is presented simulation results and conclusions.**

***Key Words*— Fault Indicator, Fault Location, Petri Nets, Power Distribution.**

## I. Introduction

THE electric power distribution networks are constantly subjected to events that generates interruptions in the supply of energy to the end users, which can be caused by a variety of factors such as bad weather conditions, contact between trees and conducting wires, equipment failure, unpredictable accidents and many more [1]. These interruptions decrease the quality indices of these circuits, causing penalties for the companies because of such situations. Therefore, it is required methods and techniques to improve the process of fault location in distribution networks.

This paper presents a methodology for fault location in electric power distribution systems through the installation of fault indicators. The implementation of such fault indicators devices in the circuits of the distribution networks has enabled companies to improve the reliability and quality of power supply [2]. According to [6], studies have shown that investments made in equipment for detecting faults have short payback time, in some cases less than one year, as well as being the most economical and appropriate solution to reduce outage time service [8]. In [7] for example, it is demonstrated the benefits achieved by the installation of fault indicators, which translates into increased reliability and quality indices.

Also, in this paper, it is presented the application of this methodology in a real distribution circuit from CODENSA. This circuit has been chosen based on several criteria which are explained in detail. One criterion is the importance that the circuit has for the company in terms of quality. For the electric utility, the chosen circuit has a high importance for the year 2014, when is expected to make improvements in the circuit infrastructure in order to improve the quality indicators. Additionally, it is proposes a Petri Net model that use the signals from the fault indicators to infer the possible fault zone.

Second section presents a summary of some work done about fault indicators placement. Third section presents in detail the criteria that are taken into account in the selection of the circuit. Fourth section contains the description of the most important elements that make up the selected circuit. Fifth section proposes the most suitable points for the placement of the fault indicators devices. Sixth section proposes a Petri Net model based on the signals of the installed devices to locate the fault. And finally, section seven describes and analyzes the results, and eighth section proposes the respective conclusions.

## II. State of The Art

On the issue of fault location in distribution systems several efforts have been done to design techniques that improve the estimation of the point of failure of a circuit. In the literature, it can be find different proposals where advanced computational methods are used to locate the point of failure by simulation, based on the fault current and the impedance of the distribution network. The problem that has these techniques is that for a fault current could be found multiple points of failure. According to [1] the location of the failed circuit is the main problem that faces the management of the distribution system when a power outage occurs. Therefore, it is relevant combine effectively a fault location technique via software with a fault location technique by means of hardware. One of the biggest drawbacks is the lack of efficient methodologies to suggest potential points for proper installation of fault indicators [4]. Several studies have been done to solve the problem of proper placement of fault indicators devices, using different algorithms and mainly addressing the problem as one of optimization. In [2] and [4] a fuzzy inference system is used for evaluating the performance of the main variables that influence the quantification of the candidate points for the installation of the devices. In [1] an evolutionary computing strategy is proposed to solve the problem of the placement of the fault indicators in the distribution system feeders. In [3] the genetic algorithm of

Chu-Beasley is used to solve the optimization problem of placement of the fault indicators. This method take into account a fixed number of available devices, resulting in a combinatorial problem of optimization that consists in find the best location of these devices. In [5], the application of the algorithms IBSFLA (Binary Improved Shuffled Frog Leaping Algorithm) is presented for the optimum placement of fault indicators in distribution networks. This algorithm solves the problem more quickly and more accurately by minimizing the cost function. In [9] the application of Immune Algorithm is evaluated for the solution of the problem of optimal placement of the fault indicators to minimize the total cost of the outage service to users and of the investment in fault indicators. This method applies to a distribution circuit in Taiwan Power Company. In [10] the location of the fault indicators is proposed by solving the optimization problem with Genetic Algorithms. The proposed method takes into account the structure requirements of the network, a reliability factor and economic parameters for minimizing the cost function.

In [1-4], the relevant parameters that serve as the basis for applying the methods proposed by the authors are described. In [2] one of the main parameters of placement is the distance in which a particular section of the feeder is located regarding to the nearest protection device. Also the load of a particular section is considered, the users profiles and the levels of short-circuit current of the system, downstream from the respective points. For [1], the location of the fault indicators should be considered only in the feeder, as it is responsible for supplying all circuit loads. Also be taken into account variables such as feeder load, number of users and the distances between any system protection and fault indicators. The load and the number of users downstream of a candidate section for installing a fault indicator can be used to determine the relative importance of placing the device at that point. If both data (load and number of users) are of high magnitude, then the section under study is a good candidate for installing fault indicators. One of the criteria used in [3] is that it is better to locate fault indicators in the beginning of those sections with branches. Another criterion says that it is better to locate the fault indicators at those points where the user's load is more critical. The fifth section summarizes these parameters proposed by the authors in order to have a basis to define the points where the fault indicators will be located in the selected circuit.

## III. Criteria for the Circuit Selection

For the proposed methodology it must be selected a circuit from the CODENSA distribution system that meets certain characteristics that enable the proper implementation of the designed solutions. Now, the distribution circuits are assessed by the quality indicators of service. These indicators allow, among other things, to guide investment strategies to improve the service in each of the circuits. The aim of this section is to explain the criteria used for selecting the distribution circuit where the proposed methodology will be applied.

Initially it is built a list with those circuits that are in the improvement plans of the year 2014. This ensures that the selected circuit, at the moment is not part of no improvement program, therefore the proposed methodology will not be conflict with another already designed program. The resulting list is comprised of 21 circuits belonging to different substations from CODENSA distribution system.

Taking these 21 circuits, it is proceed to filter them according to two criteria defined below:

*1)* The circuit must have at least one remotely controlled recloser: This criterion must be fulfilled because the state information of this equipment in the distribution network is very important at the moment of fault location. The remotely controlled reclosers have the ability to send his status information to the Control Center, and that feature makes that these devices are very useful in the operation of the distribution network. Additionally, having a remotely controlled recloser can streamline processes to assign a substitute circuit.

*2)* The circuit must have at least one substitution circuit: Because one of the objectives at the moment to attend an outage event is to minimize the adverse effect of customers, it is important to have an alternate circuit to assume the unmet load. Choosing circuits that fulfill this criterion allows achieving the above objective. It also reduces the impact on the quality indicators of the circuit.

After applying the two criteria exhibited above, the list of candidate circuits is reduced to 13. After, the circuits are classified according to three criteria that were identified as important in order to have a satisfactory result. The following describes these criteria:

*1)* The circuit must be having deficient quality indicators: The circuit with lower quality indicators has priority over other.

*2)* Circuit topology (arrangement of elements): This feature determines the pertinence of the implementation of the methodology proposed in this paper. If the circuits are very radial, it will not have relevance to implement the methodology. For this criterion were considered features like the number of remotely controlled reclosers, the number of branches in the circuit and the number of substitution circuits.

*3)* Circuit location: It is preferred those circuits that are closer to CODENSA Control Center, because if required some intervention, the trip to the site will take less time.

According to the above criteria, for each circuit is assigned a rating. As all these characteristics defined cannot be fulfilled entirely by a circuit, the rating assigned take into account a weighting for each of these criteria. Then, based on that score, the circuits were classified in order, such that the first of the list was finally selected. The following section describes the most important aspects of the chosen circuit.

## IV. Description of the Selected Circuit

After making the selection of the circuit where the proposed methodology will be implemented, it is required to describe the most important features of this system. The selected circuit belongs to a substation located 45km from CODENSA Control Center. This substation of type MT / MT is fed by two medium voltage circuits at 34.5kV and reduces the voltage until 11.4kV by two 5MVA transformers to distribute the energy through four circuits and one more that supplies the auxiliary services. Said substation, also has the ability for communicate via the GPRS network from the Control Center, which provides access to a relay concentrator SEL 2030. Such device allows connection with each of the circuit's protection devices.

The selected circuit, has a recloser that operates as the head circuit breaker, plus two bay switches. It also has an intermediate recloser used to isolate faults that occur downstream of this device. Fig. 1 shows the geographical distribution of this circuit. The recloser, the location of the points of substitution and the substation are highlighted there.

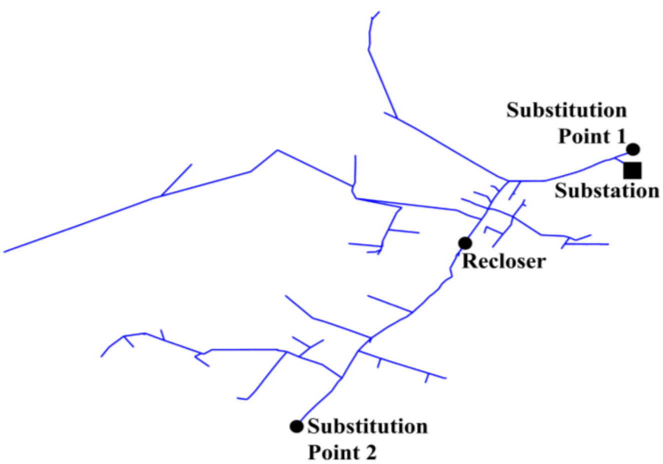



Fig. 1. Geographical distribution of the selected circuit.

TABLE I
INSTALLED ELEMENTS IN THE CIRCUIT

| Name | Type | State |
|---|---|---|
| S8687 | Fuse | NC |
| S12320 | Fuse | NC |
| S14685 | Fuse | NC |
| S12319 | Fuse | NC |
| S29020 | Fuse | NC |
| S8280 | Fuse | NC |
| S13901 | Fuse | NC |
| S9129 | Fuse | NC |
| RC409 | Recloser | NC |
| S12629 | Switch | NO (Substitution Point) |
| S7383 | Switch | NC |
| S8240 | Switch | NC |
| S8291 | Switch | NC |
| S8603 | Switch | NC |
| S8608 | Switch | NC |
| S8637 | Switch | NC |
| S8657 | Switch | NC |
| S8659 | Switch | NC |
| S8662 | Switch | NC |
| S8664 | Switch | NC |
| S8665 | Switch | NC |
| S8688 | Switch | NC |
| S8690 | Switch | NC |
| S8661 | Switch | NO (Substitution Point) |
| SD0277 | Fault Indicator | - |
| SD0278 | Fault Indicator | - |
| SD0279 | Fault Indicator | - |

TABLE II
ITAD QUALITY INDICATOR

| Year | Trimester | ITAD |
|---|---|---|
| 2008 | 1 | 3,2495E-07 |
| 2008 | 2 | 7,1536E-06 |
| 2008 | 3 | 4,8022E-06 |
| 2008 | 4 | 1,5363E-06 |
| 2009 | 1 | 8,3898E-06 |
| 2009 | 2 | 1,0937E-05 |
| 2009 | 3 | 2,2984E-05 |
| 2009 | 4 | 2,5433E-06 |
| 2010 | 1 | 2,4299E-06 |
| 2010 | 2 | 3,0141E-05 |
| 2010 | 3 | 8,8682E-06 |
| 2010 | 4 | 2,0466E-05 |
| 2011 | 1 | 6,3628E-06 |
| 2011 | 2 | 4,8781E-06 |
| 2011 | 3 | 1,7999E-05 |
| 2011 | 4 | 1,4734E-05 |
| 2012 | 1 | 4,4078E-06 |
| 2012 | 2 | 7,1327E-06 |
| 2012 | 3 | 1,0234E-05 |

Additionally, Table I presents the description of the elements that are installed in the circuit with their name, type and condition (NC: normally closed, NO: normally open). Table II and Table III show the quality indicators that are evaluated for this circuit. ITAD indicator (Table II) are presented quarterly since 2008, and SAIDI and SAIFI indicators (Table III) are shown monthly since 2011. Also the circuit has a measurement of frequency (number of failures) and the duration (hours) of the faults that were presented. Such measurements are presented in Table IV.

TABLA III
INDICADORES DE CALIDAD SAIDI Y SAIFI

| Año | Mes | SAIDI | SAIFI |
|---|---|---|---|
| 2011 | 1 | 0,000626552 | 0,000908176 |
| 2011 | 2 | 0,001235077 | 0,001968522 |
| 2011 | 3 | 0,000224566 | 0,000365636 |
| 2011 | 4 | 0,000389286 | 0,00026021 |
| 2011 | 5 | 0,001197436 | 0,0019025 |
| 2011 | 6 | 1,72272E-05 | 4,43855E-05 |
| 2011 | 7 | 0,004005708 | 0,00360804 |
| 2011 | 8 | 0,001055442 | 0,000432025 |
| 2011 | 9 | 0,000434722 | 6,06589E-05 |
| 2011 | 10 | 0,000385257 | 0,000349856 |
| 2011 | 11 | 0,000547255 | 0,000876069 |
| 2011 | 12 | 0,003528464 | 0,003589475 |
| 2012 | 1 | 0,000999134 | 0,00203107 |
| 2012 | 2 | 0,000249674 | 0,000220298 |
| 2012 | 3 | 0,000129155 | 8,35783E-05 |
| 2012 | 4 | 0,001914277 | 0,00110681 |
| 2012 | 5 | 5,56605E-05 | 6,67379E-05 |
| 2012 | 6 | 0,000810728 | 0,002067046 |
| 2012 | 7 | 0,001235486 | 0,000464474 |
| 2012 | 8 | 0,001789677 | 0,000481603 |
| 2012 | 9 | 0,000696006 | 0,001250692 |
| 2012 | 10 | 0,000158799 | 6,72747E-05 |

## V. PROPOSAL FOR FAULT INDICATORS' PLACEMENT

In the literature consulted, it is highlighted the importance of installing fault indicators in the distribution circuits because they help to reduce restoration time. Without the use of fault indicators, the average time required to determine the fault location in the feeders is proportional to its length [5]. The placement of the fault indicators should take into account several parameters defined in the cited references. The most important parameters are described below:

*1)* Distance from candidate section regarding to the nearest protective device. The protection device (e.g. a recloser) acts as a fault indicator, so it is preferred locate fault indicators devices at a suitable distance from protection devices.

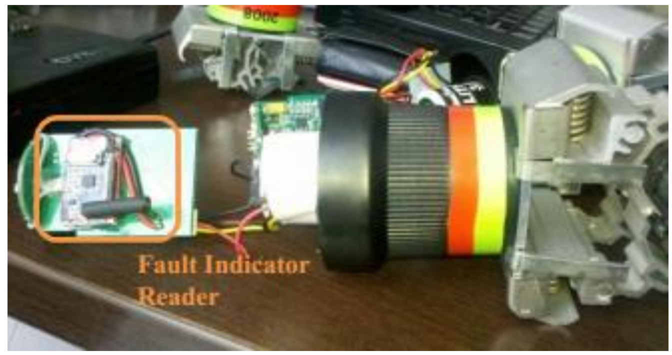
*2)* The load that support the candidate section. Circuit sections that are closest to the head are more heavily loaded. Therefore at the beginning of the circuit should be installed more indicators.

*3)* User's profiles. It is preferred to locate fault indicators at points where are connected users whose load is more critical, as described in [3].

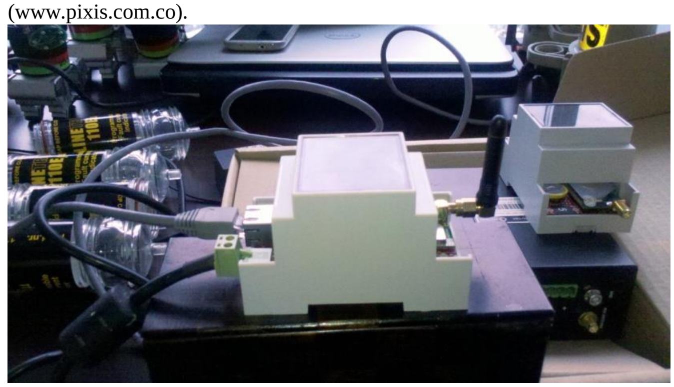
TABLE IV
FREQUENCY AND DURATION OF THE FAULTS

| Year | Month | Frequency | Duration (hours) |
|---|---|---|---|
| 2008 | 2 | 2 | 0,35472222 |
| 2008 | 5 | 2 | 0,705 |
| 2008 | 7 | 1 | 0,03055556 |
| 2008 | 8 | 1 | 0,2 |
| 2008 | 9 | 1 | 0,16666667 |
| 2008 | 11 | 1 | 0,05527778 |
| 2009 | 3 | 2 | 1,33361111 |
| 2009 | 7 | 2 | 0,85138889 |
| 2009 | 8 | 1 | 0,07055556 |
| 2009 | 10 | 1 | 0,04027778 |
| 2010 | 3 | 1 | 0,56916667 |
| 2010 | 5 | 4 | 0,80888889 |
| 2010 | 9 | 1 | 0,92055556 |
| 2010 | 10 | 1 | 0,00027778 |
| 2010 | 11 | 2 | 0,38611111 |
| 2010 | 12 | 2 | 0,53555556 |
| 2011 | 2 | 3 | 1,26361111 |
| 2011 | 4 | 1 | 0,525 |
| 2011 | 5 | 2 | 0,19277778 |
| 2011 | 7 | 3 | 0,38 |
| 2011 | 12 | 4 | 2,25083333 |
| 2012 | 4 | 1 | 0,64583333 |
| 2012 | 6 | 1 | 0,18777778 |
| 2012 | 9 | 1 | 0,15972222 |

The chosen circuit currently has three sets of fault indicators installed, whose placement will not be considered for the application of the proposed methodology. This section will describe the process of selection of the points to the placement of 8 sets of automated fault indicators. These devices have a communication system that transmits his status information to the Control Center (Fig. 4). Fig. 2 shows the communication devices that are installed for each of the sets of fault indicators. Additionally, a device for metering fault currents will also installed, and it also acts as a fault indicator. This device (DISCOS Power Sense), which will be installed in the initial part of the circuit, also has communication abilities to send information of his state to the Control Center. Fig. 3 shows the connection diagram of the DISCOS Power Sense device to the distribution circuit conductors. All this information (fault indicators and DISCOS device) will be used as input data for the Petri Net model, which will show the faulted area of the circuit. In the reviewed works [1-10] the authors used different computational techniques to the placement of the fault indicators. In this article the location of the indicators is based on the parameters described above and based on expert knowledge rules obtained from CODENSA's engineers. These rules suggest that fault indicators should be installed based on criteria that consider the installed load, proximity of the point to a cutting element (switches or fuses) and ease of access to the installation point. Initially it is intended that each set of indicators is close to a cutting element. This allows sectioning the circuit when it is in a fault state. Then it is searched that the installed load in the circuit can be distributed as evenly as possible in each of the sections that are created with the placement of the fault indicators.




(a) Fault Indicator Reader (LFI for its acronym in Spanish) installed in the fault indicator. It is responsible to transmit the status of the equipment to the Fault Indicator Modem Reader through radio frequency. PIXIS Consultoría (www.pixis.com.co).



(b) Fault Indicator Modem Reader (MLFI for its acronym in Spanish). Responsible for receiving status signals from LFI . It connects to the modem Geneco to transmit information by 3G network, which is received it in the Control Center. PIXIS Consultoría (www.pixis.com.co).


(c) Geneco Modem 3G. It is responsible to receive the signals from MLFI and send it to the Control Center. PIXIS Consultoría (www.pixis.com.co).

Fig. 2. Communications Architecture of fault indicators. (a) Fault Indicator Reader (LFI). (b) Fault Indicator Modem Reader (MLFI). (c) Geneco Modem 3G. Photos from PIXIS Consultoría (www.pixis.com.co).

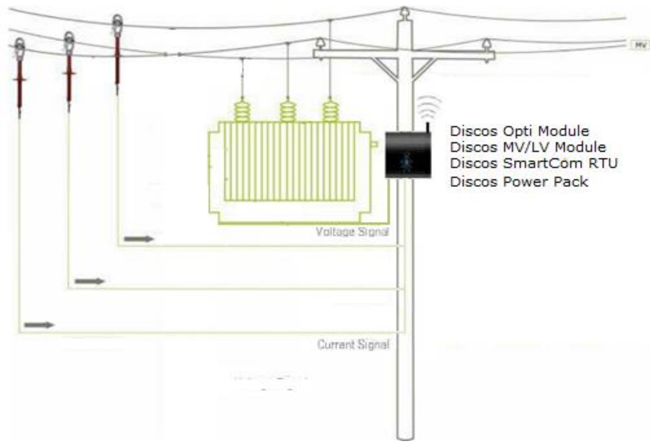



Fig. 3. Connection of DISCOS Power Sense device to the distribution circuit. This device has a data transmission system using the 3G network [11].

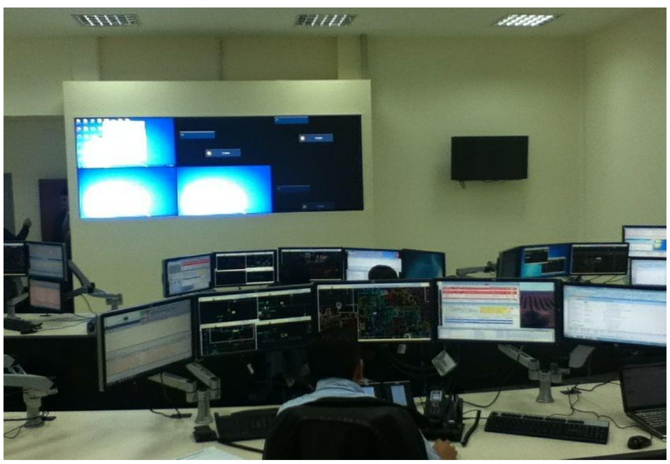


Fig. 4. CODENSA Control Center. The signals from the fault indicators devices and the DISCOS Power Sense device will be received there. Courtesy CODENSA S.A ESP.

TABLE V
DISTRIBUTION CENTERS (CDS) FOR EACH CIRCUIT SECTION

| Section | Number of CDs | Section | Number of CDs |
|---|---|---|---|
| 1 | 5 | 6 | 8 |
| 2 | 8 | 7 | 9 |
| 3 | 10 | 8 | 7 |
| 4 | 12 | 9 | 8 |
| 5 | 9 | 10 | 10 |

Table V contains the number of distribution centers (CDs) that belong to each resulting section of the circuit. A distribution center (CD) is a distribution transformer to which end users are connected. The end users represent the load that has the circuit. Finally, it is chosen the points where access is easy and secure. Fig. 5 shows the final location of the fault indicators (triangles) and the sections in which the circuit is divided after choosing the placement of the fault indicators. These sections are the basis for developing the Petri Nets model that is described in the next section.

## VI. FAULT LOCATION MODEL BY MEANS OF PETRI NETS

The location methodology proposed in this article is based on Petri Nets model. The model's main function is to indicate the area where the fault possibly is located, based on inference rules that are modeled using the Petri Nets technique. This model is feed by the state information of fault indicators, and also considers uncertainty factors and gives results based on the entire combinatorial of signals of the equipment. First the circuit is modeled based on the sections shown in Fig. 5. Each section has a status that indicates its fault status. The fault states are defined below:

*1)* FSec1*:* Fault in the Section 1.
*2)* FSec2*:* Fault in the Section 2.
*3)* FSec3*:* Fault in the Section 3.
*4)* FSec4*:* Fault in the Section 4.
*5)* FSec5*:* Fault in the Section 5.

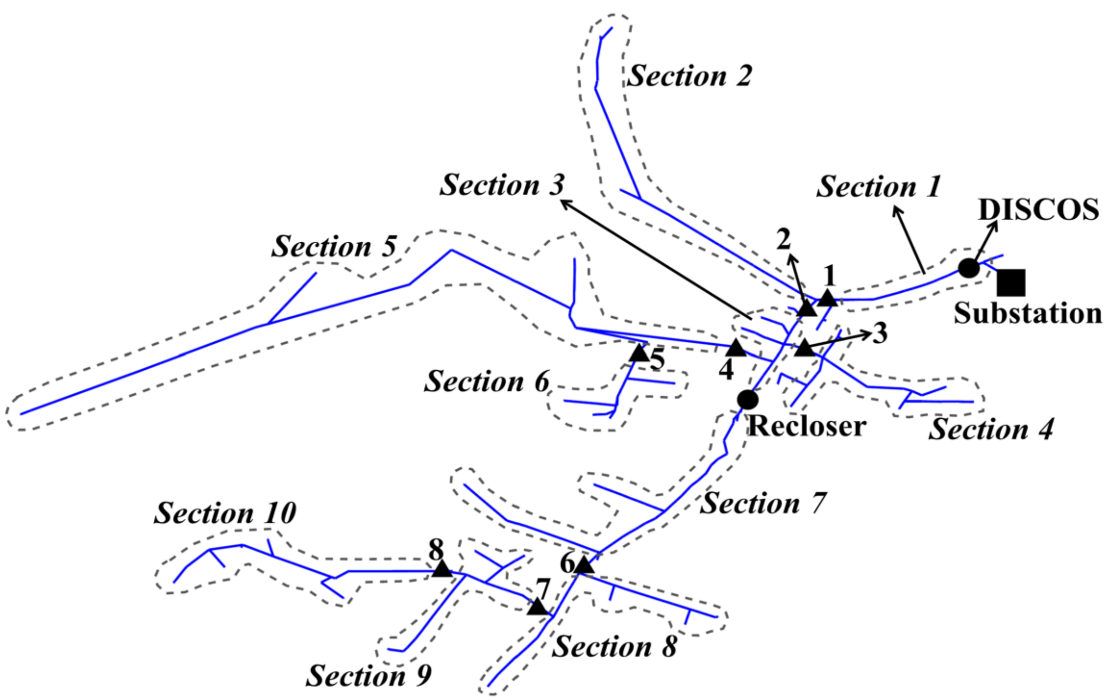



Fig. 5. Division into sections and location of fault indicators in the selected distribution circuit.

*6)* FSec6*:* Fault in the Section 6.
*7)* FSec7*:* Fault in the Section 7.
*8)* FSec8*:* Fault in the Section 8.
*9)* FSec9*:* Fault in the Section 9.
*10)* FSec10*:* Fault in the Section 10.

Also it is have the states for each set of fault indicators, of the recloser and of the DISCOS device. Having a mark at these places indicates that the device is activated and has detected a fault current in the circuit. Fig. 6 shows a simplified representation of the circuit with its sections and the equipment used to locate the fault.

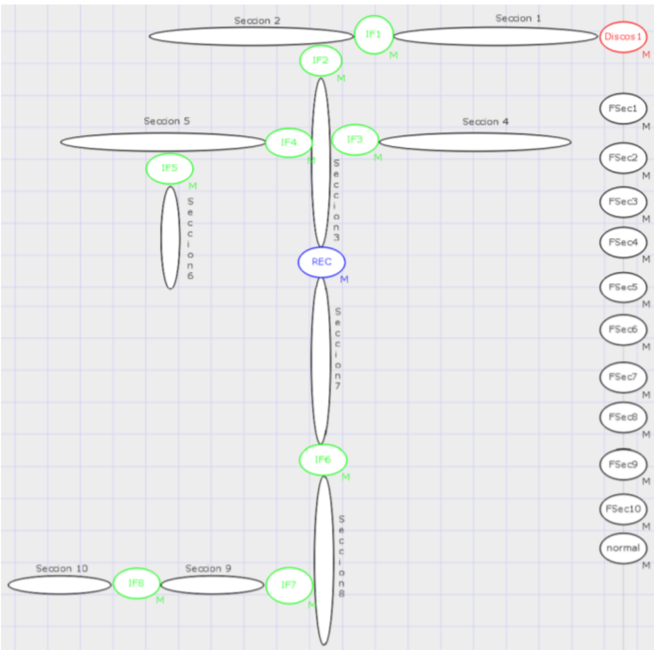



Fig. 6. Simplified representation of the circuit with fault state of the sections (right) and the status of fault indicators (IF1 to IF8), the recloser status (REC) and DISCOS status device (Discos1).

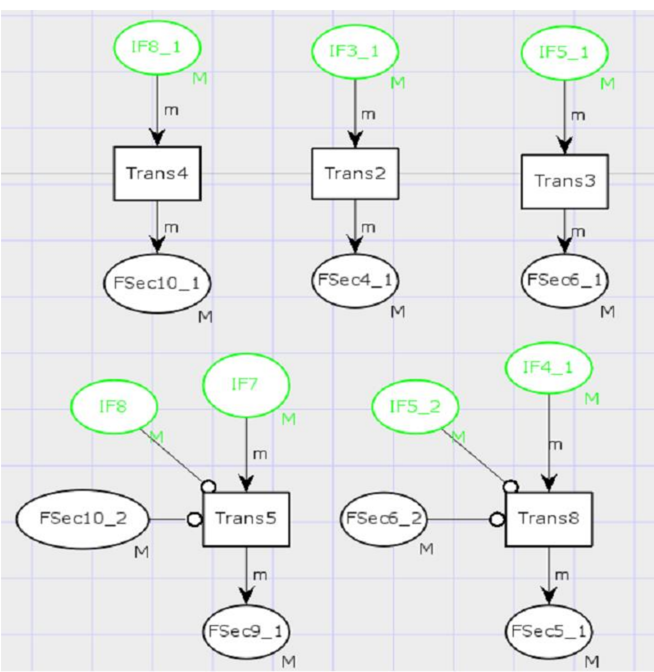



Fig. 7. Representation by means of Petri Nets of the basic rules for the faults of the sections 4, 5, 6, 9 and 10.

Now, it is has the model to infer what is the section that is in failure. This model is proposed according to rules which contain some antecedents that are basic to deduce the faulty section. First, there are some basic rules to deduce whether Sections 4, 5, 6, 9 and 10 are in failure. These rules are described below and are represented by the network shown in Fig. 7:

*1)* If fault indicator IF3 is active, then Section 4 is in fault.
*2)* If fault indicator IF4 is active, fault indicator IF4 is not active, and Section 6 is not in fault, then Section 5 is in fault.
*3)* If fault indicator IF5 is active, then Section 6 is in fault.
*4)* If fault indicator IF7 is active, fault indicator IF8 is not active, and Section 10 is not in fault, then Section 9 is in fault.
*5)* If fault indicator IF8 is active, then Section 10 is in fault.

The above rules allow identifying the section that is in fault, thanks to they are the most radial points of the circuit and therefore the inference is very basic.

To locate the fault in the other sections, rules based on some antecedents are also used. These rules basically have to do with checking the status of fault indicators that are before the section in question, and of the fault state of the previous section of the one that is being checked. The other rules that allow inferring the faulty section are described below:

*6)* There are fault in Section 1, if (see Fig. 8):
- Discos1 device is active,
- IF1, IF2, IF3, IF4, IF5, IF6, IF7, IF8 and REC are not active, and
- Sections 2, 3, 4, 5, 6, 7, 8, 9 and 10 are not in fault.

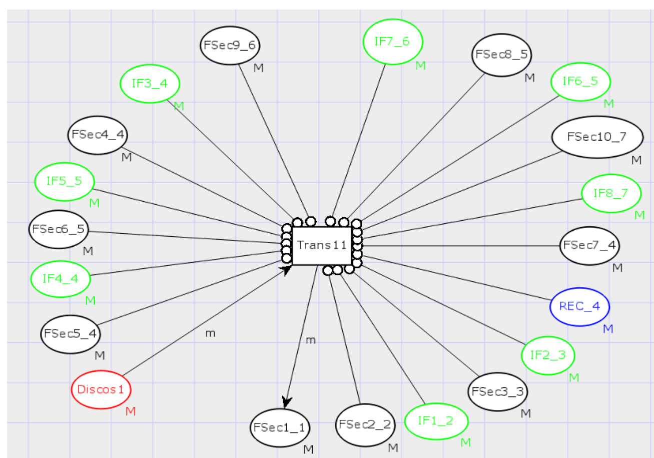



Fig. 8. Representation by means of Petri Nets of the rule to identify a fault in the Section 1.

*7)* There are fault in Section 2, if (see Fig. 9):
- IF1 is active,
- IF2, IF3, IF4, IF5, IF6, IF7, IF8 and REC are not active, and
- Sections 3, 4, 5, 6, 7, 8, 9 and 10 are not in fault.

*8)* There are fault in Section 3, if (see Fig. 10):
- IF2 is active,
- IF3, IF4, IF5, IF6, IF7, IF8 and REC are not active, and
- Sections 4, 5, 6, 7, 8, 9 and 10 are not in fault.

*9)* There are fauly in Section 7, if (see Fig. 11):
- REC is active,
- IF6, IF7 and IF8 are not active, and
- Sections 8, 9 and 10 are not in fault.

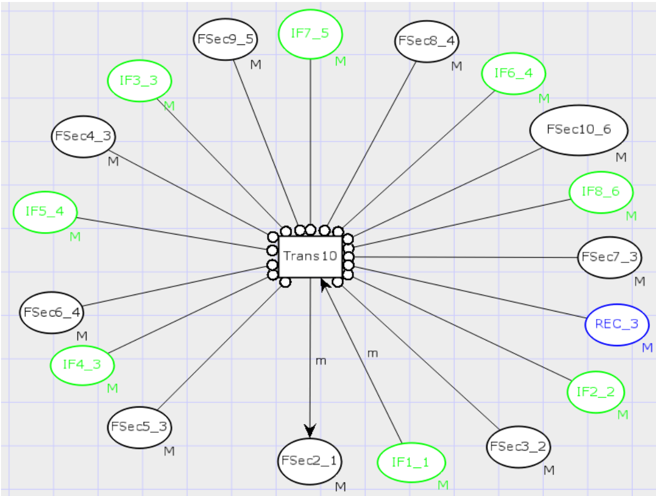



Fig. 9. Representation by means of Petri Nets of the rule to identify a fault in the Section 2.

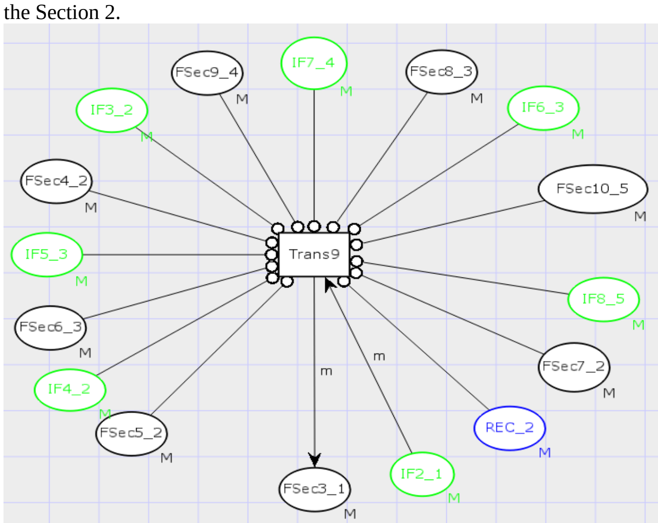



Fig. 10. Representation by means of Petri Nets of the rule to identify a fault in the Section 3.

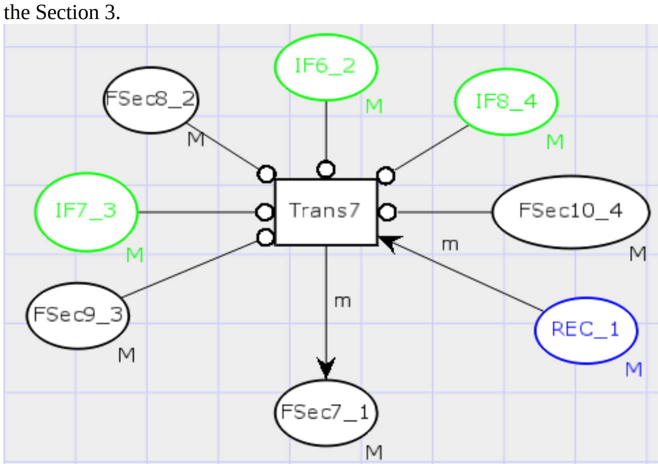



Fig. 11. Representation by means of Petri Nets of the rule to identify a fault in the Section 7.

*10)* There are fault in Section 8, if (see Fig. 12):

- IF6 is active,
- IF7 and IF8 are not active, and
- Sections 9 and 10 are not in fault.

The above rules establish completely the proposed model in this paper for the fault location in the circuit of study.

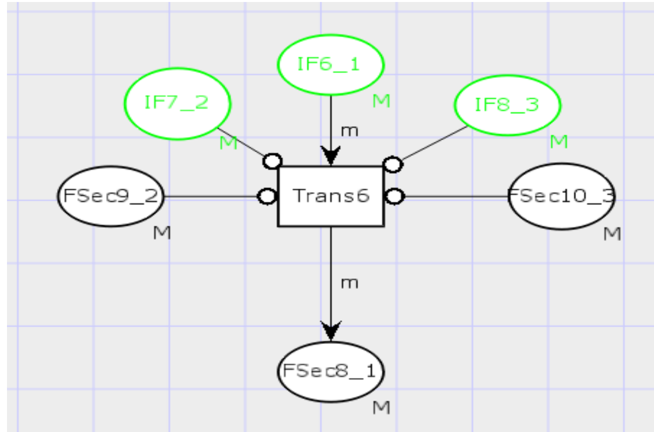



Fig. 12. Representation by means of Petri Nets of the rule to identify a fault in the Section 8.

## VII. SIMULATIONS

Now, two basic examples of failures that may occur in the circuit will be presented. With the help of the simulation tool CPN Tools, the results of these exercises will be displayed. The first case only IF7 will be active. For this, the mark on the place that represents the status of this fault indicator must be activated. Fig. 13 shows the active status of the equipment. Having mark in this place, the transition Trans5 which was presented in Fig. 7 is sensitized due to the antecedents of the network is fulfilled and can be activated. When it is activated, the mark evolves and the FSec9 place is active, where finally concludes that Section 9 is in fault. Such result is showed in Fig. 14.

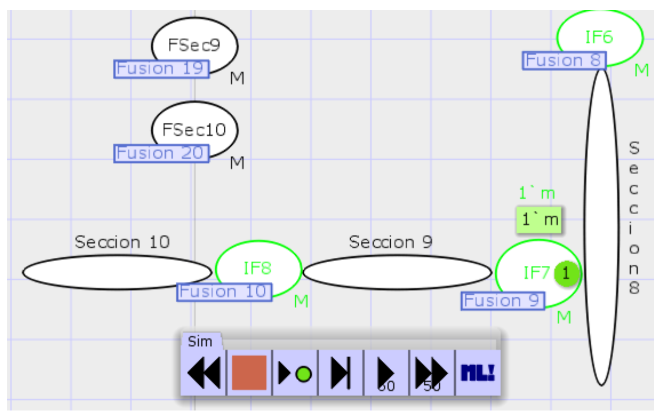



Fig. 13. Active status of the fault indicator IF7. The exhibited mark in the place IF7 of the Petri Net represents that state.

The second simulation case is to activate the IF2, the IF1 and Discos1 (Fig. 15). Here will be presented a failure in Section 3. According to Figure 10 it can see that the antecedents of the model are fulfilled (Rule 8). This causes that the transition Trans9 is sensitized and can be activated, eventually making that exists mark on the place FSec3 (Fig. 16).

## VIII. CONCLUSIONS

We have presented a full and detailed methodology for fault location in a circuit of CODENSA distribution system, based on fault indicators. It has also shown a Petri Net model to infer the section of the circuit that is in fault, which feeds on the signals that the equipment sends to the control center. This methodology has taken into account the correct placement of fault indicators, which was made based on well-defined criteria.

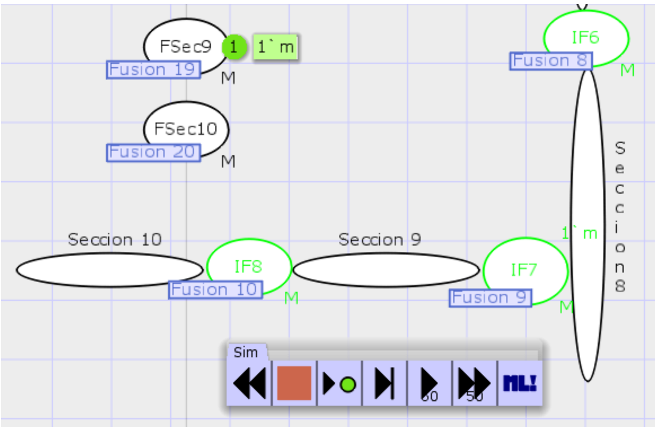



Fig. 14. The FSec9 place is finally activated, showing that the Section 9 is in fault state. The antecedents of the net (see Fig. 7) were fulfilled and the transition Trans5 can be activated.

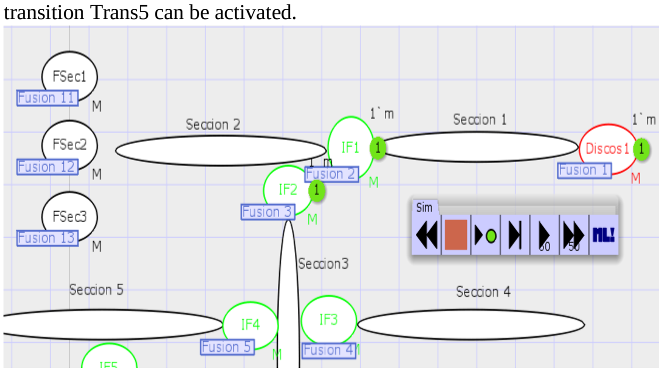



Fig. 15. Active status of the fault indicators IF2, IF1 and the Discos1. The exhibited mark in the places of the Petri Net represents that state.

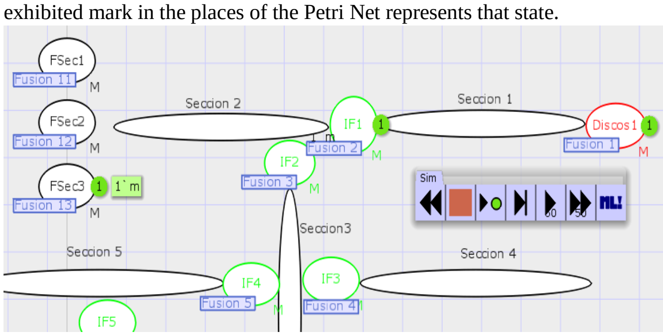



Fig. 16. The FSec3 place is finally activated, showing that the Section 3 is in fault state. The antecedents of the net (see Fig. 10) were fulfilled and the transition Trans9 can be activated.

The fault indicators are devices that help to reduce the uncertainty of the fault location, which occurs when a simulation technique is used, in which usually has the dual estimation problem. The methodology considers the natural failure rate of equipment, which corresponds to a big fortress over other methodologies where these typical situations of Control Centers are not considered.

Finally, with respect to the model proposed based on Petri Nets, it can be said that this considers basic rules to locate the possible faulted section. These rules consider antecedents needed to infer that certain section is in a fault state. The rules presented allow identifying failures in both the feeder and branch of the selected circuit. Additionally, it can see that as the failure of the section you want to identify is closer to the beginning of the circuit, the amount of antecedents of the rules of inference increases..

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