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An Intelligent Hybrid System for Power Distribution Reconfiguration

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Abstract: - This paper presents a project, which has set up a set of procedures that were introduced into computer packages, for helping the operators in recovering actions in the Brasilia Energy Company (CEB) distribution network. This project is aimed to the development of an action plan to be applied by the time of a fault occurrence in the distribution system. The developed computer package was based in artificial intelligence techniques and numeric routines, providing a hybrid system for the help of decision making of the operation centres dispatchers.

Key-Words: - Intelligent systems, Case-based reasoning, Reconfiguration, Operation, and Control center tools

1 Introduction

Usually, power systems have a natural growth that may be noticed through a systematic demand and consumption increases of electrical energy, that happen mainly in the great urban centers and regions with a major industrial activity, and simultaneously increases the complexity for administration, supervision and control necessary to attend these demands [1].

In the past years, the complexity of distribution systems operation have been increasing considerably, so beside the growth of the branch number, the investments into the system is lagging behind the growth of the system load, making the equipments to operate nearer their rated load. This makes the system reconfiguration to consider the time for repairing the fault, each branch load and an optimisation of the operational procedures.

In addition to these topics, it is possible also to include the stress in the technical staff generated by a system power breakdown. The operators must take fast decisions, some times having no overall knowledge of the system. The stress and the need for fast decisions may generate no good decisions even decisions that may damage the system (or some of its equipments). Because of this, an existing tool that helps the operator by the time of a power breakdown is very useful, because it supplies the required elements for a good decision take regarding what to do and when to do it.

Moreover, it is known that in the operator centres there are a great number of programs that monitor, in actual time, “on line”, the system operational conditions, the switches position and the power supply for consumers. These monitoring programs are tied up also to other outside processing and procedures “off-line”, comprising power flows and load forecasts to be supplied, contingency analysis and state estimators and others. The computer package developed in this project was integrated as an additional analysis tool that may be accessed anytime by the dispatcher, whether for repairing a distribution network problem or to make a topological study.

2 Overview of the Mathematical Tool

2.1 Expert Systems

The proposed intelligent system uses the technique of Expert System, between others. An expert system (ES) simulates the making of a task by one Expert. The creation of such a system able to copy a human being and his deduction capacity, unknowing the way the human being infers may be as complex as the size of the scope of the application dominion.

It is advisable to restrict the ES to a small dominion of application because more generalist be the construction of this system, bigger the knowledge base, the processing time and the probability of errors during the creation and management of rules. In projecting a distribution substation the developer needs a basic structure able to store the knowledge, to process it and to exchange messages with the user. This structure has the following basic elements:

- The knowledge base has all the facts and rules for the adequate functioning of application;
- The interface responsibility may be resumed in the communication with user, allowing the entry of information and supplying the system results;
- The inference motor consults the existing rules and

facts from the knowledge Base, infer upon this knowledge and feed back a conclusion to the user through the interface.

2.2 Case Based Reasoning

The paradigm Case Based Reasoning (CBR) presume the existence of a memory where the already solved cases are stored; uses these cases, through recovering, for helping in the resolution or interpretation of new problems; and promotes the learning, allowing that new cases (newly solved or newly spell-out) be added to the memory [2].

One CBR uses previous cases as far for evaluation, justification or interpretation of proposed solutions (interpretative CBR), as for proposing solutions for new problems (problem solving CBR) [3].

CBR has been opening new fields on computer back up regarding decision problems of a bad structure. The CBR system purpose is to recover from its memory the most similar case regarding to the new, suggest the solution or one adaptation of this as a solution for the new situation. The usefulness of the old cases is made by the similarity access of a new case with the old one.

The central methodology of the retriever prototype is the similarity determination of a new case with all the previous cases. The similarities are set up through combination functions (matching) and through the characteristics of the new case with all the previous ones. In the next sections we will show how to handle with similarities and the matching function, so as the architecture of the retriever prototype.

a) Function Matching Modified Cosine

According [4] the modified cosine function is represented as follows:

$$\text{Gcas} = \frac{\sum_{i=1}^{m} \omega_i^{n} \omega_i^{p_k} \left(1 - \left(\frac{(x_i - y_i)}{R_i}\right)\right)}{\sqrt{\sum_{i=1}^{m} \left(\omega_i^{n}\right)^2 \sum_{i=1}^{m} \left(\omega_i^{p_k}\right)^2}} \quad (1)$$

for: i = 1,...m (descriptions) and for: k = 1,...r (previous cases)

With:

$1 - \left(\frac{(x_i - y_i)}{R_i}\right)$ denotes the similarity in the i- th description of the new case and a previous case;

ω_i^{n} ≡ weight of i- th description on weight vector from new case;

ω_i^{pk} ≡ weight of i- th description on weight vector from previous case.

The modified cosine combination determines the global similarity, named “Matching degree” (Gcas), between two cases by comparison of terms frequency, that is to say, the description weight from the new case and the terms weight from previous case.

The function measures the cosine of the angle between the vectors weight of the new and previous cases, which cosine is weighed by the similarity degree along the space m-dimensions of descriptions. The denominator terms of equation above normalize the vectors weight by the determinations of its Euclidian lengths.

The similarity function is based in the pertinence (weight) of description values for the diagnostic. The similarity between the value of the present description from the new case and the value of same present description in the previous case of memory is taken as being the difference between the unit and a rate between the weights that each one of these values have for the diagnostic of the case in memory, with the extension value of the description scale.

The importance determination of one description is set up in one scale as per Figure 1. For example, presuming that the description of one specific system be the temperature and the determination of its importance pass through one scale which extension is defined as follow in Figure 2.

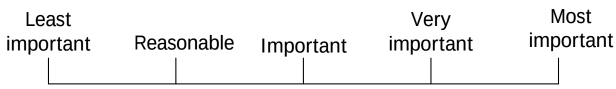

Figure 1. Determination of Description Importance.

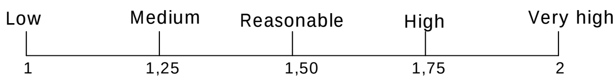

Figure 2. Temperature Quality Values.

The similarity along the description may be computed, for example, for one value of Very High Temperature (2) in combination with a value of Medium Temperature (1,25) like:

Similarity along description = 1 - (2,0 - 1,25) / 2,0

Similarity = 0,625

b) Retrieve Process

The recovery process in Case Based Reasoning comprises experience of past solutions stored into a memory known as cases. This technique aims to recover the most useful previous cases toward the solution of the new decision take problem and to ignore the irrelevant previous cases.

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The cases recovery works in the following way, as set up in Figure 3: based upon the description of the new decision take problem (new case) the basic case is searched by the previous cases starting from a decision back up. The search is made based upon similarities [5].

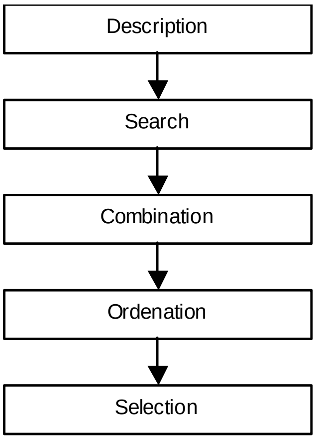

Figure 3. Recover Components of one CBR.

The previous cases get through the combination function (matching degree) and are ordered in decreasing way regarding the matching degree. The combination function determines the similarity degree of the useful potential from previous cases with one new case.

The retriever prototype requires the whole evidence body supplied by memory, that is to say, it requires that the entry case matching degree be computed against all the memory cases.

In Figure 4 we see the Retriever Prototype architecture. For each memory case a matching function is defined between the new case and the same. This function computes the Belief Function in favor of the diagnostic of this case for the case of entry.

The previous cases determined by search may be combined by Gcas and arranged in global similarity decreasing order. In the diagnostic domain, it is usual that the cases in which the same diagnostic happens by symptoms groups or different characteristics [6]. “The most adequate diagnostic” supposed for the entry situation, is the one that presents the major evidence to its favor, in other words, the one that has a bigger Belief Degree, computed by the matching degree Gcas. “The most adequate case” suggested is the one among all the cases from the class of selected diagnostic that have the bigger matching degree Gcas. The cases that belong to that diagnostic class may be of help for the new problem solution. The advantage in recovering the case is that it is possible to find in it information that were useful for the solution of previous problems which may help for solving the new case.

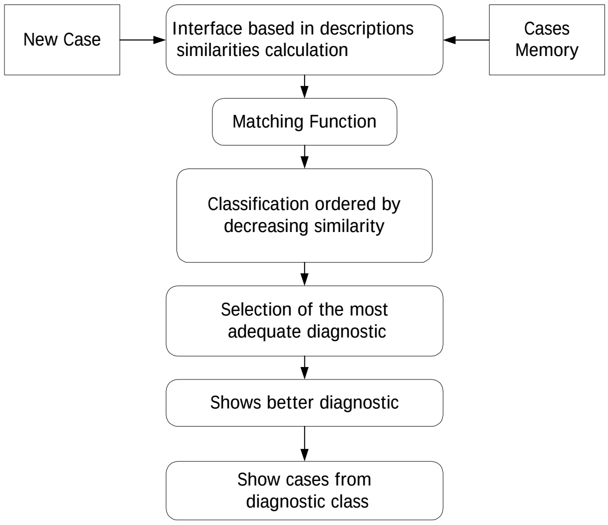

Figure 4. Retriever Prototype Architecture.

3 Description of Integration from Used Methodologies

3.1 Program Pathway

Following is presented the pathway for development program named “Switching”, with the indication of the way for information, as well as the used processing in each parcel of the data set for obtaining the result (Figure 5).

The user will generate a request through a proper interface of the Switching program, for witch the user should select what line he wants to set up in fault, from a list of lines. There are two simulation possibilities, in the first named “Simulation in Basic Mode”, does not need to inform anything more, but in the second named “Simulation in Advanced Mode” the user must inform the feeder or bus that he wants to use as a fountain for restore the powerless circuit.

With these data the pathway program starts the search process, which will be performed by Reconfiguration Expert System (REE). The REE will generate possible solutions for attending the request, being these solutions forwarded to Numerical Routines (NR), which will be responsible for the calculation of power flows, under voltages and over voltages. Finally all solutions are forwarded for the Classifying Pounded System (CPS), which is responsible for classification according the criteria for choosing lower overloads, and little under voltages and over voltages.

The CPS then will show the best solutions in a window for the user. The user also has setting tools

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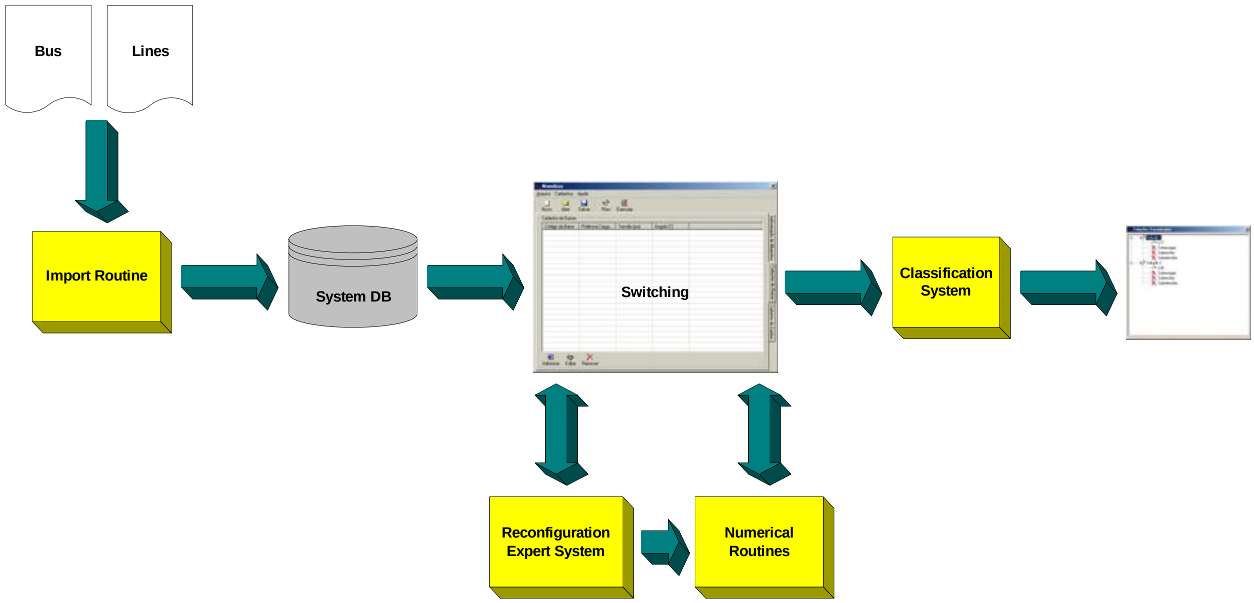

Figure 5. Program Pathway

and configuration of database, as well as a tool for the import of data about busses and lines to make possible to up date these data for other circuits of the CEB network.

3.2 Expert System for Reconfiguration

The Reconfiguration Expert System (REE) has resources for making an efficient and selective reconfiguration, after the fault is found and identified, and the fault circuit is de-energized, preventing that the fault branches or permanent defects spread out inside the electric system.

Depending on the fault the REE restores only part of the de-energized components, or only part of the load. However, there is a restoring hierarchy as presented in Table 1 [7].

The operation philosophy and the state pre and after fault of equipments, makes the fountain of starting data from restoring process. Based on these data, and after an analysis of them, the actions for restoring will be started and will have its sequence defined.

Table 1 – Restoring Hierarchy

START	Fountains	BL
↓	Transformation	TRANSFORMERS
		AUTOTRANSFORMERS
	Load	BL, FEEDERS
	Control	CAPACITORS BANKS
END		REACTORS AND SYNCHRONOUS

3.3 Numeric Routines

The numeric routines are in charge of calculation of power flow, load flow, that in one electric power network comprises basically the determination of the operation state of this network, considering its topology and a certain load condition.

This operation state comprises:

- Determination of voltages and angles for all system busses;
- Determination of active and reactive power flows through the system branches;
- Determination of active and reactive power, generated, consumed and lost in the many system elements.

In this project we will be using the Newton-Raphson method with accelerations for radial circuits, at present the most used for solution of power flow problems. Since its first formulation it has having many additions aiming to make it each time more powerful.

Generally the power flow problem is characterized by being not linear; therefore it is necessary iterative processes of numeric calculations for the problem resolution (because of this the direct methods of nodal analysis or of nets, used in the circuits theory cannot be used). The equations non-linearity comes from certain characteristics in modeling some system components.

In the analysis of power flow there is the interest of obtaining a system solution operating in permanent sinusoidal regime, because to this the modeling of the system is static, which means the equations and inequations that represents the network are algebraic and not differentials.

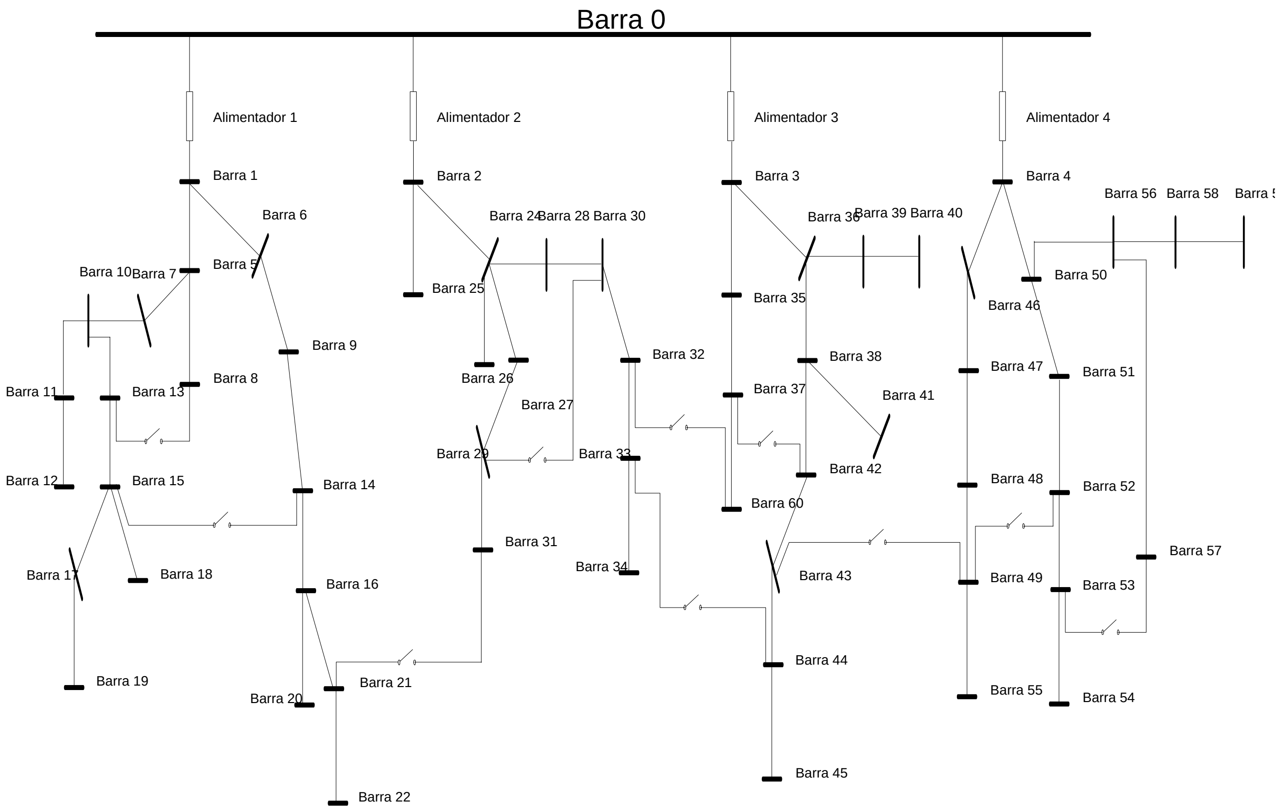

Figure 6. Pictorial Real System (In the figure, barra means bus and alimentador means feeder).

3.4 Weighted System for Classification

The Weighted System for Classification is based in Weighted Weights and was introduced by creating a set of weight rules for the many factors that are limitative in the solution, for example: overloads, under-voltages and over-voltages.

Each solution obtained by SSR is subject to this set of rules and then is presented in the window for results in ordered way from the best down to the worst.

3.5 Routine for Imports of Busses and Lines

The user has the option for importing files with lines or busses data, for this it is enough to open a new system or an existent one and use the function "Import" from menu "File", selecting whether he wants to import "Busses" or "Lines". The data to be imported will be added in the end of its respective lists.

The file for import of lines from program Switching is a spare text file with common tabulation from Windows®, is that to say, after each information should be inserted a tabulation (key TAB) as separator. The existent information in the imports file is:

Bus OfTabBus ForTabR [ohms]TabX [ohms]

The import file of busses from program Switching is a spare text file with common tabulation from Windows®, is that to say, after each information should be inserted a tabulation (key Tab) as separator. The information from import file is:

Bus CodeTabConsumption [kWh]TabDemand [kVAS]

4 Illustrative Examples

A part system of Brasilia Energy Company (CEB) distribution network is presented in Figure 6.

4.1. Example 1 – Simulating a System in Basic Mode

After loading the example file and executing the load flow, the user should the to enter with the fault data, ´is that to say, to select properly the lines which state have changed for "Fault", for example, let us put the feeder ALIM1 (feeder 1) in fault, Figure 7. For that it is enough to select the ALIM1 in the lines list and click in the button "Fault".

In our example let us apply this methodology asking the program for re-energize the bus 1. The answer given by program is shown in Figure 8.

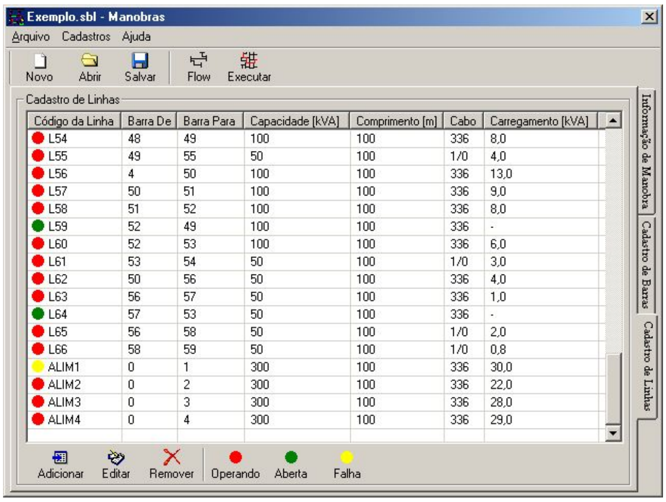

Figure 7. Changing the line state for "Fault".

Figure 8. Answer from simulation in "Basic Mode".

4.2 Example 2 – Simulating a System Advanced Mode

In our example it is possible to make the reconfiguration of bus 1 beginning from bus o (sub-station) with a search factor of 1.1 (increase of 10% in the search space). The answer shown by program is in Figure 9.

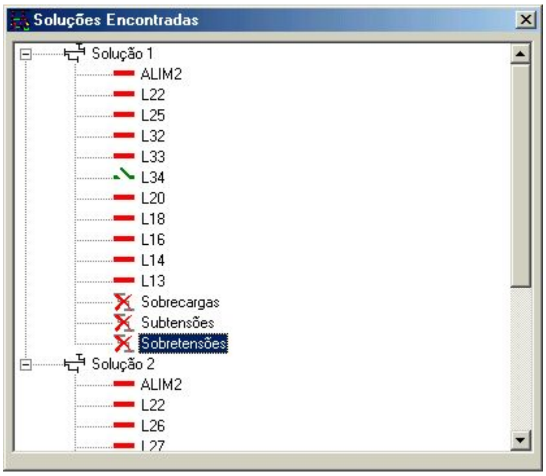

Figure 9 –Answer from simulation in "Advanced Mode"

5 Conclusions

One of the objectives of this paper was to develop hybrid systems aiming the unification of different techniques of artificial intelligence so as not to loose the project objective that was to develop a computer program that could have immediate application in the CEB operations centre. The developed computer tool comprises an expert system and a case-based reasoning.

An expert system simulates the making of a job by one specialist. The creation of such a system able to imitate the human being and his deduction capacity, not knowing how the proper human being infer, may be so complex as the size of the objective from the application domain.

It is advisable the restriction of the expert system down to a small application domain, once the more general be constructed this program, bigger the knowledge basis, bigger the processing time, and bigger may be the probability of making mistakes during the creation and ruling management.

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