Automation and Control in Electric Power Systems:- A Review of Intelligent System Applications

AUTOMAÇÃO E CONTROLE NOS SISTEMAS ELÉTRICOS DE POTÊNCIA: UMA REVISÃO DAS APLICAÇÕES DE SISTEMAS INTELIGENTES

Germano Lambert Torres
Federal University of Itajubá
Institute of Electric Engineering

ABSTRACT

There is a permanent demand for new application and simulation software, required for different purposes such as research, planning and power system operation. This paper presents an overview of some developments of the author for Brazilian power system industries. These developments are currently in operation and usually they are based on intelligent hybrid systems.

KEYWORDS

Intelligent Systems, Expert Systems, Genetic Algorithm, Artificial Neural Network, Hybrid System, and Power System Operation.

RESUMO

Existe uma permanente demanda por novas aplicações e programas computacionais para resolver os diversos problemas da operação e planejamento dos sistemas elétricos. Este artigo apresenta uma revisão de alguns trabalhos do autor para as concessionárias de energia elétrica brasileiras. Estes desenvolvimentos são baseados em sistemas híbridos inteligentes.

PALAVRAS CHAVE

Sistemas inteligentes. Sistemas especialistas. Algoritmos genéticos. Redes neurais artificiais. Sistemas híbridos. Operação de sistemas de potência.

INTRODUCTION

The power system operation (PSO), due to the high degree of uncertainty and the large number of variables involved, is intrinsically complex. The various supervision and control actions require the presence of an operator, who must be capable of efficiently responding to the most diverse requests, by handling various types of data and information. Upon the introduction of digital technology into the PSO's and the advent of the practical application of Intelligence Systems (IS) techniques, a quality leap in the operation mode was made possible. Every application, formerly based on the analog technique, must be reconsidered in terms of its basic concepts, so that an intelligent move may be achieved, with effective gains, taking advantage of the whole potential of the new technologies. Simply transferring or adapting current procedures does not allow the flourishing and incorporation of advancements into the operative procedures involving supervision and control [1].

The utilization of IS in operation and control aims at the evolution of the local supervision and control systems, incorporating practical and heuristic knowledge, optimizing the operative processes from the functional and economic points of view, in addition to allowing the automation of the operation, replacing the human decision/action with an artificial intelligence, of equal effectiveness level.

In view of the operational complexity of a PSO, which simultaneously puts together various concepts and domains, it is necessary to frame up the whole assembly so that further results may be achieved by the implementation of each fraction. Thus, there is a need for validation of the measurements (input data) and diagnosis (identification of the need for action), for determination of the strategies of operative action.

Figure 1 shows the operative architecture of a typical PSO, with the various types of operative functions, while Figure 2 shows the functional states of a PSO, both listing the various operative actions.

In the other hand, many Artificial Intelligence techniques have been quite evolutional since its initial propositions. At present, the soft computing is already a reality for the problem solving in several areas, the electric power systems area included.

Nonetheless, this fact, some gaps are still present in the several techniques. Some have more facilities in the learning process, but show difficulties in the explanation process for indicating how the answer was find. Another has facility in dealing with imprecision and partial truth, but presents major problems in process development for global search [2].

One solution to overcome these gaps could be the structure development that would be using more than one technique. This way, the more adequate characteristics of each technique could be use for the improvement of the system whole performance, and generating hybrid systems.

The integration of intelligent techniques have allowed that this field become each time more important for the power electric systems problem solving.

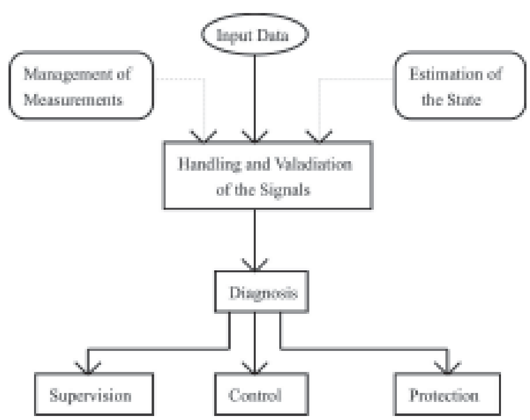

Figure 1: Operative Architecture and Functions of a Substation.

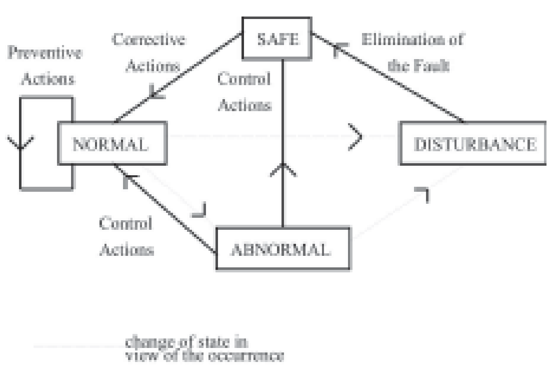

Figure 2 : Functional States of a Substation.

In Operation Control Centers, many programs and computational routines are available to operators to provide the best possible solutions for power system operation problems. Today, many advisor programs using IA techniques are available to aid operators' decision-making. Short-term load forecasting and restoration systems are examples of such program available to operators.

Intelligent System Techniques A little of story

A major existent difficulty into intelligent systems area is the impossibility in defining the perfect separation between this type of system and the conventional ones. Because of this, many works have not been properly classified. Some times works are mistakenly classifying a contribution for the Artificial Intelligence subject, when this is not true. On the other side, several researchers have not been publishing their papers bearing the name of intelligent systems, as a way of not to be involved with "buzz words".

A possible way to limit the Artificial Intelligence area is made through its association to the human brain processes. This way, the Artificial Intelligence would be the part of the computer science dedicated to the development of computer techniques for the improvement of systems with a behavior similar to those of the human brain. Two examples of this approach would be the expert systems and the artificial neural networks.

The expert systems may be considered as an application of the human brain macroscopic vision, is that to say, they look for making models out of the human reasoning processes, using several structures that contain the available knowledge. In this approach, the reasoning process (or in an ultimate analysis, the human brain work) is seen as a logic instruction succession.

Another approach is the attempt of computer reproduction of the human brain biologic elements. In this route, so called microscopic, each brain element and structure is chart out and a mathematic equivalent is constructed. This originates the artificial neural networks, beginning with the pioneer works of McCulloch and Pitts, in 1943.

In a general way, the name Artificial Intelligence, as suggested by John McCarthy in the outstanding meeting held at the Dartmouth College in 1956, formally beginning this knowledge area, it have been receiving the public attention, generating some times invalid expectations and previews.

However, in spite of the problems generated by the lack of a precise definition and the possible false expectations for achievements, this part of the computer science is one that have been undertaking more development in the last decades, showing several effective results.

Figure 1 presents a picture of dates with the main happenings and the persons that have developed pioneer works in the several areas with the respective references.

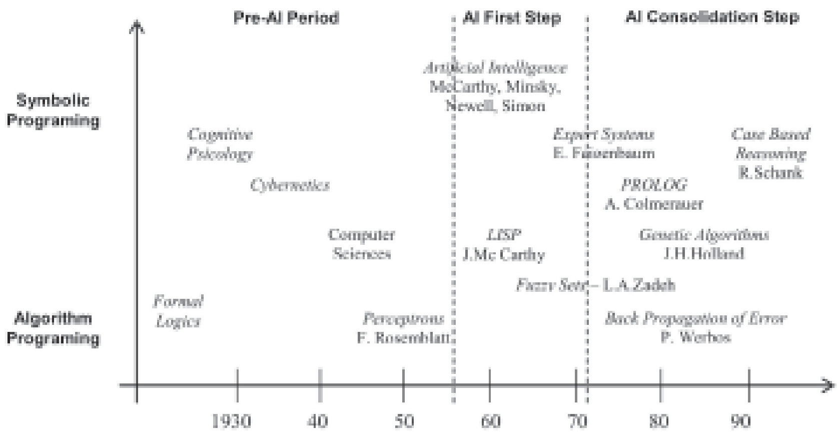

Figure 1 – Evolution picture of the techniques related to Artificial Intelligence

Definitions of Main Techniques

This section aims to present a short concept of intelligent systems main techniques and of the areas in relation to these systems.

a) Expert systems:

They are systems making its inference process out of a knowledge basis formerly stored. This knowledge basis has rules and facts regarding a specific knowledge domain. This system is construct by the knowledge engineer that has the function of extracting out of one or more experts the knowledge of one specific area, and placing them into a knowledge basis, on an edible way adequate to the inference process [3].

The major advantage of the expert systems it is the possibility these systems have for explaining the way a solution was find. This allows the users not only to know a problem's answer, but also to know the reasoning route used by the expert. The limitation of this type of technique is its learning difficulty. Several works published, generating learning strategies for the expert systems, but this area is still open.

b) Neural networks:

As informed before, the neural networks are make through the association of several artificial neurons (mathematics). The making of the networks have a biologic inspiration, and at the beginning based in research in this area. The real neurons are connected through chemical synapses, represented in the artificial network by weights (activation process of stimulation or inhibition). The central objective of a network is to be train (in other words, having the weights adjusted) to accomplish with a modeling process, forecasting, recognizing, beside other. The most famous training process is the error back-propagation.

The major advantage of the neural networks is its learning facility. The many existent structures of neural networks make possible the characterization of several problems. This technique works very well when it is necessary to extract and to represent information in a great set of numeric data. The limitation of this technique is tight up to its capacity for explaining how a solution was model, or a given answer was achieved. The black box characteristic of the neural networks do not allows the identification in its inside a similarity with the several steps of the physic process under modeling. Some developments have been made for to try the set up of a connection among the several elements of a neural network and the modeled physical system, but there are yet much to be done [4].

c) Fuzzy logic:

This is a mathematic theory that tries to represent, in a more natural way, the pertinence of an element to a given set. Its use in intelligent systems happens mainly by the capacity for representing usual language magnitudes in the real world, through sets of this theory. In the technical literature it is customary the use of this theory, mainly with fuzzy expert systems and fuzzy neural networks, respectively.

These systems win in representation flexibility. The inclusion of fuzzy logic into expert systems allows that these systems may represent linguistic magnitudes, and have a modeling of its reasoning process nearer to the human behavior [5].

The connection of the fuzzy logic with the neural networks allows that the networks may handle not only numeric data, but also linguistic magnitudes. This area have been receiving many contributions in the last years, and there are yet much to be done.

d) Genetic Algorithms

Genetics algorithms are global optimizing ones, based on natural selection and genetics mechanisms. They use an parallel procure and structured strategy, but random, aiming to reinforce searching of "high aptitude" points, that is to say, points in which the function to be minimized has relative low values [6].

Genetic algorithms are used for procurement of the best parameters for membership functions. The linking of these parameters are the population individuals (chromosomes) evaluated according the number of required iterations for parking the vehicle as per the adjustment set up for each individual.

e) Case-based reasoning:

This system type is center in the idea of using solutions of problems that happened before, for the new problem solution. This happen through the analysis of the historic information set up in a logic way as a sequence of sub-problems to be solved. These systems try to simulate the way a person solves a given problem based upon his past experience. Its describers that access the search indexes of past cases represent the problem. Once found, these cases modify to try the adjustment to the case under analysis. If this cannot happen the human intervention is required to set up a new example. This system type is indication specially when the expert system number of rules grows up much, making the good maintenance of the knowledge basis impossible, or when the quantity and complexity of the rules are great, turning impossible the knowledge acquisition process [7].

Intelligent Restoration for Power Substations with Expert Systems

Special features of the program

The post-contingency restoration of the normal operation configuration of a Power Substation (SE) is currently done by means of the intervention of the operator and follows pre-established operational criteria, which are determined by engineering studies.

Taking into consideration the growing complexity of the topologies of the SE's, which require extensive restoration instructions, there is an increase both in the probability of human failure and in the time spent for execution of the restoration actions.

The main lines of the restoration include the reasoning for identification of the need for restoration actions, of validation of measurements, of diagnosis and of the structuring of the restoration-switching scheme. All the functions have a decisive nature, and may be automated by means of utilization of the Artificial Intelligence - Expert Systems (ES) techniques, which allow the achievement of solutions with a high degree of reliability and performance.

The conception and development of an automatic system capable of restoring a SE necessarily involves the analysis and evaluation of the previously established models and the definition of the strategy for solving the problem. The inherent features of the "restoration" problem recommends the utilization of Expert Systems as the most suitable tools for equating and solving it. A system that will assist with the restoration of a SE by inference of the switching scheme requires a constant and complete vision of the operational states of the components and equipment comprising the SE. Is must be provided with the means for evaluating the agent of the occurrence, for delimitating the faulted areas isolated by the operation of the protection, characterizing whether the problem has a permanent or a transient nature and identifying the components involved and those affected.

Thus, the surveillance covers the static attributes, comprised by permanent data and attributes which characterize the component or the SE and the dynamic attributes, which describe the properties or states subjected to modifications. Is must be defined so as to generate a list of the actions required and sufficient for normalizing the operation of the SE after a partial or total disconnection of its components, restoring it, under a stable mode, back to the Electrical Power System [8].

The purpose to be attained is that of the restoration of the largest possible number of SE components. Based on the evaluation of the input data, the causes of the problem, the components involved and affected are identified. Then, after a thorough analysis based on knowledge and an evaluation of the set of conditions associated to the topology and to the operative conditions of the SE, the components that should and those that should not play a role in the restoration are identified and a decision is made as to when and how the new start-up shall take place, within the restoration sequence. Thus, the best configuration and the switching sequence for attaining the optimum post-contingency operative condition is defined.

The name of this system is ESRASE (Expert System for Substation Restoration) [1] and has been developed with 138-13,8 kV CEMIG Power System substation, as presented in Figure 3.

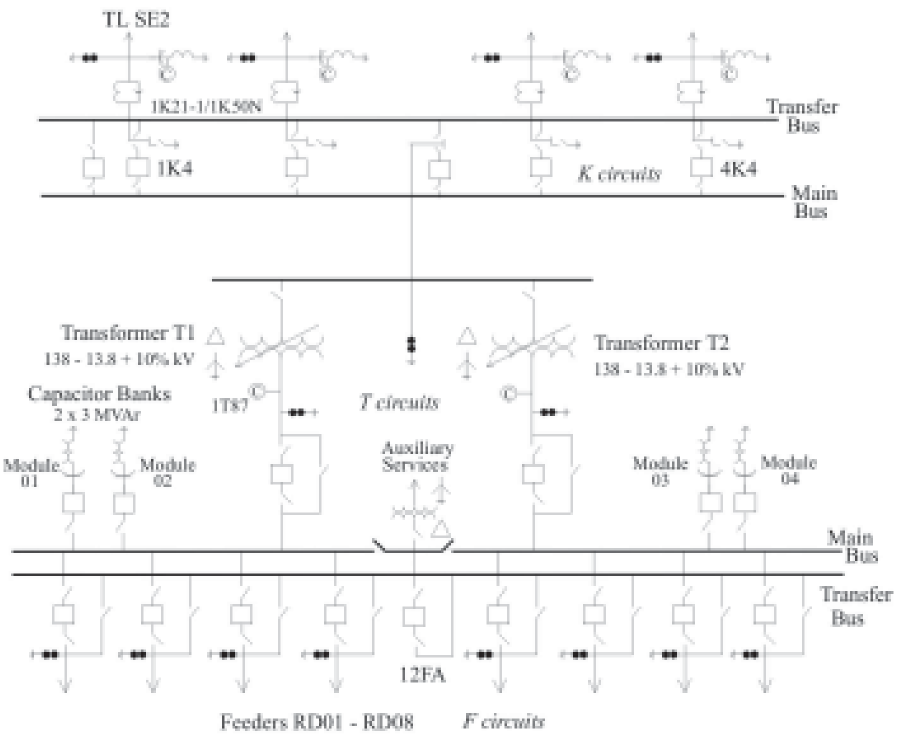

Figure 3 - Typical 138-13.8 kV CEMIG Configuration Substation.

Illustrative Example

Among the most important actions in a switching plan, the switching of disconnecting switches and circuit-breakers are to be mentioned. While performing a switching, one of the requirements of paramount importance is the interlocking. This consists in restricting the switching freedom of a given equipment with respect to the states of the other switching equipment that exist in the circuit and the control devices associated to them. In addition, this switching must consider the constraints and operating orientations present.

Considering the circuit-breaker shown in Figure 4 with its respective disconnecting switches, the following statements are valid as far as the interlocking of the opening/closing command of the switches is concerned:

- switches 1K3 and 1K5 can be switched only if circuit-breaker 1K4 is open;

- switch 1K5T can be switched only if switches 1K5 and 1K6 are open, and V(1K) is equal to zero;

- switch 1K6 can be switched only if circuit-breaker 1K4 and switches 1K3 and 1K5 are closed.

These rules hold for all circuit-breakers with the same topological characteristics, independent of the voltage or circuit level. Thus, it is possible to implement the interlocking for this kind of bay by using a set of production rules where the general structure of the predicate is:

interlocking_switch_switching(CIRCUIT,SWITCHING, SWITCHES_OPEN,SWITCHES_CLOSED)

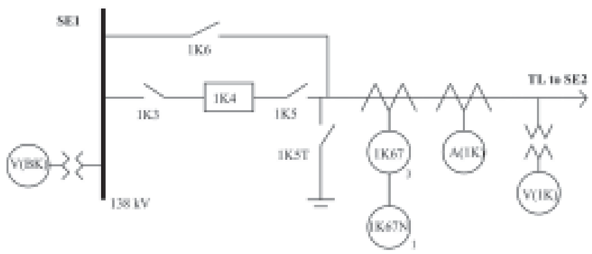

Figure 4 - Typical Transmission Line Bay 1K

A partial list of interlocking conditions written in Prolog is shown below:

interlocking_switching_device("3","off",["4","5T"],["3"]).
interlocking_switching_device("4","off",[ ],["4"]).
interlocking_switching_device("5","off",["4","5T"],["5"]).
interlocking_switching_device("5T","off",["5","6"],["5T"]).

interlocking_switching_device("3","on",["3","4","5T"],[ ]).

interlocking_measure("3"," ","A").
interlocking_measure("4"," "," ").
interlocking_measure("5T","V","A").

In the above partial list, for instance, the predicate "interlocking_switching_device" is composed by the following four arguments: number of the switch, new status of the switch, list of switches that must be opened so that this new switch status can be achieved, and list of switches that must be closed so that this new switch status can be achieved. Of course, in the case of the first fact above, in order for switch "3" to change its status from "on" to "off", itself must be included in the list of closed switches.

To send a command signal from a switching device, the program checks the signal permission with respect to the interlocking condition set; this validates or blocks the signal. When the program tries to validate a specific command of the trainee, the following messages can appear on the screen, according to the authorization answer:

More elaborate switching such as isolating a bus or energizing a transformer, join all the operating procedures and command actions necessary to its performance, including the verifications of the switching selector settings, interlocking, signaling and checks of the operating conditions.

Overview of Short-term Load Forecasting Methods

The main objective of power systems forecasting is to enable in any time an adaptation between demand and generation. This adaptation must consider load and generation characteristics and possible paths in transmission and distribution networks to supply energy to consumers [9]. Load shapes must be represented by hourly values, daily values or weekly cycles. Load shape values can be affected by weather or seasonal variations or even by weekly, monthly and annual cycles.

On the other hand, the generation characteristics can be affected by predictable elements such as: dry periods or preventive maintenance, and by random elements, as forced outage. Possible paths to supply energy to consumers are found by logical techniques and heuristic search.

Problem Formulation

The load forecasting can be devised in two general parts: peak load model and load shape model. The first one deals only with daily, weekly or monthly peak load modeling. In the second, all load shape interval is modeled. This paper presents an alternative procedure for the latter modeling.

In load shape model, the load forecasting value F(t) is obtained through operation of a standard load, B(t), and from a deviation load, W(t). This operation can be additive (eq.1) or multiplicative (eq.2).

$F(t)$

$$F(t) = B(t) + W(t) \qquad (1)$$

(2)

a. Standard Load - This value must characterize the base load of the feeder, area load or system load to be forecasted. It is calculated using historical data, that must be clustered according to time-of-day, day-of-the-week and time -of-year criteria (weekly, monthly or season of the year).

The standard load calculation can be devised in two parts. The first one makes the average of all common days in the same period. In the case under study, e.g., holidays had a similar behavior to Saturdays and Sundays and so they were clustered with them. The second part investigates on the particular characteristics for each day of the week, separately. For this to be done, a simple or weighted moving average is made. Equations (3)-(5) show the standard load calculation.

$$B(t) = B_1(t) + B_2(t) \quad (3)$$

$$B_1(t) = \frac{1}{m.n}\sum_{w=1}^{m}\sum_{d=1}^{n} L(t,d,w) \quad (4)$$

$$B_2(t) = \frac{1}{n}\sum_{w=1}^{m} L(t,d,w).B_1(t) \quad (5)$$

Where L(t,d,w) is the load at time t for the time-of-the week d and week w. The value of *n* can change form one week to another and represents the weekdays that are homogeneous. The value of m represents the number of days in the period being modeled.

Other factors can be summated to eq. (3) depending on the correlation of data. For example, in [1], it in proposed the inclusion of a second order polynomial item and weather dependent components.

b. Deviation Load - This value is used to represent the most recent variations of the load. This value contains information about latest hours or far as latest days. Autoregressive and exponential smoothing are the most common methods used to calculate the deviation of load value.

In this program, standard load and deviation load have fuzzy meaning, and three fuzzy knowledge bases are built. The first knowledge base includes historical data of the load; the second includes data of recent performance of the load. These knowledge bases are composed of fuzzy conditional statements. The third knowledge base enables the inclusion of operator knowledge of the load from the next hour to the next 24 hours. This base includes fuzzy values in the description of the rules. The operator knowledge inclusion is very important for special loads or for special characteristics due to external factors. A fuzzy logic inference engine computes the final load forecasted value [10].

This program has been extensively used to CEMIG Power System for many years with very good results [11].

Illustrative Example

This section presents some features of user interface for off-line model. Figure 5 shows the main window of the program. The upper part of the window shows the numerical data for the forecasted and used load; while the lower part shows the same data in graphical form. The user can modify many characteristics of this window, creating a personal interface.

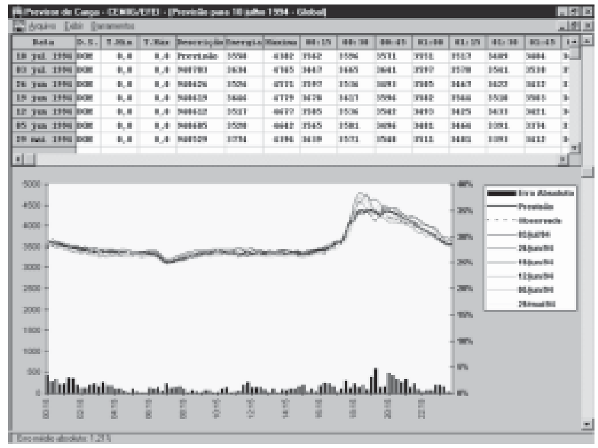

Figure 5 - Main Window in the Forecasting Program.

An intelligent system for power adaptive protection

The steady load expansion throughout the distribution network and the strengthening of load feeding regulations, enforcing more rigid penalties for breakdowns in supplying electric power, have increased the improvement of power distribution systems protection.

A new trend of studies for the improvement of equipments and methods used in distribution systems, aiming more selective protection, have generated a new concept of protection systems that be adaptive to the system they are connected to, looking for better dependability and adaptation to the continuous increase of new consumers, giving birth to the system known as adaptive protection.

In developing this system it was realized that to manage this adaptation using intelligent specialist systems, would make it easier the introduction of more strong functions, allowing the integration widening of systems and the adjust versatility for the protected circuit branch.

The objective of this project was the development of a new protection structure for the AES-Eletropaulo' substations and particularly for the DTS-Limão. Thus it was bought from ABB the protection relays REX 521-H05 and the supervision system MicroScada, which will operate together with the program that was made with this project [12].

The structure made is flexible allowing the protection system layout expansion and the inclusion of new type of relays and functions. Both systems MicroScada and SIP (System for Intelligent Parameterization - name of program developed in this work) operate on-line in accordance with the web topology configuration and the main system changes.

Special Features of this Program

The implemented methodology took in consideration the global system state, the load level as used by system, besides other outside factors related to protection systems. For that purpose were developed mathematical routines adequate to protection studies, and summed up the area engineers' knowledge as Intelligent Systems. This system for decision support was introduced using the intelligent multi-agents systems concept, by the use of many advanced techniques of Artificial Intelligence interacting with a master agent, and cooperating between themselves for the solution of problem for protection system adjustment. The objective was to sum up the implementation advantages from each artificial intelligence technique used in the classic problems of electrical systems, and suppressing their disadvantages [13].

The concept of Intelligent Agent (IA) happened inside the category of systems that act rationally, being the agent an autonomous software entity in position to feel its environment through sensors, and act inside this environment owing to actuators, for witch it is necessary to make correct inferences and be able to represent knowledge, to express results in natural language, learn and feel the world, etc.

What is rational in a given moment depends on four factors:

- The performance evaluation that defines the success degree;
- The whole previous agent's perception, named perceptions sequence;
- What the agent knows regarding the environment;
- The actions the agent may develop.

There is not a definitive and generally accepted concept by the whole scientific community for intelligent agents (IA's), but the above mentioned idea translates the used conception into implementation of all the agents introduced into this work, as shown in Figure 6.

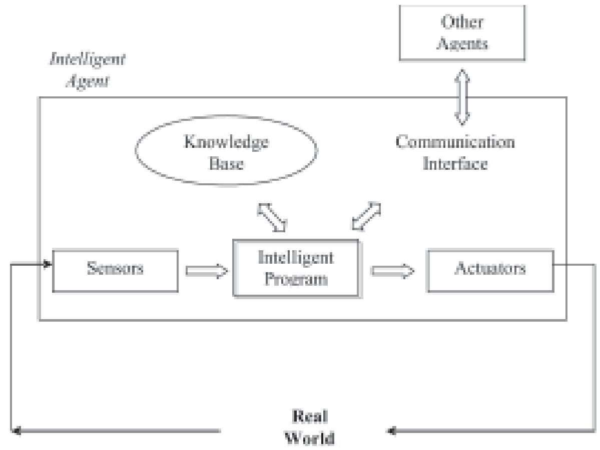

Figure 6. Used architecture from an IA

An Intelligent Multi-Agent System (MAS) has the basic premise of providing mechanisms for generating intelligent systems starting from software autonomous entities, called agents. These agents interact through a common environment used by all the MAS members, acting and changing its state.

Once each agent has a skill and private goals the MAS has to be able in providing mechanisms for interaction and coordination of these entities. This way the MAS is able to solve problems bigger than the knowledge domains of its members.

The MAS may be classified as reactive and cognitive. The reactive systems are compounded by a great number of very simple agents interacting between them and having no explicit representation of environment state and of other agents, nor of their past actions. The main influence of this MAS type comes from entomology, the science that focuses on insect's behavior. Yet the cognitive systems in general have little agents, once each agent has a rational behavior, and have a symbolic logic conception of the world, planning its action strategy according a strong mechanism of logic inference. This type of agent besides using techniques of deduction and learning, consider also characteristics aspects of human will, like believe, desire and intention.

Tests Making and Integration with MicroSCADA

Many tests were performed on SIP Program for the DTS-Limão. Figure 7 shows the sub-station circuits presenting its information's, accounting the components number.

It is possible to have information of each circuit just clicking on it. It is possible also exhibit the elements present in the respective circuit and allowing the user to define the name of the circuit breaker and relay that actuates upon it. With data from GRADE it is possible to extract geo-referred position of all recorded components, making possible to have a diagram of all circuit branches, allowing its exhibition in a graphic way and also giving way for the calculation of power flow and short-circuit level along them. Thus this window was developed having the function of to show the branch graphic diagram turning possible the execution of the power flow checking the voltage drops along the lines. Figure 8 shows the diagram of one branch from DTS-Limão already with its executed power flow.

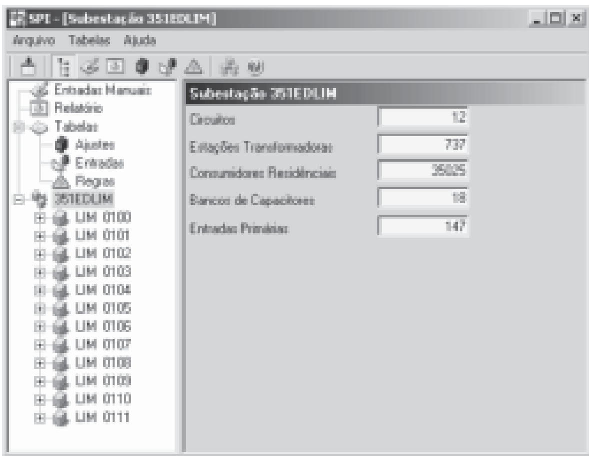

Figure 7 - Information of DTS-Limão

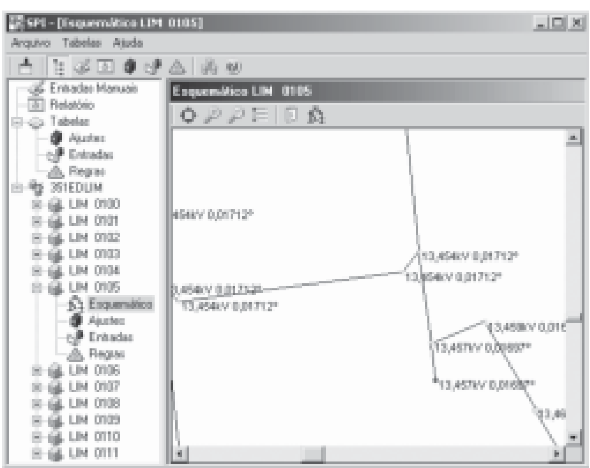

Figure 8 - DTS-Limão's Circuit Diagram

An Intelligent Tool for Distribution System Reconfiguration

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 the other hand, more and more the consumers are concerned with respect to the steady supply of power. Indexes like DEC and FEC are supervised and claimed by the controlling agencies. A reduction of the values of these indexes is under consideration to be enforced. It is known that not complying with the indexes may generate fines for the utility companies.

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.

Program Flowchart

Following it will be presented the flowchart from the Development Program named "Manoeuvre", in which it will be indicated the information route, so as the processing used in each data set parcel for obtaining the result, as shown in Figure 9.

The user will generate a request through an adequate interface in the Manoeuvre program, for this the user should select what line he wants to set up in fault in a line list. There are two simulation possibilities, in the first, named "Simulation in Basic Mode", the user does not need to inform anything else, and in the second, named "Simulation in Advanced Mode" the user needs to inform the feeder, or bus, that he wants to use as a source for recovering the disconnected circuit.

Having this data the program Routes starts the search process that will be executed by the Expert System for Reconfiguration (SSR). The SSR will generate possible solutions for the request compliance, these solutions will be forwarded for the Numeric Routines (NR), which are responsible for the power flow calculations, sub tensions and over tensions. At last, all the solutions are forwarded for the Classification Ponder System (CPS), which is responsible for the classification according the choosing criteria of smaller overloads, and little sub tensions or over tensions.

Then the CPS will present the best solutions in a window for the user. The user also has tools for the making of parameters and configuration of the data basis, so as a tool for the import of data from bus bars, to make it possible to up-to-date this for other circuits of the Brasilia Power System (CEB).

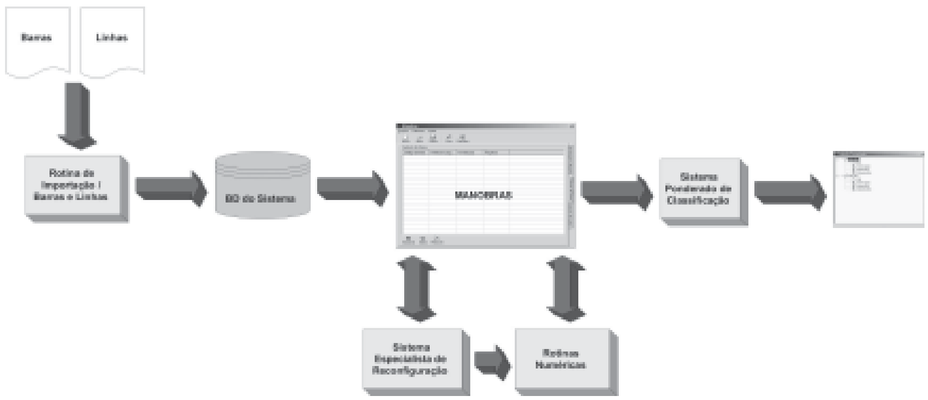

Figure 9 – Program Chart flow

Details of Each Module

a) Expert System of Reconfiguration

The Expert System of Reconfigurations (SSR) has resources for, after the fault be found and identified and the defective branch disconnected, to make the selective and effective recovering, in order to prevent that the defective branches or permanent faults spread out inside the system.

Depending on the fault, the SSR should recover only part of the disconnected components, or part of the load. Anyway, there is a recovering sequence, as Table 1shows:

Table 1 – Recovering Sequen

BEGINING		
↓	Sources	TL
	Transforming	TRANSFORMERS
		AUTOTRANSFORMERS
	Load	TL, FEEDERS
	Control	CAPACITOR BANKS
		REACTORS & SYNCHRONOUS
END		

The operation policy and the state before and after fault from equipments, make the data source that starts the recovering process. Based into these data and after its analysis, the recovering actions will be initiated and their sequence will be set up.

b) Numerical Routines

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

This operation state comprises:

· Determination of tensions and all system bus bars angles;

· Determination of active and reactive power flows through the network branches;

· Determination of the lost power, used power, and the generated reactive and active power, in the many system elements.

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

c) Ponder System of Classification

The Ponder System of Classification is based in Ponder Weights and was introduced by generating a set of weight rules for the many factors that are limiting the solution [14], for example: over loads, sub tensions and over tensions.

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

Conclusions

Power system operation and control become larger and increasingly complex, and as a consequence, to create it is more difficult to complete in time and within the budget's constraints. It has become very difficult to create these new applications with traditional software development technology. When finally finished, they are difficult to understand, to maintain, to integrate into old application and to modify for new requirements.

Studies in computer science have shown that the reuse may improve software development productivity and quality. Productivity increases as previously developed assets can be used in current applications, which saves development time. Quality may be increased as frequently reused assets have been tested and corrected in different study cases.

The main idea of this work is to present some computational packages for power system operation, and also to show the development of a computer tool based on this approach to help operators during their many tasks.

Finally, the integration of two or more numeric or intelligent techniques have been allowing to the computer systems to solve problems or find solutions that but one of the techniques alone could not get. The use of techniques together allow limitations be covered, always using each one's better characteristics.

References

[1] G. LAMBERT TORRES, G.M. RIBEIRO, C.I.A. COSTA, A.P. ALVES DA SILVA & V.H. QUINTANA - "Knowledge Engineering Tool for Training Power-Substation Operators", IEEE Transactions on Power Systems, Vol. 12, No. 2, pp. 694-699, April 1997.

[2] G. LAMBERT TORRES, J.M. ABE, M.L. MUCHERONI & P.E. CRUVINEL – Advances in Intelligent Systems and Robotics, IOS Press, 217p, ISBN 1 58603 386-7, Amsterdam, Holanda, 2003.

[3] C.-C. LIU, S.J. DICKER, G. LAMBERT TORRES et al. - "Testing and Maintenance Procedures for Expert System in Power System Operation and Planning", Electra, No. 173, pp. 92-113, Aug. 1997.

[4] W.A. FARAG, V.H. QUINTANA & G. LAMBERT-TORRES - "A Genetic-Based Neuro-Fuzzy Approach for Modeling and Control of Dynamical Systems", IEEE Transactions on Neural Networks, Vol. 9, No. 5, pp. 756-767, September1998.

[5] W.A. FARAG, V.H. QUINTANA & G. LAMBERT-TORRES - "An Optimized Fuzzy Controller for a Synchronous Generator in a Multi-Machine Environment", Fuzzy Sets and Systems, Vol. 102, No. 1, pp. 71-84, Elvesier Science, 1999.

[6] G. LAMBERT TORRES – "Hybrid Systems", Modern Heuristic Optimization Techniques: Applications to Power Systems, por K.Y. Lee & M.A. El-Sharkawi, Wiley Press, 2004.

[7] H.G. MARTINS, G. LAMBERT TORRES & L.F. PONTIN – "Para-Consistent Case-Based Reasoning", International Conference on Intelligent System Applications to Power Systems, ISAP'2005, Washington DC, USA, 2005.

[8] A.A. ESMIN G. LAMBERT TORRES & A.C. ZAMBRONI DE SOUZA – "A Hybrid Particle Swarm Optimization Applied to Loss Power Minimization", IEEE Transactions on Power Systems, Vol. 20, No. 2, pp. 859-866, May 2005.

[9] H.G. ARANGO, A.C. ZAMBRONI DE SOUZA, G. LAMBERT-TORRES & A.P. ALVES DA SILVA - "Difference Between Regular and Deterministic Chaos Processes Based on Time Analysis of Load: An Example using CEMIG Data", Electric Power Systems Research, Vol. 56, pp.35-41, Elvesier Science, 2000.

[10] G. LAMBERT TORRES, L.E. BORGES DA SILVA & J.O.P. PINTO – "MiniMax Techniques", Webster Encyclopedia of Electrical and Electronics Engineering, por John Webster,

John Wiley & Sons, Inc., 2001.

[11] G. LAMBERT TORRES - "Fuzzy Techniques for Load Forecasting", IEEE Power Engineering Society Summer Meeting, Vol. I, pp. 178-179, Seattle, USA, Jul. 16-20, 2000.

[12] G. LAMBERT TORRES, L. CRISOSTENES, R. ROSSI, L.E. BORGES DA SILVA & C.H.V. DE MORAES – "A Real Implementation of an Intelligent Adaptive Protection", 1st International Conference on Advanced Power System Automation and Protection, APAP 2004, Jeju, South Korea, Oct. 25-28, 2004.

[13] A.R. AOKI, A.A.A. ESMIN & G. LAMBERT TORRES – "An Architecture of a Multi-Agent System for Power System Operation", WSEAS Transactions on Computers, World Scientific and Engineering Society Press, ISSN 1109-2750, No. 2, Vol. 3, pp. 408-412, April 2004.

[14] K. TOMSOVIC & G. LAMBERT TORRES – On the Use of Fuzzy Logic Techniques for Addressing Uncertainty in Power System Problems, PMAPS-RIMAPS Tutorial, 83 pages, 2000.