Intelligent Multi-Agent System for Power System Restoration

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Abstract: - The intelligent system proposed in this paper has been implemented for helping the Piratining a Power and Light's technicians in the system operational occurrences. It allows the operator to go through the ways for problem solving. The use of hybrid systems with artificial intelligence techniques, together with correctional numeric techniques, make possible to solve non-systematic problems and to show to the user the reasoning path used for the problem solving. This last factor is very important in a learning process, one of the aims of this system, once it make possible for the operator to understand the way the specialist in the area uses for solving one problem.

Key-Words: - Intelligent systems, Power system operation, Restoration, Multi-agents, Multilevel Flow Modeling.

1 Introduction

The increase in the number of blackouts in the Brazilian power electric system (PES) is a consequence of system overload and lack of investments in the electric system. Besides, the long blackout impacts in consumers, economy, and in the PES itself, makes the fast and effective restoring very important [1].

One important part of PES is the electric substation, which provides the system the control, transformation and interconnection requirements. The restoring of a substation normal configuration, after a fault occurrence, is made through one human operator intervention, time and again with the help of supervision and control automated system [2].

Considering the increasing complexity of substations configuration, and that the restoring action is not an automatic procedure, the probability of an human failure, the time required for the execution of the restoring actions is a large one and should be avoided.

This paper comprises the application of Intelligent Planning together with the functional modeling technique Multilevel Flow Modeling (MFM), for the development of a decision support system for helping the substation operator regarding a restoring situation.

The combination of intelligent planning with actual engineering systems have been considered particularly difficult in view of the strain for obtaining sound knowledge in procedures from experts. Besides, this knowledge once obtained remains dependent of dominion and its re-use is scarcely applied in other applications.

The modern control centers are being improved with one more support tool for the decision take that are the Intelligent Systems. These systems have been placed between the old outlets from the several existing programs in the center (state evaluator, contingency analysis, alarms, etc), and the operators, aiming to supply one already screened information and the possible correction procedures for solving the existing problem.

2 Functional Modeling

The aim of this item is to describe briefly the basic concepts of the functional modeling technique MFM (Multilevel Flow Modeling). The MFM functions and objectives definitions will be described, through the construction principles of one MFM model. Also will be shown the basic concepts for the map out of acquired knowledge from one MFM model in one representation of intelligent planning.

In one supervision system it is important to obtain information that explain what the system parts should make (functional qualities), and why they should do it (intentional qualities). This type of information, so called mean-end, is scarcely supplied even non-existent in the classic modeling techniques, which generally explain how the different system parts interact (behavioral qualities).

The functional modeling techniques pick up what functions the system parts can do individually, or together, and how these functions are performed. Multilevel Flow Modeling (MFM) is strongly related to diagnostics, reasoning based upon models and techniques in general for modeling.

MFM uses a very high level of abstraction and is adequate for planning because it allows reasoning regarding the system functions, and an abstraction from the implementation technical details. One of the differences between MFM and other modeling techniques is that MFM extends the survey based upon models with new methods, adequate for the application in complex systems. Another important difference is the functions and objectives definition, while other techniques do not define these concepts explicitly.

3 Basic Concepts of MFM

MFM introduces objectives as important and necessary for the representation of objectives of one engineering system. These objectives are achieved if all the system parts work as aimed by the system designer. MFM uses the function concept to catch up the intentions, the functions being the outcome of interactions between the system physics components, and may change according the aimed objectives.

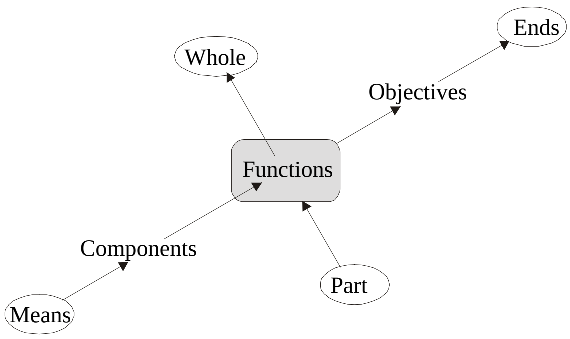

Fig. 1: Functional decomposition axes used by MFM

MFM uses two types of functional decomposition, whole-part and means-ends, for the representation of one engineering system, see Figure 1. The decomposition whole-part is used to describe one-function refinements, for presenting more details regarding its realization, or technical implementation. Still one function may represent a complex system using a high level of abstraction; this function may yet be decomposed in sub-functions representing with more details the parts that represent the system. This process generates hierarchic structures with new functions and defined objectives. The decomposition means-ends looks for the function identifications and their connections, so as the function relations with the system objectives.

3.1 Objectives and Functions

The concepts of objectives and functions are important for the representation of engineering system functionality, because all the systems of this type were built with specific purposes. The objectives should catch up the systems purposes, and the functions should express the useful behavior of physic components necessary to reach the objectives.

The following are useful concept definitions of objectives and functions adequate to the aims of MFM technique:

Objectives: define the tendency for witch some system activities or its parts are directed.

Functions: define which is the system role, or of its parts, for one or more objectives may be accomplished.

From these definitions it is possible to notice that the objectives and functions concepts are strongly related, once the MFM consider the function as an useful behavior from one system that may be explored, in accordance with its behavior proprieties, to achieve the desired objectives.

3.2 MFM Structures and Means-Ends Relations

To represent one system's functionality, MFM defines a set of relation's aims-ends that are used for describing the several relationships between functions and objectives:

Source: these functions describe the system capacity for acting as an infinite source of material;

Drain: these functions describe the system capacity to operate as a drain for material;

Transportation: these functions represent the system propriety in supplying a material transfer capacity; the transport function defines one direction for the material flow.

Warehousing: these functions describe the capacity of a system to warehouse material;

Balance Sheet: these functions describe the capacity for a system to provide a balance sheet of material;

Block: these functions represent the propriety of a system to prevent against the transfer of material between two sub-systems.

These functions are adequate for the representation of complex systems functionality that comprises the handling of mass and/or energy. The connection relation link functions through inlet and outlet points, forming a function structure.

One structure MFM is defined as a linked group of functions that process the same type of material. The structures are inter-related by objectives through means-ends relations of the type reach and condition. The reach type relation is used for describing which MFM objectives are accomplished by structure. Usually, one objective is reached by one or more functions. The condition type relation is used for connecting one MFM objective with one function pre-condition.

4 Substations Functional Modeling

The MFM model construction process is highly dependent of the desired abstraction level. A system may be described under several different points of view, and may define several representation levels.

In one substation plant, there are only energy flows, since mass and information flows be not considered. This way, but one representative level will be considered that is the energy flow level.

To construct the MFM model for a substation plant it was necessary to split up the substation in several structures: transmission lines, inlet busbar, transformers, outlet busbar, and loads. For each structure we have a MFM model that fits to one objective, that is the pre-condition of the following structure. In Figure 6, we have a MFM model for the transmission line of one single bar substation.

The MFM model of a transmission line does not include the filter and the lightning arrester, because they are not important for the recovering purposes. The two balances BaN1 and BaN2 represent two diagrams nodes. S11, D1 and S12 are united in transportation TrDS1 because they work as a set and execute the same function.

These MFM functions were defined to reach the objective G1 that is to energize the inlet busbar. For transportation TrDS1 .may work accordingly, the objective GD1 has to be reached by the second structure. It was not used a MFM model for protections, a work with a group of rules giving a Boolean operation condition was used instead. All the forecasted protections for one transmission line and the differential protection frequently used in busbars are included in the second structure shown in Figure 6.

In Figure 3 we have one MFM model for inlet busbar. The function SoB1 is activated by G1, and it is possible to have more than one structure, shown in Figure 2 that reach G1 if we have more transmission lines.

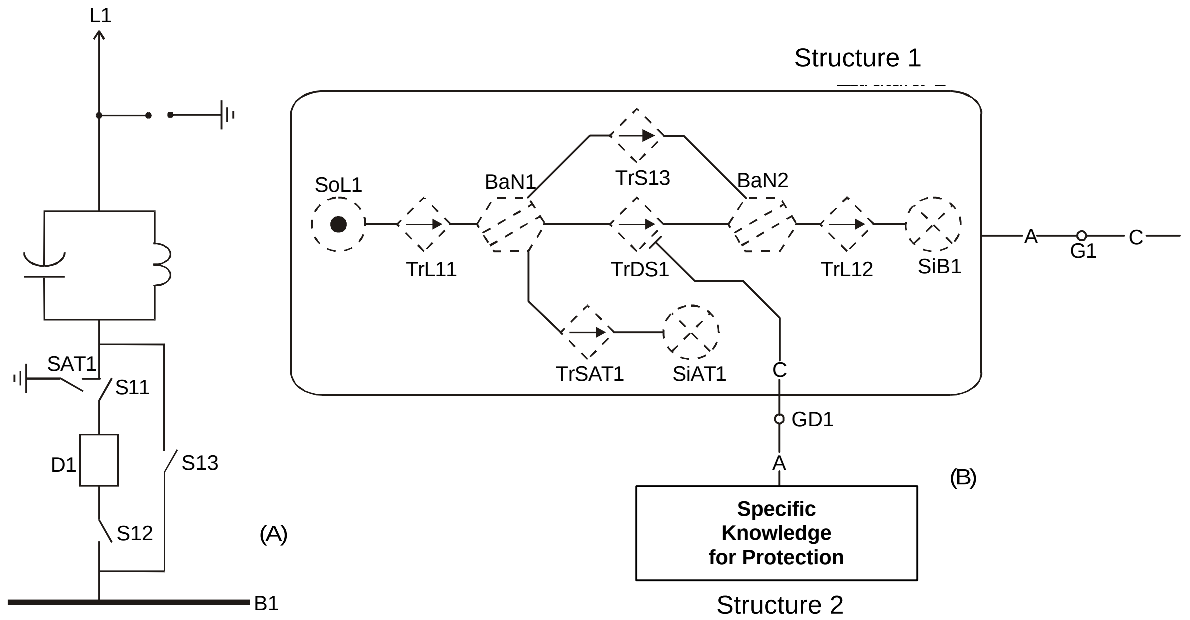

Fig. 2: (A) Diagram and (B) MFM Model for transmission lines

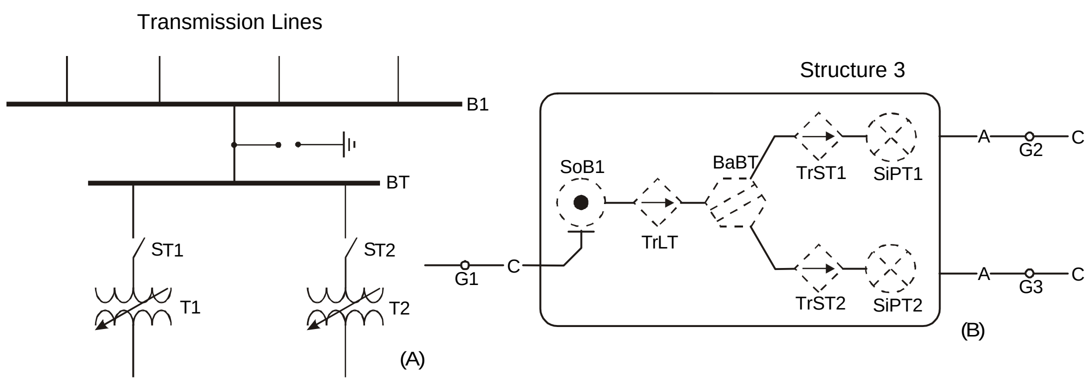

Fig. 3: (A) Diagram and (B) MFM Model for inlet busbar

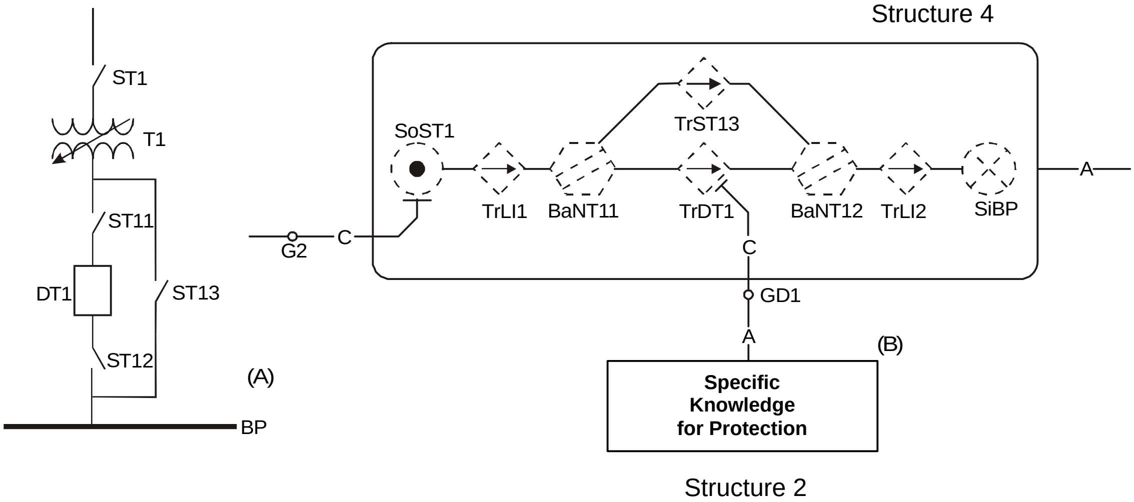

Fig. 4: (A) Diagram and e (B) MFM Model for transformer T1

As transformers have different current and voltage levels in primary and secondary windings, transformers were separated in two different functions: the drain function for the primary winding, and the supply function for the secondary winding. Having two transformers T1 and T2, each one reach one objective, G2 and G3, which are energize the transformers secondary windings.

In Figure 4, we have a MFM model for transformer T1. The function SoST1 is conditioned by objective G2. This structure reaches the objective G4 that is energize the outlet busbar. The functions TrDT1 and TrDS1 are similar in their operations.

According to Larsen [3], the process of a start-up plan development for a MFM modeled plant, may be compared to the problem for establishment of each function in the model.

One function may be set up when both the neighbor functions in the model are in states wanted by the designer and contribute for reaching the operational objectives. Before establishing a function it should be qualified. One function is qualified when it is ready to be integrated with other functions, is that to say, it is able to provide a useful behavior but it is not operating yet.

Based in these concepts, a planning domain was built composed of generalized operators QUALIFY and ESTABLISH, as shown below:

Operator ENABLE <F>
Var:
<F> Function
<NF> Next Function
<PS> Process state
<GD> Goal
Pre:
Enabled <NF>
Goal Achieved <GD>
Structural-pre <PS>
Add:
Enabled <F>

Operator ESTABLISH <F>
Var:
<F> Function
<PF> Previous Function
<A> User Task
<G> Goal
Pre:
Enabled <F>
Goal Achieved <G>
Established <PF>
Activity <A>
Add:
Established <F>

The map out functions is responsible for defining the planning variables in accordance with the acquired knowledge stored in the MFM model.

The topologic structures describe the relation's means-ends MFM. For each function defined in the model, the neighbor functions, previous and posteriors functions are identified and organized in structures.

The process state structures catch up the specific knowledge from a domain. Knowledge must be acquired as a process state when it represents one condition that should be satisfied for supporting the basic behavior of a MFM function.

The solution of a planning problem comprises a sequence of actions that once executed will drive the system for an objective state. These actions come from the domain and generally represent one user action. If one outside action is required for setting up one MFM function, then the knowledge that represents that action should be acquired and stored into the corresponding structure.

5 Support System for Systemic Decision

The proposed system is shown in Figure 5. The system is divided in four parts: one knowledge system acquisition interface, one modeling system, one map out and one planning system.

The knowledge acquisition interface generates a database from substation protections and equipment. It is possible to work with three different topologies: simple bar, main and transfer bar, and double bar, these three topologies have been chosen for searching solutions to 138-13,8kV substations [4].

The modeling system provides an intermediate step for acquiring planning knowledge; in this point the database with the MFM models is used for building the planning domain. Beside, this system keeps one structure witch adds and changes easily the knowledge of each MFM function.

The map out between the modeling and the planning system is a set of map out functions responsible for instancing the planning operators and variables. These functions keep independence between both systems.

At last, the planning system is responsible for generate a series of complex plans based in the present substation state, according the specified knowledge domain [5].

5.1 Criteria and Philosophy of Restoring

The aim is to describe shortly the criteria and philosophy of restoring usually used for 138kV substations. The restoring priorities and sequence from equipment will be described, and yet the procedures for the substation restoring after the breakdown and the related occurrence of system disturb.

The prevailing energy model for the present structure of society makes essential the steady supply of electric power, according the established quality standards. The breakdown is considered an abnormal condition, which timing and extension should be reduced in view of the generated consequences and losses. Nevertheless, the electric system defects are inevitable, whether they are generated by outside or inside causes, by electric, environment or human phenomena.

Because the majority of defects are transients, the aim is to minimize the effects and guaranty a steady operation through techniques and equipment, able to provide faster system recovery after partial or total components breakdowns.

The substation recovery is initiated only after the correct and complete elimination of defects is done. During the transient period, the protective relays fill the presence of an abnormal condition in the system operational basic characteristics (voltage, current, frequency, etc) and actuate on the switchgear in a selective way as to isolate the defective component, or the one direct involved in the failure.

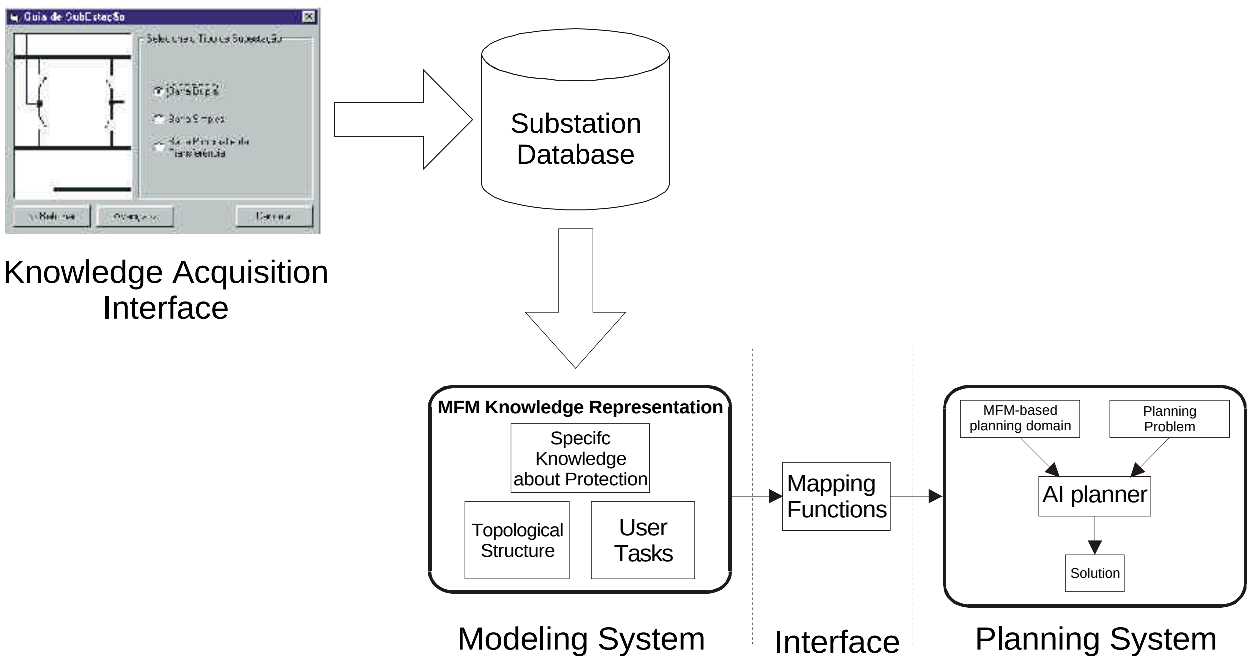

Fig. 5: Intelligent Planer Structure for restoring actions

The velocity or fastness of the protective relay action aims to reduce the extension of the occurred damage, providing the maintenance of normal operational condition in the healthy parts of the electric system. Nevertheless, depending on substation busbar arrangement, some healthy parts are shut down in view of the lack of adequate switchgear to break up short-circuit currents.

When the fault is transient, once the standard timing for elimination or removal of the cause ends, all the de-energized components may be reactivated in sequence by one recovery system. In the case of a permanent failure, disconnecting switches must be operated in such a way that the minor parts of the system, the one where the failure has occurred, remain de-energized waiting for the maintenance action. While the healthy parts, initially disconnected because of the switchgear limitations from the substation arrangement and other restrictions, should be energized.

It is very important that the restoring system has resources for one effective and selective restoring, soon as the failure be found and identified and the defective branch de-energized, avoiding that the defective circuit branches or the permanent faults actuate through the electric system.

Depending on the extension of fault, only part of the de-energized components or part of the load should be restored. However, there is a restoring hierarchy, as shown in Table 1.

Table 1 - Restoring Hierarchy

START		
↓	Sources	TL
↓	Transformation	TRANSFORMES
↓		AUTOTRANSFORMES
↓	LOAD	TL, FEEDERS
↓	Control	CAPACITOR BANKS
↓		REACTORS AND SYNCHRONOUS
END		

The operation philosophy and the previous and after fault states of equipment and protective relays, are the starting source of data from the restoring process. Based in these data and after analysis of them, the restoring action begins and will have its sequence defined.

6 Conclusions

The functional modeling technique FMT has shown to be adequate for acquiring planning knowledge, even though being efficient only regarding the substation topology knowledge. As the knowledge acquisition is based in the FMT model, to have a good model is fundamental.

The mastering of planning based in FMT may be easily understood, though it is necessary the development of specific operators according with the application. The necessary modifications for application in other types of substations is inner to the structures, in the arrangement of the FMT functions, making the maintenance easier and offering flexibility for the decision support system.

As this technique has shown to have a potential for new applications in other substation topologies, the aim is a future implementation of one interface with supervision systems and automated control for electrical substations, making valid the use of this support system for decision together with the automated system.

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