Power Systems Restoration Training - a Simulated Co-operative Approach

A. Silva [1], Z. Vale [2], C. Ramos [1]

[1] Computer Engineering Department,
Porto Polytechnic Institute
Rua Dr.António Bernardino de Almeida, 431, 4200-072 Porto – Portugal
phone: +351 22 8340500 fax: +351 22 8321159
email:asilva@dei.isep.ipp.pt, csr@dei.isep.ipp.pt

[2] Electrical Engineering Department,
Porto Polytechnic Institute
Rua Dr.António Bernardino de Almeida, 431, 4200-072 Porto– Portugal
phone: +351 22 8340500 fax: +351 22 8321159 email: zav@dee.isep.ipp.pt

Abstract. Adequate training programs for power systems restoration tasks must take into account that this is a co-operative activity involving several entities.

The proposed architecture of the Intelligent Tutoring System presented in this paper is based on a multi-agent system offering a simulated training environment.

Key words

Power Systems Restoration, Operator Training, Intelligent Tutoring Systems, Multi-Agent systems, Co-operative Learning

1. Introduction

We can see the power restoration task in power systems having suffered a severe incident as a multi-objective optimisation problem, to be performed in several successive steps and being bound by multiple constraints.

If we look at each individual task to be performed during this process, none can, under normal conditions, be considered as specially transcendent, but when we consider the whole of tasks to be handled, the various partial objectives to be attained and the multitude of constraints to be respected and conditions to be repeatedly verified, then the real difficulty of the whole process comes to fore. All this complexity must be addressed as much as possible in advance, by the careful analysis of the grid, and the definition of suitable restoration strategies.

The power restoration strategies, on the other hand, seem to be very difficult to generalise, especially due to significant differences between network topologies and characteristics, economic constraints and requirements, or simply different approaches to the restoration problem used in different countries by different companies. This is to say that any effort to establish a training program for the network operators responsible for the restoration process should be based on the identification of the basic building blocks of the restoration process upon which the specific procedures followed by their companies should be taught and drilled.

Some years ago, it was proposed the definition of what was called *generic restoration actions* (GRA) as a way of describing the generic tasks that should by force exist in any (or most) of the restoration strategies followed in the different power systems [1]. One example of these generic actions can be the pick up of a load in a way that its power requirements are met and no voltage or frequency limits are violated by the accompanying switching actions. Another obvious candidate is the synchronisation of two subsystems for which certain known pre-conditions must be met.

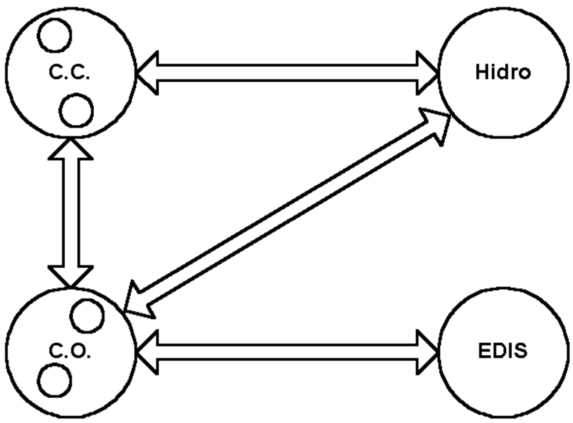

Fig. 1 Multi-agent environment

2. Operator Training

Typically, the management of a power system involves several distinct entities, responsible for different parts of the network. In the specific case of the Portuguese transmission network , four main entities can be identified:

- National Dispatch Centre (NDC), responsible for the energy management and for the thermal generation
- Operational Centre OC), controlling the transmission network
- Hydraulic Control Centre (HCC), responsible for the remote control of hydraulic power stations
- Distribution Dispatches (DD), controlling the electric distribution networks.

The power restoration process is conducted by these entities in a such a way that the parts of the grid they are responsible for will be slowly led to the their normal state, by performing the actions specified in detailed operating procedures and fulfilling the requirements defined in protocols previously established. This process requires frequent negotiation between entities, agreement on common goals to be achieved, and synchronisation of the separate action plans on well defined moments.

It is therefore clear the need for the training programs to take this fact into account by providing an environment where these different roles can be performed and intensively trained.

The way that traditionally this requirement has been addressed is based on the use of simulators. These systems are nowadays quite apt at describing accurately the behaviour of the power systems. It is therefore possible to turn them into the core of a training environment with great realism. Nevertheless, the fact that preparing these training sessions typically requires several days of work by specialised training staff, and the need to move away from their workplace at least four control centre operators during several days for the simulation to be convincing, has as a consequence that no more than 2 training sessions per year are usually attended. Another facility that is usually absent from a simulator-based training session is the capability to perform an accurate evaluation of the trainees knowledge level and learning evolution.

We see the use of the Intelligent Tutoring Systems (ITS) as a complementary tool tailored specifically to address the shortcomings of the simulators when used in a training environment. The reasons for that can be summarised as follows:

- They use knowledge about the trainee in order to lead the system adaptation to the trainee's;
- They can be fit with didactic knowledge allowing the system to choose different pedagogical strategies and to use diversified approaches whenever the trainee's evolution reaches an impasse;
- They are able to constantly monitor the trainee's performance and evolution, gathering information not only to guide the system adaptation but also to be used by the training personnel;
- They typically require very little intervention from the training staff, and can be used in the working environment without disturbing the normal working routines.

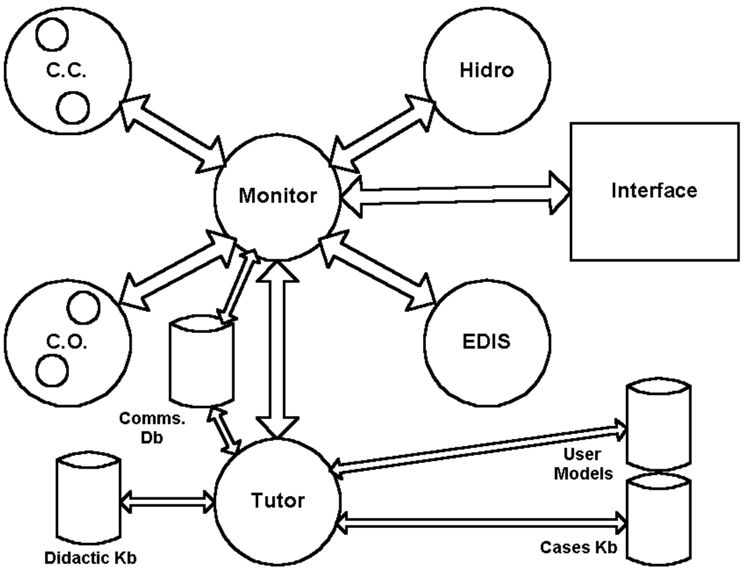

Fig. 2 System Architecture

3. Didactic issues

The previous work laid out by our research team in the area of power systems operators training has been based, from the pedagogical point of view, on a more traditional ground, by which the burden of the initiative lays always on the tutor's shoulders, leaving for the trainee a more passive role [2]. Hence, it looked as an interesting challenge the investigation of possible alternatives to this way of considering the tutorial process.

One such approach has been offered by the constructivist theories, that suggest that the learners should be given the opportunity to construct their own understanding by means of the interaction with a suitable environment. They put the emphasis in the process of learning rather than on the actual acquisition of the domain knowledge as a pre-determined set of concepts or techniques [3]. They support therefore the development of a more active attitude from the learners, by paying special attention to the *context*, or situation where the learning takes place, and the enabling of *activities* by which the learners interact in a active form with the environment, building their own knowledge out of their own experiences.

It seemed problematic from the beginning to try to use this kind of novel approach to the acquisition of the special aptitudes needed to conduct a complex process such as the power systems restoration process with its multiple objectives, multiple stages and multiple constraints. But looking further into the problem it seemed like a promising path to try and use theses views in order to build a suitable environment for the learning of the basic concepts and techniques without which there is no point in going further. So, as the trainee gets better knowledge of those basic elements and builds confidence, he can be slowly guided to a more hands-on approach to the whole process of the restoration, with intensive practice using real-life cases. In fact, we don't see how the restoration process as a set of parallel sequences of procedures performed from the beginning to the end could be learned by means of the mere interaction of the learner with the right context. Nevertheless, we think that a mixed approach could be a wise way of tackling the pedagogical problems posed by this particular domain.

4. Architecture

The chosen architecture for our system is based on the interaction of several agents personifying one of four entities that are present in the power system restoration process: National Dispatch Centre (NDC), Operational Centre (OC), Hydroelectric Generation Centre and Distribution Dispatch (fig. 1).

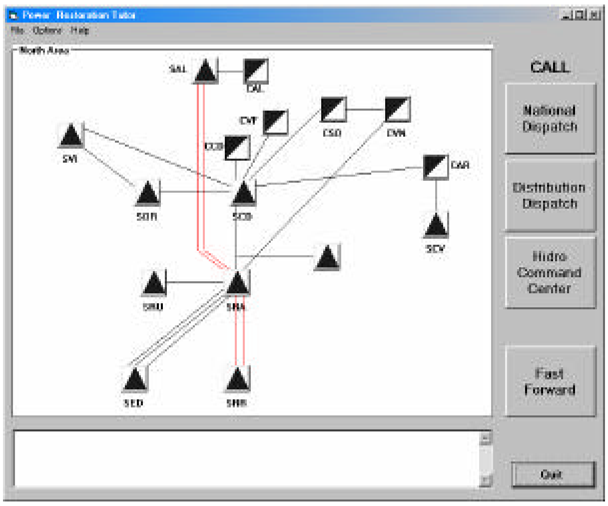

Fig. 3. Tutor Interface

We have chosen this multi-agent architecture because it seemed the most natural way of translating the real-life roles into the simulation environment. On the other hand, it seems to follow the way the domain knowledge is distributed as well as the different functions are performed.

It is known that the use of agents technology is well suited to domains where the data is split by distinct entities physically or logically and which must interact with one another to pursue a common goal [4]. It seems just to be the case with the problem at hand, where we have several entities responsible for separate parts of the whole task that must interact in a co-operative way towards the fulfilment of the same global purpose.

In our system, the trainee can choose to play any of the available roles, namely the NDC and the OC ones, leaving to the tutor the responsibility of simulating the other fictitious participants. The agents that play those roles possess the model of the ideal operator, as well as deviations to that model, be it at operational and technical level, or at the psychological level.

The restoration process being a collective one, it makes sense to make provision for the possibility of having more than one trainee using the system, be it on the same place or in geographically distinct locations. The multi-agent system uses a TCP/IP based communications protocol allowing the system to work in a distributed way.

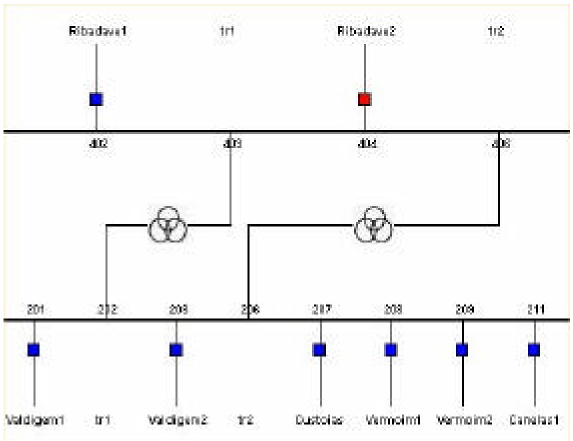

Fig. 4 Substation diagram (detail)

Those agents can be seen as virtual entities that have knowledge about the domain as well as characteristics that can be described as psychological traits, in order to approximate the simulation to what happens in real life, with real operators and their way to react to stressful and complex situations. They have assigned to them (as the real operators) duties to be fulfilled and goals to be achieved.

The communication between the agents performing simulated activities (this includes the trainee) will communicate using 3 general types of messages:

1. **Requests**, to be eventually negotiated, if the other agent has temporarily conflictive local goals.
2. **Information**, to be sent to a particular agent or to be broadcasted.
3. **Command**, a non-negotiable request.

The agents perform their duties in an asynchronous way, i.e., they execute the assigned tasks simultaneously by with only a loose coupling between them. There will be the need, as in real life, to synchronise the different agents' work at certain points in time.

Therefore, the system needs an arbiter (the Monitor, another agent) that supervises the low-level details of the process, ensuring that the simulation is coherent and convincing, apart from the important function of controlling the temporal aspects of the simulation (synchronisation and acceleration). It also monitors all the high-level communication between agents, maintaining a inter-agent message database to be used by the tutor mo dule. This and other agents will not be explicit, as opposed as the ones performing public roles.

From the implementation point of view, the system architecture is divided in two subsystems: one organised around the tutor module (itself an agent) and the multi-agent simulation environment (Fig. 2).

The tutor module, being the entity responsible for high-level details of the simulation process, must be in position to talk to all the agents involved, but obviously its main interlocutor is the trainee (s) through the interface agent.

The tutor will, as much as possible, have a low-key intervention in the tutoring process, preferring a behind-the–scenes kind of behaviour in order to give as much latitude to the trainee as possible. When a direct intervention may be needed, it will pose as an older, more experienced operator, instead of a formal trainer. This role corresponds to a realistic situation often found in the Control Centre room, and therefore will be a more natural way of presenting itself.

The tutor module will be responsible for the management of the cases library, choosing the adequate problems to present to the trainee, for the monitoring of the trainees' evolution, for the supplying of adequate help when requested or when a dead-end or a major mistake is detected, and for the evaluation of the trainee's performance. To be able to carry all these tasks, it will possess a model of the trainees using the system, to be improved with the continuous interaction between system and user. This model's contents are available for user inspection and differences of opinion between system and user about the user own knowledge or proficiency are registered and taken into account in the orientation of future sessions.

Several didactic modules are being were foreseen with the specific purpose of basic skills training. One of them will be used as a exploratory tool for the development of trainee's expertise in what concerns load pick-up techniques.

5. Knowledge acquisition

One of the issues we had to address was the need to facilitate the tasks related to the creation and maintenance of the power system network specification, including grid topology, power stations parameters and switchyard diagram descriptions.

This is a tedious and time-consuming task due to the sheer volume of information involved. One way, already devised to tackle the problem, has been the one followed by [5] , and it was based on the use of a "grid description language" to describe the power system network topology, constituents and status in an almost free-form text description.

We decided to evaluate the possibility of developing graphic tools to assist in the input of network description data, specifically the switchboard diagram data in a quick and reliable manner. The Diagram File Composer (Fig.5) gathers the data and automatically converts it into Prolog facts to be used by the interface and the simulated agents.

The switchyard diagrams are automatically built by the interface agent, making the maintenance process totally transparent.

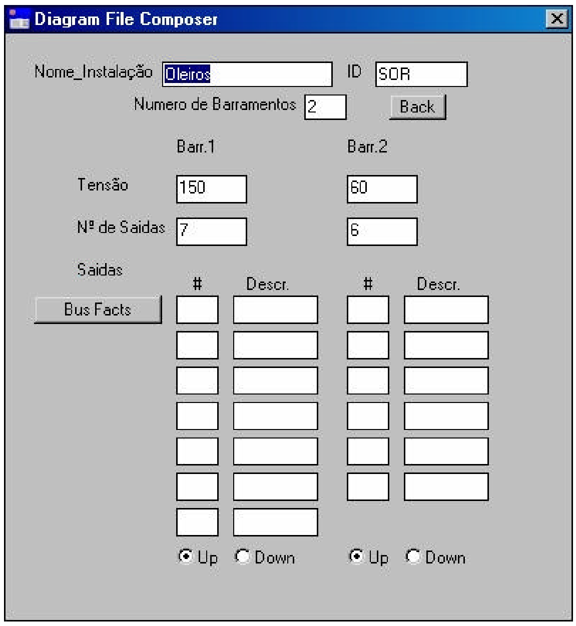

Fig.5 Diagram File Composer

We plan to use this approach also for the acquisition of the procedural knowledge needed to guide the simulated power system restoration process. This knowledge is to be used by the tutor module and the concerned agents alike. The expert will basically use the system's interface to perform the right actions and sequences for the case at hand, and the system will translate his actions into a script. Later, this script can be edited, adjustments can be made and variations introduced, in order to increase the richness of the simulation process.

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