Process Manager for Real-Time Management of the Tasks in a Power Substation

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Abstract **– This paper presents the description of a process manager for real-time management of the following modules assisting the operator activity in a high-voltage power substation: expert module; database for the information involved in the data stream within the target station, transient analyses software package (EMTP/ATP and PSCAD /EMTDC); dedicated program for real time command of the circuit breakers (depending on the parameters emerging from the expert system modules). The software ensemble integrates the complex analysis of the switched network area and the switching related phenomena (i.e. switching over-voltages and temporary over-voltages). Also it includes the effects of the above mentioned on the circuit breaker-shunt reactor as well as on the neighbouring equipment. The entire system allows the optimal solution to be established for the future purposes, based on the data from the knowledge base and on the past events (previous switching).**

I. INTRODUCTION

The size, the complexity and the territorial scattering of the power system imposes, in the aim of control leadership organisation, a knowledge of all technical and economical activities for all constitutive element characteristics and of the evolution tendencies of these. From the point of view of the organisation and control, a power system is an hierarchical system, on several levels. The coordination of productive-economical activities in every subsystem and on the entire system is made by the coordinator of the subsystem and system control centres. Regardless of the hierarchical level of command, this coordinator will realize the forecast, the plan, the program and the control of the system equipment, controlling their execution and the quality of electrical energy.

Some aspects joined with the impossibility of exact mathematical model construction as well as the solution methodologies used by human operators from control centres, have lead to an interest increase in some new technical applications in power system control entirely different from traditional methods.

Disturbances that are a result of a distributor can be classified into two types, firstly those caused by utility operations and secondly those caused by external influences. Utility operations are those actions that are planned and coordinated, such as shunt reactors, capacitors and overhead lines switching. External influences are those due to adverse weather conditions.

In a planning mode, optimal switching deals with the long-term economical factors and/or system reliability, while in the short-term operational mode, optimal switching needs an adequate algorithm to achieve all the quality parameters imposed by the energy management system. It is important to put the power system in a secure mode, so we called the intelligent control strategy a "preventive" switching.

Unfortunately, power system utilities are very reluctant to implement recently discovered possibilities to reduce switching transients. In order to investigate the reason for implementing the expert system dedicated to synchronised switching time setting and proper dispatching strategy for the reactive power/voltage control, this study has been initiated.

II. PROCESS MANAGER MODULE

The software ensemble proposed by the authors integrates the complex analysis of the switched network area and the switching related phenomena (i.e. switching over-voltages and temporary over-voltages). Also it includes the effects of the above mentioned on the circuit breaker-shunt reactor as well as on the neighbouring equipment.

The system allows the optimal solution to be established for the future purposes, based on the data from the knowledge base and on the past events (previous switching).

The main functions of the intelligent system coordinated by the process manager are:

- forecasting (i.e. describing a situation by anticipating it, having a present situation as a starting point and by using a history-based model);
- planning – placing at a certain moment in time the actions which allow reaching a final state by comparing the present state with the desired state, predicting the action consequences;
- simulation-inference based on a model of action consequences and events triggered by the system.

The process manager has the following tasks:

- command of the circuit breakers from target power station taking into accounts the Territorial Dispatching disposition;
- unloading programs involved in the process analyses and loading the command program with highest priority;
- unloading files (executables) at the end of the process.

The process organizer manages simultaneous processes in real-time. Each process controls the command of a circuit breaker in the targeted power station.

The intelligent control system for power substation is composed by the following tasks [4][5]:

- ✓ Expert module which indicates the database needed from the surveillance system.
- ✓ Program for consulting the database.
- ✓ Software package for transient analyses.
- ✓ Expert module for optimal switching time.
- ✓ Circuit breaker command program.

The program for the circuit breaker command is the only real-time task.

The process management program includes the representation of the processes and tasks in memory, the process management algorithms and the communication program between the computer and circuit breaker.

The flow of the process organizer module is presented below:

- ➢ An expert system module provides the database needed for the process analyses. The name of the database is given to the planning organiser.
- ➢ The data is taken from the database and conveyed to the expert system module.
- ➢ The expert system can indicate the optimal time for switching.
- ➢ Using the received data, the transient analyses program is run in order to check the optimal switching time.
- ➢ The program for circuit breaker command is run in real-time based on the data provided by this ensemble.

III. GENERAL CHARACTERISTICS OF THE IMPLEMENTATION

For the implementation, Unix was chosen for the facilities it offers in process development and communications. Object Oriented Programming (OOP) allows the implementation and the use of the following concepts: object, class, inheritance and polymorphism. The inheritance allows the development of new classes by describing the class specific differences from the existing classes. Another advantage is the decreased size of the application by eliminating informational redundancy. Thus the resultant models are easily understood.

The following keywords were used:

- ❑ process group – contains the following processes: database, a program conferring with the database, transient analysis program, expert system, circuit breaker command program.
- ❑ process –control key of program, is an instance in execution of a program.

In this particular application, OOP method has the following advantages:

- versatility of the application, the programs are independent from the process manager;
- the process manager is independent from the program implementation;
- changes can be performed within the programs or the process manager without changing the entire application;
- more accessible debugging and understanding of the process manager.

The C_{++} under Unix operating system was chosen for this task. Processes are represented by the "Process" class. That way, classes can be added along side the existing five, without changing the process manager. All the "Process" objects have the same interface, only a pointer is activated when a process is activating without any remark about what type of process is (database, expert system, transient analysis or circuit breaker command program).

The class is pure because it contains the following pure functions: destructor and the process running function (Run () function).

Figure 1 presents the class hierarchy.

Derivations are "public" for writing facilities. Two level classes in hierarchy correspond to the running programs for circuit breakers command in the targeted power station. The authors notice that inserting a new program module is creating a new class at level two derived from "Process" class.

Each class contains:

name – for memorizing the program name.
communication – is the communication channel between the processes part of a process group. It is common for all the processes part of a process group, input data is gathered from this channel and output data is written. Intermediate of this channel partial results are sent.

Member functions of a class are:

- constructor – creating an instance object of corresponding class. The communication channel is initialisation and data member "name" is instantiated with the name of the program at which the instance is the related process object.
- destructor
- Run() – this function call executing the program.

The "process group" is represented by the "GrupProcess" class.

Member data of this class are:

name
comunication – is the communication channel between the component processes *sebd, *set *cemtp *cbd *com – pointers to the refereed Process
state – is the variable for running a process group.

The "GroupProcess" members functions are:

constructor, destructor
Run() – for running the referred process.

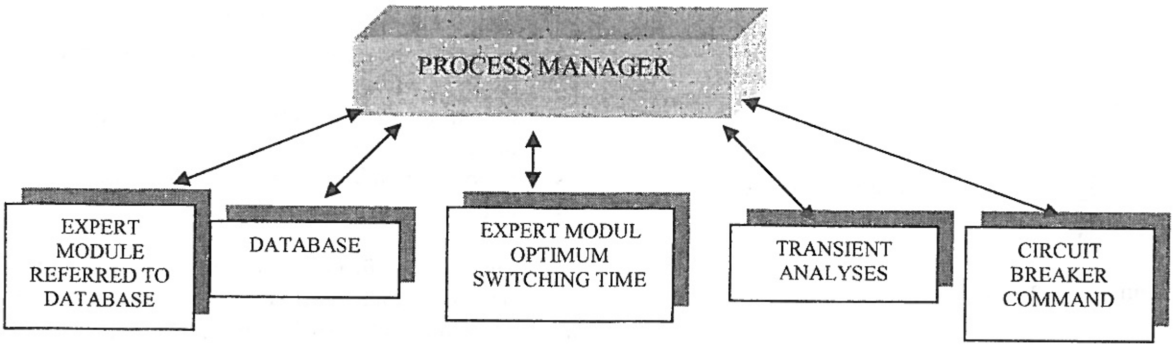


Fig. 1. Classes hierarchy

IV. FUNCTIONING ALGORITHM

This application assures the organization of working processes group and for this purpose the FIFO algorithm is used. This algorithm fetches for a Process Group queue the next run group and after running it the process manager destroy it (if it is finished) or put it in queue. It is necessary to have a queue with the processes group loaded in memory at a moment. For creating this queue, a class "Queue" was defined. At loading the "Process Manager" it will be created an instance for this class automatically.

Running steps are the following:

1. Creating the queue with the processes group that will be executed. This queue is interactive created by the user, each process group corresponding to a circuit breaker in targeted power station.
2. The main management loop – this loop is run when the Process Group queue is not void. In this loop the execution steps are the following:
   - taking the process group from the queue;
   - execution this group (ProcessGroup Run()). "State" member variable indicates which process will be executed (Process. Run()).
     - state = 1 – Run expert system module for database.
     - state = 2 – Run database process.
     - state = 3 – Run expert system module for synchronized switching time.
     - state = 4 – Run transient analyses followed by the circuit breaker command process.

After execution, this process "state" variable is incremented. If the state variable has the value 5 the Process manager will destroy the Process group (the circuit breaker command was executed).

The function ProcessGroup. Run () return after a process running (exception - when the state = 4, it will be executed two processes and then the group will be destroyed).

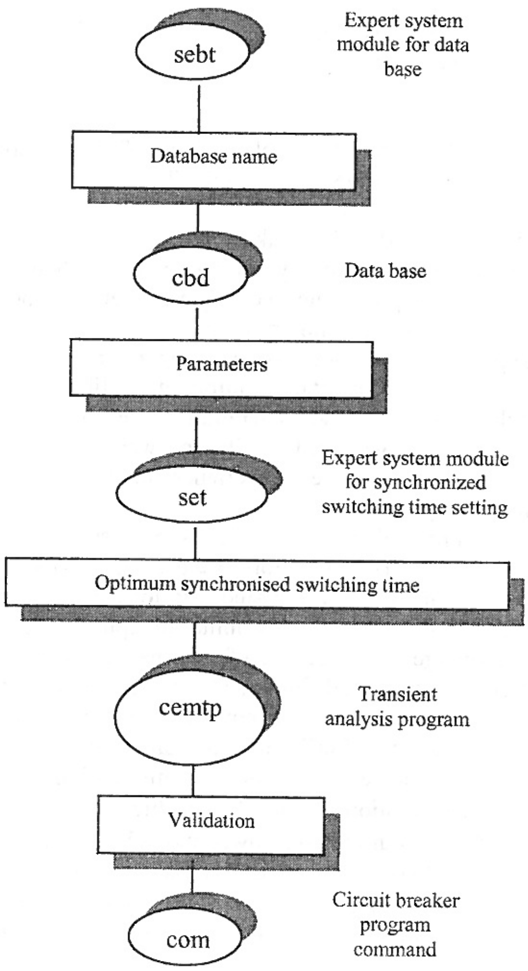
- If state = 5, the group will be destroyed
- Otherwise the group is pass at the end of the queue, and the loop is executed.

Along with the process management the Process Manager performs a memory management.

A program is loaded in memory only when it will be run (Process.Run() call).

Communication channel – it was chosen a binary channel for a data sent independence (we have in process file name – character string, integer value, etc). First the data will be transformed in character string and after that will be written in character binary code. The facility was used because the whole process is working under different operating systems, Windows and Unix.

Communication routine –is presented in Figure 2.



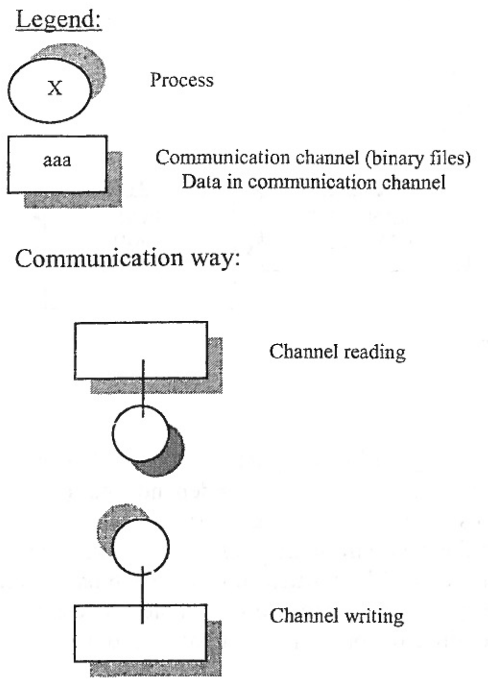


Fig. 2. The process communication algorithm

For this task Process Manager have the following procedures in the *readwr.cc* file:

write(file data)
read (file data)

V. DESCRIPTION OF THE INTELLIGENT CONTROL SYSTEM

Usually, for decision making process, operators from the power station employ their experience, heuristics knowledge, approximate techniques, operation policy and the actual process information.

Experienced power system operators combine qualitative and quantitative information like network switch status, load and generation trends, the reactive power and voltage profile, daily and weekly behaviour of consumers, with their experience, to draw a proper dispatching policy.

The hourly real and reactive loads in the substation for the next 24 hours can be forecasted using the recorded data. With the hourly forecasted data for the next day at hand, it is desirable to determine an optimal reactive power/voltage control strategy for the next 24 hours [2].

Process history and fault statistics in the substation are available as "service notes", "service operating files", "manoeuvre files" and maintenance history.

These files contains the following information:

- the substation 24 hour load profile;
- the 24 hour reactive power and voltage profile;
- the 24 hour ambient temperature profile;
- compensation equipment and power transformer limitations (top oil temperature, winding temperature and loss of life);
- review of the equipment maintenance history, oil-quality analysis;
- review of the substation regulator maintenance history and rating;
- review of number of circuit breaker switches;
- failures.

In many cases, information regarding some events in the power substation is limited to notes, made at the time and to eyewitness reports. In some cases, reports about events in the substation are subjective and uncertain.

The databases managed in a 400 kV power substation are presented in Figure 3 and contains all the information.

The intelligent system proposed by the authors is able to model the functioning of the system by using the passive data previously acquired. The basic functions of the system is previewing (i.e. describes a situation by anticipation) having as start point a current situation generally by using a model constructed on a historical base.

The system can deal with the situation that changes through the time by storing the data in the historical field of database that can be used for long term analysis. The frequency of memorization may accord the current context and the relative importance of the changes. The situation is available for each phase of the breaker. These basic information are given to the knowledge base and expert system analyses the inference rules and provides a real solution of switching.

Describing of a power substation is a complex problem involving a multiplicity of components and possible arrangements. It is difficult to formulate a generally applicable operating strategy, even for a substation. Only a subset of the possibilities can be studied in advance. In these circumstances a target system should be defined. Depending on the status of equipment, this target system may or may not coincide with the pre-switching conditions. The equipment specifications are determined (e.g. electrical characteristics, insulation level, system reliability indices the rating of surge arrester and their associated switching and lighting protective levels).

The substation elements were broken-down into four groups for the purpose of identifying and combining the relevant equipment. The categories include:

- High-Voltage line terminations;
- High-Voltage bush-bars;
- Power transformer and compensation equipment (type of the reactive power compensation);
- Protection equipment.

The conceptual description of the expert system involved in decision process in the 400 kV target substation is presented in Figure 4.

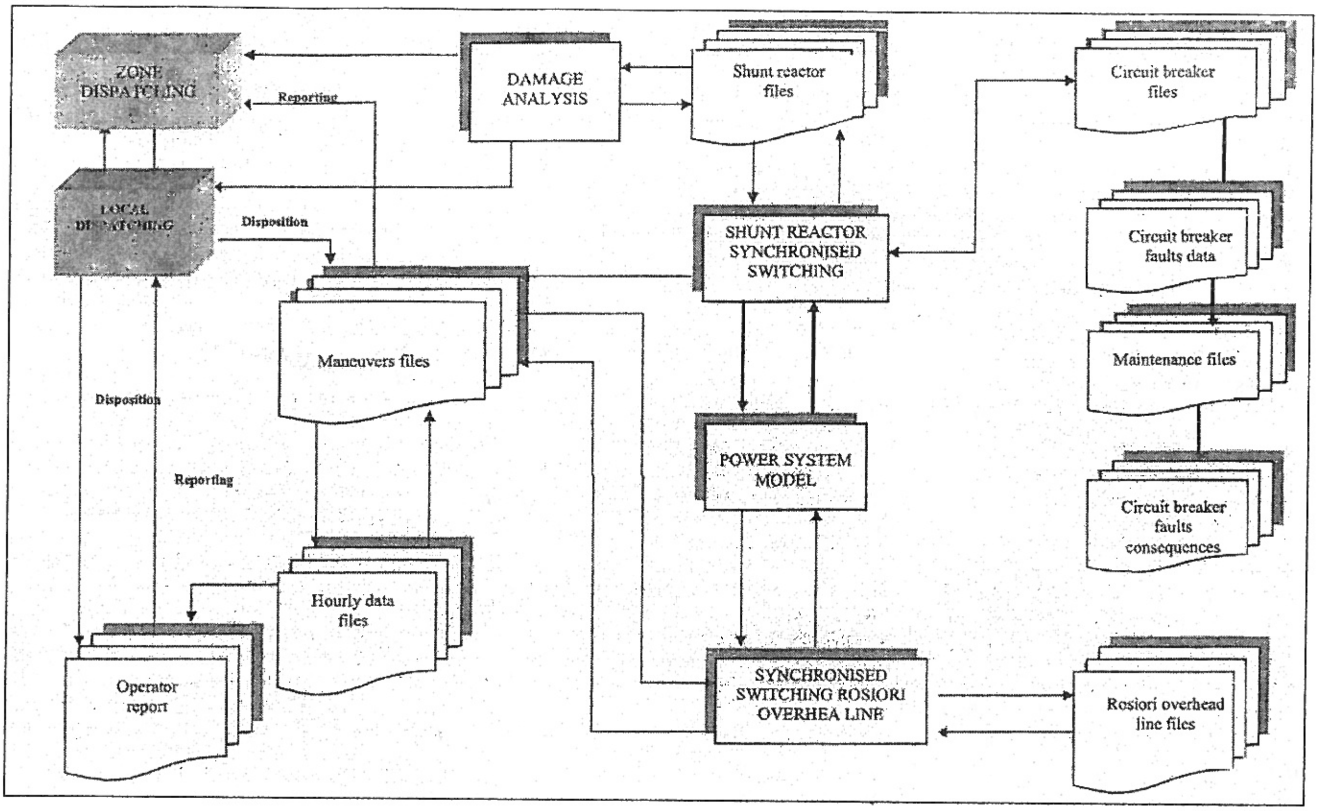


Fig. 3. Data base managed in the target power substation

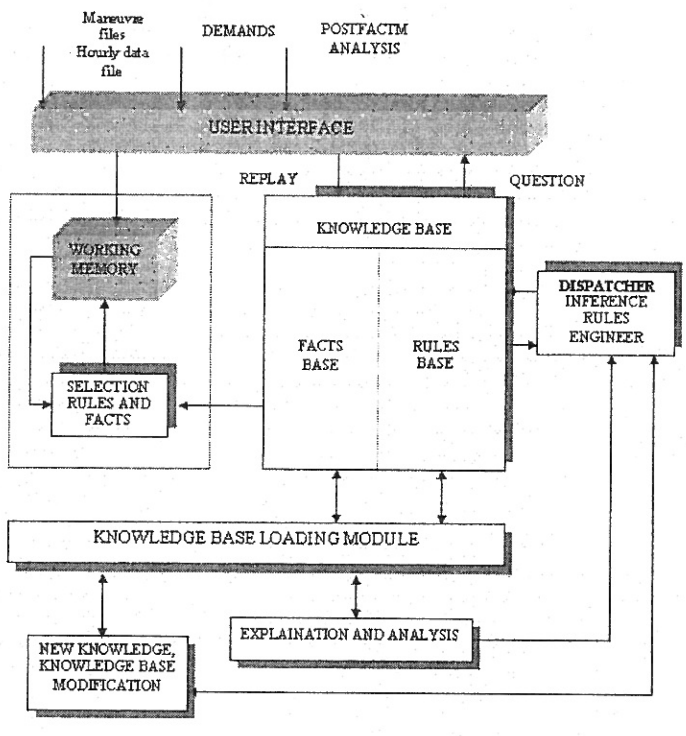


Fig. 4 Conceptual description of the expert system

VI. CONCLUSIONS

The process manager for real-time management of the tasks in a 400 kV power substation was developed for a proper use of all software components involved in the intelligent control process. The components involved in the intelligent decision process are:

- Expert module.
- Database for the information involved in the data stream within the target station (Figure 3).
- Transient analyses software package (EMTP/ATP and PSCAD/EMTDC).

- Program for real time command of the circuit breaker, depending on the parameters emerges from the expert system modules and after conferring with the above mentioned modules.
- Surveillance module for the circuit breaker switching by recording the current and voltage wave shapes.

The intelligent control for a proper dispatching strategy in a 400 kV power substation could optimize the cost and the benefit of the maintenance activities and increase the equipment lifetime. With the better understanding of the problem, the field supervision team can select the proper strategy. Cost and reliability are essential, but for some applications, environment and operational flexibility are equally important. The intelligent control system ensemble is expected to improve power system reliability.

An important advantage of developing an intelligent control system is that the substation data history is included. Most of power stations have not a complete information system, the data are not analysed, systematised, stored and reached properly. Using an intelligent control system, impending problems can be identified in advance, resulting in better use of resources and an improved life expectancy of the system equipment. Some of these problems may go undetected for weeks, affecting the system reliability.

The intelligent control strategy is complex due to the diversity and the number of phenomena involved. The methodology by which the switching time is correctly chosen in relation to the particular substation topology, electrical and mechanical characteristics will improve the quality of the dispatching policy.

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