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ExpDTS - Hybrid Dispatcher Training Simulator Expert System for operator assistance and evaluation

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***Abstract* -- Dispatcher Training Simulators are complex applications included usual in SCADA systems and using their models, data and graphic interface.**

This paper presents ExpDTS, a simple off-line dispatcher training simulator which has the main functions needed for training and was realized by the author, after a deep research in the training simulators' domain.

This simulator is a hybrid application, expert system and classical program, and has the following functions: system monitoring and control, events logging, short circuit simulation, operator assistance and evaluation.

The system state changing in time is based on load variation, and can be determined also by an events scenario chosen by the operator.

The paper presents the simulator's functions, the structure and some ideas about mathematical models, graphical interface, and way of use.

***Index terms* – expert system, power flow analysis, training**

I. INTRODUCTION

Dispatcher training simulators are important tools which can avoid human errors and lead to system security enhancement. Generally, the dispatcher training simulators are numerical applications, embedded in EMS SCADA systems, having the same graphical interface and using the same data base. Dispatcher training simulators can be made also separately from the EMS SCADA systems, installed in a special training room where the ambiance from a real control room can be reproduced.

Training can be made for system monitoring, frequency and voltage regulation, power flow modification, for actions during critical cases and for system restoration after black out.

Training simulators allow dispatchers to study difficult situations, which don't appear very often in real world but are very dangerous for the system. It is possible to simulate overloads, voltage dropping due to wrong operational planning; incidents appeared due to wrong maneuvers, lightning or equipments' malfunctioning.

Usually, the training activity is leaded by an instructor who establishes an initial state of the system modeled, introduces short circuits or chooses an events scenario, supervises the operator's activity and makes an evaluation at the end.

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The equations used for simulation have to be chosen so that the model to result as closer to reality as possible. Dispatchers can detect only slow phenomena; the fast and very fast phenomena could be modeled only from the consequences point of view [1], [2].

II. ExpDTS - FUNCTIONS AND WAY OF USE

For ExpDTS, the transmission network under the authority of regional dispatching centre from Bucharest was chosen for simulation, the other part of the Romanian power system being represented through equivalents. The substation 400kV/ 220kV Bucuresti Sud has been detailed.

ExpDTS has the following functions: system monitoring and control; maneuvers in a detailed presented station (Bucuresti Sud); short circuits simulation; events log; state saving and restoring; events scenario creation and launch; operator assistance and evaluation.

ExpDTS has a friendly graphic interface containing a main window with one-line diagram of the system modeled and a pop up menu through which other windows can be launched in order to see the system state and to operate the simulator.

A. System monitoring and control

The user can monitor the system state on the one line diagram where the voltages, currents and power flows are shown. The total consumption and the frequency are also displayed. In Fig. 1 it is represented an image on the operator workstation.

The simulation is based on a load curve and starts from an initial saved state.

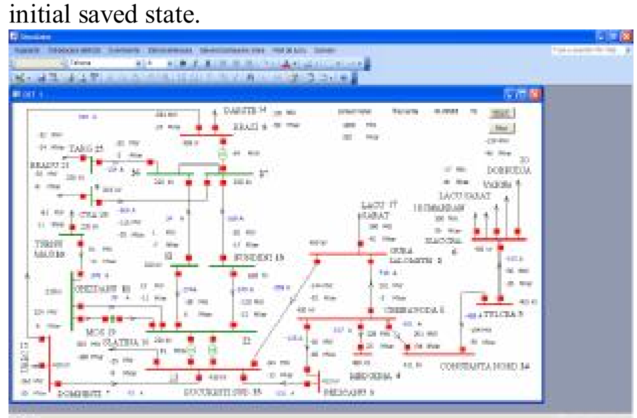

Fig. 1. Operator display

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It is possible to view information about generators, transformers and shunt reactors. For every category there is a special window for monitoring.

The operator can access an events list where all the maneuvers and trips are recorded.

Operator can modify the network topology and the production pattern in order to obtain a certain system state or in order to maintain the system security when an outage appears or when the parameters evolve in an undesired manner.

The user can connect or disconnect any line or transformer modeled using the mouse and operating the breakers placed on the one line diagram.

It is also possible to start or stop any generator modeled, using the window showed in Fig. 2. Operator can modify the voltage imposed for the generators.

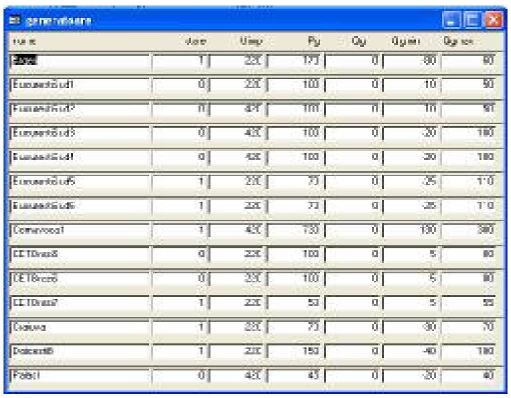

Fig. 2. Generators

In order to maintain the voltage within imposed limits the operator can modify the transformers' taps and also can connect/ disconnect shunt reactors using specialized windows.

B. Maneuvers in a detailed station

For the dispatchers who may make distance control in substations, the simulator contains a detailed represented station (Fig. 3 - Bucuresti Sud). On the diagram are represented the breakers and switches, the active power and reactive power for every bay. It is possible to simulate maneuvers, the inter-blocking functions being also modeled.
The operator is notified when he makes a mistaken maneuver.

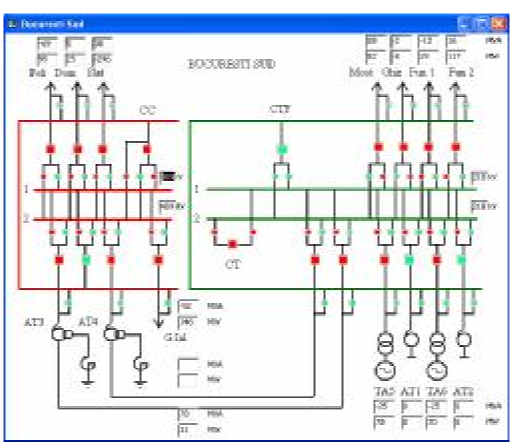

Fig. 3. Substation Bucuresti Sud

C. System state saving and restoring

During the training session the operator can save the system state. All data are saved in tables special designated. When a saved state is restored, data from these tables is transferred in the tables currently used for simulation.

D. Events scenario creation and launch

An events scenario is an events set scheduled to appear at a certain time during the training session. The events which can be introduced in a scenario are: line tripping; transformer tripping; generator tripping; all elements connected to a node tripping.

The operator can create its own scenarios. For each scenario must be mentioned the time and the element tripped. The time is specified in timer ticks. The timer produces a tick at each 5 seconds.

The scenario can be launched and stopped by the operator.

E. Operator assistance and evaluation

The expert system permanently supervises the modeled system state and each time the parameters get out of limits, it acts like an assistant which can help the dispatcher with useful messages, or like an evaluation tool which can give a mark to the trainee depending on how long he operated with bad parameters.

At the beginning of the training session, the operator can choose the mode, assistance or evaluation.

The assistance system acts in the following way when the voltages get out of limits: if the voltage is too low in a certain node then the expert system will indicate the operator one of the following solutions: disconnect a shunt reactor in a certain node; load a certain generator with reactive power. If the voltage is too high in a certain node then the expert system will indicate the operator one of the following solutions: put in operation a shunt reactor in a certain node; decrease the reactive power produced by a certain generator.

The assistance system acts in the following way when the power flows on branches get out of limits: if the power flow is too big on a certain branch then the expert system will indicate the operator to start a generator which has an influence over the power flow decreasing on that branch.

If the line tripped due to a protection or, if it was disconnected by the operator, then the expert system will indicate the operator to verify the topology conditions imposed by the planning department for that situation. The operator can verify the conditions by monitoring the system topology and he has to confirm this operation in a table designated special for this purpose.

III. ExpDTS STRUCTURE

ExpDTS is made in MS ACCESS. Data base management systems are very appropriate in order to build simulators as this kind of applications use a large data amount which it is good to be organized in data bases. The program modules are written in Visual Basic for Applications.

The fig. 4 presents the ExpDTS architecture including the expert system and the analytical program.

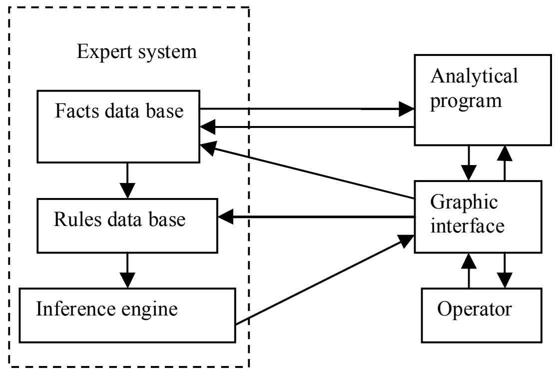

Fig.4 Hybrid simulator ExpDTS architecture

The expert system is composed of knowledge data base (comprising facts data base and rules data base) and inference engine [3].

Using the graphic interface, the operator can modify the data (facts data base) related to the system state and also the rules.

The principal modules of the analytical program are used for: power flow calculation and frequency regulation.

The Fig. 5 presents in detail the ExpDTS structure, showing the most important computation modules.

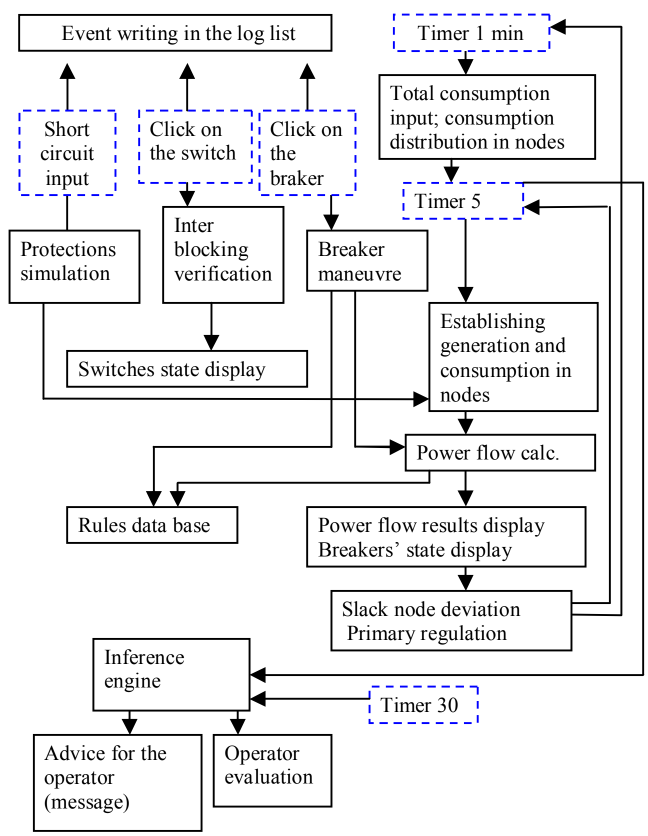

Fig.5 ExpDTS structure with all computation modules

The events which trigger the functions are represented in dashed rectangles. The events are associated to the main windows: one line diagram window, Bucuresti Sud substation window, dialog box used for introducing short circuits. The main events are: timer event, click on breakers, click on buttons, etc.

A. Expert system

The expert system makes the operator assistance and evaluation.

The facts data base is made of the ACCESS tables containing input and output data of the classical program: data for lines, transformers, generators, shunt reactors and also results obtained from the power flow calculation. The expert system uses mainly the equipments state (on/off) and the results of comparison between the voltage (and power flows) values and their imposed limits (good, low, high).

The rules data base is made of ACCESS tables with columns designated for the condition part and for the action part of the rules. The rules can be grouped in two cathegories: rules related to situations when the voltage is out if imposed limits and rules related to situations when the the power flow is out if imposed limits.

When the expert system runs in assistance mode, the actions launched when the conditions are accomplished are messages sent to the operator, advising him to modify the operational state of reactors, generators or, to verify the topology conditions imposed by certain possible congestions.

When the expert system runs in evaluation mode the actions launched when the conditions are accomplished lead to the operator's mark decreasing with a certain number of points.

The inference engine has deductive algorithm and is written in Visual Basic for Applications, like all other modules of the program.

All the rules are verified and the actions with condition accomplished are launched.

The inference engine is made of two separate modules, one for assistance and one for evaluation. The assistance module runs at each timer signal (5 seconds) and the evaluation system runs less frequently (at 30 seconds) in order to allow the operator to bring the parameters inside their limits.

B. Steady state regime

The application's associated timer launches periodically (at each 5 seconds) the power flow computation (steady state regime) and displays the results. Also, at every topology change the steady state regime is computed and the results are displayed.

For the steady state regime there are tables containing data about nodes, lines, transformers, generators, shunt reactors.

For the load curve it was built a table containing the total active and reactive power consumption for ten time intervals.

The first step of the power flow calculation is represented by the nodes consumption determination. At the start time there is a consumption defined in each node. From the table containing the load curve, every minute a new record is read.

The new consumption in every node is calculated taking into account the initial value and the total value, and using a proportionality factor.

The steady state regime is calculated using Newton Raphson method [4].

The difference between the total active power generated and the total consumption, including the losses is taken by the slack node and represents an input for the primary frequency regulation.

C. Frequency regulation

A power deficit in the system means a frequency decreasing. At this deficit, the primary regulation actions in maximum 30 seconds loading the generators. The primary regulation reserve is 1.5% from the installed capacity of each qualified group. For the modeled system it means approximately 10MW. Each group increases/ decreases its generation depending on its own droop, with its own velocity (MW/ sec).

The dispatcher can modify the units' production over the system so that the reserves can be restored.

D. Protections consideration

In order to simulate the protections the next assumption is made: all the protections action efficiently and are well set.

When a short circuit appears on a line, the protections will action correctly and the line trips. The operator can see this fact on the display and in the events list.

The steady state regime is calculated every time a line or transformer trips.

E. Voltage regulation

The primary voltage regulation is included in the steady state regime calculation as the voltage on PV nodes is imposed and the generators will use the reactive power available in order to maintain this voltage.

The secondary voltage regulation has to be made by the operator who can change the imposed voltage on generators so that the generators will use the maximum reactive power.

Also, the operator can modify the taps for the transformers and can connect/ disconnect the shunt reactors.

IV.TEST CASE

One of the test cases studied on this simulator was the disconnection of a shunt reactor in order to bring the voltage inside the limits.

Starting from a state where the shunt reactor in Smardan Substation is in operation and launching a scenario which contains the disconnection of Isaccea - Dobrudja 400kV line by protections, we will obtain a state where the voltages in Isaccea area are too low (397 kV).

If the assistance system is started, it will indicate the operator to disconnect the shunt reactor in Smardan Subtation.

In Fig.6 the initial state is presented and the shunt reactors state is shown in the small table.

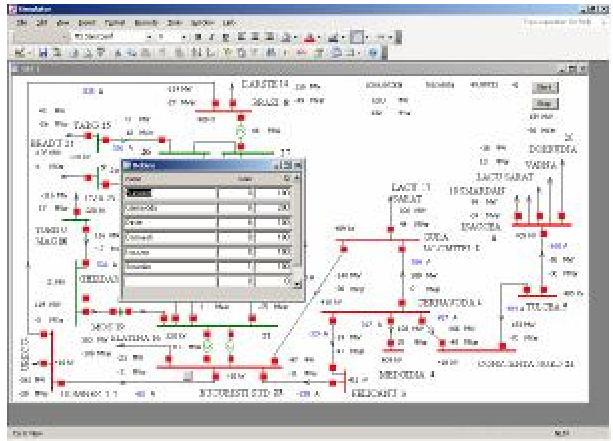

Fig.6 Initial state, with shunt reactor in operation in Smardan Substation

In Fig.7 Isaccea Dobrudja 400kV line is disconnected by protections, following the scenario chosen and the voltage in two substations decrease from 405kV at 397kV.

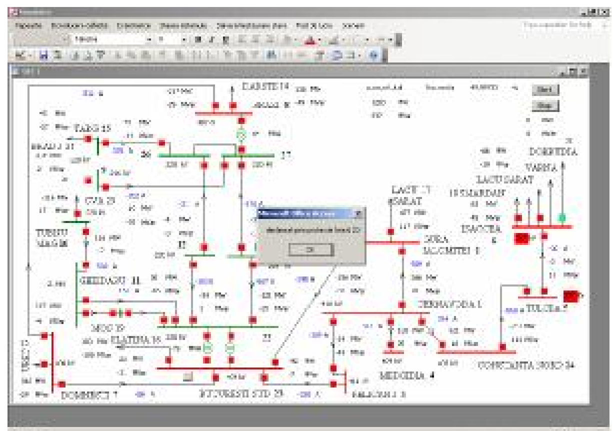

Fig.7 Isaccea- Dobrudja 400kV line disconnection

After the operator disconnects the shunt reactor in Smardan Substation, the voltages are increased again at 408kV, entering in the accepted limits interval. The final state is shown in Fig.8.

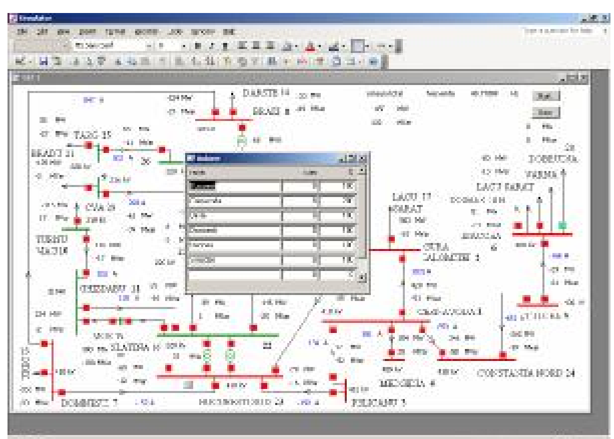

Fig.8 Final state, with shunt reactor disconnected in Smardan Substation

V. RESEARCH CONTINUATION

ExpDTS is at the present time a simple simulator which has the main training functions and a small network modeled.

This simulator can be improved and developed introducing: 110 kV network model for the regional dispatching area studied (Bucharest); merit order for generators (market rules); contingency analysis; new rules for assistance expert system applicable when the power flow exceeds the limit imposed in a critical section defined in the system, or in order to regulate the voltage using the transformer taps, or in order to offer more indications related to the secure system operation.

VI. CONCLUSION

In Romania have been made many training simulators designated to operators working in power stations or substations. This was a very hard work which needed a lot of human and financial resources.

ExpDTS is the first simulator designated to dispatchers and it has been build in order to study the problem, to gather as much information as possible in this field.

Also, ExpDTS shows haw an expert system can be integrated into a dispatcher training simulator in order to offer assistance to the operator or to evaluate him during the training session.

VII. REFERENCES

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Daniela Bolborici was born in 1972 and graduated the University Politehnica from Bucharest in 1996.

She worked at ICEMENERG research institute in Bucharest from 1996 to 1999, and was involved in building training simulators for substations operators.

In 1998 she began to study models and algorithms for Dispatcher Training Simulatos in order to obtain Ph.D. diploma at University Politehnica from Bucharest under the kind advice of Ph.D. Professor Mircea Eremia.

In present Daniela Bolborici is Project Manager at Transelectrica SA, National Dispatching Center and is involved in tasks regarding EMS SCADA system.