EUROSTAG, SOFTWARE FOR THE SIMULATION OF POWER SYSTEM DYNAMICS. ITS APPLICATION TO THE STUDY OF A VOLTAGE COLLAPSE SCENARIO.

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1. THE NEED TO BETTER UNDERSTAND THE POWER SYSTEM DYNAMIC BEHAVIOUR.

The power system operating conditions become today more and more complex, because they must take into account many new elements :

- the recovery of the load growth;
- the differences of cost and the availability of the energy produced. They induce power transfers between utilities and regions;
- the extension of the interconnection between the power systems;
- the environmental constraints, which limit the possibility to reinforce the transmission systems and to create new generating sites.

As a consequence, the electrical systems will be operated in the future closer to their physical limits. This evolution reduces the stability margins and increases the risks of generalized incidents, intolerable for the economy and the consumers.

In order to allow the people to assume their professional responsabilities, it is thus necessary to better understand the dynamic behaviour of the electrical systems and to know more accurately the stability margins. This is the only way to be sure that the power system security will not be jeopardized.

The EUROSTAG program was developed to answer these needs. It is dedicated to the dynamic simulation of the power systems, and fulfils the following three basic requirements :

- a single software program to simulate fast and slow phenomena in a continuous way;
- for any phenomenon, a performance at least equal to those of the specialized software programs;
- faster and easier studies.

2. DESCRIPTION OF THE EUROSTAG PROGRAM.

2.1. GENERAL.

EUROSTAG is a time domain simulation program, developed by Tractebel and Electricité de France for transient, mid-term and long-term stability analysis of large power systems.

The modeling and the algorithm used in the program make it an efficient tool for the simulation of extreme conditions of the system. It allows a detailed study of voltage instability phenomena.

2.2. SOLUTION TECHNIQUE.

EUROSTAG solves the general short-, mid- and long-term dynamic problem using an implicit integration method. The differential and algebraic equations are solved simultaneously with a variable integration time step.

The stepsize varies automatically according to the actual behavior of the system (typically from 1 ms to 100 s) in order to secure a constant accuracy of the calculation process. In fact, the truncation error is calculated at each step for the determination of the exact step length to be used.

The program exploits sparsity based techniques and manages, when possible, the numerous discontinuities of the modelization on a local basis, allowing a smooth variation of the stepsize and a high accuracy.

It uses the same modelization of the components whatever the disturbance, the behavior of the system or the duration of the simulation is.

The program is able to reach any steady state conditions of the system and can be used for quasi steady state analysis. An interactive eigenvalue calculation allows the dynamic stability to be studied around any steady state conditions reached during the simulation.

2.3. ON-LINE OPERATIONS.

Various manoeuvres and operations can be initiated at predetermined moments or during the simulation by user intervention. This is made possible by the graphic monitoring of the changes of the system's main quantities.

The following operations can be carried out :

- opening and closing circuit breakers (even if a separation or resynchronization occurs, the relevant phenomena being simulated);
- shutdown and start-up of generating units;
- shutdown and start-up of induction motors;
- switching loads and compensation means on and off;
- transformer tap-changer operations;
- changes in set-points of controllers.

2.4. MODELING CAPABILITY.

EUROSTAG has extended and flexible modeling capabilities thanks to graphical input facilities for the direct coding of block-diagrams of new models defined at the user level.

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Presented at the IEE Colloquium on "Interactive Graphic Power System Analysis Programs"- 20 March 1992

This graphical macrolanguage is used to code any classical library of AVR, turbine or governor models, but also to code boiler models, SVC or HVDC models, static or dynamic load models etc...

EUROSTAG has also a flexible capability of simulating automatons which are represented as a set of equations determining the conditions and the moment of an operation on the system. All the possible on-line operations can be ordered by an automaton model. This concept is mainly used to model relays, ULTC and centralized control systems.

Beside these facilities, the following models are available :

- synchronous machines :the model allows two rotor windings in each axis with a mutual coupling between field winding and damper in the d axis, and separate saturation characteristics for d and q axis;
- standard models of AVR (comprising rotor current limiter), turbine, governor and boilers;
- standard Static Var Compensators models;
- relays and protection systems, defined as automatons;
- models of AGC and AVC;
- model of load sensitive to voltage and frequency;
- models of dynamic loads;
- induction motors :
  - simplified model neglecting rotor transients;
  - detailed model which comprises a 2 winding rotor transients calculation;
- detailed ULTC and transformer models.

Further developments are currently in progress. They covers in particular the following topics :

- unsymmetrical conditions;
- extended HVDC multiterminal systems with DC unsymmetrical conditions
- flexible AC Transmission Systems.

The program has been designed to be run on powerful workstations and is currently used for systems having up to 5000 - 10 000 state variables (typically 1000 - 2000 nodes and a few hundred of machines).

2.5. APPLICATIONS.

EUROSTAG replaces the classical transient, long-term and dynamic stability programs and allows higher accuracy than classical programs thanks to its extended modelization and its ability to simulate simultaneously fast and slow transients.

The robustness of the algorithm and the modelization capabilities allow the simulation of voltage collapse scenarios, even if they are very complex (simulation of load increase, operator actions, cascading effect, automatic tap-changer actions, loss of synchronism due to low voltage, ...) and very long (one hour or more).

EUROSTAG includes an interactive output analysis program for displaying and printing simulation results. The observation of any quantity of the system is possible without any prior declaration. The post-processing program computes and displays any internal variable or observable quantity (f.i. MVAr on a line, impedance as seen from a line extremity or output of any block of a block-diagram of controller ...), after the simulation and at the request of the user.

3. EXAMPLE OF APPLICATION : THE STUDY OF A VOLTAGE COLLAPSE.

3.1. Description of the system.

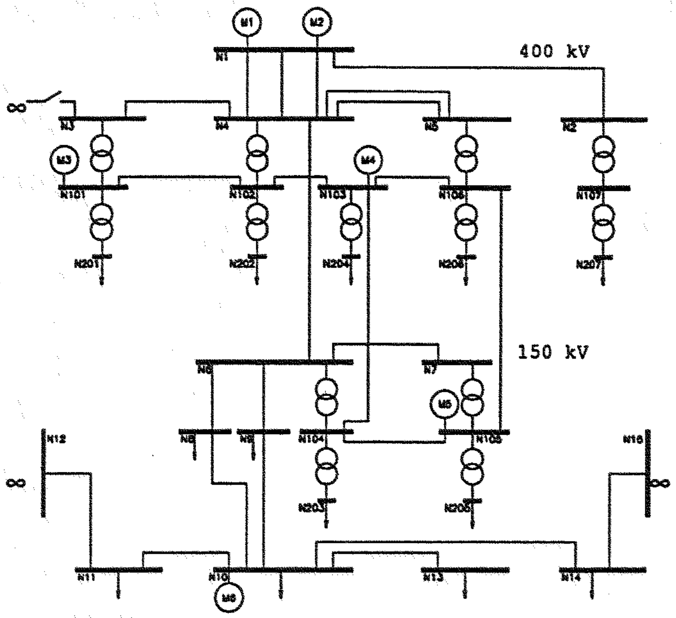

Figure 1 : The electrical system.

The system illustrated in Figure 1 is an hypothetical one having two voltage levels (400 and 150 kV).

The loads are simulated behind 150/70 kV subtransmission transformers fitted with automatic ULTC. The load in each node includes induction motors, the remaining part being an equivalent impedance.

The external system is simulated by means of three infinite busses. During the simulation, the connection between N3 and one infinite bus trips.

The AVR'S are represented in detail. Nevertheless, they remain didactic ones. Power system stabilizers and rotor current limiters are taken into account. In this example, the exciter can stay on its ceiling during a maximum fixed time span and then becomes limited, regulation acting as the protective device. (see Figure 2)

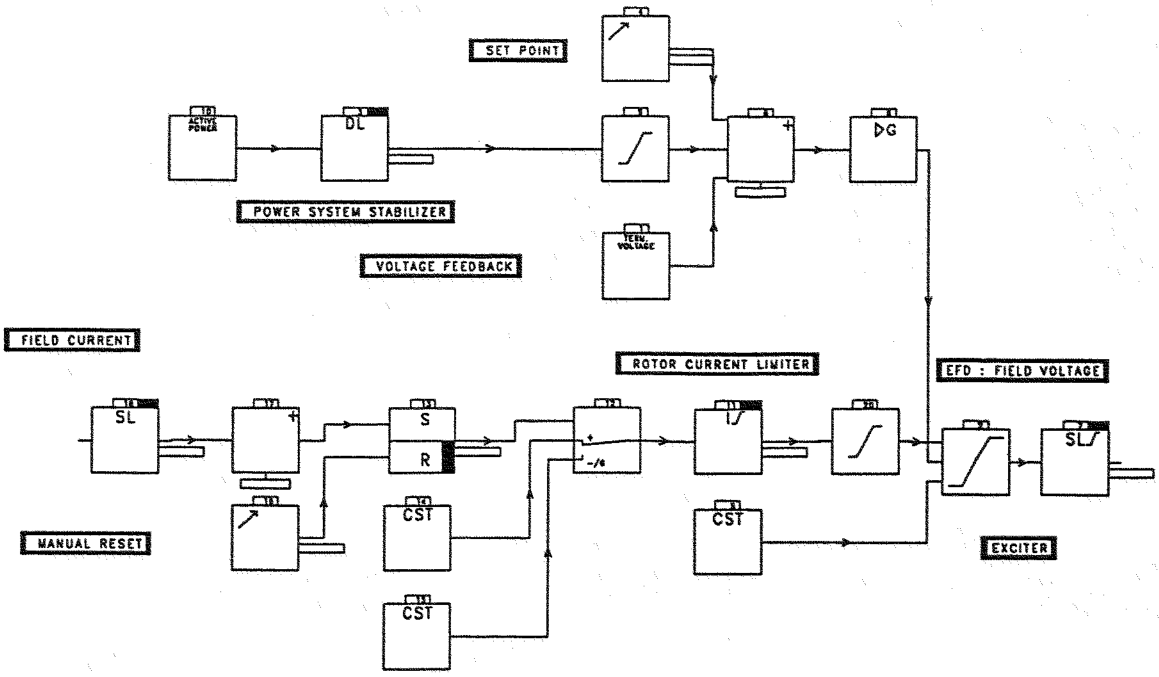

Figure 2 : Block-diagram of the AVR's

Unit M1 has a very low excitation limit : due to a bad setting of the rotor protection, the current is reduced to 2.3 p.u. if the threshold (3.2 p.u.) is reached (no load nominal voltage as base).

Different automatons and protective devices are taken into account :

- loss of synchronism protection : tripping of the unit after 1 or several pole slippings;
- undervoltage protection on the units;
- Tap-changer automatons regulating the low voltage side of 150/70 kV transformers.

3.2. Description of the scenario.

It is initiated by a load pick-up of 30% in two hours. At time 5000 s, the line connecting N3 with infinite bus trips.

Once the load pick-up is ended, and the power system stabilized, the unit M2 is tripped (at 7400 s).

As a consequence of this tripping, and following the action of the automatic tap-changers, the rotor current limiter of unit M1 enters into action. This limiter is bad tunned and reduces drastically the excitation, provoking the loss of synchronism of the unit M1.

After this second tripping and further tap changes, the voltage at the terminals of machines M3, M4 and M5 becomes too low and these units trip successively by undervoltage protection for M4 and by loss of synchronism for M3 and M5.

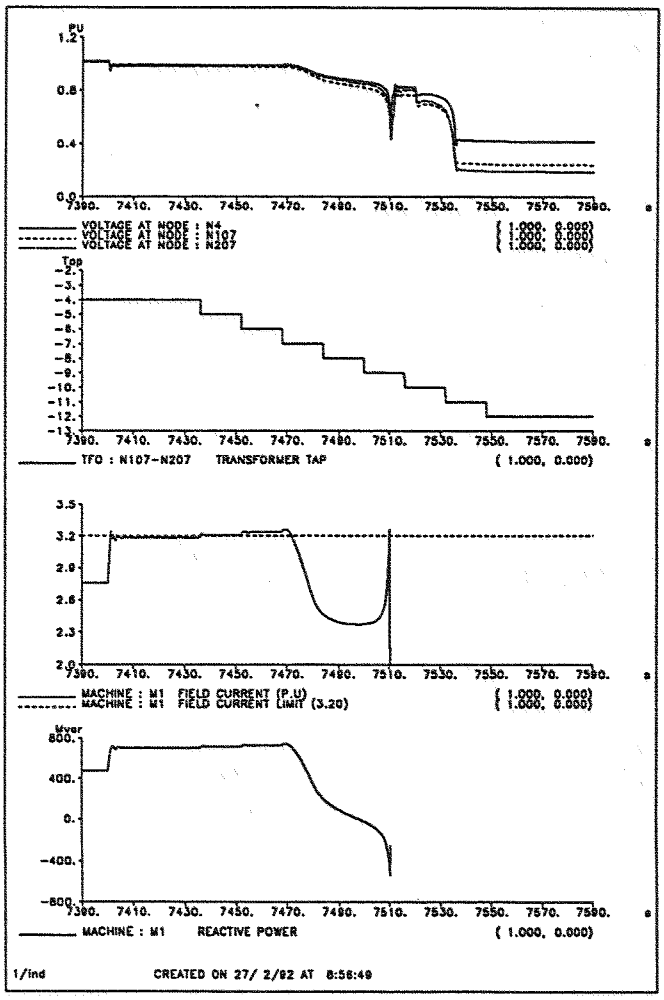

Figure 3 : The voltage collapse phase.

Figure 3 illustrates the evolution of some significant variables during the voltage collapse period starting at the tripping of the unit M2 :

- the voltage at nodes N4, N107 and N207 (in p.u.);
- the automatic tap changes occuring at transformer N107-N207;
- the field current of the unit M1, which exceeds the threshold (3.2 p.u.) and is reduced to 2.3 p.u. some 25 seconds later.
- the reactive power of the unit M1, which is reduced when the rotor current limiter enters into action.

4. BIBLIOGRAPHY.

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