

REALIZATION OF THE EAST-WEST INTERCONNECTION PROJECT SHOULD BE STARTED WITH A FULL-SCALE EXPERIMENT

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1. INTRODUCTION

Now the geographical size of the UCTE power grid, from Portugal to the eastern boundary of Poland, amounts to about 3 000 km. If the East-West interconnection project will be realized, the distance from the outermost eastern to the utmost western points of the interconnection would reach 9 000 km, and, taking into account the power systems of Russian Far East, and those of North Africa and Middle East, it can exceed 12 000 km. Such an interconnected power system will have pronounced wave characteristics. One of these characteristics consists in that the wave of frequency, caused by emerging of a large active power imbalance in one part of the power grid, will be moving, at a finite speed, along the transmission system. Under some conditions, this wave of frequency can give rise to continuous low-frequency oscillations. The investigation of

this phenomenon presents both scientific and practical interest and it must forego the establishing of the interconnection.

In order to fulfill the investigation properly, it is necessary to form a group of international experts who could apply their skills and modern research tools jointly. There are several ways to put this idea into practice. One of them consists in forming a consortium around the experts who took part in the full-scale experiment made in the Siberian Interconnected Power System in November 2002 [1]. The experience obtained during these tests could be a good base for preliminary investigation of the possibility of the East-West interconnection. Indeed, the experiment is of paramount importance to certify the dynamic model of the UPS/IPS network. Certification of the dynamic model is the general requirement for the East-West interconnection. Some results of the experiment and initial steps of validation of the UPS/IPS dynamic model will be discussed here.

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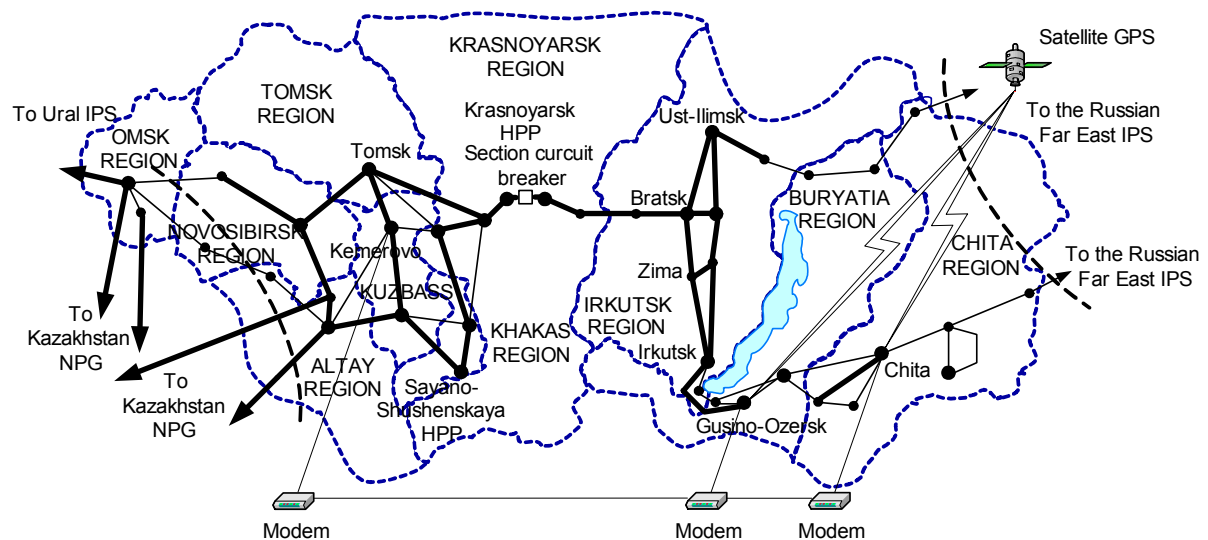


Figure 1 - Configuration of the Siberian Interconnected Power System. IPS- Interconnected Power System, NPG- National Power Grid, HPP- Hydro Power Plant, SPP- Steam Power Plant

2. OBJECTIVES OF THE SIBERIAN TESTS

The cause of this exploration was the necessity to make sure that the program and the models being used for more than 10 years for long-term stability assessment in power systems, simulates dynamics properly. The other motives to execute the full-scale experiment were the start of processes of deregulation in the power industry and an absolute necessity to guarantee that the frequency in Russian power systems can satisfy the European standards. One of the actions to achieve this consists in an estimation of the frequency-control capacity of the power plants.

Simulation of long-term dynamics in large-scale power systems is another side of this exploration. This paper presents the conditions of the preparation, the realization and the results of the simulation of the processes which existed during the experiment.

3. DESCRIPTION OF THE TEST

The Siberian Interconnected Power System was separated from the Russian Power

Grid during the experiment, and it included the following power systems as shown in Fig. 1. The places of separation are shown by dotted lines.

The experiment consisted in making a series of trials (5 trials in total) giving rise to active power imbalances and in recording active power and frequency to check the correctness of the system automatic actions. The 110 kV and 220 kV transmission lines, which shunt a two-circuit 500 kV transmission line at the Krasnoyarskaya Hydro Power Plant (6 000 MW, 12x500 MW), were disconnected. One of two 500 kV section circuit breakers at the Krasnoyarskaya Hydro Power Plant's busbar was open. Thus, the eastern and western parts of the Siberian interconnected power system became connected only by one 500 kV circuit breaker.

During the experiment, the power flow (in both directions) through the circuit breaker was made such that, on its disconnection, a frequency deviation of ± 0.3 Hz in each part of the power grid was reached [1].

In order to perform the experiment with maximum accuracy, in addition to Russian

measuring instruments, two digital fault recorders, known as BEN 5000, produced in Belgium were installed. That permitted to the authors of the paper to compare the results of the simulations with the full-scale tests. One of oscillograms obtained during the tests is shown in Figure 2.

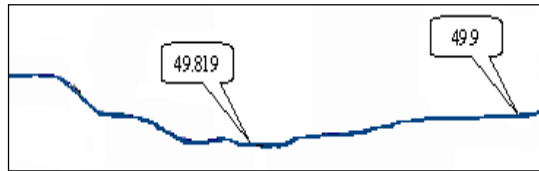


Figure 2 - Oscillograms of frequency during trial №2, obtained from BEN equipment at the Gusinozerskaya steam power plant.

4. DESCRIPTION OF PAG AND EUROSTAG

The simulation of the above mentioned full-scale experiments in the Siberian Interconnected Power System were done with the use of PAG and EUROSTAG software packages. The results obtained in one of five trials have been represented and discussed in [1]; some of them are shown in Figure 3.

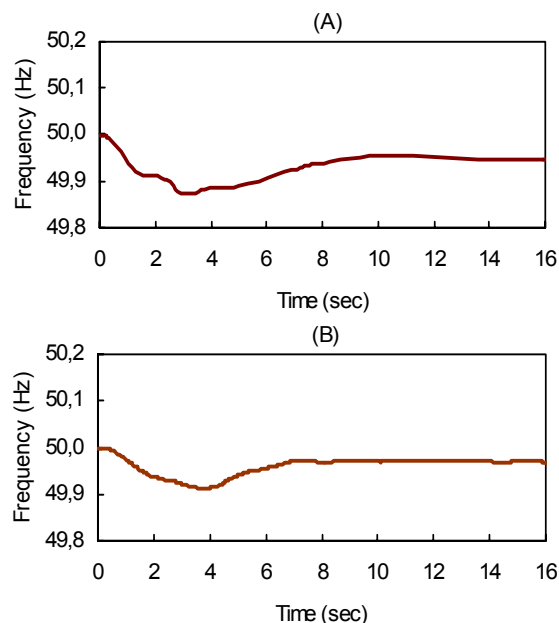


Figure 3 - The modeling of frequency in trial №2: (A) using EUROSTAG software; (B) using PAG software

4.1. PAG software package

PAG software package has been developed by the Siberian Electric Power Research Institute. PAG includes the power-flow calculation program, the program of short-term/long-term dynamics calculation and structural analysis on the base of the wave approach discussed in [2] and [3]. The computational algorithm uses the implicit method of numerical integration with variable steps and orders. The Newton method is used for solving the balance equations. The method of the double factorization of the system matrix is used for the solution of the set of linear equations by iteration.

The program permits to model the power systems automatic controllers, programmable by the user. PAG has the following restrictions: (a) 100 synchronous machine, (b) 300 nodes, and (c) 400 branches.

Significant characteristics of power system's electromechanical oscillations are their spectrum, their so-called "maps of motions", and wave structures. They are obtained by means of calculation of eigen frequencies and wave functions for the system's dynamic model chosen under varying location of the nodes (so-called observation points or reference nodes) at which trial harmonic disturbances are applied as explained in [2] and [3].

4.2. EUROSTAG software package

EUROSTAG has been developed by TRACTEBEL and Electricité de France. It is a general purpose stability program using an extended modelling of the power system and allowing the simulation of its dynamic performance over a long period of time, even in case of intermingling of fast (transient) and slow (long term) phenomena.

EUROSTAG uses an implicit simultaneous integration method and an automatically variable stepsize (and order) able to secure a constant accuracy of the simulation whatever the behaviour of the power system. EUROSTAG covers all the range of electromechanical transients, from short circuit to daily load variation. It has been designed for large scale power systems (20 000 state variables and more)

4.3. About modelling

Long term dynamics simulation by means of EUROSTAG or PAG most of the time asks for a stepwise method and iterative analysis. The 1st step is modelling of the system. The components are modelled by using the standard library, or in case of specific needs, by coding special block diagrams. Model parameters are gathered or evaluated. The 2nd step consists in the validation of models and parameters. Controller models and their tuning are validated by means of steady state stability analysis (eigenvalue analysis) or by performing standard tests (simulating well known behavior). The 3rd step is interactive simulation. The dynamic scenario is built progressively and the modelling is refined, if necessary. The 4th step represents interactive analysis of the results with the post-processing program. The 3rd and 4th steps are repeated iteratively until the results are satisfactory. In this process the domain of validity of the modelling is checked and put in accordance with the operating points reached and the phenomena displayed during the simulation [4].

5. BUILDING AND VALIDATING THE ENTIRE UPS/IPS MODEL

5.1. General

The final aim is to support the study of the East-West interconnection. This study must deliver “proofs by simulations”. To

make the simulations possible, adequate models of TESIS (UCTE+CENTREL) and UPS/IPS systems must be set-up. This paper describes the modelling of the UPS/IPS systems. The model must be, to a certain extent, certified.

This certification will be based on two complementary actions. The first part of that specific work will be devoted to the preparation of a fully documented dossier about data, mathematical models of power plants and networks of the UPS/IPS power system. The second part will be based on information from the digital fault recorders suitably deployed in the system, to assess the power/frequency control operation and to allow a certification of power system models, including load models.

5.2. Ways and means

These works must be realized beyond those made in the framework of the Tacis Project EREG 9601 :“Synchronous Interconnection of the TESIS and UPS Networks - Requirements and Feasibility”.

The ways and means necessary to reach our present goal can be summarized as follows:

- Definition of the suitable Data Quality (D.Q.) approach in the preparation of the models and parameters;
- The set-up of the “right” system model which must be as detailed as necessary, but must remain as simple as possible. The basic dynamic models for UPS/IPS power plants simulation will be those developed during the Tacis Project ERUS 9411 “Stability of Operating Regimes at Power Stations”;
- The preparation of the specific dossier including the certified models and parameters for the different power plants and the networks;
- The installation of digital fault recorders in the UPS/IPS system to get the basic information allowing the certification of the global model.

5.3. Certification methodology

The comprehensive certification of all power plant models, of all parameters implies huge efforts beyond the scope of this investigation. Hence the method which will be used for certifying power system models, at least in the domain considered, will be based on the comparison of simulation results with recordings made following real incidents, or possibly specific tests.

To be effective, such a procedure imposes the use of well built simple models, taking into account the basic physical characteristics of the different control systems and processes.

The methods will be specific to each domain considered: the modelling of power plants and the modelling of networks based on works realized during previous projects. Some aspects will be reconsidered in the frame of system model certification.

The measurements will be realized by suitable digital fault recorders which have to be installed for that purpose in the UPS/IPS system. Similar devices have been installed in Western Europe by different companies

5.4. Data Quality

Data quality (D.Q.) procedures will be developed in details at the beginning of the project. The main idea behind them is as follows. In a first step, each significant item within the system model will be identified: the origin and the validity of the model available as well as of its parameters. Then, in a second step, the user will decide in full knowledge of the facts those for which complementary investigations could be necessary to

guarantee for the model and its data a sufficient quality.

The methods will be specific to each domain considered: the modelling of power plants and the modelling of networks.

5.4.1. Modelling of power plants

A library of models has been built for Automatic Voltage Regulators, speed governors and boilers in service in UPS, in the framework of the Tacis Project ERUS 9411. The different units in the system will be modelled using this models library and the corresponding sets of parameters, if they are confirmed by the D.Q. procedures. If some units are equipped with prime movers or controllers which are not yet modelled, specific models could be proposed and developed to complete the Russian models library.

To set-up the D.Q. procedures for the power plants modelling, the analysis of the following information sources will be considered:

- The procedures used when putting power plant into service;
- The procedures in application after power plant servicing;
- Tests made on a regular basis during power plant life.

The results of these investigations will permit to describe comprehensively where the actual control parameters are coming from. In case of doubts about some parts of the developed model, specific investigations could be proposed for tuning the related parameters, like for example the application at model level of the practical rules used for setting control parameters in real situation (for example the gains setting of additional signal loops in AVR, whose function is equivalent to Power System Stabilizers).

5.4.2. Modelling of networks

In the framework of the Tacis Project EREG 9601, a system model valid for the year 2005 has been proposed. The D.Q. procedures will analyse globally the origin of data for the different components of the model: analysis of reception tests (like those of transformers), field tests, measurements before putting devices into service (like line parameters), and computations based on physical descriptions etc.

The technical procedure used previously for "equivalencing" the lower voltage parts of IPS will be evaluated taking the best suited IPS as example.

Similar models will be set-up in due course for studying specific situations. These will be suited for checking real world events detected by the digital fault recorders.

5.5. Digital fault recorders

Measurements realized during perturbations will be used for checking the validity of the model set-up for UPS system, in the domain of low frequency oscillations. This is necessary to limit the uncertainties related to load behaviour, to system "equivalencing" of generating sets connected at lower voltage levels and not explicitly represented, etc.

The proposed method consists of using planned tripping or real events which take place at random in the system and to record them in different sites. Hence to simulate the identified events, considering the data sets prepared as described above, and to compare measurements and simulated results. Some iterations could then be necessary to refine the modelling and finally to assess the quality of the model (the same method has been used by RWE and REE to prove the quality of their modelling of UCTE and TESIS).

This supposes the installation of digital fault recorders, hence:

- The preparation of technical specifications for these devices;
- The determination of the number and locations where they will be installed, in the frame of a specific budget;
- The acquisition and installation;
- The preparation of the procedures which will be used to collect the recorded data (stored in digital fault recorders) and the additional information about the corresponding initiating perturbation.

5.6. Simulations

Simulations will be used for performing investigations on the recorded incidents. The steady-state stability of the interconnected system will be investigated.

These simulations will be realized considering:

- Linear analysis around an operating point. This will be made using EUROSTAG to generate the linear model, and a specific module based on Arnoldi method to analyse the less damped modes of oscillation;
- Time domain simulations of the full detailed model, to account for possible non linear oscillations.

The size of the dynamic model imposes the use of a powerful computer and a specific version of EUROSTAG.

6. RECOMMENDATIONS FOR FURTHER TESTS – FULL SCALE TESTS

As proposed hereabove, a preliminary task which must be solved in order to accomplish UCTE - UPS/IPS inter-connection consists in preparing and carrying out several full-scale experiments, similar to those fulfilled in the Siberian IPS, in the specially defined zones of UPS/IPS. These zones could be constructed from some IPS bordered upon

each other. The zones must be determined by ISO-UDC depending on the conditions situation. These investigations could be realized in the short term. The interim is determined by the time for rigging UPS/IPS with suitable digital fault recorders which will use GPS service.

Figure 4 represents an example of frequency wave propagation that can be obtained during the suggested tests. As it follows from the figure, there are two phases of wave propagation in power system: (a) phase of standing wave and (b) phase of travelling wave.

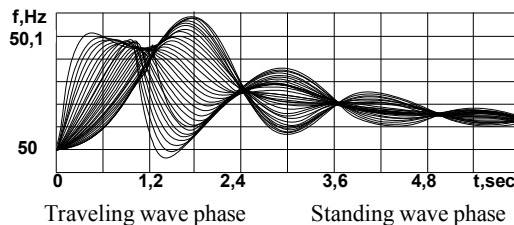


Figure 4 - The frequency wavelength allocation in the large-scale power system

This picture has been observed under simulation of frequency behaviour in some nodes, under arising large imbalance of active power. Here each curve conforms to one of the nodes which are dispersed along transmission system. If the number of digital recorders placed along transmission system will be sufficient, under certain conditions such results can be obtained in the full scale experiment too.

After having reached a consensus with UCTE on the feasibility of East-West interconnection, trial synchronization and tests of the same nature could be fulfilled on the UCTE – UPS/IPS interconnected.

7. CONCLUSION

The full scale tests on the Siberian Interconnected Power System have been successfully conducted and exploited with the contribution of an international team of experts. This experimentation has demonstrated the feasibility of the

validation of the power system mathematical model at low frequency.

The same team of experts proposes a methodology that can produce a dynamic model of the whole UPS/IPS system. This model will be certified by an extended test campaign applied to the whole interconnected network.

The availability of such validated model shall be a major prerequisite and a huge contribution to the study of the synchronous operation of UPS/IPS – UCTE systems.

It is understood that a quick start of the application of the proposed methodology would constitute the most efficient way to speed up the demonstration of the technical feasibility of the East-West interconnection giving time for advanced studies and possible controllers or defense actions adaptations, before the target date of interconnection (2008-2010).

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