21, rue d'Artois, F-75008 PARIS
http : //www.cigre.org)

C2-205

CIGRE 2008

Digital models perfection for solving problems of IPS/UPS systemic reliability

A. BONDARENKO, V. GERIKH, A. ZHUKOV
JSC "SO-CDO UPS"
A. GERASIMOV*, A. ESIPOVICH
JSC "NIIPT"
YU. KUCHEROV
SC "Mosenergo"
Russia

M. ZORIN
NEK "Ukrenergo"
The Ukraine
N. RESETNIKOVA
GUP "Belenergo"
Belarus

SUMMARY

The high level of the systemic reliability of IPS/UPS synchronous zone is provided due to continuous scientific and technical support of its development and day-to-day operation. As one of the basic research tools the digital models of the whole power system and its separate fragments are applied. At the same time the principle of the common infobase is applied during various digital models creation.
With the advent of new microprocessor regulating devices in the UPS of Russia, implementing complex control laws, the available digital models of electric power systems became inadequate from the point of view of providing both a quantitative assessment of stability margins , and a qualitative coincidence of the history of electromechanical transients to a reality after normative perturbations. This has led to the necessity of perfection of digital models of complex power systems by including in their structure detailed microprocessor control devices models.
In the modern dynamic models the most detailed representation is used for the automatic voltage (excitation) controllers (AVR) and power system stabilizers (PSS). Digital modeling of the AVRs and PSSs is carried out using their full mathematical description. For the creation of digital models of modern domestic AVRs the EUROSTAG and PSS/E software are used. In the environment of this software the full digital models of semi-conductor, analog-digital and digital excitation controllers were realized.
The adjustment and verification of AVR digital models is made by the comparison of the response characteristics of regulating channels with the data of tests of industrial samples or the data provided by the AVR producers. Response characteristics of the microprocessor AVR are distinguished by their high stability, therefore it is sufficient for them to verify the typical model. After that the model can be applied for any generator for the sampling of the adjustment of AVR channels. All semi-conductor excitation controllers have specific features, therefore their models for each concrete installation requires additional tuning, which is carried out on the base of full-scale test data. Example of verification of the model of analogue excitation controller and PSS of the North-West TPP is given in the report.
Aforementioned approaches guarantee the reliability of operational computations with the use of digital models and allow to use them for solving various problems, such as the analysis of emergencies and development of recommendations of their prevention, examinations of various projects regarding maintenance of transient and small-signal stability, adjustment of the power system stabilizers on functioning installations, analysis of low-frequency oscillations, sampling of adjustments of counter-emergency automatons, etc. Examples of practical use of IPS/UPS reference digital model and its separate fragments are given in the report.

KEYWORDS

Power system – Digital model – Regulator – Stability.

* Gerasimov_a@niipt.ru

Introduction. The high level of the systemic reliability of IPS/UPS synchronous zone is provided due to continuous scientific and technical support of its development and day-to-day operation. As one of the basic research tools the digital models of the whole synchronous area and its separate fragments are applied. At the same time the principle of the common infobase is applied during various digital models creation. This guarantees that all investigations of steady-state load flow, transient and small-signal stability will be performed in the model of the same detail level, and also gives the opportunity to avoid possible errors, which appear during the initial data conversion from one software to another, and also to avoid the additional inaccuracies during equivalenting.
Down to the end of 90-ies, for the estimation of stability margins simplified digital models were applied, where various regulating devices, such as automatic excitation controllers, power system stabilizers, speed governors and turbine power regulators have been accounted with simplified representation.
With the advent of new microprocessor regulating devices in the UPS of Russia, implementing complex control laws, the available digital models of electric power systems became inadequate from the point of view of providing both a quantitative assessment of stability margins, and a qualitative coincidence of the history of electromechanical transients to the reality after normative perturbations.
All this has led to the necessity of perfection of digital models of complex power systems by including in their structure detailed microprocessor control devices models, which in turn have been preliminary verified.
Automatic controllers modelling. In the modern dynamic models the most detailed representation is used for the automatic voltage (excitation) controllers (AVR) and power system stabilizers (PSS). Digital modeling of the AVRs and PSSs is carried out using their full mathematical description. For the creation of digital models of modern domestic AVRs the EUROSTAG and PSS/E software are used. In the environment of this software the full digital models of semi-conductor, analog-digital and digital excitation controllers were realized.
The adjustment and verification of AVR digital models is made by the comparison of the response characteristics of regulating channels with the data of tests of industrial samples or the data provided by the AVR producers. Response characteristics of the microprocessor AVR are distinguished by their high stability, therefore it is sufficient for them to verify the typical model. After that the model can be applied for any generator for the sampling of the adjustment of AVR channels. For example, the response characteristics of UNITROL 5000 excitation controller produced by ABB (fig. 1, 2) are gained during its test on power system physical model [1].

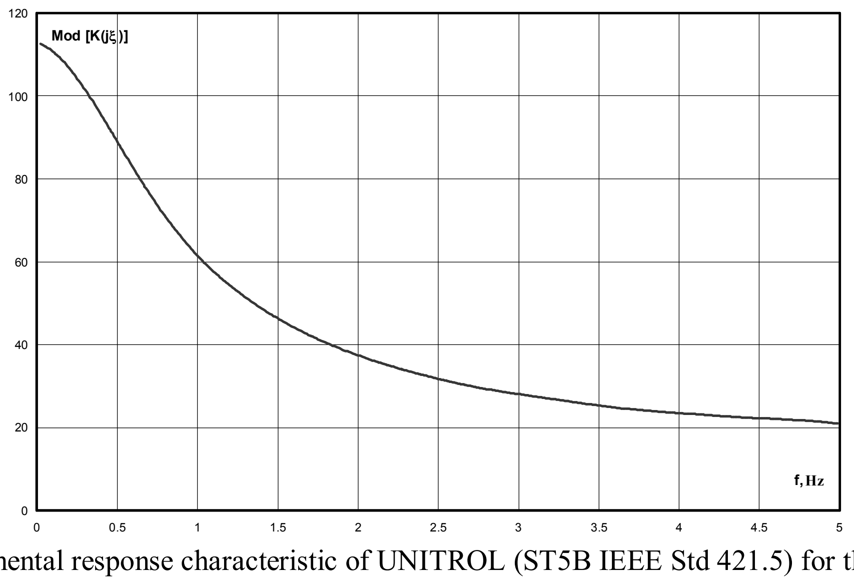


Fig. 1. Experimental response characteristic of UNITROL (ST5B IEEE Std 421.5) for the excitation system of model oscillator of power system physical model.

All semi-conductor excitation controllers have specific features, therefore their models for each concrete installation requires additional tuning, which is carried out on the base of full-scale test data.

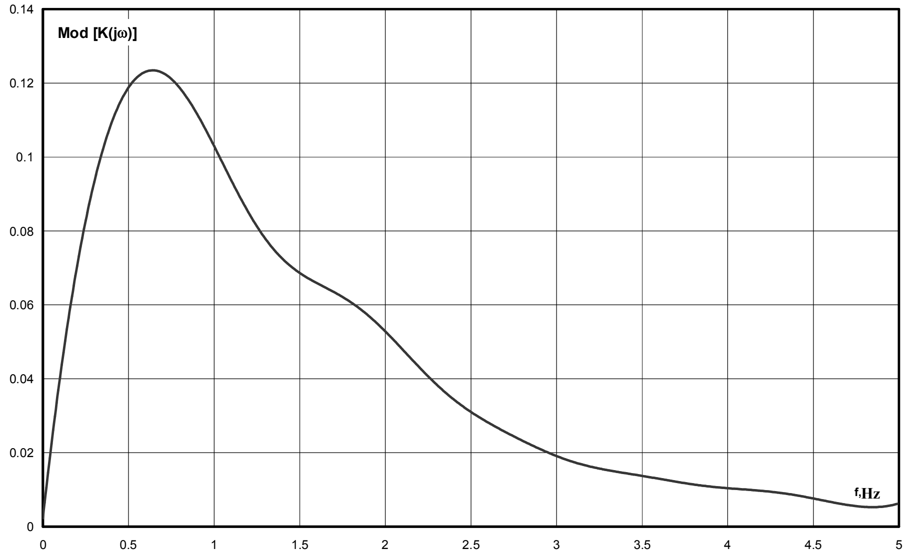


Fig. 2. Experimental response characteristic of power system stabilizer UNITROL (PSS2B, IEEE Std 421.5) for the excitation system of the model oscillator of power system physical model.

So for verification of digital model of the semi-conductor excitation controller and power system stabilizer of generator of a combined-cycle unit №1 of Northwest combined heat power plant the response characteristics of this regulator have been obtained for all its channels. Basing on these characteristics the digital model was verified and adjusted. On figure 3 an instance of the verification of one of the channels is given.

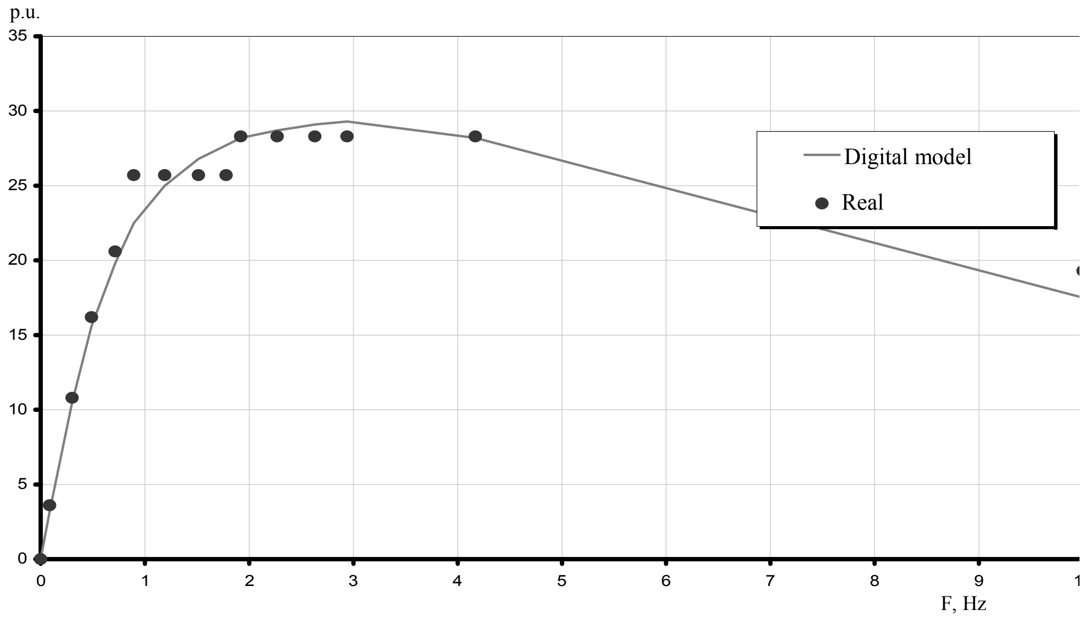
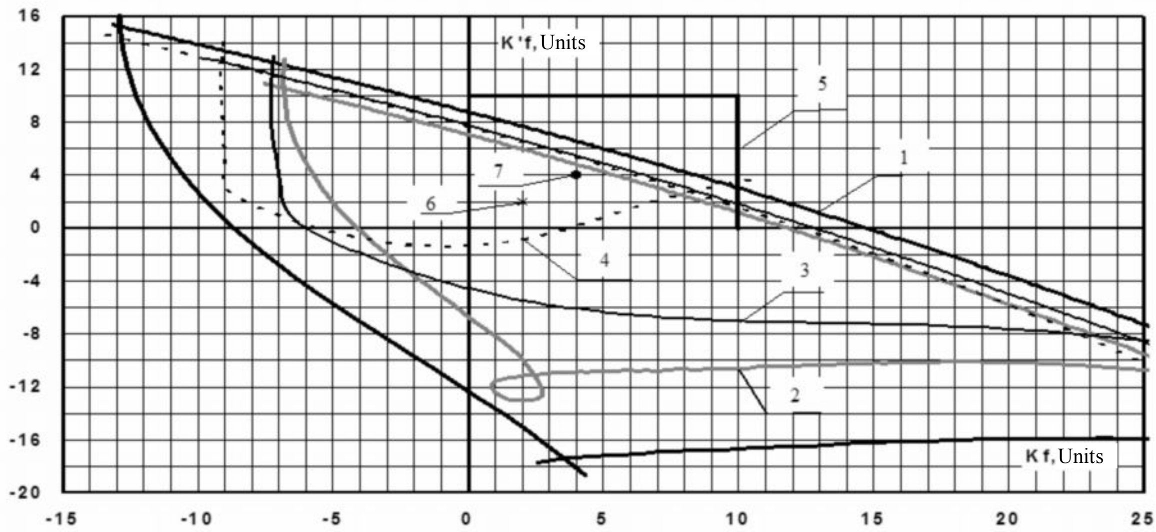


Fig. 3. Voltage derivative channel verification.

<u>**Analysis of emergencies.**</u> Aforementioned approaches guarantee the reliability of operational computations with the use of digital models and allow to use them for solving various problems, such as the analysis of emergencies and development of recommendations of their prevention, examinations of various projects regarding maintenance of transient and small-signal stability, adjustment of the power system stabilizers on functioning installations, analysis of low-frequency oscillations, sampling of adjustments of counter-emergency automatons, etc.

In 2001 the solution to switch the combined-cycle unit №1 of Northwest power station on parallel operation with NORDEL power system via the single-circuit 330 kV overhead transmission line was taken. The accepted output scheme makes additional requirements to power and voltage regulating systems of the combined-cycle unit. Investigations of operation conditions, small-signal and transient stability were performed for guaranteeing stable parallel operation of the power station in the power system. Investigations were carried out on the digital model, which includes detailed model of Northwest power station with verified models of excitation controllers and power system stabilizers and NORDEL power system model. Computations have shown, that after various perturbations in the power system there are slowly damped low frequency oscillations (0.25÷0.55 Hz). These oscillations were also registered during an active power monitoring on the line linking Northwest power station and NORDEL. The special software [2] allowed gaining stability areas in a plane of coefficients of amplification of a power system stabilizer of the oscillator of the steam turbine of a combined-cycle unit for all of the possible operating conditions. Also this software allowed choosing an optimal adjustment of the power system stabilizer which should ensure both small-signal stability and high quality of damping of large post-emergency oscillations (fig. 4).



1 – normal conditions; 2 – underexcitation conditions; 3 – S.C. experiment scheme; 4 - S.C. experiment scheme, PSS switched-off; 5 – range of possible tunings; 6 – tuning №1; 7 – tuning №2

Fig. 4. Areas of small-signal stability for the generator №3 of combined-cycle unit of N.-West cogeneration plant in case of its operation in NORDEL power system.

System tests in NORDEL power system have confirmed the efficiency of chosen PSS adjustments [3]. In the figure 5 the oscillograms of transient phenomenon after a three-phase short-circuit with clearance time 0.12 s in NORDEL power system is shown.

In such a way, for the analysis of the reasons of the incident occurred on May 25th 2005 in Moscow power system, a detailed digital model of this power system was created. By means of this model the emergency process with modeling of the dispatcher's actions and operation of relay protection has been reproduced on 57 minutes interval. This model allowed appraising the operations staff's actions, to reproduce alternative scenarios of control and to formulate measures for reliability augmentation [4]. For instance in figure 6 the reproduction of voltage variation in 110 kV network of Moscow power system in a final phase of the emergency is given.

On digital model the low-frequency oscillations have been reproduced and adjustments of power system stabilizers of Kola nuclear power plant were chosen. These adjustments provide a successful damping of low-frequency synchronous oscillations on weak-ties of the Kola - Kareliya - Leningrad 330 kV transit in North-western IPS (fig 7, 8).

WAMS in IPS/UPS – new opportunities. Fundamentally new possibilities on perfecting of digital models were opened by the commissioning in

IPS/UPS of system of monitoring of transients (WAMS). With the help of this system the verification of reference dynamic model of the synchronous zone [5] is made. During allocation of recorders of first stage of WAMS the singularities of the synchronous zone were considered. Singularities lies in the fact that IPS/UPS power system represents a stretched power pool system consisting of a number of concentrated electric power systems linked with rather weak and heavy loaded intersystem power transmission lines. Organization of registration of processes on interstate and intersystem power lines

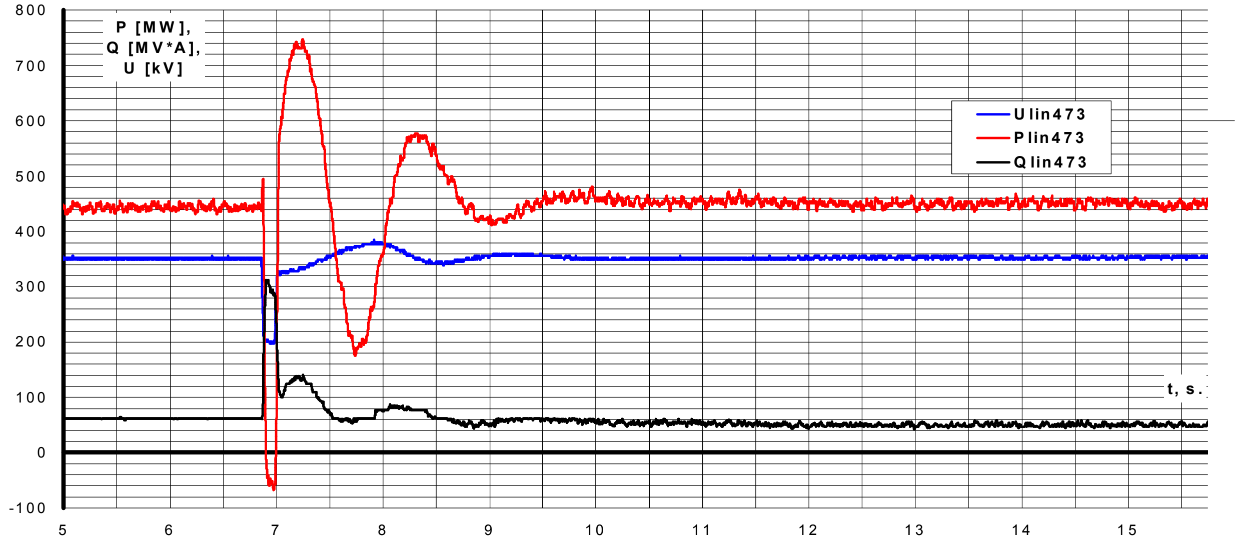


Fig. 5. Evaluation of efficiency of chosen PSS adjustments during system experiment performed in NORDEL power system.

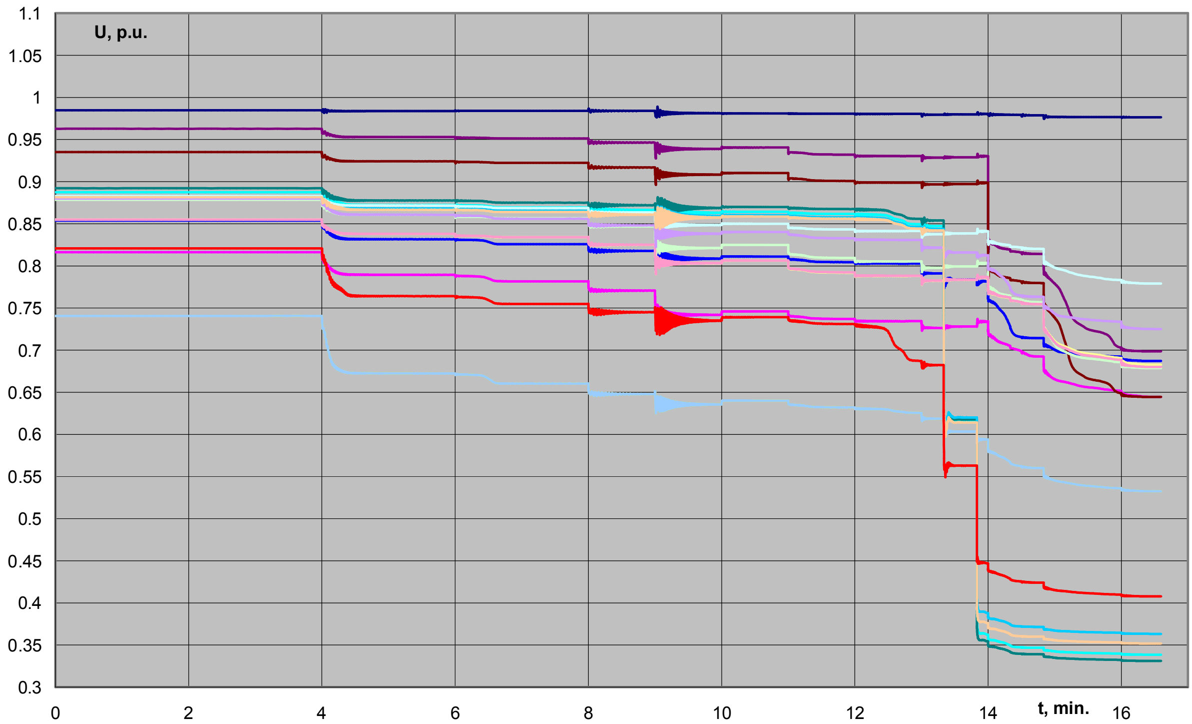


Fig. 6. Blackout in Moscow power system reproduction. Voltage variation in 110 kV network in a final phase of the emergency.

and also on the lines inside large electric power systems included in IPS/UPS such as IPS of Siberia, Kazakhstan, Central Asia and Ukraine allows to determine all basic components of electromechanical oscillations typical for IPS/UPS as a whole. The first results shows, that commissioning of the first stage of WAMS has ensured the possibility of execution of full-scale verification of reference dynamic model of the synchronous zone. By means of this verified model the frequency characteristics of power pool have been obtained for the first using the technique presented in [2], fig. 9.

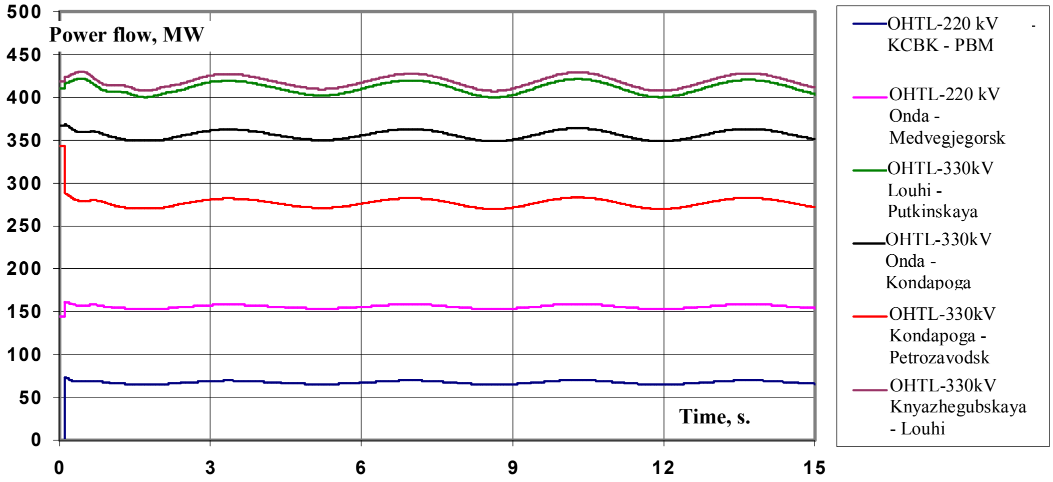


Fig. 7. Reproduction of continuous synchronous oscillations after a disturbance.

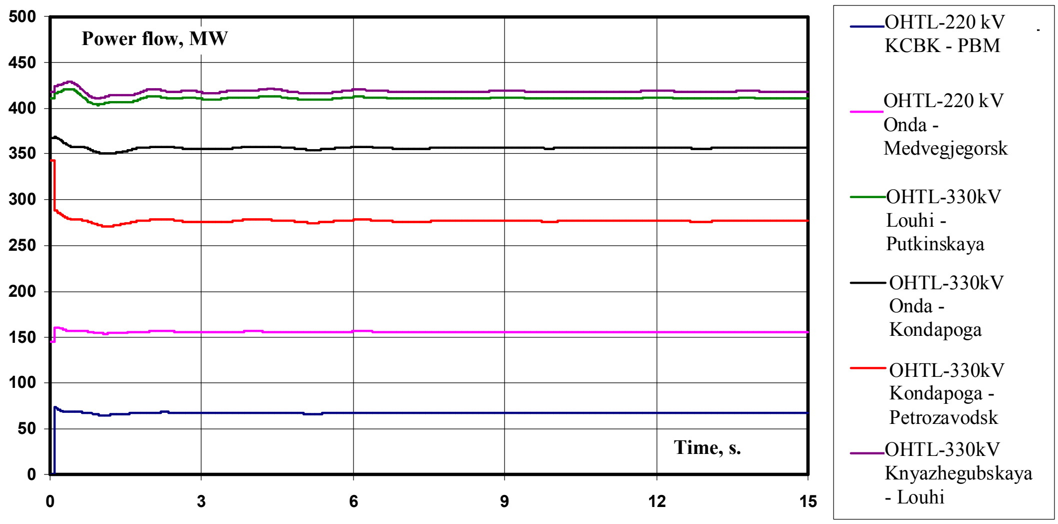


Fig. 8. Reproduction of a disturbance after adjustment of the PSS tunings.

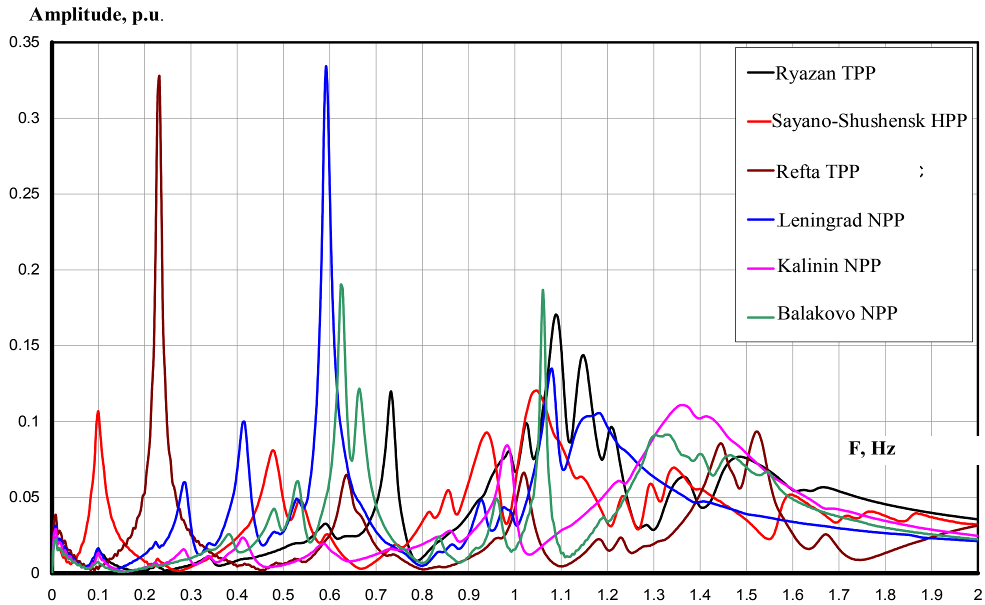


Fig. 9. IPS/UPS regime response characteristic

Conclusion. The given examples show that authentic digital models ensure an adequate analysis of dynamic behavior of electric power systems, allow to compute more precisely the areas of admissible operating conditions of electric power systems which basically are defined by the stability margins in the post-emergency conditions, to choose the set points of counter-emergency automation devices, to investigate the emergencies and to develop recommendations on their prevention, to choose the effective tuning of power system stabilizers etc. All this contribute to rising the system reliability level.

BIBLIOGRAPHY

[1] A. Gerasimov, T. Guschina, A. Esipovich, A. Zekkel, G. Kiriyenko, N. Michurin. Electrodynamics Power System Simulator for Bulk Power Systems Investigations and for Testing, Debugging and Adjustment of Various Digital Control and Automation Systems. (2005, IEEE, St.-Petersburg PowerTech Proceedings).

[2] A. Gerasimov, A. Esipovich, A. Zekkel. Adjustment for Power System Stabilizing Channels Structure of Generator's Automatic Excitation Regulators. (2005, IEEE, St.-Petersburg PowerTech Proceedings).

[3] A. Gerasimov, A. Esipovich, A. Zekkel, A. Gilev, I. Gryaznov and others. Optimization of tunings of excitation regulators of North-West cogeneration plant for the ensuring of power station parallel operation with Nordel power system. (Power Stations, №4, 2004).

[4] A. Gerasimov, A. Esipovich, L. Koshcheev, N. Shulginov. Investigations of Moscow power system operating conditions during blackout 24-25 may 2005. (Electrichestvo, №1, 2008)

[5] B. Ayuev, A. Gerasimov, A. Esipovitch, Y. Kulikov. IPS/UPS transients monitoring. (International Scientific Conference «Monitoring of Power System Dynamic Performance» Moscow, 25-27 April, 2006).

[6] A. Bondarenko, V. Gerikh, V. Kreslins. N-1 reliability criterion interpretation. (C2-106, CIGRE 2006).