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IPS/UPS transients monitoring

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SUMMARY

The purpose of the Wide Area Measuring System (WAMS) for the integrated and unified power systems (IPS/UPS) of the Commonwealth of Independent States (CIS) and Baltic countries is outlined.
The WAMS provides information needed for on electric power system (EPS) behavior in both transients and steady state condition estimation.
Three-ties control structure of WAMS are following: the first level –Phasor Measurement Units (PMU) multifunctional measuring transducers and communication server installed at the EPS substations, the second level – automated work stations (AWS) allocated in the Interconnected Dispatch Office (IDO) of the Unified Electric Systems (UES) of Russia and dispatch centers of CIS and Baltic countries, the third (the highest) level – AWS of System Operator – Central Dispatch Office (SO-CDO) of UES.
The approaches to determining the expedient locations of the PMU's in EPS are presented as well. The synchronized measurements should cover the entire territory of CIS and Baltic countries. The PMU shall be installed in major load nodes, power stations and substations, to make it possible to verify and adjust the digital model of IPS/UPS. The installed PMU's have to make it possible to measure intersystem power flows for estimating various control area behavior and for controlling secondary frequency regulators performance.
This paper defines the structural scheme of the informational interchange between IPS/UPS power systems.
Monitoring of electric power system dynamics provides an additional opportunity to estimate static and dynamic stability, allows to validate digital models, enhances state estimation, facilitates accident analysis and simulation exercises.

KEYWORDS

Transients, Dynamic performance, Synchronized measurement, Low frequency oscillation, Informational interchange.

1. INTRODUCTION

An essential progress has been there in the development and application of the so-called Wide Area Measuring Systems (WAMS) [1], meant for measuring regime parameters in major electric power systems (EPS). These WAMS are widely used for both to verify digital models and to solve issues pertaining to information support of EPS operation control. Their appearance allowed to eliminate shortages of information regarding electromechanical transients. This information is essential for an adequate analysis of EPS dynamic performance.

In spite of the fact that duration of transients determined by speed-torque characteristics of electrical machines is measured, as a rule, in seconds, these transients qualitatively define further system performance – transition to a new steady condition or to emergency state. More accurate modeling of transients will make it possible to specify transmission capacity limits regarding lines and sections and adjusting the conditions areas.

Accuracy of electromechanical transients modeling depends on how accurately the digital model describes:

- generator excitation regulators,
- turbine speed governors,
- load dynamic characteristics,
- protection and automation means.

Correctness of the models can be checked most effectively by comparing transients' parameters measured by WAMS with similar digital parameters under the same disturbance. Important here is to synchronize the measured parameters using high precision signals transmitted once in a second from the satellite positioning system. Then creating WAMS any emergency state in EPS plays the role of passive experiment. Studying the succession of such experiments will continuously bring new information on dynamic performance of the system. It will help to improve the digital models, to solve the other tasks in order to make condition controlling more effective.

2. WAMS AIM AND TASKS

The purpose of WAMS is to absorb the new technology of transients' parameter measurement, which complements the remote measurement system existing in IPS/UPS.

The technology makes it possible to improve condition control quality of the EPS dynamic performance study.

An in-depth experimental study of electromechanical transient phenomena, that form transient condition, makes it possible to attack the following new tasks regarding conditions quality improvement.

1. IPS/UPS digital Model Verification

Any model need to be verified, especially one designed for the analysis of electromechanical transients.

Model verification involves a comparison of transient parameters (frequency, power flows) measured synchronously in various pour system nodes and branches with the parameters computed on its basis for the same disturbance.

Verification objectives:

- models of automatic control units;
- load models for specifying their static response and dynamic characteristics;
- IPS/UPS digital model as a whole.

2. *Low Frequency Oscillations Verification and Analysis.*

After frequency fluctuation detection it may be possibly to monitor low frequency oscillations (if occur) for 15 minutes. Analyzing oscillations amplitude and mode of its propagation allows to define the source of oscillation and to recommend damping measures.

3. Voltage Monitoring in Grid Nodes

- Load stability control and voltage collapse preventing;
- Defying actions to control adjustable reactive power sources;
- System voltage levels imaging.

4. Accident Analysis

Developing analysis methodology for system and regional level accidents; developing standard accident analysis procedures.

5. Electric power system state estimation.

Using voltage phasors of the grid nodes, where PMUs are installed, makes it possible to create the grid "framing", to lessen the problem of convergence and to shorten the state estimation time. It is particularly important for IPS/UPS in view of lengthy transmission lines.

6. Voltage Phase-Angles Monitoring at Grid Nodes

It becomes possible to specify transmission capacity limits regarding certain lines and sections by comparing on-line calculated and measured voltage angles. Specifying the limits downward will make it possible to lessen interruptible customers capacity if power shortage in the system occurs.
Quick identification of asynchronous condition becomes possible, too.

In the course of WAMS operation and development, a number of other new tasks may appear. Their solution will become possible as a result of in-depth study of power system dynamics on the basis of transients' parameters detailed analysis.

3. WAMS ARRANGEMENT

WAMS diagram is shown on figure 1. This diagram presents three levels of WAMS.

On the first level currents and voltages are measured with the help of the Power Measurement Unit (PMU).The received information on normal condition currents and voltages is transmitted to the communication server (CS), whose architecture is shown on figure 2, is synchronized with the help of exact time markers and is archived. Communication server controls the current condition according to the configuration file settings, which define the signs of coming emergency.

Those signs are:

- Rate of frequency change. Configuration file setting can be defined in the interval of (0.05÷2) Hz/s with a step of 0.05 Hz/s.
- Voltage level, which can be significant in the interval of (0÷120)%.

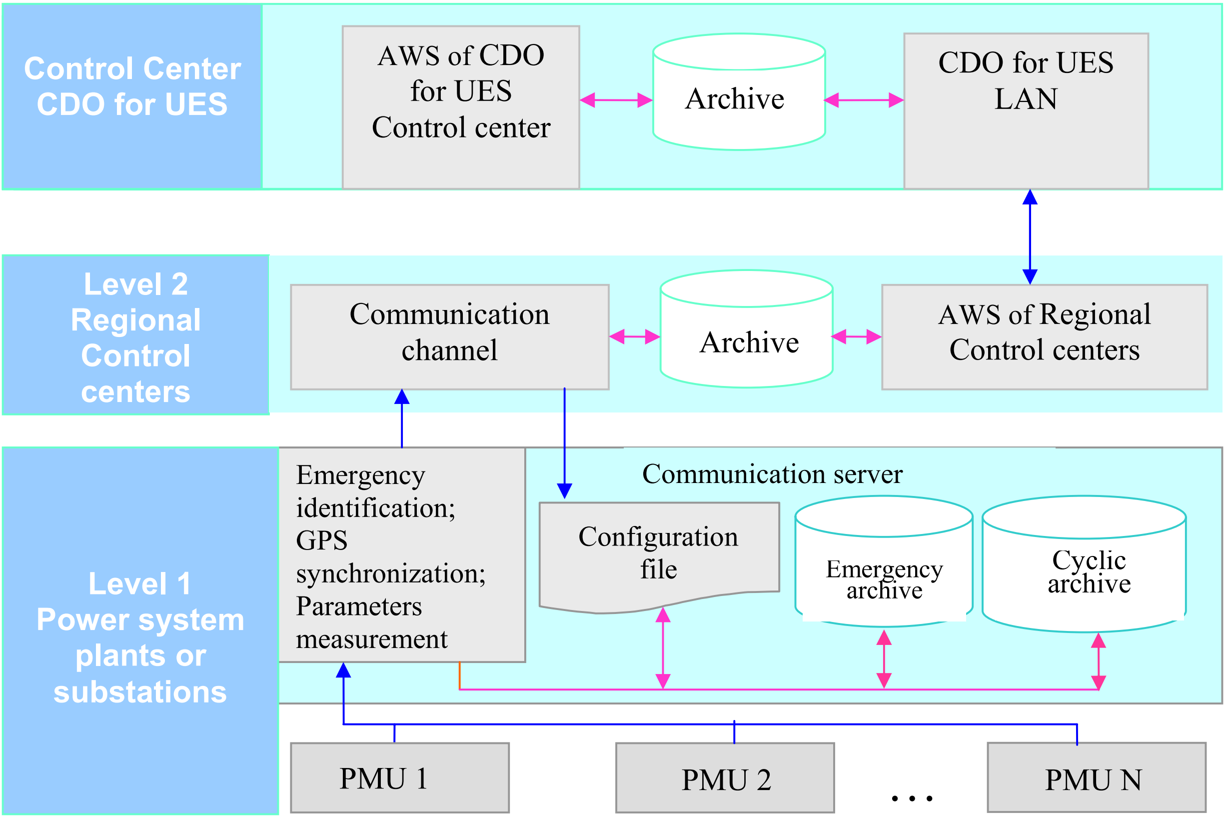

Fig. 1. WAMS diagram

In case emergency condition is identified, its parameters are recorded in emergency archive. Emergency condition record contains parameters of 100 seconds of pre-fault condition, and parameters of 1000 seconds of emergency condition.

The second WAMS level is in the regional WAMS control centers allocated in the IPS Dispatch Offices (IPS DO) of UES of Russia. The regional automated work stations (AWS WAMS) are allocated on this level.
At each AWS WAMS software (SW WAMS) is used with the following functions:

- Configuration files composition for CS. With the help of standard Windows interface a user can preset the following parameters for each PMU);
- Ensuring authorized access to the archive data and configuration files on CS via dial-up connection;
- Computing of the transient parameters on the basis of received archive data;
- Transforming data storage server format into Comtrade or Csv (comma separated values) formats.

Emergency state parameter information that was received from communication server is:

- processed and transmitted to IPS DO for further use;
- transmitted to the third level for integration and procession.

The third WAMS level, the Control Centre, is allocated at SO-CDO. AWS WAMS of the highest level is nested in it. Each emergency state parameters coming from regional WAMS control centers are integrated here. Information on each accident is analyzed and is used to solve the above mentioned tasks. Control centre distributes information on each registered accident to IPS DO of UES of Russia and to dispatch centers of CIS and Baltic countries.

4. PHASOR MEASUREMENT UNITS ALLOCATION IN IPS/UPS GRID.

In order to resolve issues faced by the WAMS, it is essental to allocate phasor measurement units in consideration of the following requirements:

1. It is necessary to allocate the units in major generation centers – at power stations and substations, to make it possible to verify and adjust digital models of IPS/UPS.
2. While allocating the units IPS/UPS stretched structure should be taken into consideration. Energy facilities equipped with phasor measurement units should be distributed from the East to the West and from the South to the North of IPS/UPS. It will allow low frequency interzonal oscillations controlling and damping measures defying.
3. Recorders allocation scheme should make it possible to measure inter-area flows for estimating various control areas performance.
4. It makes sense to install recorders at secondary frequency control power stations in order to estimate effectivness of this control.

Choosing of the optimal installation sites for PMU was carried out in view of the possibility of the implementation of actual tasks of the monitoring of a power pool and the future tasks of control of a power system. This choosing was performed using the analysis of dynamic properties of an electric power system made on its digital model at the test perturbations – the power unbalances.

The synchronous zone of the IPS/UPS represents the stretched power pool consisting of some concentrated electric power systems, linked by rather weak intersystem and interstate transmission lines. The analysis of electromechanical transients at the origin of power unbalances has confirmed that in most cases each IPS perceives exterior power deficiency as a concentrated electric power system. In this case, the installation of PMU should be made on the lines, which are a part of the intersystem and interstate cuts and which loading is controlled and limited if necessary by the dispatching personnel of the System Operator. It is obvious that the organization of the registration on these intersystem and interstate ties first of all will allow the revealing of all of the main components of the electromechanical oscillations typical of a power pool as a whole.

The transients' registration on these ties also will create premises for the organization of an electrical regimes control system. At the same time, a number of large and stretched electric power systems, such as the IPS of Siberia, IPS of Kazakhstan and Central Asia and the IPS of Ukraine, is impossible to consider as the concentrated electric power systems: at the origin of the exterior capacity deficiency inside each of these IPSs, there are some groups of power plants which movement can be considered as inphase. The boundaries of such groups, as a rule, coincide with the cuts controlled by dispatching services. On the lines of these internal cuts it is also necessary to install PMUs.

As an example, on the fig. 2 the variation of frequency on buses of 500 kV substations of the IPS of Siberia at the origin of exterior power deficiency is given. From this figure it follows that in the IPS of Siberia four concentrated groups of power plants and three interior cuts on which digital recorders should be installed are available.

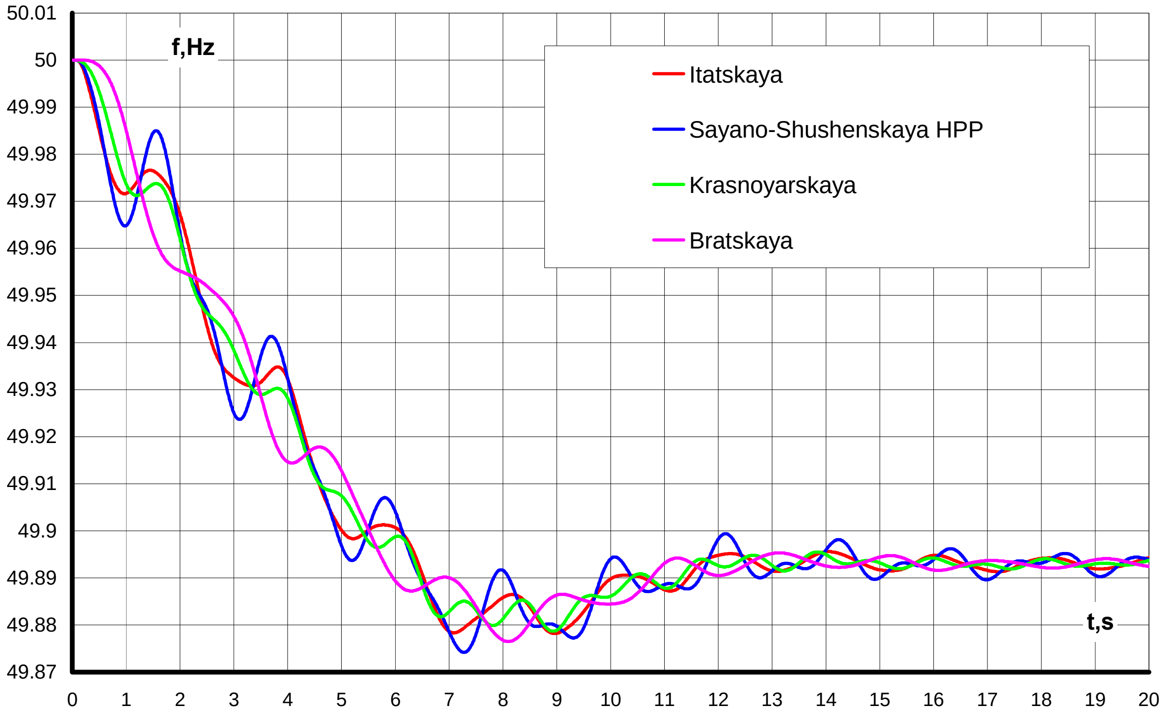

Fig. 2. Variation of frequency on buses of 500 kV substations of the IPS of Siberia at the origin of exterior power deficiency

At the same time, the frequency analysis has shown that a number of power systems behave as one concentrated power pool, and the installation of PMU on the interstate ties between these power systems is not a priority. In particular, such power systems are represented by the electric power systems of Latvia and Lithuania, while the electric power systems of Estonia differs (fig. 3).

The analysis of a separate IPS's behavior and character of the power flows variation on the intersystem and interstate ties has allowed to draw the conclusion that on the majority of the controlled intersystem and interstate cuts the measurement of the total power flow can be replaced by the measurement of the power flow on one of the cut's lines. This allows minimizing the number of points of registration of the first stage of the SMART-WAMS. It appears to be possible when the variation of power flow on the line qualitatively repeats the variation of the total power flow on the cut. As an example, on the figure 4 the following is shown (in different scales): the total power flow on the controllable cut between the IPS of the Middle Volga and the IPS of the Urals and the power flow on the 500 kV line "Beketovo" - "Bugulma".

In many cases it is possible to reduce the general number of points of registration even more, due to the optimum choosing of the place of its organization. It appears to be possible in the case when the point of the registration can be used for the control of the power flows over two adjacent intersystem or interstate cuts. So, for example, into the structure of the intersystem cut between the IPS of Centre and the IPS of Urals the 500 kV line "Kostroma" - "Vyatka" is included. Researches have shown that the measurement of the power flow on this line can be replaced with the measurement of the power flow on the adjacent 500 kV line Kostroma TPP - "Kostroma". It allows using the point of registration on the Kostroma TPP for measurement of the power flow in the cut between the IPS of the Centre and the IPS of the Urals as well.

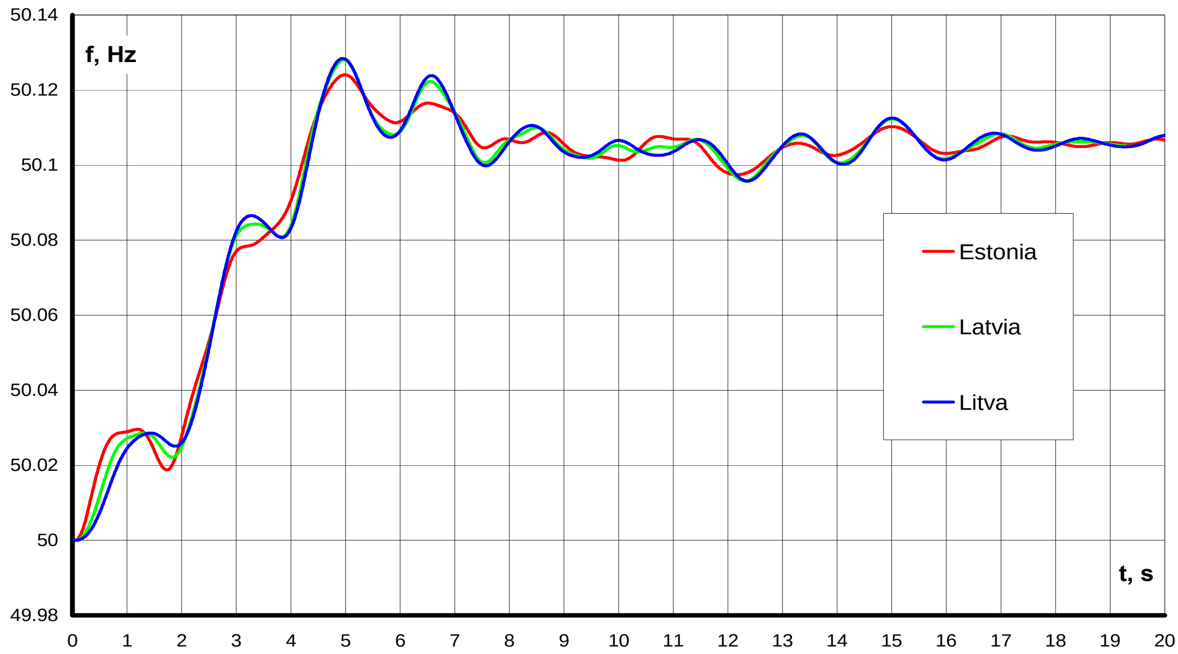

Fig. 3. Character of frequency variation in the electric power systems of Baltic States at exterior power deficiency.

The organization of the point of registration on the Volgodonsk NPP also provides controlling of two intersystem cuts at once: between the IPS of the North Caucasus and the IPS of the Centre and between the IPS of the North Caucasus and the IPS of Ukraine by registering of the power flow on the 500 kV overhead line Volgodonsk NPP - "Ugnaja" and on the 500 kV overhead line Volgodonsk NPP - "Shahty".

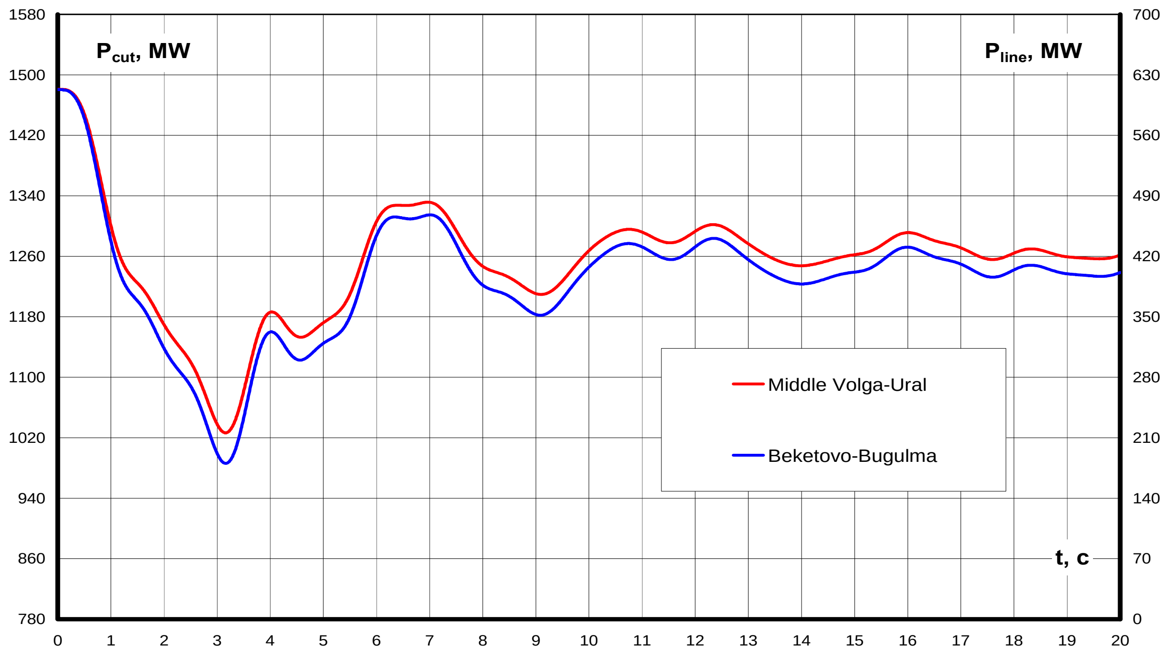

Fig. 4. Variation of the power flow on the intersystem cut the IPS of the Middle Volga – the IPS of the Urals and on the 500 kV transmission line “Beketovo” - “Bugulma” at the exterior power deficit.

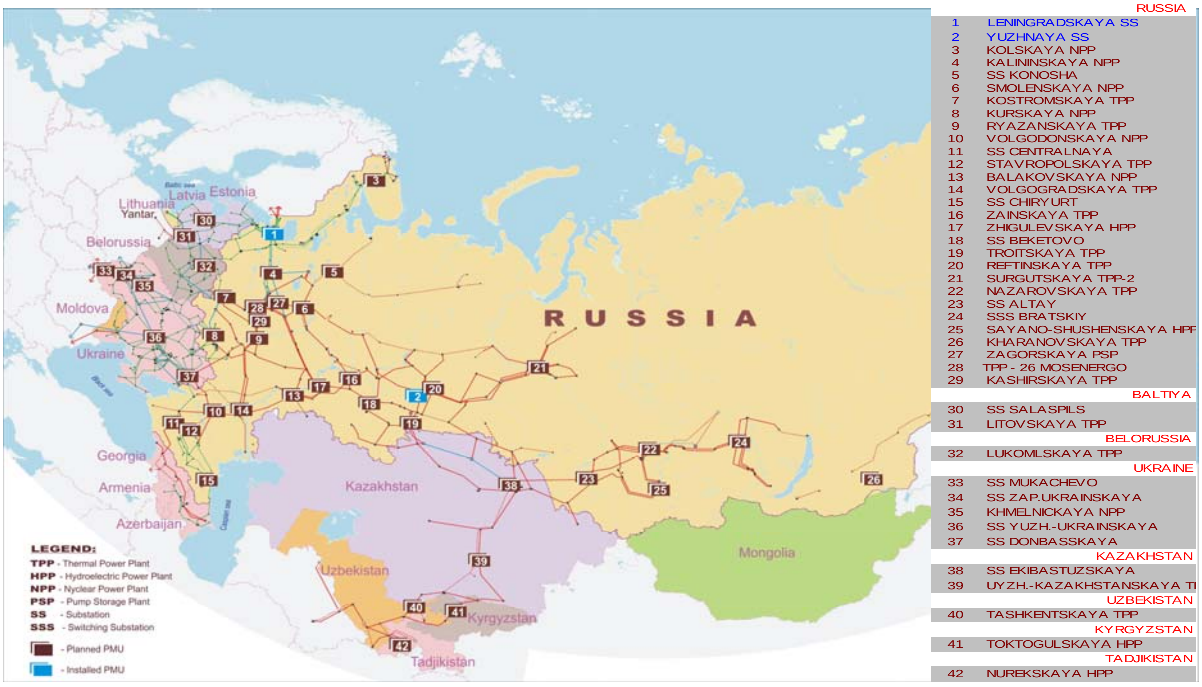

Fig. 5. Scheme of phasor measurement units allocation in IPS/UPS

The stated procedure of registration places choosing for the SMART-WAMS PMUs provides the solution of monitoring priorities and creates preconditions for the organization of the IPS/UPS electrical regime control in the near future.

In accordance with the above principles the locations for PMU allocation shown on Fig. 5 were chosen.

At the present time two POWERLOG recording devices operate in IPS/UPS WAMS. They were installed and put into service at the end of April 2005 at Leningradskaya and Yuzhnaya substations (IPS DO of Ural

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