SCIENCE AND APPLICATION MEETING
MODERN APPROACHES TO ELECTRIC POWER SYSTEM RELIABILITY SUPPORT

Syktyvkar, May 22-23, 2013

Organized by

Institute for Social, Economic and Energy Problems of the North, Komi Science Centre of Ural Branch of the Russian Academy of Sciences
Melentiev Energy Systems Institute of Siberian Branch of the Russian Academy of Sciences
Department for Automated Electrical Systems of Ural Power Engineering Institute, Ural Federal University
"Komienergo", Branch of Joint Stock Company "MRSK of the Northwest"

RESOLUTION
by Science and Application Meeting

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The Meeting was devoted to the 60th Anniversary of the Department of Energy of the Institute of Social, Economic and Energy Problems of the North at the Komi Science Center of the Ural Division of the Russian Academy of Sciences. The meeting comprised 21 oral presentations and 3 poster presentations (attached); there were 31 actual and 19 distant participants involved, with 16 of them holding Doctor of Science and 12 Candidate of Science Degrees. The participants represented academic organizations, institutions of higher learning, industrial science organizations, and production facilities from the cities of Arkhangelsk, Cheboksary, Haifa (Izrael), Irkutsk, Kishinev (Moldova), Moscow, Nizhniy Novgorod, Saint-Petersburg, Seville (Spain), Syktyvkar, Vancouver (Canada), and Yekaterinburg. The Department of Energy team is heartily grateful to all the participants for their actual and distant involvement in the meeting and for their assistance in carrying out the event.

The participants have found it necessary to point out the following.

1. Under the conditions of reforms, for supporting reliability of electric power systems and the United Power System (UPS) of Russia in particular, the following directions are deemed critical:
   − Assessing the power system adequacy in the middle term (from one to seven years) and in the long term (15 years) outlook;
   − Developing the generating supply of the areas within the United Power System of Russia and planning for interconnections between the areas in view of the adequacy level required;
   − Development planning for the transmission network based on the probabilistic analysis of the network reliability and the cost efficiency of power supply to the transmission network nodes;
   − Real-time power system state estimation using synchronized phasor measurements;
   − Utilizing consumers' equipment for global navigation satellite systems GLONASS/GPS in electric power systems;
   − Standardization of intelligent protecting devices and automatics.

2. In 1993–2005, little attention had been given to the issues of power system adequacy assessment in the development of the United Power System of Russia. The reasons for that were related both to the management reorganization of the electric power industry and to the power system redundancy that was caused by a considerable setback in the electric power use. Over the recent years, however, the situation has appeared to be improving. According to the Russian law "*On electric power industry*", in view of the proposed Technology Regulations for Operating Electric Power Systems[2], and considering the new edition of the Guides for Power System Design Development[3], the System Operator of the United Power System Company ("SO UPS", JSC) has been assigned with the authority role in assessing the power system adequacy.

The annual issues of the medium-term development documents – "*Schemes and programs for the development of the United Power System of Russia for the next seven years*" and the "*Territorial development programs for the subjects of the Russian Federation for the next five years*" – support the necessity to realize the proposed requirements in carrying out probabilistic assessment of power system adequacy in the areas within the United Power System of Russia. The standard adequacy should be ensured by the UPS System Operator at the level of the United Power System, the Integrated Power System, and within the UPS areas; and at the nodes of the transmission network, the standard adequacy should be realized by the Federal Grid Company of United Energy System ("FGC UES").

The reports presented at the power system adequacy session have demonstrated that collective efforts are required from the UPS System Operator and the UPS Federal Grid Company, joined by academic institutes, universities, and industrial science organizations, in order to further develop the existing methodical approaches in the following directions:

− Implementation of a model for the design diagram of the United Power System of Russia incorporating up to 120 areas and 250 system-forming interconnections;
− Improvement of methods and software to include process management recording capabilities (e.g., loading variations, primary equipment maintenance schemes, water supply and fuel material availability for hydraulic and thermal power stations, etc.);
− Software development for assessing electric power system adequacy for powering transmission network nodes;
− Theoretical and practical substantiation for power system adequacy indices instrumental for making managerial decisions, including data on practical application of adequacy indices in foreign countries;
− Software development for recording of scheduled and unscheduled outages of primary equipment, for scheduling the energy use for assessment areas and transmission network nodes, etc.;
− User interface development for making assessments of power system adequacy and its integration into the middle-term planning for electric power systems.

3. One which has deserved attention is the North American Electric Reliability Corporation (NERC) that has a valuable experience in annual reliability assessments of the bulk power system

[2] Approved by the joint session of the Scientific Council of the Russian Academy of Sciences on the problems of reliability and security of large power systems and the Science and Engineering Board at the Non-Profit Partnership "Science and Engineering Council of the United Power System" on the 16th of May, 2011.

[3] Developed by the OAO Energosetproekt Institute and approved by Non-Profit Partnership "Science and Engineering Council of the United Power System", at the Technical Regulation in Electrical Power Engineering section on the 20th of July, 2012.

(BPS) in North America provided for a 10-year reliability outlook. The website of NERC (www.nerc.com) has the reliability assessments presented on display since 1990. The recent assessment conducted in November 2012 reports on the North American BPS reliability for the 10-year period observed from 2013 to 2022. The reserve margin provided for 26 assessment areas of the North American BPS is defined as the difference between the total resource capacity and the system peak demand in the area (measured in MW or as a percent of the system peak demand). The resource capacity in an assessment area equals the one-peak generating capacity available in that area plus the balance of the contractually committed power transfers (both operational and emergency) from the neighboring areas, plus the supply-side load reduction payable in the market. The system peak demand in the assessment area equals the total demand minus the capacity that an operator can reduce in the event of deficiency of resources (by calling back to the customers via mass media, through voltage reductions, using rotating blackouts, and/or by enabling long-term contractual arrangements). In terms of NERC, the power system adequacy corresponds to Capacity Resources Adequacy.

4. Over the recent 25 years, the English-speaking and the Russian-speaking reliability schools of power engineering have to a great extent been developed independently one from the other. Still unavailable are Russian versions of such fundamental books on power system reliability as: Billinton R., Allan R.N. *Reliability Assessment of Large Electric Power Systems,* Boston, Dordrecht, Lancaster, Kluwer academic publishers, 1988. 296 p.; Billinton R., Li W. *Reliability Assessment of Electric Power Systems Using Monte Carlo Methods,* New York and London, Plenum Press, 1994. 351 p.; Billinton R., Allan R.N. *Reliability Evaluation of Power Systems*, Second Edition, New York and London, Plenum Press, 1996. 509 p.; Li W. *Risk Assessment of Power Systems: Models, Methods and Applications*, IEEE Press, 2005, 325 p.; Li W. *Probabilistic Transmission System Planning*, IEEE Press and Wiley &Sons, 2011. 376 p.

In this regard, it is deemed necessary to seek assistance from the UPS System Operator and the UPS Federal Grid Company in publishing the books by W.Li: *Probabilistic Transmission System Planning (2011),* and *Risk Assessment of Power Systems: Models, Methods and Applications (2005),* which have been translated at the Institute of Social, Economic and Energy Problems of the North. The former book in Russian translation can advisably be issued in view of its second revised edition scheduled for 2014.

The report presented by Wenyuan Li at the meeting demonstrated the efficiency of transmission network development planning performed for one of the regional power systems in Canada based on the probabilistic reliability and economic analysis.

5. An urgent issue of improving the monitoring system under the conditions of power system intellectualization can be solved by applying synchronized phasor measurements to power system state estimation. The presentations at the meeting on this issue resulted in the following outcomes:
− To provide efficient security analysis at a high quality level, the corresponding research activities in Russia should be increasingly coordinated in the field of observabilty analysis methods and synthesis techniques using synchronized phasor measurements in power system state estimation. The Russian UPS System Operator and the UPS Federal Grid Company are envisioned as specific customers interested in the software products to be developed in order to create prototypes having efficient knoware and operational instructions along with skilful software development capabilities for implementing full-fledged applications. An alternative of the UPS System Operator and the UPS Federal Grid Company being oriented to foreign software developments, which also entails

maintenance and upgrading, poses an imminent threat of breaking the national cybersecurity and implies deterioration in domestic power system reliability.

− The presentation reported by the University of Seville from Spain is regarded as a comprehensive overview covering the results obtained in the course of studies in the field of synchrophasor-assisted power system state estimation. The researchers from the University of Seville (Antonio Gómez - Expósito et al.) had participated in the creation of a prototype complex designed for evaluation of the Paneuropean network and its components, with reliability evaluation experiments performed. The presentation demonstrates the efficiency of scientific and practical efforts joined in the course of investigation and probation of the synchronized phasor-assisted methods applied to real objects. Expansion of the contacts between Russian and foreign specialists is deemed beneficial;

− As of today, the poor availability of phasor measurement units for power systems is hindering implementation of all the benefits of PMU-based power system state estimation, and a combined use is therefore employed comprising both traditional and synchronized measurements, which raises strictness of requirements to PMU data validation algorithm. Meanwhile, local estimation is already available for some objects, with bad data detected for noncritical synchronized phasor measurements;

− When applying synchronized phasor measurements to the power systems state estimation and parameter estimation, it is necessary that the systematic errors affecting the estimation results be accounted for, with the sources identified and the set of observed regularities analyzed for such errors;

− Measurement placement reinforcement, which provides topological observability under normal operating conditions, during branch outages and loss of measurements, in view of the observability quality, will considerably reduce the effect of measurement errors on the accuracy of resulted estimations;

− In the challenging conditions of incomplete and inadequate information, modern programs for power system state estimation should allow for the circuit breaker status validation and for determination of the topology of power system network. Research and methodological developments for solving this problem are required, taking into account both the digital substation capabilities and the artificial intelligent techniques available;

− On the basis of Komi power system, a pilot project is advisable to be implemented with the aim of using PMU-based devices of ENIP-3 model developed by ZAO Energoservice Engineering Center (Arkhangelsk), which static and dynamic characteristics are in compliance with the IEEE C 37.118.1 – 2011 Standard; and related applied research can be performed at the Institute of Social, Economic and Energy Problems of the North (Syktyvkar), aimed at utilizing the PMU-based devices in state estimation and parameter estimation of the power systems.

6. Global navigation satellite systems GLONASS/GPS provide widely separated locations of power systems with very accurate time synchronization (100 nanosecond and better) within a common precision time reference. The synchronization systems based on global navigation satellite systems (GNSS) can be found prone to the effect of both deliberate jamming and unintended interference. Noise-immune GNSS equipment providing accurate time synchronization is vitally important for ensuring improved security and high efficiency of power system performances. Solutions offered by Russian specialists are instrumental in providing GNSS customers with the equipment with noise immunity considerably improved.

7. The presentation by V. Gurevich (Israel Electric Corporation) stated that digital protective relays are produced by some tens of large companies in the world, with the lack of standards regulating requirements to their size, internal structure and, partially, software. As a result, relays produced by various companies are not interchangeable, which causes customer dissatisfaction, hinders

competition, hampers improvement in intelligent protecting devices, and causes increased risks of grid blackouts in power systems. Standardization for digital protective relays in their design and software, optimization in the number of functions performed by one module, limited use of free software logic, clearly defined specifications and testing requirements, improved cybersecurity and enhanced stability to deliberate jamming, regulation of reliability evaluations and the basic reliability indices for protective devices, form the important trends in the improved performances of protective intelligent electronic devices.

8. The presentation made by V. Postolati and E. Bykova (the Institute of Power Engineering, the Academy of Sciences of Moldova) illustrates the practicability of compact controllable overhead lines (OHL) to be implemented widely in electricity transmission. Using such lines can reduce power transmission costs by decreasing the ratio of construction capital investments and by utilizing backup equipment more efficiently. Improvement of power system performance and reduction in power loss were demonstrated by example of using compact single-circuit and double-circuit compact 220 kV OHL as compared to 220 kV OHL of conventional design.

APPLICATION

The meeting program

Y.Kucherov ("SO UPS", JSC, Moskow), ***Y.Chukreyev*** *(ISE&EPN KSC RAS, Syktyvkar).* The Development of Power System Adequacy Assessment Methods for Russian UPS in the Medium Term

N.Belyaev, *A.Egorov, V.Chudniy, («STC UPS», JSC, Saint-Petersburg).* Development for the Future Planning of the Power for Computational Models of Russian UPS

I.Medvedev, ***V.Futjanov.*** *("Komienergo", Syktyvkar).* The Ensuring of the Reliability of Electric Power Supply for Consumers in the Komi Republic by "Komienergo"

N.Manov *(ISE&EPN KSC RAS, Syktyvkar).* Long-Term Reliability Assessments of North Americas Bulk Power System by NERC

W.Li (BC Hydro, Canada). Probabilistic Reliability and Economic Analysis in Transmission Planning (N.Manov presented the report in Russian)

V. Oboskalov *(Ural Federal University, Yekaterinburg).* Filled Demand Algorithm for Power System Resource Adequacy Determination

M.Chukreyev*. (ISE&EPN KSC RAS, Syktyvkar).* Power Systems Adequacy Assessment with Usage Computation Software for UPS of Russia

V.Gurevich *(Israel Electric Corporation, Haifa, Israel*). Actual Problems of Standardization for Digital Protective Relays (the video report in Russian)

A.Mokeev. *("Engineering Centre "Energoservice", Arkhangelsk).* Development, Testing and Introduction Features of Phasor Measurement Units

G.Nudelman, A.Oganesian, P.Golovin (VNIIR,Cheboksary). The Utilizing of Consumers Equipment for Global Navigation Satellite Systems GLONASS/GPS in Power Systems. Problems and Decision Ways (M.Uspensky presented the report)

A. Gómez-Expósito, A. de la Villa Jaén, C. Gómez-Quiles (University of Seville, Spain). Synchrophasor-Assisted Power System State Estimation (the video report in English, the translation into Russian was presented by M.Khokhlov)

I.Golub *(ESI SB RAS, Irkutsk).* PMU-Based Analysis and Synthesis of Power System Observability

I.Kolosok*, E. Buchinsky (ESI SB RAS, Irkutsk).* Algorithms for Linear State Estimation of Electric Power Systems by the Test Equation Method Using Synchronized Phasor Measurements

I.Kolosok, ***E.Korkina****, A.Paltsev (ESI SB RAS, Irkutsk).* Decomposition of Power System State Estimation Problem Using WAMS Measurements

A.Glazunova (ESI SB RAS, Irkutsk). Studies on the Properties of Measurement Information to Accelerate Dynamic State Estimation of Power Systems (I.Kolosok presented the report)
E.Korkina *(ESI SB RAS, Irkutsk).* Impact of Instrument Transformer Errors on Synchronized Phasor Measurements
M.Khokhlov *(ISE&EPN KSC RAS, Syktyvkar).* Identifiability of Errors in the Synchronized Phasor Measurements
G.Shumilova, *N.Gotman, T.Startseva (ISE&EPN KSC RAS, Syktyvkar).*Approaches to the Electrical Network Topology Verification based on Artificial Intelligence Technology
M.Uspensky *(ISE&EPN KSC RAS,Syktyvkar), S. Smirnov (Komi RDU, Syktyvkar), Y. Zarubin (Syktyvkar).* Research of Power System Restoration Algorithm after Blackout by Imitating Modelling
G.Shumilova, ***N.Gotman****, T.Startseva (ISE&EPN KSC RAS, Syktyvkar).*Search of the Interrelation Between Probability of Unsecurity State and Distance from Dynamic Security Boundary for Regional Power System
V.Postolatiy, E.Bykova (IPE ASM, Republic of Moldova, Chishinev). New Technical Decisions in Construction of Electric Transmission Lines 110, 220 kV with High Capacity and Reliability (N.Manov presented the report)

Poster papers

B.Papkov, M.Sharygin (State Technical University, Nizhny Novgorod). Development of Aggregative Modeling Methods for Production System in Estimation of Power Failure Consequences
V.Vukolov, B.Papkov (State Technical University, Nizhny Novgorod). Reliability Improvement for the Distribution Electrical Network
V. Zorkaltsev (ESI SB RAS, Irkutsk). Long-Year Temperature Changes Investigations in the Context of Heat Supply Reliability

The accepted abbreviations:

ESJ SB RAS - Melentiev Energy Systems Institute of Siberian Branch of the Russian Academy of Sciences
"FGC UES", JSC - "Federal Grid Company of the United Energy System", Joint Stock Company
ISE&EPN KSC RAS - Institute for Social, Economic and Energy Problems of the North, Komi Science Center of Ural Division of the Russian Academy of Sciences
"MRSK of the Northwest", JSC - "Interregional Distribution Grid Company of the Northwest", Joint Stock Company
"SO UPS", JSC - "System operator of the United Power System", Joint Stock Company
"STC UPS", JSC - "Scientific and Technical Centre of the United Power System", Joint Stock Company
VNIIR - the All-Russian Scientific Research Institute of Relay Construction