PRINCIPLES OF POWER SYSTEM EMERGENCY CONTROL UNDER DEREGULATED ELECTRICITY MARKET: THEIR APPLICATION FOR RECONSTRUCTION OF THE SIBERIAN REGIONAL CONTROL CENTER

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SUMMARY

There are two general reasons in order to modernize the Siberian and Russian Far East Interconnected Power Systems emergency stability control. The first of them consists in arising the competitive energy market in Russia. Another reason consists in availability both of up-to-date computing, and communication technologies for Russian engineers. Furthermore, so-called opening computing technologies allow to join the research forces of different groups of experts, including international teams, in order to create the universal system protection schemes (SPS) complexes. Two places for implementation and experimental tests of such SPS complexes will be suggested in the paper. The report focuses on some principles of complexes’ functioning.

Keywords – Interconnected Power System – System Protection Scheme - Decentralized Control

1. INTRODUCTION

New control strategies are very important in conditions of deregulation of electricity industries. Just now Russian electricity industry is proceeding to competitive energy market. This process determines a necessity of reconstruction of Russian Power systems' emergency control. Competitive energy market obliges in time to organize the technological structure that has to meet the requirements of reliability of power systems. This circumstance could be the basis for revision of general principles of power systems emergency control. For instance, recently, three interconnected power systems of Russia, which serve the Northern Caucasus, Middle Volga and Ural, have combined their research resources in order to create the standard complex of SPS. This report focuses on the one more project of the SPS complexes, more adapted to competitive energy market. It is designed for the Siberian and Russian Far East Interconnected Power Systems that are situated in Asian part of Russia.

In new conditions the SPS complexes should prevent breakdown or instability of large-scale power systems caused by both technological, and economical reasons. Consequently SPS complexes should be introduced into the structure of control of competitive energy market to guarantee safety of power

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system in any difficult-predictable emergency situations.

The official position of the System Operator Central Dispatching Office (SO-CDO) of the Russian Power Grid concerning emergency control system organization in conditions of the competitive energy market presumes to make completely competitive sector of ancillary services including emergency control. Thus, SPS can become an investment object, including private capital. Consequently it is necessary to explain basic principles of the SPS organization in new economic environment both to potential investors and future users of the ancillary services, and to point to advantages of investment into SPS complexes, including the Siberian and Far East regions of Russia.

One of the competitive energy market characteristics is a decrease of transmission system capability margin. This feature results in worsening of control during the emergency conditions. Another characteristic of energy market is the dependence of energy price formation from transmission system's bottleneck problems. In this case, power producers may be free in pricing where such critical situation is arises, and the consumers will be compelled to pay a higher price, in comparison with the price that could be paid in case of sufficient transmission system capability.

Modernization of the existing SPS structure in the Siberian Interconnected Power System has already begun. The operation principles of the SPS system have been offered about 30 years ago. The principles consist in combining centralized and decentralized control. The SPS complexes maintain synchronous operation of power plants in selected region. Collected information about state of the power network in the area of control is being transmitted with the use of telemetering and teleindication systems. Decision concerning the control action is being executed on the basis of this information automatically. These control actions, in case of necessity, are transferred to the place of their realization by special channels of communication. There are, at least, eight areas in the Siberian Interconnected Power System where the SPS complexes are necessary. Now there are only two complexes.

The SPS conception based on the use of modern means of communication and automation in the Russian Far East Interconnected Power System has been stated in [1]. Partial implementation of this concept has begun in the following way: (a) reconstruction of the Zeya Hydro Power Plant's (HPP) centralized SPS complex that uses the obsolescence special computer; (b) creation of the Bureya HPP's centralized SPS complex; (c) modernization of the Primorskaya Steam Power Plant which utilizes the mechanical relays for realization of control logic; (d) projection of the modern communication channels including digital data transmission with the use of optical-fiber communication lines. Thus, it may be expedient to enlarge the tasks of the SPS complexes, which can be solved successfully with the use of present-day system of information exchange in power systems.

Practical realization of new conception in the Siberian and Russian Far East Interconnected Power Systems ought to take into account the differences between their market models. In the first power grid the real competitive energy market will exist. The centralized directives will regulate the energy market of the Far East Interconnected Power System. These differences will exist only during initial stage of the transition to the free pricing. Taking into consideration that these power systems are contiguous with each other and will cooperate at the energy market, it seems rational to develop the organization principles of such interaction, including the SPS principles. One should note that the character of information exchange in the SPS structure and in market control may be identical, and consequently main decisions for software and hardware of control centers can be identical too. It is advantageous to use experience acquired at one object in order to use at other ones. One of possible ways to adapt the emergency control system of the Siberian and Far East Interconnected Power Systems to competitive energy market conditions will be discussed in the next section.
2. PROMISING SPS INFRASTRUCTURE

The potential variant of the SPS complexes structure for the Siberian and Russian Far East Interconnected Power Systems is shown in Fig. 1. The suggested alternative is based on the use of the up-to-date means of communication and high-productivity industrial controllers. Such decisions will allow to completely realize the capabilities of the Internet-technologies, Global Positioning System, technologies of artificial neural network in order to adapt SPS to the competitive energy market.

In Fig. 1 the circles of large diameter designate so-called “coordinating control systems” of the Siberian and Russian Far East Interconnected Power Systems. They are positioned in Kemerovo and Khabarovsk cities where the SO Integrated Dispatching Offices (SO-IDO) are situated. Circles of smaller diameter designate so-called “coordinating controls complexes”, and their places coincide with the places of the SO Regional Dispatching Offices (SO-RDO). The so-called “local” and “centralized” SPS complexes are represented as double controller with four dark arrows that point to different directions. It symbolizes telecontrol, telemetering, and teleindication. White arrows designate the channels for data transmission.

At present, in Russian power systems, the channels for data transmission can be constructed by several manners: (a) high-frequency communications with the use of transmission lines; (b) technology of optical-fiber communication lines; (c) Internet; (d) satellite communication. Two dotted white arrows symbolize data exchange between the centralized SPS complexes of the Siberian Interconnected Power System, Ural Interconnected Power System, and Far East Interconnected Power System. The interchange of the information regarding power networks models should be used both in SPS and SCADA systems.

The coordinating control complexes at SO-RDO should be integrated with SCADA of the power systems. Their basic functions are: (a) forming the power network model of the controllable region and transfer it to the coordinating system; (b) receiving the power network model of the whole power system from the coordinating system and next transferring of the information to the centralized complexes belonging to SO-RDO. The possible placing of the coordinating complexes are main cities of the Siberia and Russian Far East. The centralized complexes must be created at the main power stations of power systems. The local centers have to be placed at the 500 kV substations which border upon the Ural Interconnected Power System and National Power Grid of the Republic of Kazakhstan.

Thus, the functions of the existent centralized complexes should be transmitted to the centralized complexes with much smaller extent of centralization. At the same time the functionality of these complexes should be greatly increased, as the complexes have to solve the task of selecting the control
actions taking into account the power network current model received from the coordinating system. The regional power network models have to be prepared by the SPS coordinating centers and next transferred to the SPS coordinating system.

The coordinating system of the Far East Interconnected Power System should also be created on basis of the SO-IDO SCADA complexes. Accordingly, the coordinating complexes must be integrated with the SO-RDO SCADA. The centralized complexes have to be positioned at the Zeya HPP, Bureya HPP, and Primorskaya Steam Power Plant.

3. TENDENCY OF SPS COMPLEXES EVOLUTION

Fig. 2 explains the authors' conception regarding evolution of the SPS complexes. The term “simple” signifies using decision tables or analytical dependence between types of disturbance and control actions needed to avert power system instability. The term “complicated” implies utilization of power network model for selecting the control actions. The use of the technologies of open systems in computing area allows moving from the SPS particularized complexes to universal complexes. This transition should be based on the software made by different programmers or programmer groups. It is possible in case of compatibility of various hard- and software employed for SPS complexes.

The top of the SPS complexes evolution diagram is universal digital control complexes intended for the control actions forming during a post-fault time interval (behavior-prediction). This term corresponds to recommendation of CIGRE [3]. However, at present such opportunity is absent in power systems of the Siberian region because up-to-date communications are not available else. For this reason, particularized digital control complexes based on post-fault principle are absent too. Now the authors of this paper are working on construction of the universal SPS complexes that can be employed for the SPS coordinating system, SPS coordinating centers, and SPS centralized complexes based on the pre-fault time principle (behavior-assumption). The next step in this direction will be development of the SPS complexes with post-fault principles. First of all, such opportunity exists at the Zeya and Bureya Hydro Power Plant. The Zeya Hydro Power Plant uses, and the Bureya Hydro Power Plant should utilize, so-called “multiple dynamic braking” that allow to replace control action such as generator rejection by dynamic braking coupled with control action such as turbine unloading discussed in [1] and [2]. This combination of the control actions allows to realize SPS particularized and universal digital control complexes with post-fault behavior-prediction principle including complicated method shown in Fig. 2.

The simulation programs, developed by several Siberian Research Institutes, such as the ANARES-2000 and PAG software complexes allow doing it. These complexes can become the example of integration of two programs worked out by different developers [2]. The software is already used for
creating the SPS complexes in the Russian Far East Interconnected Power System and can be used for working out the SPS complexes in the Siberian Interconnected Power System.

4. SPS COMPLEXES SOFTWARE

If to develop universal software, not specialized, it may be useful for all control levels, and thereby, investment incentives will appear. We consider an industrial controller as a “elementary digital device” that has different number of output depending on the solving tasks. If the software is identical, it will be possible to transport user's programs from one elementary digital device to another. The Compact PCI controller completely meets these requirements and gains popularity. Fig.3 illustrates the software structure that is planned to be used in the SPS of the Far East Interconnected Power System. The concept consisting in using three software complexes, PAG, ANARES-2000, and “Otsenka” already has been discussed in [2]. Next segments discuss the possible directions of development of the SPS complexes.

4.1. Special Software Package

Putting into operation the all of six hydroelectric generators at the Bureya HPP and constructing one more 500 kV “Bureya HPP - Khabarovskaya” 500 kV transmission line the appearance of advanced communication channels will take place. Therefore, it will be reasonable to stop using the principle “behavior-assumption” with the use of “decision table” in order to form control actions. It will be possible to proceed to the "behavior-assumption" principle with the use of the regional network model. In this case, increase of controls efficiency can be reached only when the network model adequately reflects the current operation condition. The main problem is to estimate the state of the power transmission system that is directly connected with the task to confirm the accuracy of the method of parameters telemetering and teleindication. It should be noted that the distributed structure of the Bureya HPP's SPS complex is based on controllers and workstation of operator. This allows to cardinaly change the approach to organization of the power system state estimation, including confirming the accuracy of telemetering and teleindication in the SPS complex of the Bureya HPP.

During several decades the work on improving the software complex "Otsenka" have been continued. The most up-to-date approach to solving the task of power systems' state estimation has been suggested in [3]. “Otsenka” software package, English equivalent is “Estimation”, is intended to solve the problems listed below (but not only):

- on-line collecting the information regarding the current network topology;
- identification and detection of the false data in measurements and suppression of their effect on the state estimation results;
- filtering of random measurements errors or estimation and calculation of non-measured state variables;
- identification of measurements variances and evaluation of equivalent circuit parameters.

Now it is a multifunction software complex that according to the data from telemetering and teleindication using the methods of state estimation, allows to define a current mode of power system (modules and phases of nodal voltage, overflows of active and reactive powers.) At the present time this software is used in dispatcher offices of a number of Russian power systems. It meets the requirements of the emergency control concept of the Far East Interconnected Power System that has been discussed in [1]. The methods and algorithms used in the software complex have been discussed in [4]. For solving the task of the data assurance in a real time it is necessary to apply so-called “method of control equations” related to methods of a priori analysis. This method owing to appearance of modern automation means can be improved in order to eliminate errors of state estimation as a result of gross errors of telemetering. The main directions of work now are the application of “genetic algorithms” and “artificial neural networks” in order to confirm the accuracy.
of telemetering with the use of “control equations” [5]. The controls complexes of the Bureya and Zeya HPPs with their powerful computing resources completely meet the requirements of practical applying the modern methods of the power systems state estimation. These complexes also correspond to forming the power network model for realization of the “behavior-assumption” principle. One of the main features of the present version of the software “Otsenka” consist in accelerating the processes of obtaining the results, which can be reached by the use of distributed data-processing systems.

The conception of distributed data-processing systems coincide with the approach of the Siberian Electric Power Research Institute to organization of distributed SPS complex on the basis of "behavior-prediction" controllers of the Bureya HPP. Integration of PAG and ANARES-2000 software will allow to obtain fundamentally new software. It will become a good engineering solution for the SPS of the Bureya HPP and Zeya HPP. These power plants can be the first objects where these solutions will be implemented. Further direction of this work leads to realization of the coordinating control system and coordinating control complexes. Transition to competitive market of electric power will inevitably lead to integration of SPS with control systems of the competitive energy market on the level of SO-RDO and SO-IDO.

4.2. Software Structure Variants

Productivity of the centralized complexes, coordinating complexes, and coordinating system already is sufficient for solving tasks usual for SCADA: (a) computation and optimization of power-flow in the controlled region; (b) transient stability assessment and simulation of the long-term dynamics with the SPS operating; (c) determination of the limits of transmission system capacity during both normal, contingency, and post-contingency operating conditions. These software complexes can solve also tasks of reception and elaboration the information about power network state, assessment of the network to expose weak ties. The structure and the size of control actions have to be stored in the database, special tables named “virtual controls device” in the present paper. It is the smallest quantity of tasks that should be solved. They should be solved with three above mentioned software packages. Fig. 3 represents them as tasks of the control program I.

![Fig. 3. Potential structure of software complexes](image-url)
The “Strategic Power Infrastructure Defense” concept has been suggested in [6]. The concept is intended to create a universal control system for emergency control in deregulated energy market environment. This control structure has to prevent power system instability that can be caused by different conditions, both economical and technological. This task can be solved with the use of the multiagent approach [7] that approximately is similar to the approach suggested for the Russian Far East Interconnected Power System. The approach consists in the use of different software packages developed by various groups of engineers and researchers in order to employ it for diverse targets. Indispensable condition for realization of the concept is the presence of reliable communication and high-productivity controllers. In these conditions, the automation devices of coordinating complexes and coordinating system have to decide problems that are not ordinary for Russian control systems: (a) assessment of system vulnerability in conditions of the competitive energy market; (b) monitoring of hidden failures of the protective systems; (c) self-healing strategies in cases of full or partial system outages. These tasks conform to points of the control program II shown in Fig. 3.

5. SPS COMPLEXES HARDWARE

Fig. 4 illustrates the structure of the SPS of the Bureya HPP, which has been suggested in the project being executed at present time. Six VME-controllers coupled with two Compact PCI controllers allow to create distributed SPS that ought to realize I and II control programs shown in Fig. 3. The main function of VME-controllers is control by the multiple dynamic braking. There are two possible control strategies for dynamic braking at the Bureya Hydro Power Plant: (1) using classical approach; (2) employing Fuzzy Logic. Comparison of these control strategies in detail has been done in [2]. Subsidiary function of VME controllers consists in accordance of own simulation possibility to distributed SPS centralized complex in order to improve computing productivity of the all complex. In this case the task of post-fault correction of control action such as turbine unloading can be feasible. The task of distributed SPS complex is to simulate short and long terms dynamic when different controls are employed. Next step is valuation of transmission system's capability margin. With the use of the above considered SPS structures, the pre-fault behavior-assumption simple and complicated principles of the SPS can be replaced with the post-fault behavior-prediction complicated principle SPS at the particularized and universal complexes.

The same SPS complex (with the exception of VME controllers) has been created at the Zeya Hydro Power Plant this year. The same complex could be employed in the SO-IDO coordinating systems and SO-RDO coordinating complexes. This decision could be standard for SPS control centers situated at the SO-RDO places of the Siberian and Russian Far East Interconnected Power Systems.
7. CONCLUSION

Evolution of competitive energy market in Russia demands the SPS decentralization. Concentrated emergency control centers have to be replaced by geographically distributed centralized control complexes. The function of the SPS complexes of the SO-IDO is to provide centralized complexes with information for solving the tasks of the control actions dosage. In large-scale interconnected power systems, it is necessary to use the information resources of SO-RDO in order to maintain the high level of emergency control and congestion management. The emergency control system devices located in SO-RDO have to be identified as coordinating complexes.

Development of special software for control complexes leads to creation of universal databases. It allows to use the software worked out by different groups of researchers. New controls complexes have to be free from hardware made only few years ago, since this hardware do not correspond to the up-to-date requirements made by competitive energy market. In new economic environment one should avoid to use general accepted ways of emergency control. It is necessary to look for new technical decisions.

In order to realize the above-mentioned information structure, it is necessary to foresee the implementation of channels for data transportation. It is the main task for projects of the electrical network reconstruction in the Siberia and Russian Far East.

It would be interesting to pool the research resources of different countries in order to use the most up-to-date special software for universal controls complexes. One of the places where the results of such cooperation could be tested and implemented right now are the Zeya and Bureya Hydro Power Plants. Two places for realization of the SPS concept may become the Siberian and Russian Far East regional control centres.

8. REFERENCES