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Coordination of Operation and Emergency Control of Joint Power Grids

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1 INTRODUCTION

The trends in expansion of electric power systems (EPSs) and changes in the conditions of their operation have led to considerable transformations in their structure and operation. These transformations are conditioned by the following factors:

- Increasing scale of power systems, expansion of territories to be serviced, interconnection of different power systems for joint operation which results in creation of interregional, interstate and intercontinental power interconnections;
- Decentralization of power supply due to a wider use of distributed generation sources that are connected to the distribution network nodes;
- Restructuring of power industry, which often makes its structure drastically different from the technological structure of EPS as a technically single unit and from its control structure;
- Liberalization of relationships in the electric power industry which leads to many participants of relationships with different, often opposing, interests, in the course of expansion, operation and control of power system.

All these factors essentially complicate power system operation, increase its changeability and unpredictability, raise danger of severe emergencies with undesirable development and massive consequences for a system and consumers and, therefore, call for prompt and more adequate response of control systems. This generates the need to improve and develop principles and systems of power system operation control which can be based on:

- new systems for measurement of EPS operating parameters (PMU) and their control (FACTS, energy storage devices, etc.) that significantly improve EPS observability and controllability;
- modern communication systems, new information technologies and artificial intelligence methods, highly efficient computers, which totally change the processes of acquisition, transmission, presentation (visualization) and use of information on power systems;
- efficient mathematical control theory methods in multi-criteria non-coincident conditions.

Joint operation of power interconnections of regions or countries within an extended super power interconnection, practical impossibility of visualizing the information on its current state, various principles of control and different software applied in different power interconnections, as well as confidentiality of some information make us apply distributed algorithms to process data on system state and develop control actions while improving and developing EPS control systems.

Modern systems for measurement of power system state variables and their control, new communication and information processing systems, etc. make it possible to create one of the most important stages of power system control, i.e. their operation and emergency control, on a new basis and with essentially higher efficiency.

The presented approaches are unfolded further in the paper and serve as a basis for the international project “Intelligent coordination of operation and emergency control of EU and Russian power grids” (ICOEUR project), developed by the international consortium of organizations [2]. The project is implemented in accordance with the 7th Framework Programme for cooperation between European Union and Russia in the field of energy and Federal Target Programme “Research and developments in the priority fields of science and technology complex of Russia for 2007-2012.” The paper presents a short description of the project and the results expected from its implementation.

2 MAIN PART

2.1 The system of monitoring, forecasting and control

Time sequence of individual stages of monitoring, forecasting and control of operating conditions is shown in Fig. 1. In essence this combination of stages represents a comprehensive system providing stability, reliability and controllability of modern power systems. At the same time from the viewpoint of efficiency of this system it is essential to increase the adaptability of control and improve coordination of the control stages, means and systems.

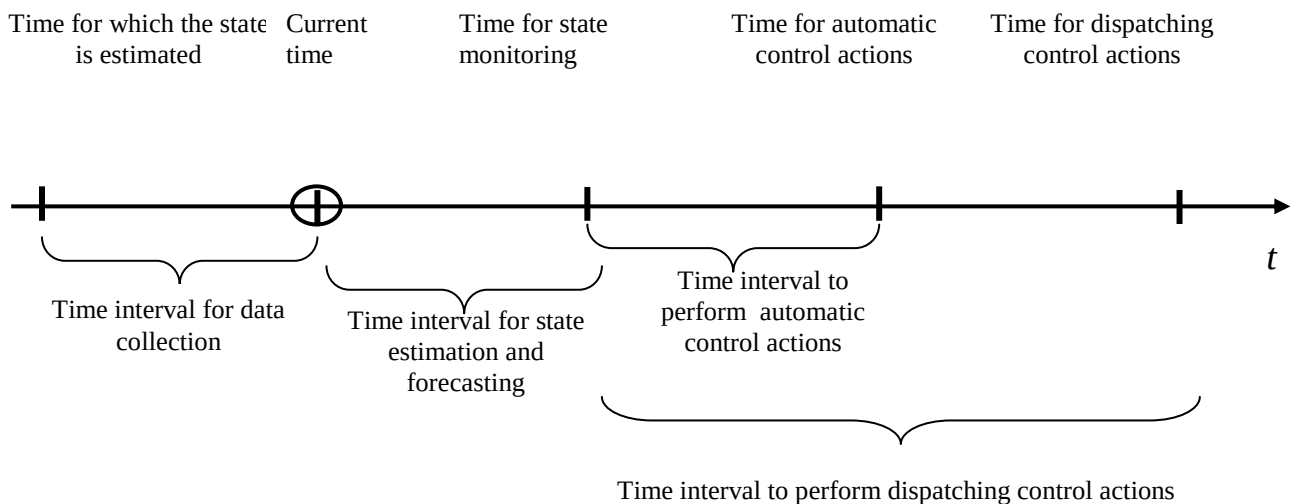


Fig. 1: Time diagram of the system for monitoring, forecasting and control in EPS

Fig. 2 shows the states of EPS and respective blocks of problems of monitoring, forecasting and control of operating conditions that correspond to these states [1]. The blocks of monitoring and forecasting of the EPS normal, pre-emergency and post-emergency operating conditions include the following problems:

- System state estimation;
- Forecasting the parameters of expected operating conditions. Forecasting is necessary because during the procedure of state estimation current state is estimated with some delay, while monitoring and control problems require some advance estimation of system state (“to control is to foresee”); let us note that for these two blocks of problems the advance time can vary;
- Detection of weak points in the system in the expected operating conditions;
- Determination of margins for transfer capabilities of ties in the expected conditions; This is necessary to efficiently use the margins in the operating conditions and automatic control through appropriate control actions;
- Visualization of expected conditions;
- Determination of indices and criteria for transition from normal to pre-emergency conditions and, vice versa, from post-emergency to normal conditions.

The enumerated problems have certain specificity when applied to normal conditions, on the one hand, and to pre-emergency and post-emergency conditions, on the other hand. Pre-emergency and post-emergency conditions (at system restoration) require higher speed of algorithm operation and

smaller time intervals between individual states for which the problems of operation monitoring and control are solved.

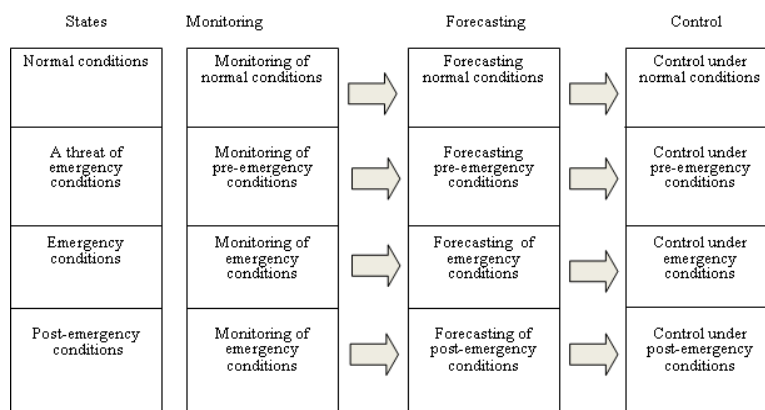


Fig. 2: Correspondence between EPS states and blocks of problems of operation monitoring, forecasting and control

A separate problem is monitoring of emergency conditions. Dynamic nature of emergency conditions requires that the results of monitoring be promptly transferred to dispatcher. They should have an integrated form and indicate dangerous points in the system in terms of undesirable development of emergency. The primary information, however, obtained as a result of emergency conditions monitoring, should arrive at the automatic control devices and systems with the view of their adaptation to the current power system emergency state.

In addition to monitoring and forecasting of the operating conditions the efficient adaptive methods and algorithms for choosing the points of control action application and adjustments on the basis of advanced achievements of the control theory and artificial intelligence play an important part in increasing the control adaptability. The methods and algorithms are implemented by dispatcher and automatic control systems, and provide adaptation of controls to the current system state and possible disturbances.

Considerable expansion and improvement of control coordination can be carried out in the following directions [1]:

- a) Expansion of EPS operation control coordination:
 - in terms of time - from coordinated design of control systems to their implementation through dispatching and automatic devices;
 - in terms of situation – coordination of on-line dispatching, continuous automatic and discrete emergency control.
- b) Extension of a range of devices intended for coordinated control of EPS operating conditions:
 - Development of traditional systems, including automatic voltage regulators (AVR) and speed governors of synchronous machines, automatic emergency control devices, etc.;
 - Use of new devices for measurement and control – PMU, FACTS, energy storage systems, etc.
- c) Development and extension of principles and systems for coordinated online dispatching and emergency control to distribution electric networks with distributed generation.
- d) Harmonization of commercial interests of participants in the markets for electricity, capacity and ancillary services and the need to provide EPS reliability and survivability.
- e) Development of new criteria and new methods for monitoring, forecasting and control of operating conditions in order to provide effective coordinated control for all participants in the wholesale market, power system reliability and survivability.

2.2 International ICOEUR project

The International ICOEUR project “Intelligent coordination of operation and emergency control of EU and Russian power grids” [2] has two main goals:

- To develop methods and tools for intelligent and secure monitoring and control of large scale power systems and especially their interconnections,
- To conceptualize the technically and economically optimal realization of future large scale interconnected power systems of European Union and Russia.

Two comments should be made on the main goals of the ICOEUR project. First, intelligent monitoring and control mean wide application of methods and tools of modern computer technologies and artificial intelligence for power system monitoring and control. Second, both goals are interconnected and though they are equally important the second goal should be implemented considering the efficiency of developed methods and systems for monitoring of EPS conditions and their control. On the whole the implementation of the project supposes achievement of certain compatibility of recommended methods and computer tools, including equipment as well as principles and procedures for monitoring and control as applied to power interconnections of European Union and Russia in the case of their integration for joint operation.

The ICOEUR project suggests solving the following problems:

- Development of construction principles and structure of distributed hierarchical system of a wide-area monitoring of power interconnection conditions on the basis of state estimation, forecasting and visualization of EPS state variables;
- Development of methods and software for implementation of distributed hierarchical system of on-line control of jointly operating power interconnection the basis of state estimation and forecasting EPS state variables.
- Development of methods and software for implementation of distributed hierarchical system for operation control of jointly operating power interconnections on the basis of state estimation and forecasting of EPS state variables by the methods of operating condition optimization;
- Development of methods and software for implementation of distributed hierarchical system for emergency control of jointly operating power interconnections on the basis of state estimation, forecasting of EPS state variables, principles of adaptation and coordination of emergency control devices and systems;
- Development of technology for coordinated intelligent operation and emergency control of jointly operating power interconnections on the basis of distributed hierarchical system of EPS state estimation, forecasting of state variables, optimization of system conditions and emergency control of EPS.

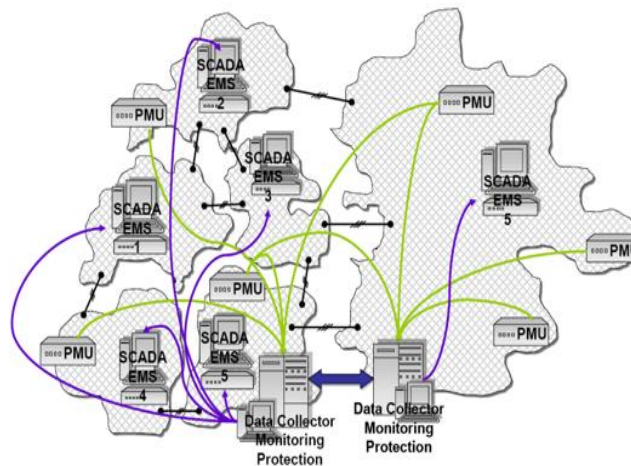


Fig. 3: Structure of information exchanges in the system of EPS state data actualization

Solution of the foregoing problems will make it possible to provide operability of the distributed hierarchical system for operation and emergency control of jointly operating power interconnections owing to coordination and adaptability of control at different levels, and enhancement of control efficiency on the basis of advanced methods, information technologies, computer tools and technical solutions.

2.3 Objectives and expected results

Effective and reliable operation of large scale interconnected power systems is possible provided the following requirements are met:

- A distinctive choice of the methods for interconnecting power systems and the technologies applied in the course of the electric power industry development;
- Effective monitoring and control of operating conditions of power systems and power system interconnection as a whole;
- Sophisticated and effective systems of emergency control intended to cope with critical and emergency situations in EPSs of all partners within the power system interconnection.

The ICOEUR project structure in the form of Work Packages and interrelations among them are shown in Fig.4. Let us consider the objectives and expected results within the Work Packages.

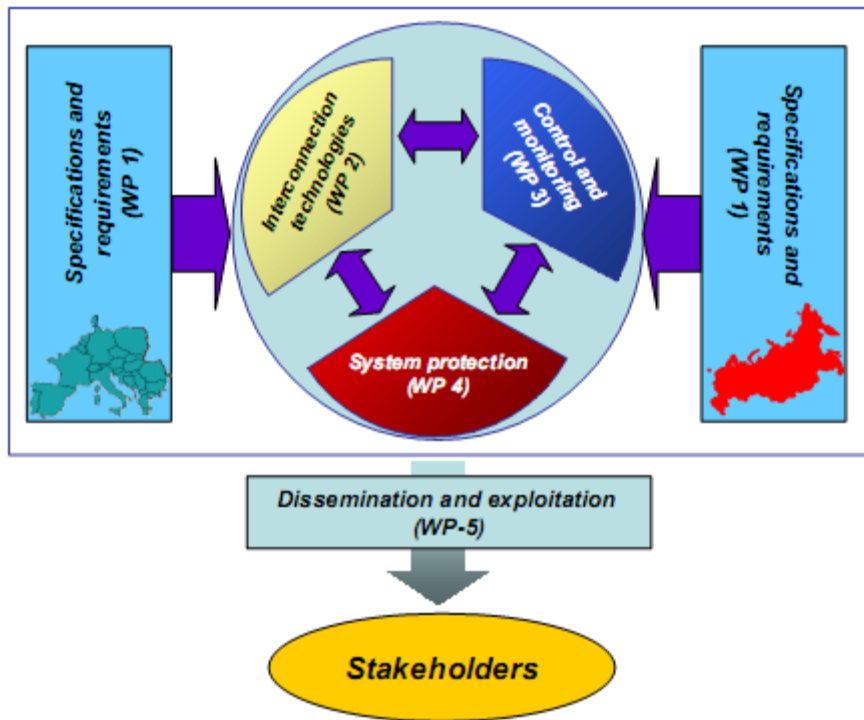


Fig. 4: ICOEUR project structure

Work Package 1 is related to identification of requirements for strengthening and expansion of European Union and Russian power systems to be interconnected. This concerns both formation of transmission electric networks and interfaces between the interconnected systems, and technologies and systems of power system operation monitoring and control. Besides, the requirements for jointly operating power system interconnection can relate to specific features of electricity markets of the partners. Their analysis is envisaged within the Work Package in question. Another problem from Work Package 1 deals with the development of a real model of European Union and Russia interconnections.

The objective of Work Package 2 is to choose and study the technologies for optimal expansion of power systems to be interconnected and interface between them. The studies suggest analysis of operating conditions of the systems to be interconnected and the interconnection as a whole, analysis of stability of the power system interconnection and its parts, as well as the efficiency of tools intended to provide stability. The Work Package also envisages estimation of costs and benefits related to the interconnection of European Union and Russian power systems.

Work Package 3 addresses the development of coordinated procedures and methods for monitoring the operating conditions of power systems and their control. Consideration is given to the capabilities of implementing communication tools and data exchange between control centers. The distributed system of information support, monitoring of EPS operating conditions and their control [3] is suggested, respective distributed algorithms for state estimation of power systems and

optimization of their operating conditions are developed. This approach is going to be implemented on the basis of distributed WAMS and WACS, whose efficiency should be shown in the model of the interconnection to be developed in Work Package 1.

Work Package 4 deals with reliability problems of power systems within the interconnection, and their emergency control. The methods for estimation of power system operating reliability and operational risks of insufficient reliability are devised. Besides, the methods for preventing development of disturbances and division of power systems under unfavorable development of disturbances are to be provided. Prototype of the software system intended to analyze operation of large scale power systems and control them is created (Energy Management System – EMS).

Work Package 5 plays an additional role and is related to the interaction among participants in the project within the respective consortium. This Work Package also suggests that the results of the project should be accessible to the external parties potentially interested in these results.

The studies to be conducted within the project make it possible to accomplish the objectives of the project.

3 CONCLUSION

Power systems evolve towards their interconnection for joint operation and creation of interregional, interstate and intercontinental super power interconnections. The joint operation of power interconnections that have different principles, procedures and rules of control calls for control coordination to achieve efficient functioning, system reliability and survivability of such a super power interconnection. The technology to be developed in the framework of the international ICOEUR project, i.e. the technology of intelligent distributed operation and emergency control for jointly operating power system interconnections will ease the solution to the considered problem.

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