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TRAINING SIMULATOR FOR ON-LINE CONTROL OF ELECTRIC ENERGY SYSTEM MODE AS THE ELEMENT OF SMART GRID TECHNOLOGIES

Growing trends towards using smart grid intelligent networks technologies along with the problems of electric networks optimum control require training, knowledge verification and evaluation of controller staff operation by means of training simulators of on-line and counter accident control. Structure and basic facilities for creation of such training simulator intended for maintaining economic mode of EES can be used for realization of such training simulators.

Key words: *on-line control, intelligent network, training of on-line and controller stuff, training simulator.*

Introduction

System-forming networks, interconnecting territorially and administratively ESS is the basis of modern interconnected electric energy systems (IES); electric energy systems [EES] are separate transactors of energy market. Historically, the designation of these systems was the exchange of load, repair or emergency reserve of power to provide power balance of IES, with the advent of energy markets the approach to system-forming networks has changed. Additionally they became transit corridors for interconnection of decentrelized (regional) systems of electric energy generation with great technological diversity of energy sources in EES [1, 2].

Redistribution of powers among overloaded power lines with the reserve of power allows to improve transport possibilities and efficiency of utility operation at the expense of energy supply volumes increase. However, optimality criteria of such redistribution are different (depending on tasks put forward and interest of energy exchange partners). For EES one of the criteria is loss of power from own and transit energy transfers, optimal control over which influences all the participants of IES.

Control of parallel functioning of EES, taking into account system limitations and constraints in intersystems connections is complex dispatching problem, the solution of this problem is possible as a result of formation of integral control system with redistribution of the part of functions on the basis of *Smart Grid* technology [3]. Operation with such integrated system provides obtaining of certain knowledge and skills, this task in the concept of intelligent networks is solved by means of training, verification of knowledge and evaluation of controller staff operation at training simulators of on-line and counteraccident control. Intelligent center of intelligent networks concept are mathematical models used in training simulators, that is why development of the above-mentioned models is under way in a number of countries [4].

The aim of the given research is the elaboration of the structure and basic fundamentals for creation of the simulator, intended for on-line control of EES economic mode with considerable technological diversity energy sources.

Problems of determination and control of power losses in EES

Characteristic is the case, when power from system A (transmitting system) is supplied in system C (receiving system) through electric networks of the system B (transit system) (Fig. 1). Passing through the networks of transit system, this power is overlapped on internal power flows and induces additional power losses of the network B. Due to heterogeneity of electric networks of transit system transit power distorts natural flux distribution not only in high voltage (HV) networks, but also in the networks of low voltage (LV). Variations of flux distribution occur in such a manner, that total losses in the system increase as well as losses in HV and LV networks. In which networks, HV or LV, losses increase greater, depends on transformation ratios and coupling autotransformer.

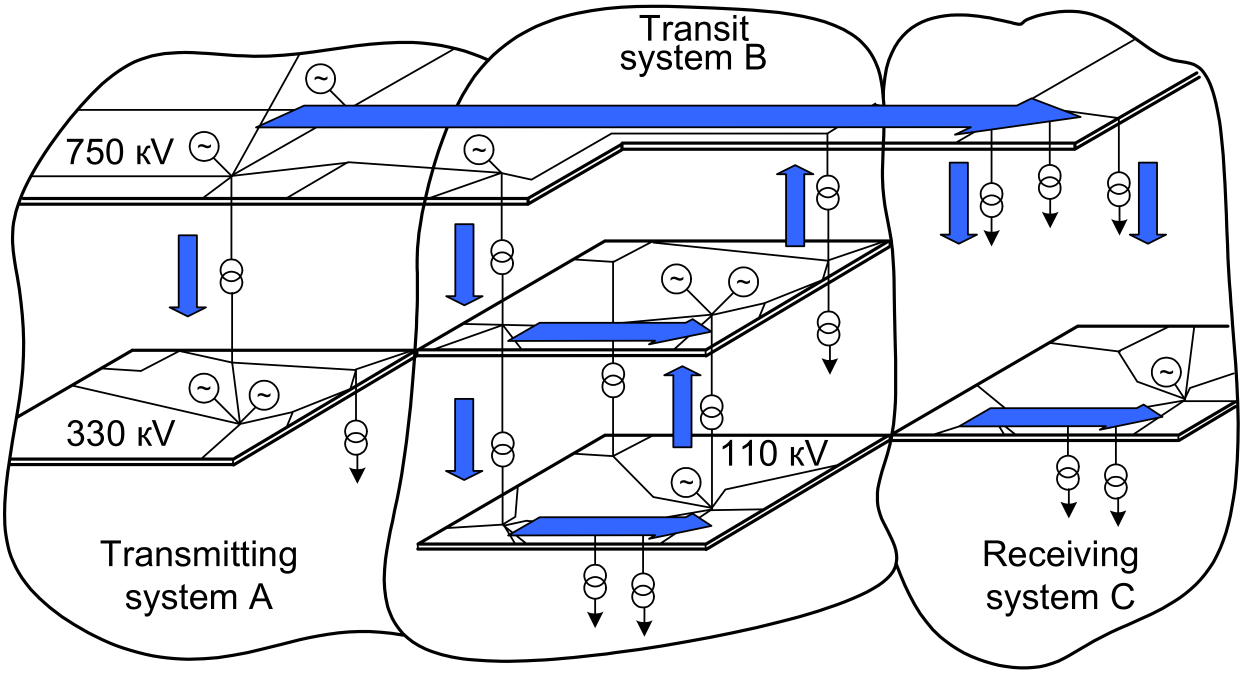

Fig. 1. Fragment of EES, through which power transit passes

The following problems emerge and can be solved in the system B due to power transit through it.

1. Determination of losses in the system, caused by power transmission from system **A** go **C**, to cover their cost at the expense of the above mentioned systems.

2. Analysis and evaluation of transfers impact, including transit transfers, on the modes, in particular, on the losses in HV and LV networks.

3. Elaboration of measures aimed at losses optimization in HV and LV networks. Depending on conditions of operation and interaction between entities several problems can be put forward:

– minimization of total losses in HV and LV network, determining optimum value of transformers and coupling autotransformers coefficients

$$\min\{\Delta P_{\Sigma} = \Delta P_{HV} + \Delta P_{LV}\},$$

where ΔP_{HV}, ΔP_{LV} – are power losses in HV and LV networks, correspondingly ;

– “displacement” of transfers, induced by high voltage network from LV network to HV network

$$\min\{\Delta P_{LV}\}.$$

Such task can be actual if external transit power transfers are available. It is expedient economically to perform their transmission across high voltage networks. However, due to heterogeneity of EES and other factors LV levels are also loaded by them. “Displacement” of the transfers from LV electric networks increases their carrying capacity and it is very critical in maximum loads modes;

– “discharge” of HV networks into LV networks. Such necessity can appear, when HV network is overloaded, and LV network is not overloaded. To control the situation additional losses, caused by transit fluxes must be determined.

4. Determination of losses caused by power fluxes in radial part of LV network. Two cases are possible:

– all losses are referred to and covered by energy supply company and are not divided between separate regional networks ;

–losses are determined and covered among.separate regional networks, so that they proportionally covered their cost.

The solution of the above-mentioned problems requires calculation of power losses in electric system networks and allocation of their separate components for optimization depending on the problem, put forward. The realization of the obtained optimum solutions is connected with the increase of intensity of usage of the existing regulating advices by controller staff, that requires corresponding knowledge and skills, obtaining of which is not possible without regular trainings and simulation of typical situations.

Training simulator of on-line control EES normal modes

Progress of new technologies and establishment of bilateral exchange of information between energy enterprises in accordance with standards and approaches of *Smart Grid* concept provides gradual transition to automatic system of optimum control of EES normal modes. However, determining factor, providing the conditions of adequacy of control actions and quality EES on-line control is regular improvement of staff qualification level on the basis of engineering systems and computing facilities. One of the basic forms of staff qualification level increase are counteraccident trainings in dispatching centers of energy generating and energy supplying companies. However these trainings do not provide development of staff's skills regarding optimization of electric energy system normal modes, but are intended for training, verification of skills, regarding rapid elimination of emergency situations as well as training measures how to prevent emergency situations.

Efficient means for solution of this problem is creation of computer-based simulators, intended for training on-line staff in the sphere of modeling of energy system normal modes and their optimum control. Such systems, using modern hardware and software facilities, provide high adequacy of solution of electric energy transmission and distribution in EES and their control.

For teaching, controller staff trainings and staff certification training simulators, containing two basic components - *Power System Model – PSM* and *Control Center Model – CCM* are used [4].

Usage of such structure for the development of training simulators for EES operators, along with filling of power system model with real data, obtained from on-line information complex (OIC) allows to conduct trainings, regarding optimum maintenance of the mode, in parallel with working operation staff. This allows to evaluate instantly the actions of trained staff, approach training conditions to real ones and further to make collective decisions regarding optimum mode maintaining.

In accordance with PSM/CCM – structure, the simulator must comprise two main levels. Each of them has its functional value and software-hardware facilities, corresponding to *Services Oriented Architecture – SOA* (Fig. 2). Application of this architecture is an important requirement to the development of the software according to the concept of intelligent networks development [5], since it enables to replace parts of the software of simulator without violations of interconnections and its general structure.

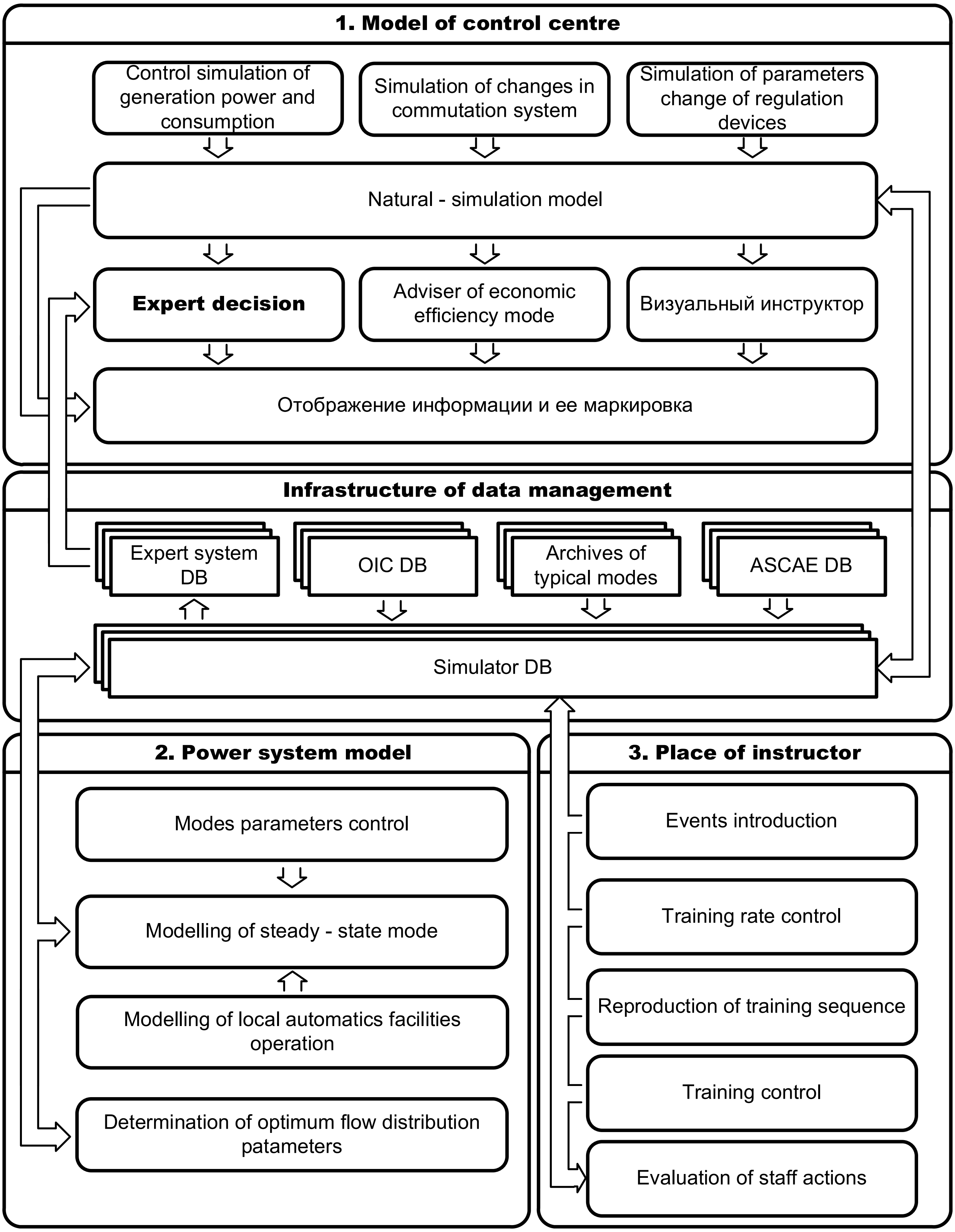

Fig.2. Structure of the simulator for training operator for optimum on-line control

The first level enables to realize control center model by means of available graphic interface, for instance, of available SCADA – system. On this level the connection with data base (DB), reading from DB and reflection of the current state of equipment and mode parameters as well as generation of optimum control commands for the process in real time occurs.

Usage of graphic interface of SCADA – system is justified by the fact, that such systems have built-in analytical tools to maintain communication between objects of service – oriented architecture, that is why Control Center model can be realized on the basis of random SCADA – system with graphic interface and DB support.

On the second level by means of power system model the reproduction of steady-state modes, using natural data from DB of on-line information complex of EES or DB of automatic control system of commercial account o electric energy (ASCAE), is also performed parametrs of simulation mode are controlled. Modes optimization stipulates natural modeling of steady-sate EES modes on the basis of formed vector of power system intended parameters [6, 7]. Formation of the vector is rather complex task, solution of which is one of the basis functions of *Smart Grid*.

The place of instructor (see Fig. 2) is provided for change of training mode from automatic (based on OIC data), into role mode, in this mode the instructor controls the rate of load change, introduces sudden events, corrects wrong decisions, evaluates quality of training , etc. Hence, application of the developed structure of the simulator intended for training of the operator on the basis of EES simulation model, that takes into account the parameters of the system form OIC OB (i.e. natural-simulation model of EES [7] enables to provide training of the personal, improve quality and efficiency of controller's training and staff certification regarding optimum support of electric energy system mode.

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