Automatic control system for voltage and reactive power regulation in active-adaptive grid of power cluster “Elgaugol”

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Elga coal deposit is the largest coal deposit of Russia. It is located in the south-eastern part of Yakutia, 415 km east of the city Neryungri and 300 km from Baikal-Amur Mainline. The deposit has proven coal reserves at 2.7 billion tons and about 30 billion tons of forecast reserves.

For power supply of Elgaugol industry there will be built three substations and two power transmission lines 220 kV 268 km length each, and also a special crossing of Zeya reservoir. In addition, reconstruction of substation “Prizeyskaya” will be held. Above-mentioned substations will form the first Russian cluster of active-adaptive grid “Elgaugol” with the technology platform for the implementation of active-adaptive control model.

Scheme of electrical network “Elgaugol” is shown in Fig. 1.

One of the problems to be solved when creating an active-adaptive grid of power cluster “Elgaugol” is the development of an optimal adaptive automatic control system for voltage and reactive power regulation (AASOU).

The purpose of the system is to automatically maintain specified levels of voltage on the substations buses and simultaneously minimize power losses and improve power quality in the terms of changing modes of operation and the composition of powered equipment.

AASOU designed as a two-level system. The upper level solves the problem of determining optimal levels of voltage and reactive power flows.

The lower level is consists of centralized adaptive automatic control systems of every substation of power cluster “Elgaugol”. The lower level computes and transfers control instructions for local control systems of means of reactive power compensation (MRPC) and checks the results. AASOU functional block diagram shown in Fig. 2.

Usually for design of automatic control systems substation submitted like an object that includes several managed elements and a several controlled parameters. That is actually the substation is a multi-dimensional and multi-connected object.

However, there is another way to use substation as an object to control. Our investigations allows us to propose a new method of automatic control of MRPC, which can be described by the simple expression

$U_1 = U_0 + A \cdot k$.

Where:

U_1 - voltage on the controlled bus;

U_0 - reference voltage;

A - a value proportional to a cumulative reactive load of MRPC installed on a substation.

k - proportionality factor.

In this case substation is represented as an object to control, which has one managed element and one controlled parameter.

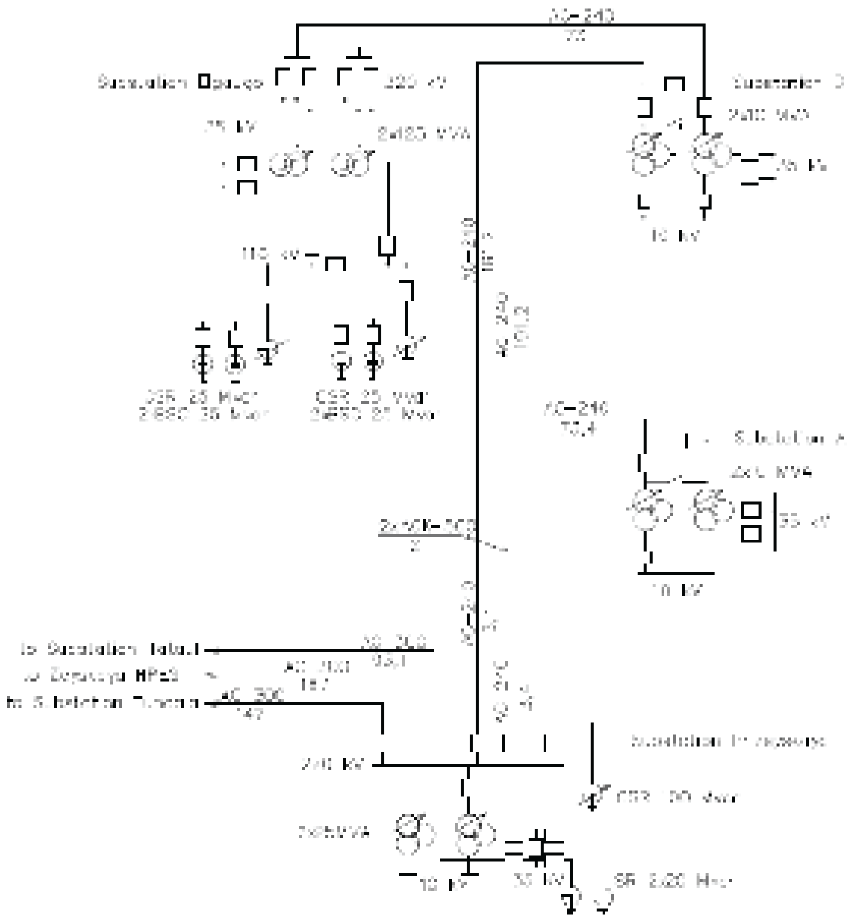

Figure 1.

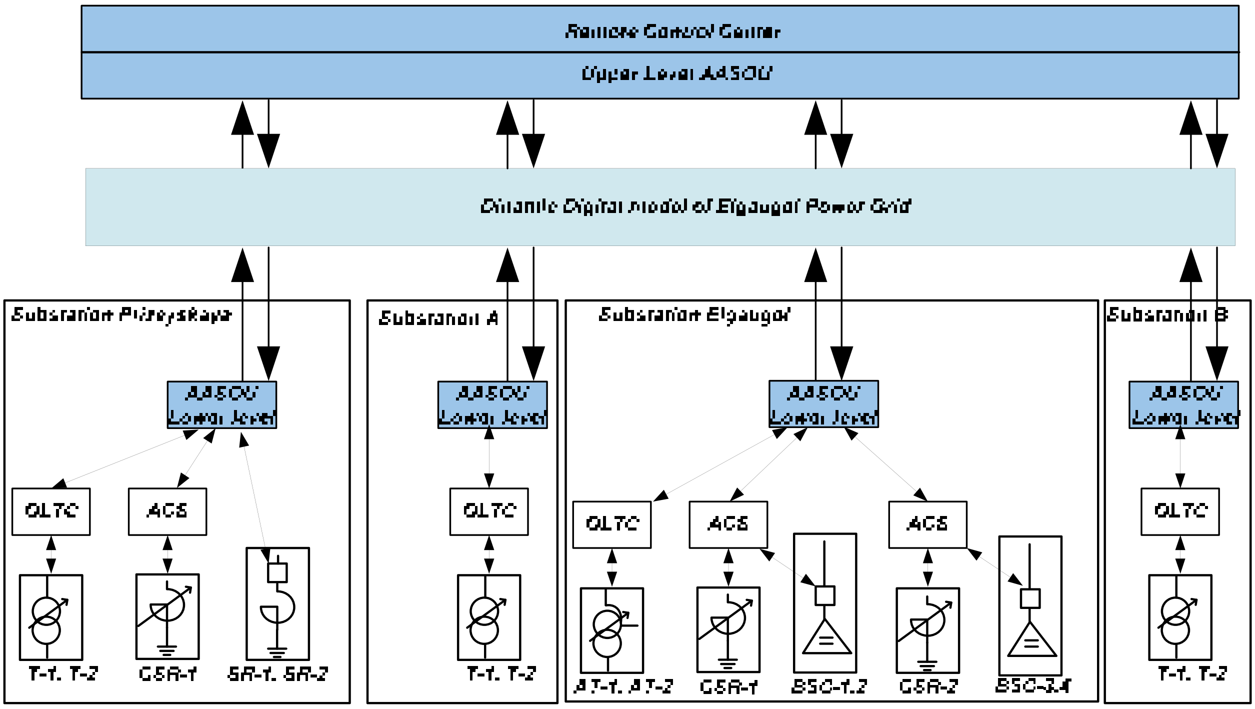
Remote Control Center
Upper Level AASOU
Dinamic Digital model of Elgaugol Power Grid
Substation A
Substation Elgaugol
Substation B
AASOU Lower level
OLTC
ACS
T-1, T-2
GSR-1
SR-1, SR-2
AT-1, AT-2
BSC-1,2
GSR-2
BSC-3,4

Figure 2.

The object scheme which illustrates the proposed control method with use of generalized control signal is shown in Fig. 3.
As a result, required level of voltage on the controlled bus (U1) can be associated with a certain value of parameter (A) proportional to a cumulative reactive load of MRPC installed on a substation, which must be compensated at the substation to maintain this level of voltage.

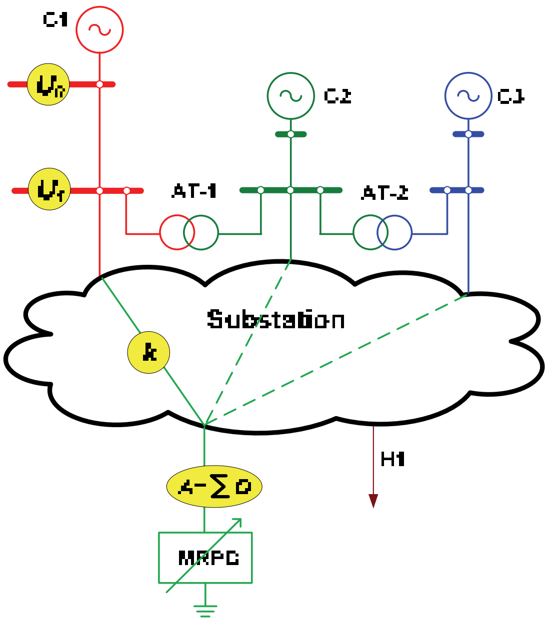

Figure 3.

The value of proportional factor (k) is defined by the changing modes of operation and the composition of powered equipment of the nearby electrical network and the substation as well.
The developed method of automatic control is described by execution of five steps:

1. Receiving of optimal reactive power flows and voltage values on the all buses of the substations of power cluster Elgaugol (From the upper level of AASOU).
2. Calculation of transformation ratio of transformers and autotransformers on the basis of optimal voltage values on the substation buses. The calculated values are transmitted for execution into a controller of OLTC.
3. PI regulator determines the value of the generalized control signal A, proportional to a cumulative reactive load of MRPC to be compensated at a substation to maintain the optimal voltage level.
4. Calculation of load of MRPC on the basis of generalized control signal value in accordance to special rules that provides minimizing of losses and improving of power quality. Calculated load values are transmitted for execution into controllers of MRPC.
5. Based on the measured voltages on the buses and the corresponding to it measured values of the reactive load of MRPC at the current step and in the previous step calculates the correction factor, which is then used to adjust the PI controller. In this way the influence changes of compensated reactive power at the voltage is taken into account.

Special software for AASOU has been developed to implement this method of automatic control.
The functional structure of the system AASOU is shown in Fig. 4.

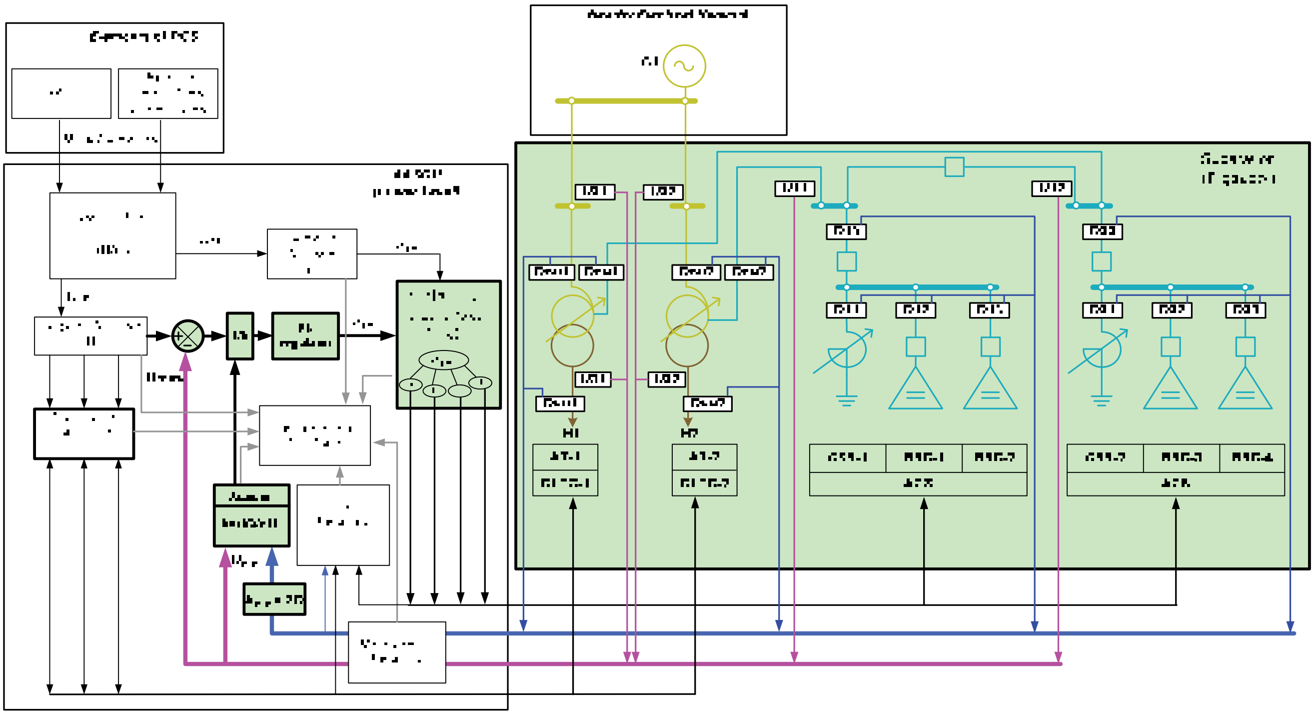

Figure 4.

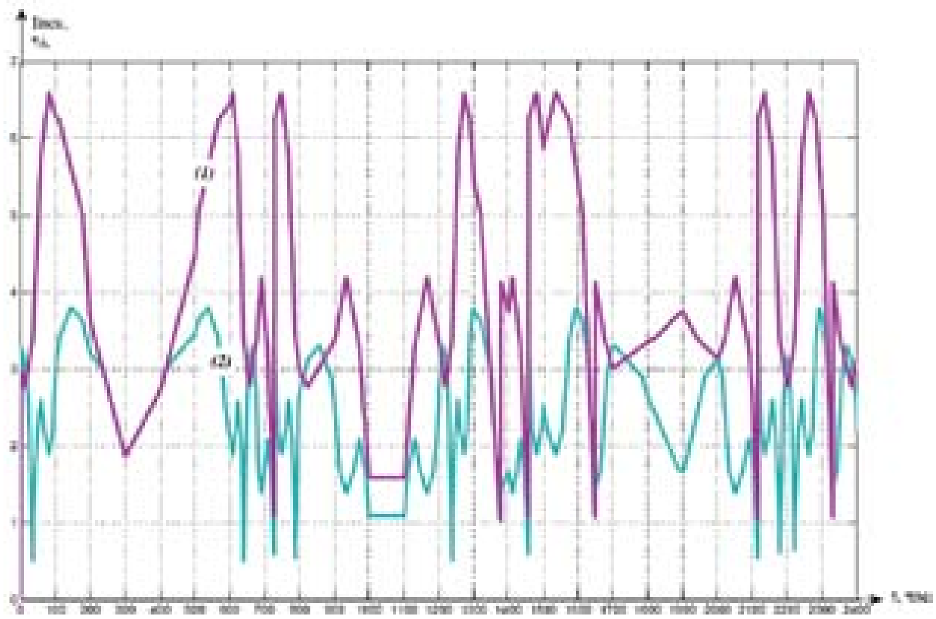

Figure 5.

The structure contains the four basic units: “Elements of PCS”, “Substation”, “Electrical networks”, “AASOU” and connections between them.
Unit “Elements of PCS” includes HMI and a communications to a remote control center.
Unit “AASOU” includes mode switch block, blocks of setpoint adjusters, PI regulator block, MRPC load calculation block, adapter block, tap position calculation block, block of measurement reliability, block of control reliability, block of self-diagnostics and alarm.
Unit “Substation” includes main substation equipment with local automation of controlled shunt reactors, local automation of circuit breakers, OLTC automation and measurement transducers.
Unit “Electrical networks” includes connections of the substation with nearby electric networks. These networks directly affect the operation of substation, but its parameters can not be measured directly in the substation.
To test the described solution a computer model of the substation and nearby electric networks was created as well as digital prototype of AASOU.

Analysis of the influence of the developed algorithms on the level of losses and power quality is carried out by comparing the losses and the value of currents THD produced by MRPC for two cases. First case is uniform loading of MRPC and second case is loading MRPC with the values computed by the prototype of the AASOU.
Under certain experimental conditions, operation of AASOU prototype leads to reducing the maximum level of currents THD is more than 1.5 times. Graph of the changes of currents THD values for two cases is shown in fig. 5.

In addition, operation of AASSOU prototype reduces power losses in MRPC more than 15% (compared to a uniform distribution of the reactive load between MRPC). Graph of the changes of losses for two cases is shown in fig. 6.
Saving energy losses in MRPC under certain conditions is 8068 kWh per day. And for the year it could reach around 2,920 MWh or about 3.6 million rubles ($115000).
Other results of the analysis showed that the use of an adapter block allows to stabilize the duration of transition process in terms of mode changing of electrical networks and powered equipment composition. This is very important for the stability of the interaction of the upper and lower level of AASOU.

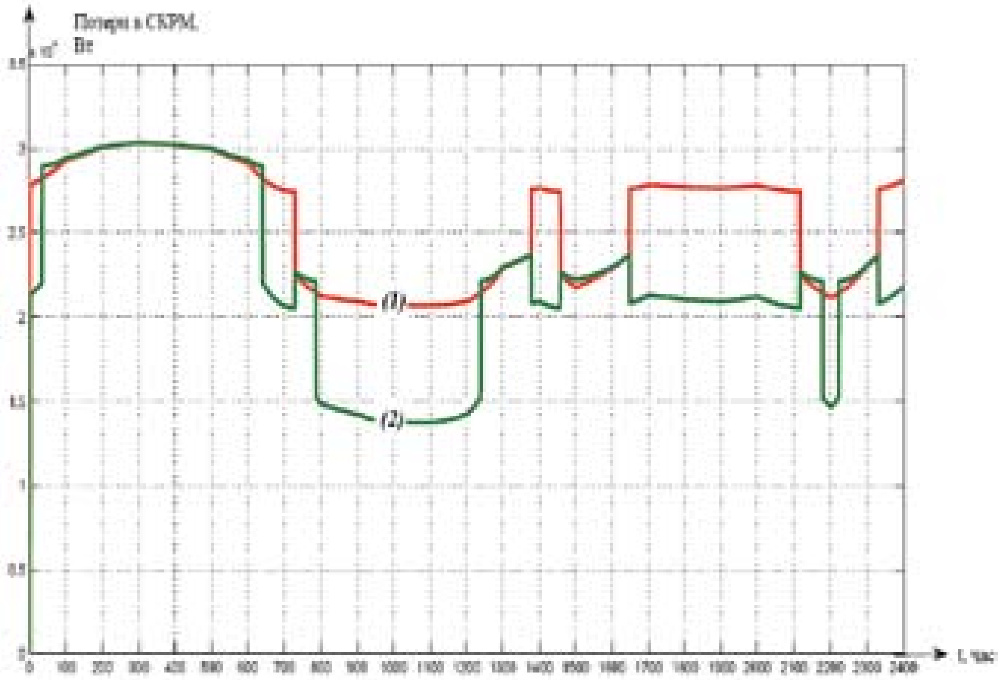

Figure 6.

Conclusion.

1. Proposed and investigated a new method of automatic control for voltage and reactive power regulation.
2. Developed a structure of automatic control system AASOU based on a special presentation of the substation as control object, characterized by the use of a generalized control signal.
3. Developed a digital prototype of the system AASOU and a computer model of substation and nearby electric network.
4. The test of the system AASOU prototype was held. It showed the effectiveness of proposed decisions.
5. The main benefit of the system AASOU is maintaining specified levels of voltage on the substations buses and simultaneously minimize power losses and improve power quality in the terms of changing modes of operation and the composition of powered equipment.
6. The structure of the system AASOU allows its further improvement. Such as performing alignment of equipment remaining life and self-organization of the system if substation divides to independent control areas.

Publications.
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3. Волошин А.А., Косарев А.А., Косарева Е.Г., Костенко В.В., Лапезов В.Н., Лисицын М.В. Системы автоматического регулирования напряжения и реактивной мощности электростанций и подстанций. Электрические станции, №4, 2007 г. (ISSN 0201-4564).

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I graduated the Moscow Power Engineering Institute (MPEI) in 2004 with degree in engineering of Power Engineering (Specialty – Relay Protection and Automation of Power Systems) and also with degree in economics (Speciality – Economics and management at the enterprises of electric power). Both specialties graduated with honor. In 2010 I defended my PhD thesis on the voltage control and reactive power compensation in electric power systems.
Position in company
I am Deputy Director of Development of Entel LLC and research associate in Department of relay protection and automation of power systems of MPEI. I am doing my research and development in the field of intelligent control systems for substations and power systems.
Achievements.
I'm author of over 4 articles in Russian scientific journals. Development of more than 7 PCS for substations with the voltage level of 500 - 750 kV. In 2007, I was awarded a first degree in the nomination of automated process control in the second All-Russia competition of young professionals in the field of energy.