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M.Bekker[1], V.S.Portnov[2], A.K.Tursunbayeva[2], A.D.Maussymbayeva[2], N.A.Alpysbayeva[2]

[1]«Electricity Market Solutions» company, USA;
[2]Karaganda State Technical University
(E-mail: vs_portnov@mail.ru)

Development of power supply systems and evolution of the organisation of electric power industry models

In work the short review of development of power supply systems and models of their organisation is given. Now in Europe, Asia and America there are some large national and transnational power associations of various degree of integration. The electric power industry organisation, despite the big variety of forms of realisation worldwide, followed the general logic generalised in concept of industrial model. This model was unique up to the end of 70-th years when in a number of the world countries there have been begun the practical experiments directed on searches of new more effective principles of the organisation of electric power industry. Preconditions to re-structuring and a decontrol in electric power industry of a steel of achievement in technological area which have led to occurrence of competitive generating blocks of smaller capacity. The greatest influence on decontrol possibilities in electric power industry was rendered by progress in systems of transfer of the electric power. The level of technological development reached in the world allows to start creation of new technical systems of 21 centuries already today. The further innovative development will change model of the organisation and management principles in electric power industry, will demand reconsideration of a role and a combination of development of the large centralised and small distributed generating sources.

Key words: power supply systems, industry, competitive generating blocks, innovation, generating sources, evolution, industrial, transfer.

Introduction

The power industry passed a long way from small local installations of power supply before large international power associations.

Possibilities of competitive restructuring of power industry and emergence of the modern electrical power markets were caused by the reached level of technological development of power industry, the unprecedented opportunities connected with development and large-scale distribution of the computer equipment and means of telecommunications.

The evolutionary spiral of development of technologies in power industry gives again chance for emergence of effective local systems of power supply of consumers (the distributed small generation, «clever» networks) that inevitably conducts to further changes of model of the organization of power industry, will increase reliability of power supply and efficiency of functioning of the electrical power markets.

In the present article the short review of development of power supply systems and models of their organization is given.

Formation of power supply systems and power associations

Formation of electrical power systems in industrialized countries happened similarly [1]. Commercial use of electricity began with numerous small power plants — sources of the electric power were established at the separate industrial enterprises, in public buildings, houses, etc. The central power plants serving more

wide range of consumers came to change by it (the whole inhabited quarters, etc.), and it led to emergence of the first power units. As power plants were small, for power supply of one city it was necessary to use tens such power plants. Need of increase of reliability of power supply of consumers from different sources led to association of electric networks and adjustment of parallel work of power plants. Thus, the first power supply systems serving rather small territories were created.

In process of development of production technologies and transfer of the electric power there was an integration of power supply systems. The public power plants of the bigger power serving the cities and large areas began to be constructed. Thus for increase of reliability of power supply the electric network connecting power plants not only through a distributive network of consumers, but also directly with each other started being created, i.e. the backbone network began to be formed.

Economic efficiency of integration of units and power plants (economic effect of production scale) caused further increase in range of transfer of power industry, and, as a result, increase of tension of power lines and increase in their capacity. As a result of the territory of the states became covered by an electric network from several levels of the highest tension of a class 100, 200, 400 of kV. Started being constructed interstate and intersystem (within one state) power lines of various tension for the solution of specific objectives — an exchange of capacity and the electric power, and also realization of intersystem effect.

Thus in the territory of the various countries of the world the uniform electric network of various tension was created and preconditions for deeper integration of power industry of the certain states and regional power supply systems in one country were created [1].

Inevitable consequence of integration of power associations was increase of probability of cascade development of accidents which involves risks of violation of power supply of big territories and the whole states and can lead to big economic damage at consumers and in the power industry. Ensuring reliable, economic and high-quality power supply of consumers in operating conditions of big power supply systems (power associations) required creation of special systems of a dispatching and antiemergency control.

Examples of formation of the international power associations

Formation of big power supply systems and transnational power associations happened to various extent of integration and realization of intersystem effect. On a choice of the principles of the organization of parallel work of national power supply systems and international power associations had impact various factors — features of historical development and economic system (planned or market economy), dominating form of ownership in power industry (state or private), geographical features of the country (the territory, existence of energy resources and their placement, etc.), interests of national security, etc.

Now in Europe, Asia and America there are some large national and transnational power associations of various extent of integration. The largest associations of the world are: The European network of system operators in power industry (ENTSO-E), North American power association and the uniform electrical power system created in the former USSR (now association of power supply systems of CIS countries).

The European network of system operators in power industry — ENTSO-E was created in July, 2009 on the basis of integration of several power associations of the European countries — ATSOI, BALTSO, ETSO, NORDEL, UCTE and UKTSOA (fig. 1).

UCTE (English Union for the Co-ordination of Transmission of Electricity) — power association of the European countries, one of the largest power associations in the world. It is based in 1951. In the last year of the existence of UCTE united 29 system operators from 24 countries of continental Europe. UCTE included power supply systems of France, Spain, Portugal, Germany, Austria, Italy, Belgium, Holland, the Western Denmark, Switzerland, Luxembourg, Slovenia, Croatia, Poland, the Czech Republic, Slovakia, Hungary, Greece, Bosnia and Herzegovina, Macedonia, Serbia and Montenegro, Albania, Bulgaria, Romania. Before inclusion in structure of UCTE of a power supply system of Hungary, Poland, Slovakia and the Czech Republic worked as a part of the power association **CENTREL**.

UCTE is connected with NORDEL through an insert of a direct current. Great Britain (**UKTSOA**) and Ireland (**ATSOI**) are connected among themselves and with UCTE underwater cable lines of a direct current. Synchronously with UCTE the allocated part of the integrated power system of Ukraine works. Synchronous communications with UCTE have also Morocco, Algeria and Tunisia.

NORDEL — power association of countries of Northern Europe — Finland, Sweden, Norway and East Denmark (the continental part of Denmark works as a part of UCTE). There is a nonsynchronous communication of NORDEL with a power supply system of Iceland. Through an insert of a direct current in Vyborg

carries out parallel (but not synchronous) work with the Power pool system of Russia and the countries of the former USSR (IPS/UPS).

BALTSO (English Baltic Transmission System Operators) — the organization created for the purpose of coordinating of parallel work of power supply systems of the Baltic States — Estonia, Latvia and Lithuania. Basis date — on March 30, 2006.

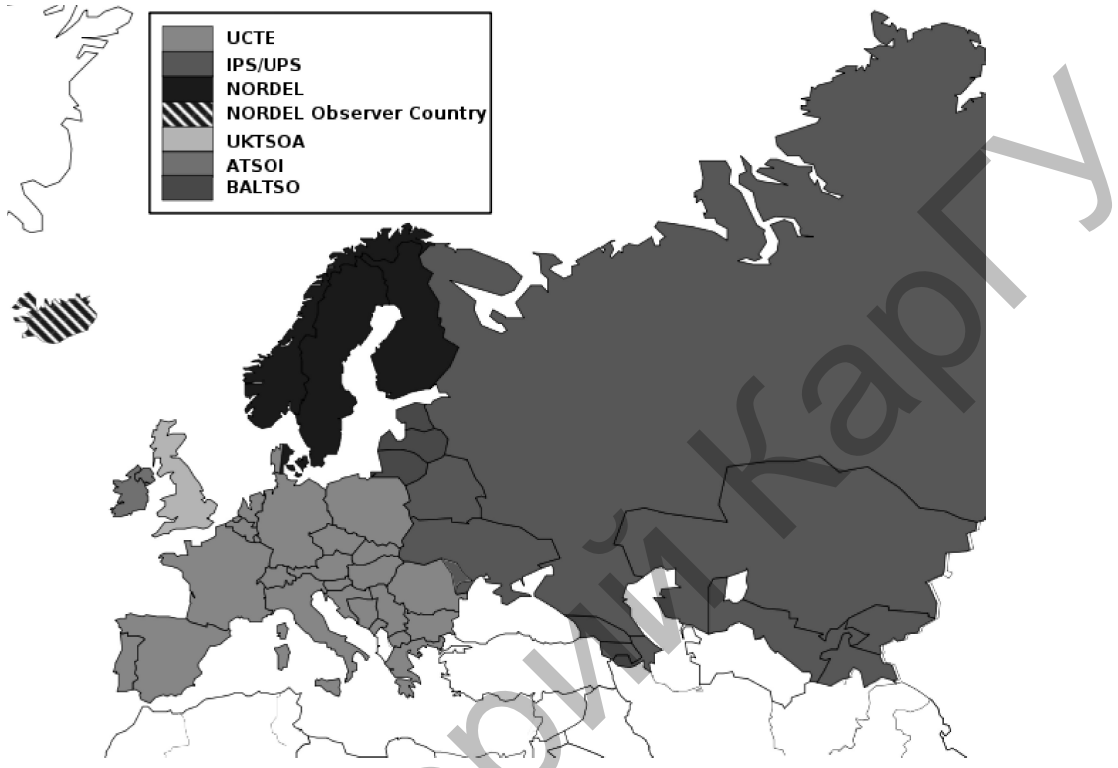


Figure 1. European network of system operators

Historically power associations of the Western and Northern Europe were created in the conditions of market economy advanced economically the countries. Their structure included the power supply systems almost completely balanced on capacities and the electric power and provided with big reserves of power and capacity of electric networks. The joint work allowed them to use more rationally energy resources and to reduce the price of electricity generation, to increase reliability of power supply in extreme conditions and quality of the electric power though the effect from the joint work was used only partially. Here the decentralized system of an operational and antiemergency control carried out by dispatching services of national power supply systems works. Coordination of functioning and partially development is carried out by supranational coordinating bodies (in UCTE — the Union Secretariat), developing offers on rational development of the systems, defining optimum operating modes of national power supply systems and the main backbone electric networks of association, but not participating in operational work on maintaining a mode. Thus at decision-making interests of national power supply systems are priority.

Power associations of the Central and Eastern Europe were created at centrally planned economy and in the conditions of domination of state ownership. They were created as a part of the integrated power system «World» (SEV member countries) and an integrated power grid / by the USSR. Therefore national power supply systems aren't always balanced on the power and the electric power and have significantly smaller reserves of power and capacity of electric networks. Here the intersystem effect was more realized. In the power associations CENTRAL and BALTIA the centralized system of supervisory control led by TsDU respectively in Prague and Riga with a wide range of tasks was kept. Having only recommendatory functions, she participates in operational work on elimination of emergency operation. In national power supply systems of these associations the centralized system of supervisory control also is used.

In America the North American power association including power supply systems of Canada, the USA and the northern regions of Mexico is the largest. It consists of four nonsynchronously working power associations: Western, East, Texas, Quebec and Alaska (fig. 2).

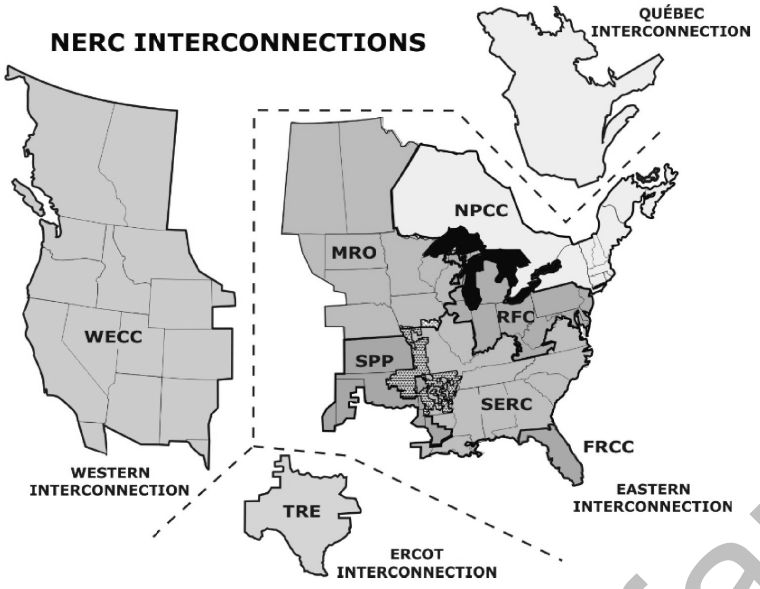


Figure 2. Power association of the USA and Canada

As a part of East and Western power association the corresponding adjacent power supply systems of Canada (except a power supply system of Quebec) synchronously work. The western power association and power association of Texas have electric communications with various power districts of power industry of Mexico. The majority of these North American power associations are connected among themselves by the lines of a direct current (LDC) and can controlled overflows of the electric power through inserts of a direct current. So, East power association is connected with the Western power association 6 LPT, with power association of Texas — 2 LPT, with power association of Quebec — 4 LPT.

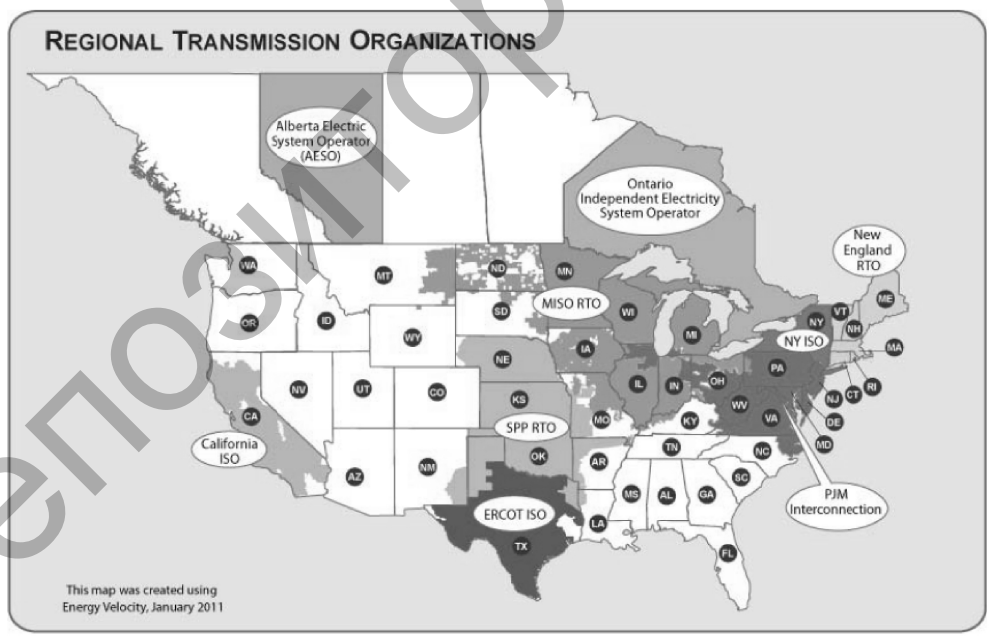


Figure 3. RTO of the USA and Canada

The basis of North American power industry is made by some hundred public private companies, the municipal power companies and the electrical power cooperatives providing production, transfer, distribution and electric power sale in certain territories. Each company provides independent technical policy.

Various methods of dispatching management of the main network provide numerous dispatching centers. Many power companies create the voluntary Unions (pools) or enter into the Regional organizations on coordination of operation of a network (English Regional Transmission Organization — RTO).

In the territory of North America ten RTO and independent operators of system (ISO) acting in their framework are already created provide a uniform non-discriminatory mode of operation of the main electric network (including the centralized control), belonging to the RTO participating companies, provide coordination functions on development of generation and networks in the zone of responsibility (fig. 3). Within RTO the modern high-organized markets of the electric power (additional system services, and in certain cases — capacities) are organized.

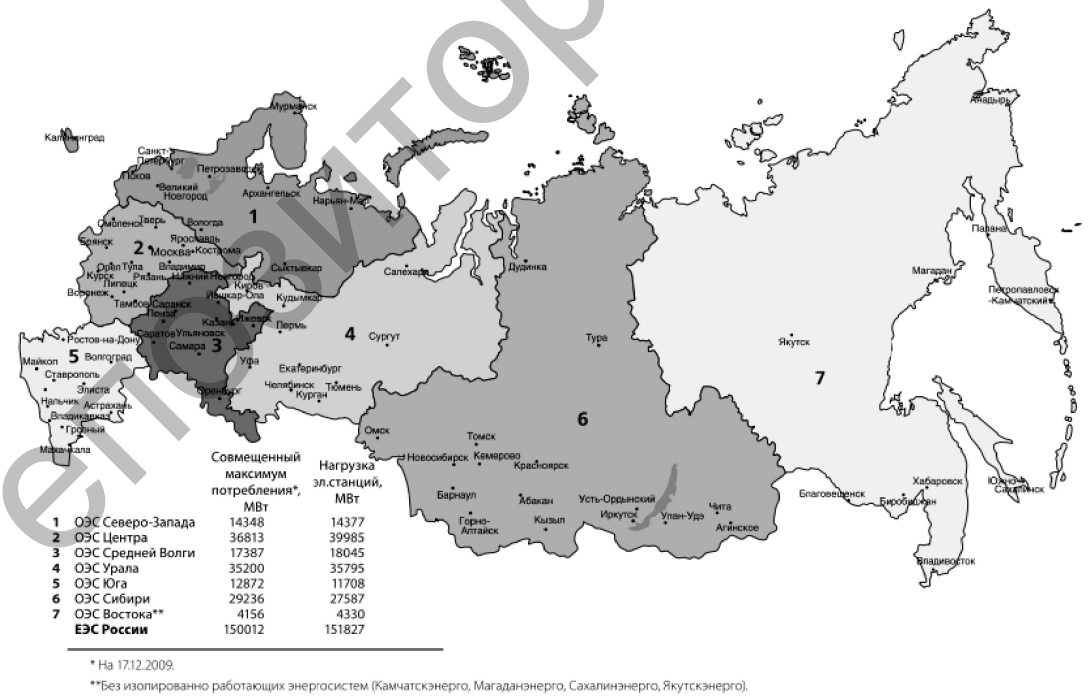
The general coordination and control of functioning and power industry development (from positions of ensuring reliability) provides the North American corporation on reliability in power industry (English North-American Electricity Reliability Corporation — NERC), recently created on the basis of earlier existing public organizations — North American council on reliability in power industry and several regional councils on reliability. NERC received the status of the Organization authorized by the state on ensuring reliability in North American power industry (English Electricity Reliability Organization — ERO).

At such difficult structure the power industry of the USA and Canada in essential degree is exposed to state regulation at regional level (from authorities of states and provinces) and at federal level. For its regulation and establishment of fair relationship with consumers the powerful legislative base is created.

This control system and developments by North American power association arose historically, and it gradually evolves towards bigger centralization of dispatching management. The begun reorganization of the market relations in power industry of the USA and Canada with emergence and expansion of the zones RTO with independent operators of system (ISO) and creation of a new control system of reliability (ERO) will allow to improve system of supervisory control and to increase reliability of work of all North American electrical power system.

Association of power supply systems of Russia and other CIS countries

Formation of power association of CIS countries (then EEC of the USSR) began in 1956 with association of the Russian integrated power systems (OES) of the Center and Central Volga. In different years power supply systems of all republics of the country entered into structure of EEC of the USSR.



		Совмещенный максимум потребления*, МВт	Нагрузка эл.станций, МВт
1	ОЭС Северо-Запада	14348	14377
2	ОЭС Центра	36813	39985
3	ОЭС Средней Волги	17387	18045
4	ОЭС Урала	35200	35795
5	ОЭС Юга	12872	11708
6	ОЭС Сибири	29236	27587
7	ОЭС Востока**	4156	4330
	ЕЭС России	150012	151827

* На 17.12.2009.

**Без изолированно работающих энергосистем (Камчатскэнерго, Магаданэнерго, Сахалинэнерго, Якутскэнерго).

Figure 4. Power supply system of Russia and CIS countries

The basis of this association is made by the Power pool system of Russia (UES of Russia) largest on the territory as a part of which seven Unified Energy Systems work. In parallel OES of the Center, Central Volga, the Urals, the North West, the South and Siberia work. In parallel working as a part of OES of the East of a power supply system form a separate synchronous zone.

Now in parallel with UES of Russia power supply systems of Belarus, Estonia, Latvia, Lithuania, Georgia, Azerbaijan, Kazakhstan, Ukraine, Moldova and Mongolia work. Through a power supply system of Kazakhstan with UES of Russia power supply systems of Central Asia — Uzbekistan, Kyrgyzstan, and also a power supply system of Tajikistan (till 10.11.2009) work (fig. 4). Also in parallel with a power supply system of Norway separate generators of hydroelectric power station of the Kola power supply system work. From electric networks of Russia power supply of a number of the allocated regions of China is carried out.

For ensuring survivability and reliable power supply of consumers of such large power association as UES of Russia, covering big territories and having big overflows of power at rather small reserves of power and essential restrictions of capacity of intersystem electric networks, was created the centralized hierarchical, multilevel system of dispatching management.

As a whole power association of Russia and CIS countries should take place still a long way of creation and debugging of new rules and mechanisms of management and development of national power supply systems and intersystem interaction, trade in electric energy (capacity), etc. that in new conditions (creation of the independent states, liberalization and power industry privatization) in maximum measure to keep advantages of the joint work of power supply systems, reliability and survivability of their functioning, profitability and quality of power supply of consumers.

Industrial model of the organization of power industry

Technical and economic features of power industry regardless of conditions of its development worldwide had defining value when forming organizational structure and system of regulation of this branch. Among these features it should be noted:

– continuity of processes of production and the consumption, caused by impossibility of storage of the electric power (in significant scales), and rigidly certain communications of the producer and the consumer through remote networks of an electricity transmission;
– high capital intensity of power industry at strongly expressed effect from production scale (economy of specific expenses at concentration of generating capacities).

Under the influence of these factors the power industry organization, despite a big variety of forms of realization worldwide, followed the general logic generalized in concept of industrial model. This model was only up to the end of the 70th years when in a number of the countries of the world the practical experiments directed on searches of new more effective principles of the organization of power industry were begun.

Characteristics of the industrial model (IM):

– high extent of coordination of the production which is carried out by one operator of a power supply system in big territories;
– close long-term connections of the operator responsible for functioning of the integrated power system, with vertically integrated energy companies possessing monopolies on production-transfer-distribution-sale of the electric power in the (franchize) territories;
– the state regulation of power industry providing control of investment decisions, price level establishment on the electric power, etc.

Transition to THEM was caused by a number of advantages which this model provided as for branch, and society as a whole, and particulars:

– distribution of risk of long-term investments. Big capital intensity of power industry and long-term character of investments in the absence of long-term obligations from consumers I demanded granting to the power companies of certain guarantees which would reduce their risks and stimulated long-term investments. In a framework IT such guarantees became: granting the power supplying company of monopolies on power supply of a certain territory (a guarantee from appearance of the competitor) and state regulation of tariffs for the electric power (a guarantee of compensation of the current and investment expenses financed by all consumers in an exclusive zone of service);
– receiving the economic and technical effects of integration of a production activity in the vertically integrated power companies and in their power associations.

Transition from industrial power industry to competitive model

Preconditions to restructuring and deregulation in power industry were achievements in technological area which led to emergence of competitive generating blocks of smaller power (a scale effect of production lost the former importance). Important role progress in development of gages also played, communications

and information processing (increase in opportunities for collecting and data processing, on carrying out mass trade operations).

However, probably, in power industry progress in systems of transfer of the electric power has the greatest impact on possibilities of deregulation.

Need of restructuring and power industry deregulation first of all locates an inefficiency of state regulation. The system of state regulation faces two fundamental problems: 1) she can't create strong incentives for producers of the electric power to increase the efficiency as it is easy as it can make the competitive market, and 2) regulators have no necessary incentives [2].

The aspiration to leave for restrictions of growth of efficiency of the power industry, created by traditional system of state regulation, induced a number of the countries of the world to carrying out reform of power industry which brought the competitive beginnings in the organization and functioning of this branch. Similar transformations, but already at the international level, connected with stimulation of efficiency of electrical power system of Europe by creation of the all-European market of the electric power and competition encouragement, the European Union carries out.

For last years in the world various ways of transformation of industrial model of the organization of power industry with competition start among producers of the electric power were tested: from the simplest forms of competitive selection within keeping exclusive structure of power supply to the markets with a free access of consumers of the electric power to a network.

Evolution of approaches to introduction of competitive mechanisms in power industry in the generalized look can be presented as follows:

– the organization of the competition of the existing power company monopolist with independent producers of the electric power without providing their free access to a transport network. Their functioning is carried out on a contract basis with the monopolist under special control of regulators;
– the organization of the competition of existing monopoly with independent producers of the electric power with providing the rights of a free access to them to a transport network. In this case the circle of competitors at monopoly will extend as now any independent producers and other monopolies having equal access to the integrated transport network, and not just independent producers from energy area, served by this monopoly can potentially enter the competition to it.
– the most consecutive realization of this approach assumes carrying out competitive restructuring of power industry with full functional division of power industry on kinds of activity (generation and sale — the competitive sphere, transfer and distribution — the adjustable sphere);
– providing a free access of consumers of the electric power to the integrated transport network. It actually means transfer to consumers of an option of the supplier within all integrated power system or within this region (see fig. 5). Ensuring this right assumes also a free access of producers to a network, i.e. simultaneous realization and the previous option.

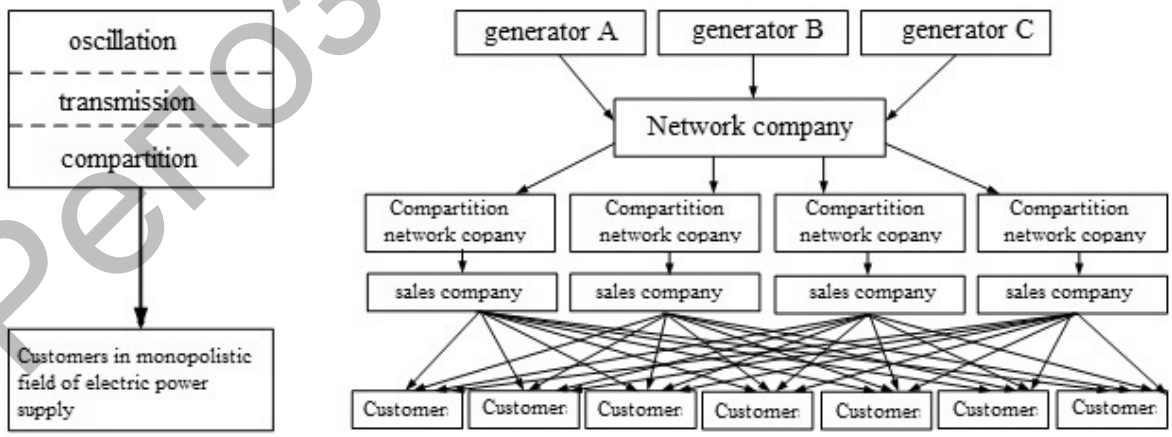


Figure 5. The choice scheme the consumer of the supplier within all integrated power system or within this region

The markets of the electric power are extremely difficult systems and are subject to emergence of problems with a market force in local zones of the market because of the insufficient capacity of power lines.

In short-term prospect the solution of the problems arising at start of the markets of the electric power, probably, will cost dearer, than benefit brought by them. These problems are caused generally by action of two organic shortcomings of the market of the electric power from demand:

• The first organic lack of the market of the electric power from demand — lack of measuring instruments and calculations for the electric power in real time. It results in absence or insufficiency of reaction of consumers on the prices, or, in other words, in insufficient price elasticity of demand.

• The second organic lack of the market of the electric power from demand — lack of control facilities in real time a power stream to specific consumers. It doesn't allow to provide forcibly observance of conditions of contracts and leads to that the system operator appears in position of the closing supplier (i.e. the supplier of «the last hand») in real time.

Whatever difficult were the arising problems of start of the competitive market, already in practice is proved, as in these conditions it is possible to construct the efficient market, but it has to be correctly designed, and its introduction has to be accompanied by creation of system of multidimensional and reasonably applied regulation.

At deregulation of power industry there are two fundamental problems which demand the decision, — technological complexity of the market of the electric power and local market force. The problem of technological complexity can be solved by means of rather well developed set of rules and market regulations, but a problem of local market force, it is necessary to solve, at least, now by means of administrative mechanisms.

The major tendencies in technological development of power industry and their expected influence on the organization and power industry functioning

The evolutionary spiral of development of technologies in power industry brought in the end of the 20th eyelid — the beginning of 21 eyelids to emergence of generating installations of the low power comparable by the efficiency to large generating installations. It created necessary economic preconditions for broad development of effective local systems of power supply of the consumers entering the competition to model dominating now of centralized power supply.

Besides, the reached level of technologies in the sphere of electronics, the computer equipment and telecommunications created preconditions for emergence in the future of so-called «clever» networks within which flexible management of processes of electricity consumption and direct participation of consumers in rendering services already will be provided to the most centralized system of power supply.

Emergence of technologies of «clever» networks will allow in the long term:

– in the most effective way to use resources of the distributed small generation for depreciation of power supply of consumers, and also for rendering system services to the centralized system of power supply (participation in regulation of the production schedule of a power supply system, granting a reserve, etc.);
– to give to consumers opportunity to pay the electric power for the prices of real time, flexibly reacting to growth/reduction of prices at peak/offpeak o'clock that will increase reliability and flexibility of power supply of consumers and efficiency of functioning of the markets of the electric power as a whole;
– to give to consumers opportunity independently to choose level of reliability of the power supply;
– to provide large-scale use of VIE in centralized and local systems of power supply, having reduced needs for organic fuel for power industry.

The level of technological development reached in the world allows to start creation of such technical systems of 21 eyelids already today. The main obstacle for large-scale transition to «intellectual» power industry now — lack of economic and commercial effectiveness. However with a rise in prices for traditional fuel resources, reduction in cost of new technologies, toughening of requirements to environmental protection, etc. the situation will change, and the developed countries of the world, having finished necessary cycle NIIOKR and demonstration projects, will be able to pass quickly enough to large-scale practical use of the distributed energy resources in power industry.

Conclusion

Further innovative development will change model of the organization and the principles of management in power industry, will demand reconsideration of a role and a combination of development of the large centralized and small distributed generating sources, will change a way of interaction of consumers with the centralized power supply system, will make new demands to design of the centralized power supply system and to rules of functioning of the markets of electric energy.

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М.Беккер, В.С.Портнов, Ә.К.Тұрсынбаева, Ә.Д.Маусымбаева, Н.А.Алпысбаева

Энергожүйелердің дамуы мен электроэнергияны ұйымдастыру әдістердің эволюциясы

Мақалада энергожүйелерді дамыту мен оларды ұйымдастыруға қысқаша шолу жасалған. Қазіргі таңда Еуропада, Азияда және Америкада әр түрлі дәрежелі интеграциялы бірнеше үлкен ұлттық және трансұлттық энергоұйымдар жұмыс етуде. Ақпараттық-өлшеуіш жүйелерінің технологиялық ұрпақтылық қасиеттері және текті қабілеттілігі жайлы сұрақтар талқыланып, тепе-теңдік емес термодинамика көлемінде ақпараттық-өлшеуіш жүйелерінің текті қабілеттілігін анықтауға мүмкіндік беретін формула алынған. Бұл формула негізінде алынған теңдеу жүйенің текті қабілеттілігін эксперимент жүзінде есептеуге мүмкіндік береді. Ол теңдеу белгілі Мур заңының математикалық өрнегі десек те болар еді. Бірақ Мур заңының ежелгі заманнан бері келе жатқан интерпретациясына қарағанда текті қабілеттілік туралы ұғым бірінші рет енгізіліп отыр. Бұл ерекше айтылатын жағдай. Сонымен қатар ақпараттық-өлшеуіш жүйелерінің қаншалықты ұғымы бар екендігі жалпы термодинамика тұрғысынан қарастырылды.

М.Беккер, В.С.Портнов, А.К.Турсунбаева, А.Д.Маусымбаева, Н.А.Алпысбаева

Развитие энергосистем и эволюция моделей организации электроэнергетики

В статье дан краткий обзор развития энергосистем и моделей их организации. Отмечено, что в настоящее время в Европе, Азии и Америке существует несколько крупных национальных и транснациональных энергообъединений различной степени интеграции. Авторами подчеркнуто, что организация электроэнергетики, несмотря на большое разнообразие форм реализации в различных странах мира, следовала общей логике, обобщенной в понятии индустриальной модели, которая была единственной вплоть до конца 70-х годов, когда в ряде стран мира были начаты практические эксперименты, направленные на поиски новых более эффективных принципов организации электроэнергетики. Определено, что предпосылками к реструктуризации и дерегулированию в электроэнергетике стали достижения в технологической области, которые привели к появлению конкурентоспособных генерирующих блоков меньшей мощности, а наибольшее влияние на возможности дерегулирования в электроэнергетике оказал прогресс в системах передачи электроэнергии. Доказано, что достигнутый в мире уровень технологического развития позволяет приступить к созданию новых технических систем XXI в. уже сегодня. Дальнейшее же инновационное развитие изменит саму модель организации и принципы управления в электроэнергетике, потребует переосмысления роли и сочетания развития крупных централизованных и малых распределенных генерирующих источников.

Сведения об авторах

Беккер Михаил — директор проекта, советник по электроэнергетическим рынкам «RESET» программы USID, PhD, профессор, США.

Портнов Василий Сергеевич — начальник Управления послевузовского образования доктор технических наук, профессор, Карагандинский государственный технический университет, e mail: vs_portnov@mail.ru

Турсунбаева Асель Кенжибековна — профессор кафедры разработки месторождений полезных ископаемых доктор технических наук, Карагандинский государственный технический университет, e-mail: atursunbaeva75@mail.ru

Маусымбаева Алия Думановна — старший преподаватель кафедры разработки месторождений полезных ископаемых кандидат технических наук, Карагандинский государственный технический университет, e-mail: aliya_maussym@mail.ru

Алпысбаева Назым Амангазиевна — декан факультета экономики и менеджмента кандидат технических наук, профессор, Карагандинский государственный технический университет.

Information about authors

Bekker Mikhael — Director of the project, an adviser to the electricity market «RESET» program of USID, PhD, professor, USA.

Portnov Vassilyi Sergeevich — Head of the Department of postgraduate education, Doctor of technical sciences, Professor, Karaganda State Technical University, e-mail: vs_portnov@mail.ru

Tursunbayeva Assel — Professor of chair of development of mineral deposits, Doctor of technical sciences, Karaganda State Technical University, e-mail: atursunbaeva75@mail.ru

Maussymbayeva Aliya — Senior lecturer of chair of development of mineral deposits, Candidate of technical sciences, Karaganda State Technical University, e-mail: aliya_maussym@mail.ru

Alpysbayeva Nazym — Dean of economic and management department, Candidate of technical sciences, Professor, Karaganda State Technical University.