

Principles of controlling intersystem power flows in the conditions of the electricity market

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Abstract. The principles of electricity market control in relation to intersystem communications is analyzed in the paper. Electricity market can be both intersystem communications and legal entities of transmission and distribution networks of power systems. As an example, parallel operation of two power systems through the intersystem communication with different operating costs was considered.

Key words: power system, intersystem communications, electricity, electricity market

1 Introduction

In accordance with the current legislation of many countries, including the Republic of Azerbaijan, radical structural changes have taken place in the energy sector. The state monopoly in the power sector has been eliminated, and some sectors have completely changed their form of ownership [1, 2].

Under these conditions, economic principles are added to the main technological principles of control. Moreover, both of these principles are not independent, but closely interrelated and interdependent. Their joint realization works as a whole for the integral indicator-efficiency. This is associated with the need to maximize the satisfaction of both the economic interests of energy producers (electric power industry) and the economic interests of its consumers while complying with numerous restrictions of technological and economic nature, as well as the interests of the state and society in the ensuring energy security of the country [3].

2 National Dispatch Center

In a market economy, the National Dispatch Center (NDC) operates in a multi-criteria environment. NDC becomes a guarantor of effective functioning not only of the electric power industry, but also of the entire economy.

The experience of North American and European UPSs (UCTE, NORDEL, CENTREL) shows that the NDC implements almost independent control over the operation of their power systems, ensures their reliable

and economical operation, regulates technological and economic relations within the energy association [4].

Economic aspects within the framework of dispatch services tasks were previously expressed mainly in the problem of conduct of optimal mode with observance of the criterion of minimum costs under the existing constraints. This is the problem of optimal distribution of powers [5].

In market conditions, a much wider and more serious range of problems is revealed [2], one of which is reflected in this paper in the form of recommendation criteria.

Intersystem communications are a market where acts of purchase and sale of electricity are realized. In this case, it is determined how much can be sold/bought and at what price. Subjects on the market in this case are power systems of power systems of energy association.

Similar processes take place in power systems, where as a market are substations of connection of transmission and distribution networks, at the ends of which are concentrated, respectively, suppliers (power plants) and buyers (consumers-loads) [6-8].

In both cases, the regulators of these processes are dispatch centres that perform the combination of technical and economic criteria. The activity of dispatch centres under these conditions should be based on two main provisions:

1. In the electric power system (EPS), the optimal capacity allocation should be ensured according to the criterion of minimum costs and consideration of constraints [5, 6].

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2. The action of NDC should be subject to the basic laws of market economy - the laws of Supply and Demand [4].

Moreover, both of these provisions are inseparably linked. The first provision is well known and is successfully applied in the practice of power system regime management at all hierarchical levels of ASDC. Therefore, in our paper we will focus on the second provision.

3 Laws of Supply and Demand

The Laws of Demand and Supply are represented as the respective curves shown in Figure 1 [4, 9, 10]. The directions of slope of the curves reflect the logic of the laws on the market:

The higher is the price of a product, the less it is bought (Demand curve - S) and vice versa.

The higher is the price on the market, the more goods the manufacturer is ready to offer to the market (Supply curve -D) and vice versa.

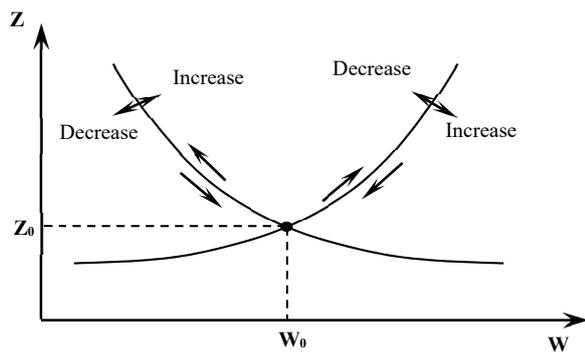


Fig. 1. Demand and Supply curves. Z - costs, W - quantity of product

The issue of the price that would satisfy both subjects is solved in the market at the point of intersection of the curves, where the so-called equilibrium price is established. Subjects in the interconnection market are power systems, each of which, depending on the load schedule, can be either a seller or a buyer of electricity, i.e. the power flow through the intersystem communication can be reversible.

In the electricity market, the Demand and Supply curves can be represented in the form of dependencies of the relative increment of costs (fuel or cost) on the transferred active power. Such characteristics are available in power systems. The peculiarity is that they undergo changes under the influence of a number of factors. These factors can be divided into two categories. The first category of factors leads to an upward or downward shift of the Demand and Supply curves, while the second category requires a transition from one

“operating point” to another while keeping the curve positions unchanged (Fig. 1).

The first category includes such factors as:

- forecast changes in loads;
- changes in fuel prices;
- change in equipment prices;
- seasonal factor;

The effect of these factors should be taken into account by dispatch centres mainly at the level of long-term and partially short-term planning.

Such a factor as a change in the number of consumers or producers of load fluctuations lead to the movement of the “operating” point along the corresponding curves, which should be taken into account at the levels of short-term planning and operational management.

Demand and Supply curves for EES are represented as dependencies of relative growth of costs on the increase in generated capacity. Some publications [3] introduce the concept of commercial cost - the value of the system relative increase in costs (fuel or cost) when EES operates in the optimal mode. In other words, it is the cost per additional 1 MWh of electricity produced.

When solving the issue of sale-purchase of electric power, the operating personnel should be guided by the ratio of the existing tariff for electric power on the wholesale market and its commercial cost within the power system.

4 Parallel operation of power systems

As an example, let's consider parallel operation of two power systems through intersystem communication (Fig. 2). Both power systems have a power reserve. This means that each of the EPSs is ready to sell or buy free capacity. However, the EPSs have different operating costs.

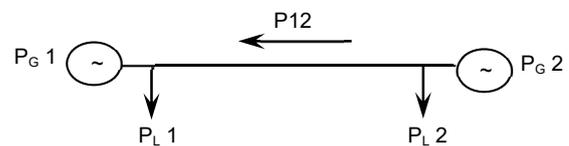


Fig. 2. Parallel operation of 2 power systems via inter-system communication

If we assume that within the time of short-term planning and operational management the tariff for electric power on the wholesale market is stable, then the dependence $T_{opt}(P)$ is linear and parallel to the abscissa axis. The degree of benefit (or damage) from the purchase of electricity on the wholesale market can be estimated by combining this characteristic with a

similar characteristic of the power system $T(P)$. In the initial optimal mode, the load power is equal to P_0 at costs $Z_0 = T_0 P_0$

When the load of the power system increases by ΔP , consumers can be supplied either by additional loading of their power plants, but the costs will increase to $Z_1 = T_0(P_0 + \Delta P)$, or by purchasing from the wholesale market, and in this case the costs will be equal to $Z_{ws} = T_{ws}(P_0 + \Delta P)$.

Let us show the practical realization with a concrete example. The deficit “Absheron” node (Fig. 2) along with its own generating sources (Shimal PP, Baku PP, Sumgait PP) is fed by capacities from two sides: from the Azerbaijan TPP through the “Sharg” section and from JSC UES of Russia through the intersystem communication of the 330 kV overhead line “Yashma - Derbend”. In case of load increase in the “Absheron” node, make-up can be carried out either from the Azerbaijan TPP - at the internal tariff (3.88 cent/kWh), or through the intersystem communication - at the wholesale tariff (3.0 cent/kWh) [11].

In the process of operational regulation the dispatcher will decide the question: “Until when it is profitable to load the units of Azerbaijan TPP, and when the purchase from the wholesale market gives economic benefit (and from Azerbaijan TPP - damage)?”.

Below, Table 1 summarizes the baseline and calculation information for one 300 MW unit of the Azerbaijan TPP.

Table 1. 300 MW unit of Azerbaijan TPP

P, MW	E gr/kWh	Z ₁ , u.	C ₁ , cent/kWh	Z, million dollars.\$
150	18,41	0,1105	3,99	23,94
200	24,46	0,1468	4,03	32,21
250	30,51	0,1832	4,06	40,63
300	36,56	0,2195	4,10	49,19

In it:

E – is the relative increase in fuel consumption.

$$E = 0,26 + 0,000121P$$

Z₁ – cost increment in US dollars

C₂ - specific cost of thousand m³ of gas (\$69).

K - conversion coefficient of fuel equivalent in m³ of gas (0.87).

C₁ - electricity tariff taking into account the incremental cost for additional kWh

$$C_1 = C_0 + Z_1 \quad (C_0 = 3.88 \text{ cent/kWh})$$

Z - costs,

$$Z = PTC_1$$

If the interconnection capacity limit is 400 MW, the number of hours of its use is 1960 and the wholesale tariff is 3.0 cent/kWh, the costs are as follows:

$$Z = 400 \cdot 10^3 \text{ kW} \cdot 2750 \text{ h} \cdot 0.03 \text{ \$/kWh} = 33 \text{ mln. \$}$$

Figure 3 shows the cost characteristics of domestic and external wholesale tariff.

In the initial mode the unit of Azerbaijan TPP operates with 15-16% reserve, i.e. the capacity of the unit is 250 MW.

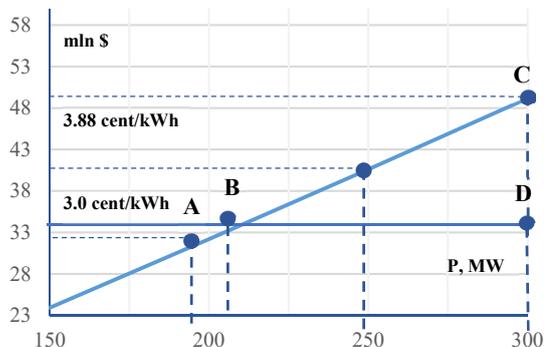


Fig. 3. To determine the benefit (loss) of purchasing electricity on the wholesale market

When the load in the system increases, the dispatcher can increase the capacity of the *AB* unit to 205 MW. Further satisfaction of consumers is beneficial due to the flow through the intersystem communication (*BC*).

According to the internal tariff with benefit, the dispatcher has the *AB* range on the graph.

Benefit or damage is determined from the ratio of the areas under the wholesale characteristic and the EPS characteristic. Point *B* is the equilibrium point: at this point, mutually beneficial energy exchange is ensured and they are ready to conclude contractual agreements, because after it $S_{bc300\ 281} > S_{bd300\ 281}$, the energy system benefits from purchasing electricity from the wholesale market at the equilibrium tariff (T_0) for each megawatt hour.

Thus, both provisions apply: optimal distribution of capacities under the condition of ensuring minimum costs and the Laws of Supply and Demand.

A similar result can be obtained by equating the costs (cent):

$$3_1 = PTC_1 - \text{production of electric energy} \quad (1)$$

$$\text{and } 3_2 = PTqC_2 - \text{for used fuel} \quad (2)$$

where *q* is the specific consumption per 1 kWh

In this case, *C*₁ refers to the fuel component of the tariff, which is about 80%.

$$\text{From equality (1) and (2) follows } C_1 = qC_2 \quad (3)$$

The calculation results and their comparison with the first approach are given in Table 2,

$$(q = 320 \text{ g/kWh}, C_2 = 69 \text{ dollars/thousand m}^3).$$

Table 2. Comparison of calculation approaches

P MW	Costs in million dollars USA		Difference%
	Method I	Method II	
150	23,94	24,26	1,3
200	32,21	32,35	0,4
250	40,63	40,44	0,5
300	49,19	48,52	1,4

As we can see, the difference in the results is insignificant.

A similar method can be applied to a power plant or the system as a whole. Moreover, in each case, method II is preferable. Thus, according to the readings of JSC Azerenerjy for 2023, the tariff can be determined.

$$C_1 = qC_2 = 3.1 \text{ cents/kWh.}$$

An increase in the cost of 1000 m³ of gas to the selling prices of natural gas abroad (by 2.7 times) leads to an increase in the tariff to 8.37 cents/kWh, which indicates an underestimated level of the current tariff of 3.88 cents/kWh, corresponding to $q = 320 \text{ g/kWh}$.

The special point *B* on the characteristic moves in the operational cycle of power system load control in accordance with the dispatcher load schedule and is controlled by the dispatcher, as well as when changing the specific fuel consumption, the fuel component of the electricity tariff (60-65%), the fuel tariff. Transferring these characteristics to analytics and introducing them into the computer system will allow for the operational management of power flows while observing technical and economic criteria.

Conclusions

1. It is necessary to work out methods for obtaining economic characteristics from station and EPS units in real time within the framework of the APCS of stations and the EPS ASDC.

2. It is necessary to work out methods for obtaining functions of the proposal for economic characteristics within the framework of the EPS ASDC. It is important that these functions are obtained by the seller and the consumer using a single method.

3. The NDC must have a method for continuously monitoring these functions in order to make timely corrections.

4. There must be open and accessible information communication in the system and between the systems.

References

1. N.Yusifbayli, V.Nasibov, A.Huseynov, R.Alizade, K.Suleymanov Rudenko International Conference “Methodological Problems in Reliability Study of Large Energy Systems” (2023)
2. Guseinov A.M., Yusifov N.A. Problems of Energy, **No. 2**, (2000)
3. McConnell K.R., Brew S.L., Flin S.M. Economics, principles, problems and policy, (2011)
4. Osak A.B., Domyshv A.V., Sorokin I.V. System research in energy. (2005)
5. Venikov V.A., Zhuravlev V.G., Filipova T.A. Optimization of power plant modes of energy systems // Textbook for universities of energy specialization. Universities, (1981)
6. Yusifbeyli N.A., Nasibov V.Kh., Alizade R.R. “Methodological issues of studying the reliability of large energy systems”, “Reliability of energy systems in the context of energy transition” (2022)
7. Letun V.M., Gluz I.S. Electric stations., **№3**, (2003)
8. Volkova I.O., Shuvalova D.G., Salmikova E.A. Active consumer in the intelligent energy system: possibilities and prospects, <https://publications.hse.ru/mirror/pubs/share/folder/xnto5eu7bd/direct/71899800>
9. Pazouki, S., Mohsenzadeh, A., Haghifam, M. R. IEEE Pes General Meeting Conference & Exposition, National Harbor, MD, USA: 27-31 July, (2014)
10. Zhang, X. et al. IEEE Trans. Power Syst. **31(1)** (2015)
11. N.A. Yusifbayli, A.M. Huseynov, H.B. Guliyev, A.F. Aliyev, O.B. Azadkhanov Methodological issues in the study of the reliability of large power systems. Issue 68, Irkutsk (2017)