Flexible allocation of costs between electricity and heat as a factor for improving the CHP competitiveness

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Abstract. The review of cost allocation methods when forming cost of energy with the combined production was carried out. Their strengths and weaknesses were revealed. The article is devoted to the development of the distribution system costs in the form of energy cost.

Key words: combined heat and power (CHP); cost allocation method; method of separation of fuel consumption; cost of energy.

1. Introduction
The existing pricing rules for combined heat and power (CHP) plants participation in electricity market do not take into account major CHP function, which is combined production of heat and power [1,2]. During market transformations we observe an efficiency reduction of CHP production and commercial activities in comparison with that for condensation power plants (CPP). One of the main reasons for it is that electrical and thermal energy cost formations do not take into account modern competitive market requirements [3–5].

One of the main issues concerning bare cost formation for power produced at a CHP plant is development of economically feasible technique for total expenses allocation between electrical and thermal energies and calculation of bare cost of an energy unit [6]. Power enterprise management efficiency is greatly affected by cost allocation method which is used for bare cost formation.

Calculation and allocation of expenses at CHP plants are worldwide based only on market mechanisms and do not take into account production process technology and fuel consumption division [7].

In Germany the approach for thermal and electrical energy cost calculation at CHP plants is fully economic, in Russia it is called independent cost efficiency approach [8].

Two approaches are used in Denmark [8]. One of them is economical and is based on comparison of alternative schemes for thermal and electrical energy production. The other one states that electrical
power of cogeneration turbine decreases when transition from condensation operation mode to heat supply from turbine bleed (for a predetermined hourly heat consumption and specified technical conditions) takes place. Further, for turbine unit the derating factor is determined. It is the electrical power decrease at transition to cogeneration mode for 1 GJ of heat, supplied from turbine bleed at constant steam consumption to the turbine unit head. This approach is used for analysis of power plant operation efficiency, while the first approach is chosen for calculation of cost indicators.

In France, the above mentioned approaches for cost allocation are used when electrical energy price is predetermined and after its sale income is estimated. Further, it is subtracted from total production costs, and the rest is charged to heat. This is known as thermal energy price [8]. In order to estimate the efficiency of fuel usage at CHP plant, the following approach is used: the heat generated at a CHP is put equal to the heat produced at the boiler house. This means that specific reference fuel consumption at CHP and boiler house accept to be equal. The rest fuel consumption is charged to electrical energy. Consequently, the full effect from combined generation is charged to electrical energy. This approach corresponds to Russian physical one.

Despite a large variety of cost allocation approaches for combined cycle, there is not any dispute about the way for CHP cost indicators determination. It is carried out solely basing on market mechanisms and it isn't connected with production process technology and fuel consumption division at a CHP [6].

It should be noted, that the major part of thermodynamic methods are based on the following principles:

1. Allocation of fuel consumption between generated electrical and thermal energies;
2. Allocation of relative-fixed costs is proportional to the chosen allocation base (fuel consumption, fuel cost, etc.)

The economical approaches are commonly based on CHP total costs allocation between generated energy types according to methods for cost accounting of 1kW-h electrical energy and 1GJ thermal energy [9].

The choice of cost allocation method between thermal and electrical energy has a great impact on the production bare costs [10,11,12].

Inefficiency of the described approaches is proved by the absence of the feasibility for CHP to overcome the economic crisis arisen from collapsing demand for the generated thermal energy.

CHP market success is defined by its competitiveness for heat and power. Let us consider flexible cost allocation between power and heat as one of the factor for CHP competitiveness improvement.

Now the cogeneration effect is charged to the both energy types for the existing cost allocation methods. However, now it is not possible to calculate the generated energy cost depending on the energy market environment and flexibly respond to its change.

The first step is devoted to consideration of the flexible cost allocation impact on the ability to function at the regional power market and local CHP heat market.

2. Experimental data and discussion
For several CHP plants of the Moscow region we have calculated a variety of variants for cost allocation between heat and power. Heat costs are charged from 0 to 100%, and, consequently, from 100 to 0% for the electrical energy, with 5% step. We have created a cost allocation diagram, which shows all possible variants of cost allocations expressed in "heat cost"-"electrical energy cost" coordinates (Figure 1). Bare costs for the introduced above approaches are market in points. It can be seen, that these data agree with theoretical curve of cost allocation.
Figure 1. Heat and power cost allocation diagrams.
Using this diagram, the CHP plant can choose optimum bare costs for power and heat depending on price levels at power markets and set prices for its products.

Consequently, CHP plants could drive flexible pricing policy, which allows attracting new and retaining old customers. An ability of free cost allocation between heat and power might become an additional source for it competitiveness improvement both at heat and power markets.

The profit of a cogeneration power plant consists of two components: profits from the sale of electricity and profits from the sale of thermal energy. Acting in market relations, manufacturers seek to maximize profits. There are several ways to increase profits:

1. Increasing of price. It is well-known that in market conditions pricing is affected by the ratio of supply and demand.
2. Increasing of production. But in the energy industry it is impossible to increase production at will.
3. Reducing the cost of production.

Income \((I)\) is an integrative indicator for production and business activities of an enterprise. It is a surplus value, obtained during production process, expressed in money terms (for example, rubles/year).

\[
I = Rs - E = (P - C) \cdot V, \text{ (rubles/year)}
\]

where \(E\) is expenditures, rubles/year; \(Rs\) is sales revenues, rubles/year; \(P\) is price, rubles/item; \(C\) is cost, rubles/item; \(V\) is overall input, items.

CHP plant income consists of two components: electrical energy and thermal energy sales income.

According to the market relations, the manufacturers tend to gain maximum income (Figure 2). There are several ways for this.

1. Market price raising. It is well-known, that demand and supply balance greatly influences the pricing at market conditions.

Price is a fundamental economical category, which is a product unit cost, expressed in money terms. The process of price formation is called pricing. Prices for power production are called tariffs.

![Figure 2. Income maximization condition.](image)

Basing on the given above analysis we created an income factor model for CHP plant operating at thermal and electrical energy markets simultaneously (Figure 3).
Governing factors for enterprise production price making are the following:

- Production cost (it is influenced by cost allocation method for CHP plant);
- Projected income;
- Competitor prices;
- Financially reliability;
- Governing body and other social institutions requirements;
- Uniqueness of certain product characteristics.

The development of enterprise pricing strategy includes 6 steps, which are presented in Figure 4.

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**Figure 3.** Income factor model.

**Figure 4.** Pricing strategy development steps.
Figure 5 presents an algorithm for thermal and electrical energy cost forming at a CHP plant. The algorithm allows building a variety of cost allocation options, and selecting the cost distribution ratio, which allows obtaining the maximum profit.

1. Choose a step using which we will calculate a variety of cost allocation options.
2. For initial calculations, we assume that all costs relate to electricity, i.e., the distribution coefficient of heat costs = 0%.
3. Calculate the values of heat and electricity cost at a given cost ratio.
4. Choose prices for heat and electricity based on statistical data for the past relevant periods and analysis of prices on the energy markets.
5. Determine the planned sales volumes of both types of energy at a selected price based on demand graphs for previous periods.
6. We calculate the revenue and profit from the sale of energy.
7. We proceed to consider the next cost distribution ratio for the selected step.
8. Operations 3-6 are repeated until a profit is calculated with the heat cost distribution coefficient = 100%.
9. Thus, according to the results of the calculation of the maximum profit, the best value of the cost distribution coefficient is determined.
Figure 5. Algorithm for energy cost formation at a CHP plant.

Figure 6 presents a detailed algorithm for calculation of cost allocation variants.
The designed algorithms were used for computation of CHP-20 characteristics using Mathcad and Excel.

The algorithm from Figure 6 was used to calculate a variety of variants for cost allocation with heat charging from 0 to 100% with 5% step.

According to the algorithm from Figure 5 and factor model from Figure 3, we calculated income and costs for combined production of thermal and electrical energy. The calculated data was used to create a chart for CHP plant income dependence on cost allocation coefficient, Figure 7. It was performed under the condition of simultaneous operation of the cogeneration plant at electrical and thermal energy markets.
The obtained data show that the maximum income is reached at heat cost allocation coefficient, which is equal to 0.55.

As it is known, the cost allocation method is prescribed in the accounting policy of the enterprise. Accounting policy is adopted for the fiscal year. Thus, this algorithm can be used in operational accounting, when planning price bids for the day-ahead market. And in accounting there is a method which allows one to increase efficiency for the whole period.

The peculiarity of the Russian energy markets is that contracts for the supply of heat and electric power are concluded once a year, while electricity is sold every day. It is necessary to take into account the difference in the distribution of fixed and variable costs in order to avoid double counting that does not comply with the current legislation of our country.

In connection with the above stated, fixed costs are proposed to be allocated according to current methods (for example, physical method or ORGRES method). The proposed method of flexible cost allocation will be applicable only for variable costs, which will include fuel costs. Features of the distribution of costs are clearly presented in table 1. In connection with this division, at fixed costs, you can introduce the concept of average daily fixed costs for subsequent use in calculating production costs.

| Features          | Thermal energy market | Electrical energy and power markets |
|-------------------|-----------------------|-------------------------------------|
|                   |                       | Electrical energy market            | Power market                        |
| Expenses           | Alternating and constant components of expenses | Alternating component of expenses | Constant component of expenses |
| Period             | For a year            | For a day                           | For a year                          |
| Cost allocation    | Constant expenses are allocated according to the existing method, alternating expenses are allocated according to the proposed method | Expenses are allocated according to the proposed method | Expenses are allocated according to the existing method |

Table 1. Features of cost allocation.

Thus, the proposed algorithm can be used not only for planning the price of electrical energy on the day-ahead when submitting a price bid, but also for taking into account the actual prices of electricity based
on the results of the auction. In the first case, the application of the algorithm is an additional burden on
the trader, which may entail the expansion of staff and the introduction of additional staff. In the second
case, taking into account the actual prices, the adjustment of the planned indicators (sales volumes,
prices, share of cost allocation with flexible distribution) for future periods can be carried out. These
functions fall on the departments involved not only in planning, but also in analyzing the financial and
economic activities of the enterprise.

3. Conclusions
The implemented investigation proves that calculation of cost allocation is of great importance for
energy cost formation at CHP plant. We have developed a number of recommendations concerning cost
allocation coefficient choice during thermal and electrical energy cost formation. This is aimed at CHP
business efficiency improvement.

The main scientific and practical results are the following:
1. Various cost allocation approaches were analyzed, their advantages and disadvantages, which
   influence CHP plant operating efficiency were revealed.
2. We developed a model for CHP income maximization under the condition of its simultaneous
   operation at electrical and thermal energy markets.
3. We developed an approach for thermal and electrical energy cost formation, based on cost
   allocation coefficient choice in view of income maximization.
4. The developed approach was approved at an operating plant.

The approval results show that the implementation of the developed approach gives on opportunity
to increase the total income of the CHP plant due to attraction of new consumers.

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