Evaluation of capital investments in energy equipment of a power plant by a power function

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Abstract. The paper proposes the use of a power function for evaluating capital investments in the main and auxiliary equipment of a power plant as a universal method for solving a wide range of applied and research problems. This approach allows assessing investments, based on the technical specification of the power plant such as parameters of working fluid, the climatic zone of operation, the type of equipment, type of fuel, etc.

1. Introduction

To solve a wide range of applied and research problems, it is often necessary to determine capital investments in power units in conditions of uncertainty of price parameters of the main equipment and auxiliary systems. This issue is complicated by the discreteness of price indicators, the different costs of the same type of equipment from different manufacturers, the situation in the actual markets of power engineering, inflation, discounting features, political decisions such as sanctions, various types of duties or subsidies. At the same time, capital investments can be estimated with sufficient accuracy, based on the technical indicators of power units in the form of parameters of the working fluid, installed capacity, the climatic zone of operation, type of equipment, type of fuel, etc.

2. Parametric power function

In general, the power function for estimating capital investments has the following form:

$$K_k = K_0 \cdot \prod_{i=1}^{p} c_i \cdot \prod_{j=1}^{m} \left( \frac{x_j}{x_{0j}} \right)^{n_j}$$

where $K_k$ is the capital investments in the $k^{th}$-technical system; $K_0$ – the basic value of investments; $c_i$ – correction coefficients that depend on the technological scheme and type of equipment; $x_j$ – defining parameters; $x_{0j}$ – basic values of defining parameters, $n_j$ – degree indicator.

Full capital investments in a power plant are defined as:

$$K = \sum_{k} K_k$$

where $K_k$ describes the main elements and technical systems of a power plant (boiler, turbine, fuel supply system, flue gas purification systems, electrical equipment, etc.)

This approach is used to solve scientific and applied problems of comparing different versions of a power plant [1, 2, 3] in which the costs of engineering, delivery and installation of equipment,
construction of auxiliary and main buildings, commissioning and other works, and services are divided proportionally between all systems and units [4].

The parametric power function for determining capital investments in a steam turbine is shown below as an example:

\[
K_{ST}^{ST} = K_0^{ST} \cdot \prod_{j=1}^{3} c_j \cdot \prod_{i=1}^{7} \left( \frac{x_i}{x_j} \right)^{n_j}
\]  

\( K_0^{ST} = 5.5 \cdot 10^6 \) $ is the basic value of investments for a steam turbine (for the Russian Federation, it is defined as the average value for «Power machines» Ltd. and JSC «The Ural Turbine Works» in the installed power range of 30–800 MW over the past ten years using the dollar exchange rate). The basic values of parameters \( x \), exponents \( n \), and correction coefficients \( c \) are shown in table 1 and table 2. These indicators are determined empirically so that the total investments reflect the design features, delivery to the installation region, and dismantling conditions. The design features are taken into account by the complexity of manufacturing (the number of steam extraction and adjustable diaphragms) through the coefficients \( c \), and thermodynamic factors, when higher temperatures and pressures lead to an increase in the cost of construction materials, through the parameters \( x \). The values of all indicators and coefficients are selected from the condition to ensure that the final cost of a steam turbine corresponds to the indicators and prices that are declared by manufacturers, and used in engineering organizations of the Russian Federation.

**Table 1.** Correction coefficients for a steam turbine.

| Contributing factor                     | Characteristic of the factor                  | Designation | Value |
|-----------------------------------------|-----------------------------------------------|-------------|-------|
| Type of the turbine                     | Condensing turbine                            | \( C_1 \)   | 1.0   |
|                                          | Cogeneration turbine                          |             | 1.3   |
|                                          | Cogenerating turbine with steam extraction    |             | 1.4   |
|                                          | Backpressure turbine                          |             | 0.6   |
| Region of placement                     | Central of Russia, Ural                       | \( C_2 \)   | 1.0   |
|                                          | Siberia                                       |             | 1.07  |
|                                          | Far East                                      |             | 1.12  |
| Removal and compensation of accidents   | Dismantling after service life development and accident compensation | \( C_3 \)   | 1.2   |

**Table 2.** Basic parameters and exponent indexes for a steam turbine.

| Name of the factor                                      | Parameter Designation | Parameter Value | Degree indicator Designation | Degree indicator Value |
|---------------------------------------------------------|-----------------------|-----------------|-------------------------------|-------------------------|
| Installed capacity of the turbine, MW (\( N\) - installed capacity, MW) | \( x_1^0 \)           | 30              | \( n_1 \)                     | \(<330 \text{ MW}: 0.8\) |
|                                                         |                       |                 | \( >330 \text{ MW}: 0.95–0.0045N \) |
| Superheated steam pressure, MPa                         | \( x_2^0 \)           | 14              | \( n_2 \)                     | 0.2                     |
| Superheated steam temperature, °C                       | \( x_3^0 \)           | 545             | \( n_3 \)                     | 1.0                     |
| The temperature of reheated steam, °C                   | \( x_4^0 \)           | 545             | \( n_4 \)                     | 1.3                     |
| Amount of low-pressure parts                            | \( x_5^0 \)           | 1               | \( n_5 \)                     | 0.2                     |
| Amount of high- and middle-pressure parts (of the turbine) | \( x_6^0 \)           | 1               | \( n_6 \)                     | 0.3                     |
| Number of hours of installed capacity usage, hours/year | \( x_7^0 \)           | 6000            | \( n_7 \)                     | 0.2                     |
3. Results and discussions

The equations for determining capital investments in the boiler unit, electrical part and auxiliary equipment of a steam power plant are drawn up similarly. The power function estimations of investments are compared with actual offers from the energy markets of the USA, Europe, and China [5], figure 1.

It can be seen that capital investments in steam power plant systems in Russia is 20–50% lower than in the United States and Europe and 20–30% higher than in China, depending on the unit capacity and type of equipment. The calculated index of capital investments in steam turbine units for the Russian Federation coincides with the value for China due to the fact that in [5] for China adopted turbines of the Leningradsky Metallichesky Zavod (LMZ, St. Petersburg).

4. Conclusion

The method for estimating capital investments in power units based on the power parametric function has been developed. Shown, that the use of the power function of the proposed form reflects the real order of prices with sufficient confidence and allows evaluating investments in both aggregates and technical systems of a steam power plant. A similar approach with using a parametric power function can be used to estimate capital investments in gas turbines and combined-cycle plants.

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**Figure 1.** Capital investments in steam power plant aggregates and systems [5]:

- a – boiler;
- b – steam turbine;
- c – auxiliary equipment;
- d – electrical equipment.

Notation:

1 – Germany, 2 – USA, 3 – parametric power function calculation (Russian Federation), 4 – China.
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