Simulation calculation and analysis of energy-saving and efficiency-increasing of thermal power plants reform project

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Abstract. Taking the third stage of National Energy Group Shengli Power Plant project as an example, the application effects of a number of hybrid transformation measures on the heat consumption of steam turbines were calculated, and the heat consumption of the unit was used as the characteristic value to compare the energy-saving benefit of various transformation measures. The results show that, there is a positive correlation between back pressure optimization and other energy-saving transformation measures, which can enhance the efficiency improvement effect of joint transformations. Among the three and four retrofit measures, data verification found that the ranking of the heat consumption benefits caused by individual retrofit measures: back pressure optimization retrofit> full cylinder efficiency retrofit> waste heat utilization retrofit> low pressure cylinder efficiency retrofit> medium pressure cylinder efficiency improvement transformation> high pressure cylinder efficiency improvement transformation> external steam-cooling transformation.

1. Introduction
The electric power industry is an important component in the national economy. At present, the thermal system consuming lots of energy, the transformation measures for power plant can achieve the effect of energy saving and emission reduction[1]. By analyzing the potential of energy saving and increasing efficiency of enterprises, the transformation measures can reduce the energy consumption and capital cost. So, there is a huge space for energy-saving transformation to develop[2]. In actual operation, power plant units will not operate completely in accordance with the design conditions, but will be in variable operating conditions with external dispatching instructions. In addition, the level of the equipment performance, the level of operating personnel and other aspects will affect the operating status of the unit, causing the operation of the unit to deviate from the design conditions[3]. The specific contents of variable conditions include the decrease of internal efficiency of steam turbine, leakage of shaft seal, temperature deviation of main steam and reheat steam, desuperheating water volume, leakage of steam, heater terminal difference, and external heat supplyment[4].

2. Characteristics of simulation calculation
In fact, we can generally calculate the impact of a single factor on the economy of the unit through the several algorithms previously studied, and also can understand the influence level of a certain factor
change on the whole unit[5]. It lays a good foundation for studying the overall economic effect of the unit. However, when the above factors are combined, how much impact on the unit's economy, the relationship between the various factors need to be studied separately. The simulation calculation research we are talking about is to analyze the impact of the above factors on the economy, to find the relationship between them. Therefore, it is very important to build the simulated thermal system. The scientific evaluation system has the following conditions: ① high representativeness ② comprehensive information ③ data true and reliable.

The benefit of an indicator reflects the significance of an indicator in the simulate system. There are many calculation methods for simulating thermal system. The index benefit differences between indicators are mainly caused by the following three reasons:

① The evaluators pay different attention to each index, which reflects their subjective differences; ② Each index plays a different role in the evaluation, which reflects the objective differences among the indexes; ③ The different reliability of each index reflects the different reliability of information provided by each index.

Due to the existence of the above three factors, the design index for transformation measures can be considered from three aspects when considering the benefit:

① The benefit of each plan is reasonably given by the decision maker's empirical judgment, generally subjective assignment, such as AHP analytic hierarchy process; ② The index benefit is determined by the amount of information transmitted by each index in the evaluation, such as entropy method; ③ Rely on the objective degree and reliability of the index evaluation value to reflect the benefit such as gray correlation analysis.

The first type mentioned above belongs to subjective empowerment, while the latter two belong to objective empowerment. The subjective assignment mostly uses qualitative methods to determine the benefit: common methods include expert consultation method (Delphi method), AHP, Rating method, etc. Among them, AHP method is more common. Objective assignment is to determine the benefit through the relationship or degree of dispersion between mathematical quantitative indexes. The common methods are entropy method, principal component analysis, grey correlation, fuzzy comprehensive evaluation, factor analysis, TOPSIS method and so on. The specific evaluation calculation steps of these methods are different, and the usage scenarios are also different.

3. Steps of simulation calculation for modification measures

The first step: determine the scale and construct the judgment eigenvalue. This step is the source of the original data, such as using the basic energy consumption index of the unit, combining with the expert scoring to judge the benefits of various energy-saving transformation measures, and determining the recommended transformation measures according to the basic energy consumption index and expert ranking.

The second step: eigenvalue and benefit calculation. The purpose of this step is to calculate the benefit value. If you need to calculate the benefit, you need to calculate the eigenvalue first. For traditional coal-fired generating units, the calculated characteristic value preferably adopts the unit heat consumption index. At the same time, it is necessary to check the consistency of the energy efficiency benefits of various energy-saving renovation measures.

The third step: consistency test analysis. When implementing and calculating energy efficiency benefits of transformation measures, there may be logical errors. For example, A is more important than B, and B is more important than C, but C is more important than A. Therefore, it is necessary to use consistency to check whether there is a problem. If the data does not pass the consistency test, it is necessary to check whether there are logic problems, etc., and re-calculate a number of energy-saving retrofit measures item by item and conduct a collaborative energy efficiency analysis.

Step 4: Analyze the conclusion. If the benefits have been calculated and the judgment matrix meets the consistency test, the energy efficiency analysis conclusions of the retrofit measures can finally be drawn.
4. Calculation example of energy saving effect of hybrid transformation measures

Taking the third-phase engineering project of National Energy Group Shengli Power Plant as an example, the application influence of a number of hybrid transformation measures on the heat consumption of steam turbines was calculated. The heat consumption of the unit was used as the characteristic value to compare and analyze the energy-saving benefit of various retrofit measures. In view of the mixed transformation measures, 6 types of transformation plans were drawn up, including the simultaneous application of three mixed transformation measures and the simultaneous application of four mixed transformation measures. Various specific transformation plans were as following, shown in Figure 1 to 6:

**Figure 1. Energy consumption benchmark of unit thermal system**

**Figure 2. Energy consumption benchmark + total cylinder efficiency increasing 2% + external steam cooling + waste heat utilization**
Figure 3. Energy consumption benchmark + total cylinder efficiency increasing 2% + external steam cooling + back pressure optimizing 2KPa

Figure 4. Energy consumption benchmark + total cylinder efficiency increasing 2% + waste heat utilization + back pressure optimizing 2KPa
Figure 5. Energy consumption benchmark + external steam cooling + waste heat utilization + back pressure optimizing 2KPa

4.1. Energy saving effect of three mixed transformation measures
According to the energy-saving effect of three hybrid transformation measures, four kinds of transformation measures are calculated and analyzed, including energy consumption benchmark + full cylinder efficiency + external steam cooling + waste heat utilization, benchmark + full cylinder efficiency + external steam cooling + back pressure optimization, benchmark + full cylinder efficiency + waste heat utilization + back pressure optimization, benchmark + external steam cooling + waste heat utilization + back pressure optimization. The energy efficiency calculation results of the thermal system are shown in Fig. 2 to Fig. 5.

Compared with the three hybrid transformation measures based on the full cylinder transformation and the three hybrid transformation measures based on the cylinderless transformation, their energy-saving effects are significantly different. Among the three mixed transformation measures based on the whole cylinder block transformation, the energy saving transformation measures of the two schemes, namely, full cylinder lift efficiency + external steam cooling + back pressure optimization and full cylinder efficiency + waste heat utilization + back pressure optimization, the benefit of steam turbine heat consumption is higher than that of the three hybrid transformation measures based on the non block transformation. However, the benefit of steam turbine heat consumption is lower than that of the three hybrid retrofit measures based on no cylinder retrofit. Therefore, it can be inferred that among the three mixed transformation measures, the effect of energy saving and consumption reduction benefits of cylinder transformation measures is not in an absolute dominant position. In comparison, the scheme with back pressure optimization and transformation measures has more obvious advantages in energy saving and consumption reduction.

4.2. Energy saving effect of four mixed transformation measures
According to the energy-saving effect of the four hybrid transformation measures, the transformation measures of energy consumption benchmark + full cylinder efficiency improvement + external steam cooling + waste heat utilization + back pressure optimization of the thermal system of the unit are calculated and analyzed. The calculation results of energy efficiency of the thermal system are shown in Figure 6. It can be seen from the figure that under the condition that the four mixed transformation measures are applied at the same time, the heat consumption of the unit steam turbine is reduced from 7705 kJ / kWh to 7396 kJ / kWh, and the heat consumption is reduced by 309 kJ / kWh.
5. Conclusion
Among the three and four transformation measures, through data verification, it is found that according to the order of heat consumption income caused by single transformation measure: back pressure optimization transformation > whole cylinder efficiency improvement transformation > waste heat utilization transformation > low pressure cylinder efficiency improvement transformation > medium pressure cylinder efficiency improvement transformation > high pressure cylinder efficiency improvement transformation > external steam cooling transformation.

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