The Study of Energy Efficiency Computer Evaluation Method of Coal-fired Unit in Thermal Power Plants

Yuanyuan Li*, Zhenning Zhao, Jinjing Li
North China Electric Power Research Institute Co. Ltd, Beijing, China

*Corresponding author: li.yuan.y@jibei.sgcc.com.cn

Abstract. At present, it is an urgent requirement to evaluate energy efficiency for different types of coal-fired unit fairly and correctly. The study establish a method for carry out energy efficiency evaluation fully and objectively in order to determine the potential of a performance advantage, technical management and operation. The method can help management to find out downside and bottlenecks, plays a part in reward effort and punish laziness and improve lack for unit.

Keywords: Energy efficiency, evaluation, performance.

1. Introduction
At present and even in the future, thermal power plants is still the main power supply support of domestic power industry. Under the dual pressure of safe operation and environmental protection, it is very necessary to develop a set of more normable and reasonable evaluation method to reflect the energy efficiency in order to better measure the overall level of safety, energy saving, environmental protection technology and management of thermal power enterprise. It takes an important role for improving the competitive strength and long-term profitability of the enterprises. The study build a scientific and reasonable energy efficiency evaluation method which help compare different types of thermal power plants based on development of thermal power production process.

2. The Energy Efficiency Evaluation Factors
The universal energy efficiency evaluation method are often divided into statutable evaluation method and scientific evaluation method. The statutable evaluation method is a legal stipulation and established by the government or the appropriate department. It include stochastic frontier method, Simple index comparison method, large unit evaluation method, and so on. Its main characters are wider applicable, simpler model and lower grading rule. The scientific evaluation method is multi-index and multi-link comprehensive evaluation method, such as Taylor expansion method, Composite Indicator Construction method, DEA method, Technique for Order Preference by Similarity to an Ideal Solution method, TOPSIS method, and so on. Its main characters are smaller applicable, more complicated model and more deeply connected to energy efficiency. These methods are universally applicable to evaluate industrial process, but cannot guide the optimal operating in power station because of low accuracy. The energy efficiency evaluation method of coal-fired unit in this paper take design condition, real performance after the installation and objective factors of outer-environment fully into account in order to evaluation fairness [1, 2].
2.1. Design performance
The design performance should be taken into consideration firstly when the evaluation coal-fired unit as a unit. It is optimum performance or ideal performance in under design condition, such as formula (1):

$$b_g = \frac{q_{TB}}{293.08 \eta_B \times \eta_{gd} \times (100 - L_{cy})} \times 10^7$$  \hspace{1cm} (1)

$b_g$ is the power supply coal consumption, g/(kW·h); $q_{TB}$ is heat rate of steam turbine, kJ/(kW·h); \(\eta_B\) is the combustion efficiency of boiler, %; \(\eta_{gd}\) is the pipes efficiency, %; \(L_{cy}\) is the power consumption rate, %.

2.2. Inherent performance
The coal-fired unit design completed is constantly required to manufactured, installed and debugged to operation. Because there are so many links and the coal-fired unit cannot achieve design performance. Therefore, it needs to be fully considered the difference of the natural performance and congenital condition of unit. The real performance when coal-fired unit is given management is inherent performance. For the moment, all equipments, including heated surface of boiler, steam turbine blades, heated surface of heater are the cleanest and the smoothest level and is in optimal status. The performance is optimal based on real material basis and is called inherent performance. Then gauged the energy efficiency value is inherent performance value, using the power supply coal consumption measured by performance test under design conditions to represent. It represents the general level of design, manufacture and installation.

Inherent performance can be obtained by performance acceptance test usually. So inherent performance can be obtained by insulting many test report. If the value comes purely from previously performance acceptance test report, the value must fit the requirements. The value of the design power supply coal consumption, the design boiler efficiency, the design turbine heat rate and other important auxiliary equipments power consumption rate under three conditions (50%THA, 75%THA and 100%THA) should be chosen to fitting according to output factor. The change law of these values as the change of output capacity can be get as a baseline for corrective performance calculation. If the value comes purely from previously performance acceptance test report is not fit the requirements, a new performance test need to be carried out to determine the inherent performance value. The boiler efficiency test, the turbine heat rate test and power consumption rate test should be carried out at the same time. The single test should be combined with the heavy repair process in order to insure completely remove flaws as a result of the unit operation [3].

2.3. Inherent performance departure
The inherent performance departure is a departure between the inherent performance under design condition and design performance. The inherent performance departure is expressed as the inherent performance departure value. The design boiler efficiency, the design turbine heat rate test and the measured power consumption rate can be used to calculate the design power supply coal consumption. The measured boiler efficiency(revise to design coal and design air temperature of air preheater entrance), the measured turbine heat rate (revise to design ambient temperature or design water temperature of circulation pump entrance) and the measured power consumption rate (revise to design ambient temperature) can be used to calculate the power supply coal consumption as inherent performance value. The inherent performance departure value is equal to the inherent performance value minus design performance value. It is calculated by formula (2):

$$\Delta b_{g,n} = b_{g,pt} - b_{g,ds}$$  \hspace{1cm} (2)
Δbg,n is the inherent performance departure value under design conditions, g/(kW·h); bg,pt is measured power supply coal consumption corrected to the design conditions, g/(kW·h); bg,ds is measured power supply coal consumption based on boiler efficiency test, the turbine heat rate test and power consumption rate test, g/(kW·h).

The inherent performance departure represent the level of design, manufacture and installation. So it can be used to appraise the renovation potential of unit. A low number means good quality of manufacture and installation and less renovation potential while higher Numbers means worse quality of manufacture and installation and more renovation potential.

The inherent performance departure is a significant cause of the lower energy efficiency of coal-fired unit and need to be improve.

The influence of inherent performance departure should be excluded when inspecte the technical management level of the unit. The change of inherent performance departure is a curve with change of unit load. The plant managers should find out the causes of low inherent performance and rectify in order to elevate unit level.

2.4. Actual performance
The actual performance is the performance of unit in actual working conditions. It can be get by tests or statistics according to DL/T904 and expressed by actual performance value.

2.5. Desired performance
Under actual operating conditions, if the performance is optimized and called desired performance. The desired performance value is expected value and optimum value in actual operating condition, and has an important significance for the unit operation. The purpose of ascertain desired performance is compare with the actual performance. For ease of evaluate the actual performance level, reducing resource consumption should take desired performance value as its aim.

Convert inherent performance to the performance in actual operating conditions, then add external condition performance departure is desired performance.

The desired performance is attainable performance of evaluated coal-fired unit based on inherent performance and actual operating conditions. The calculation formula is as follows:

\[
bg, x = bg, ds + \Delta bg, x + \Delta bg, e
\]

\(\Delta bg, x\) is inherent performance departure, g/(kW·h); \(bg, ds\) is the power supply coal consumption based on the design boiler efficiency, the design turbine heat rate test and the measured power consumption rate, g/(kW·h); \(bg, x\) is desired performance value of the power supply coal consumption, g/(kW·h); \(\Delta bg, e\) is performance departure caused by external condition change, g/(kW·h).

2.6. Best performance
The best performance is the best actual performance of the sametype of units and represent the best performance value. It represent the best design, the best manufacture, the best installation and the best management level. The difference between the best performance value and desired performance value represent the potential of upgrade transformation of unit. The best performance value can be get from units evaluate results in of the profession or from actual survey results.

2.7. Several performance relationships
Usually, there is good economic indicators and bad economic indicators in different units or different power-generation plant. Even excellent coal-fired unit, the boiler coal consumption value is greater than design value and the main economic indicators can't reach design level. So the management need
evaluate the level of technical management and the unit operation, find out the difference in every performance and analyze the causes and improve. The relationships of several performance as shown in Figure 1.

Figure 1. The relationships of several performance.

3. **The core content and method of energy efficiency evaluation**

3.1. **The core content of energy efficiency evaluation**

a. The appropriate correction formulas and curves of design performance based on design specification should be prepared in advance. Design performance can get according to design data from the manufacturers or the performance test reports.

b. Calculate the inherent performance value according to design performance value and performance test date. According to design performance value in different load from design specification and test data in different load from performance test, the level of energy efficiency and inherent performance departure in design coal and ambient temperature can be obtained.

c. Calculate the desired performance value according to external conditions correction based on design performance. Calculate the desired performance value and external conditions influence according to inherent performance departure external conditions departure.

d. Evaluate energy efficiency according to performance departure.

3.2. **Evaluate the level of design, manufacture, and installation according to inherent performance departure**

If inherent performance departure is positive, inherent performance is worse than design performance. So the cause of lower inherent performance, such as low level of manufacture and installation, low matching of equipments, large departure of design date, and so on, should be found out and improve.

3.3. **Evaluate the level of technical management according to the departure between desired performance value and actual performance value**

The departure between desired performance value and actual performance value represent the level of technical management and unit operation. The smaller departure, the higher level of technical management, and it means the closer actual performance to ideal performance. The bigger departure,
the lower level of technical management, and it means the further actual performance to ideal performance, so the unit need to improve performance by optimize internal operations.

3.4. Evaluate overall upgrade potential of unit
The overall upgrade potential of unit can use the departure between best performance value and desired performance value. The smaller departure, the higher level of desired performance. The bigger departure, the lower level of desired performance, and the greater upgrade potential.

The unit achieve best performance often need to overall upgrade, such as carry out promote parameter reformation. But there is large work quantity. Considering some best performance value have some untruthfulness and judge upgrade potential is not easy, the feasibility study should be carried out cautiously in order to prevent fail cause of overly object.

3.5. The overall energy efficiency evaluation of unit
Inherent performance, upgrade potential and management level can be compared separately or overall. The overall energy efficiency evaluation need confirm weight for each factor in advance. There are same weights for different unit. Evaluate energy efficiency of unit by weighted average method. Through the evaluation, management have develop in-depth knowledge for unit and puts forward some discussion and remedial suggestions.

4. Conclusions
Based on equipment performance, technical management and upgrade potential of unit, the study divide the power supply coal consumption into three departure according to inherent performance departure, external conditions departure, and so on. There are both definite objectives and simple and feasible methods. In order to capture a deterioration and cause of the total capability of unit in time, the energy efficiency supervisors should carry out an overall energy efficiency evaluation at least once a year. Professional staff with high technical levels should participate in overall energy efficiency evaluation in order to judge cause of performance degradation.

References
[1] Robert Yie-Zu Hu, Current status of energy efficiency policies and measures in Taiwan [PPT]. In 2011 U.S.-Taiwan Clean Energy Forum, 2011.
[2] Zhou P., Ang B.W., Poh K.L., A mathematical programming approach to constructing composite indicators [J]. Ecological Economics, 2007, 62: 291-297.
[3] DL/T 1929-2018 Method for energy efficiency evaluation of Coal-fired Unit, 2018.