Measures to improve electric and electronic efficiecny in power plant

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Abstract. Electric efficiecny is an important index in power plants which related to the net power output to the grid and also reflects the energy saving level which may lead to reward or penalty by the government. In this paper, measures to improve the plant electric efficiency and methods and design experiences to narrow down the gap between calculations and actual electric efficiceny are discussed. An example of plant power efficiecny in 2x1000MW power plant is also illusterated in this paper, of which the plant power efficiecny could be reduced to 3.2%.

Keywords: Electric efficiency, power output, plant power consumption, auxiliary power efficiceny.

1. Background

Power plants are not only producers of electric energy, but also consumers of electricity. The auxiliary power consumption rate, which is also called as plant power efficiency, is an important indicator in the production of power generation enterprises, and its level directly affects the effectiveness of energy conservation and consumption reduction. With the attention paid to energy conservation and emission reduction of power plants, the attention paid to “plant power rate” and “electric efficiency” has been greatly improved in terms of operation assessment, evaluation and comparison of design schemes.

2. Calculation methods of plant power efficiecny

According to DL/T5153-2018, *Technical code for the design of auxiliary power system of fossil fired power plants,* when selecting the capacity of auxiliary power supply, it shall be calculated according to the maximum possible operation mode of the auxiliary machine of the unit [1].

Main calculation principles are as follows:

(1) Equipment in continuous operation shall be calculated;

(2) When the unit is in operation, the equipment that operates infrequently and continuously shall also be calculated;

(3) The equipment that operates frequently but in short time, or frequently and intermittently shall be calculated, and the actual effect of the equipment on the temperature rise of the transformer can be taken into account for proper conversion;

(4) Equipment with infrequent and short-time operation, or infrequent and intermittent operation shall not be calculated, but all equipment powered by electric reactor shall be calculated;

(5) Only the operating part of the mutually standby equipment powered by the same auxiliary power supply is calculated;

(6) All equipment for mutual standby but powered by different auxiliary power supplies shall be calculated. While the standby load supplied by different transformers shall not be calculated in the plant power rate.

2.1. Calculated load

According to appendix F from DL/T5153-2018, the calcualted load Sc could be considered as follows:

$$S_C = \sum (KP)$$

Sc refers to the calculated load, kVA.

K is the equivelent index.

P is the calculated motor power, kW.

The calculated power of the motor depends on the operation mode of the equipment. Equipment operation modes include: frequent and continuous, frequent and intermittent, frequent in short-time, infrequent and continuous, infrequent and intermittent, and infrequent in short-time. The corresponding ratio of calculated power (P) to rated power ($P_{N)}$ is shown in Table 1.

Table 1. Ratio of P/PN

P/Pe	Continuous	intermittent	Operation in short time
Frequent	1.0 P_N	0.5 P_N	0.5 P_N
Infrequent	1.0 P_N	0	0

The recommended value of equivelent index K is provided in Table 2.

Table 2. Equivelent index [2]

Motor	K
Motor of Feed water pump and circulating water pump	1.0
Motor of condensating water pump	1.0
Other High Voltage Motor	0.85
Other Low Voltage Motor	0.7

2.2. Plant power rate calculation

Plant power rate is related to the calculated load, average power fator of motors and the rated power.

$$e = \frac{S_c cos\varphi}{P_e} \times 100\%$$

In which, *e* refers to the plant power rate (%), *cosφ* is the average power fator of motors in operation, and here the value of 0.8 is used while *Pe* refers the motor rated power.

2.3. Discussion of the value of K

For many years, the above calculation formula has been adopted in the design and calculation of the auxiliary power consumption rate in China, but the calculation results often exceed the actual operation value.That is, there is a certain positive error between the design calculation value of the auxiliary power consumption rate and the actual operation value, which has become an indisputable fact, and the results often have a certain impact on the economic evaluation at the design stage. Therefore, it is necessary to analyze the original calculation formula of auxiliary power consumption rate, find out the causes of errors, and propose a new calculation method (load rate method).

Through the investigation and analysis of the actual operation of the main auxiliary equipment and low-voltage auxiliary transformer load of the existing representative operating units in China, and by using the comparison of the actual operating load data and the power (capacity) of the equipment nameplate, the load factor for calculating the designed auxiliary power rate is proposed, which is defined as "K_L". Through the selection of the "K_L" value and the comparison and analysis with the actual operating auxiliary power rate of more than 10 actual operating power plants, the average error between the calculated value and the actual value is less than 2% (the maximum error is only about 4%, and the minimum error is greater than zero and less than about 0.2%). The calculation accuracy is improved by about 90% on average.

$$e_r = \frac{\sum K_{L1} K_b P_d + \sum K_{L2} S_{db} COS\varphi_{av}}{P_e} \times 100\%$$

In which e_r is the plant power rate. K_{L1} is the load factor of high voltage motor and K_b is the Viarable frequency index. For example, K_b is used as 0.7 for the condition of using viarable frequency drive (VFD) while 1.0 for the condition without VFD. P_d is the rated power of high volatage motor (kw). K_{L2} refers to the load factor of low voltage motor while S_{db} refers to the low voltage transformer capacity (kVA). $Cos\varphi_{av}$ is the average power factor of motor and here 0.8 is used.

The recommended load factor is shown in Table 3.

Table 3. Load factor

Motor /Transformer	K_{L1}/K_{L2}
Motor of high pressure Feed water pump	0.8
Motor of circulating water pump	0.8
Motor of condensating water pump	0.9
Other High Voltage Motor	0.75
Low Voltage Transformer	0.5

The coal handling system only works for about 4 hours a day, so the load rate is low. According to previous experience, the working condition of desulfurization system (FGD) is greatly affected by the sulfur content of coal. Considering the influence of dual speed operation, the circulating water pump adopts the middle value of the power at high and low speed.

3. Measures to low down the plant power rate and improve electric efficiency

To improve efficiency and reduce energy consumption, the working conditions of the main auxiliary equipment selection shall be set in the high efficiency area as far as possible. Due to the reasonable optimization of design and selection, the motor capacity will be reduced, and the power consumption of the motor will be reduced accordingly.

3.1. Thermal system

For the ultra supercritical primary circulation boiler, the auxiliary power is mainly consumed by the auxiliary equipment of the boiler system that is often in continuous operation. Therefore, the key to reduce the auxiliary power consumption of the unit is to deeply tap the potential of auxiliary power saving and reduce the power consumption of auxiliary equipment [3]. Generally, the auxiliary equipment of the ultra supercritical primary circulating boiler is supplied by the boiler manufacturer. Careful calculates on the power consumption of the auxiliary equipment through a large amount of rich experience accumulated through close cooperation with the boiler manufacturer in the design stage is an important measure to reduce unnecessary margin, shaft power and motor power.

For the steam turbine system, improving the thermal efficiency of steam turbine, adopting thermal insulation measures, and applying the advanced manufacture technology, could reduce energy loss, and heat consumption.

3.2. Viarable Frequency Drive

With the development of electronics technology, microelectronics technology and control theory control technology, medium and low voltage inverters have been widely used in various industries with their high efficiency drive, good control characteristics and very significant energy-saving characteristics. The application of frequency converter in power plants is undoubtedly one of the best hardware means to reduce the auxiliary power consumption rate and achieve energy conservation. At present, more and more power plants carry out technical transformation of frequency converter drive for some medium and low voltage auxiliary machines with large load changes. In some newly-built power plants, the owner also clearly proposed to the design company that the VFD should be considered for important auxiliary equipment.

Usually the motor of condensate pump and industrial water pump adopts VFDs, which avoids the energy loss of valve opening, which is to control the flow, thus effectively reducing the plant power rate.

3.3. Motor System

Generally, motors operate continously all year around, and the efficiency directly determines their power consumption [4]. For example, a 45kW motor can increase its efficiency by 1% and save nearly 4000kWh annually. The efficiency of Y series motor is about 1.5% higher than that of JO series motor on average, while the high efficiency motor, of which the efficiency is even better, is about 3% higher than that of Y series motor. YX, YE, YD, YZ and other series of high efficiency motors will be preferentially selected, with obvious power saving effect. Generally, the investment in renewing all motors can be recovered within 1-3 years.

4. Plant power rate calculation for the 2x1000MW thermal plant

In a typical thermal power plant, the high voltage motor calculation sheet is displayed in Table 4 while low voltage in Table 5.

Table 4. High Voltage Motor Calculation Sheet (one Unit)

Equipment	Rated Power (kW)	SET	Set in operation	Load Factor	VFD Index	Shared	Calculated Load (kVA)
Condensating Pump	2800	2	1	0.9	0.7	1	1764
Circulation Water Pump	1800	3	3	0.8	1	1	4320
PA Fan	3000	2	2	0.75	0.7	1	3150
ID Fan	7500	2	2	0.75	0.7	1	7875
SA Fan	1900	2	2	0.75	1	1	2850
Mill	900	6	5	0.75	1	1	3375
Boiler start-up Circulating Pump	700	1	1	0	1	0.5	0
FGD Absorber Pump A-F	2586	1	1	0.75	1	1	1940
Oxidiation Fan	355	2	1	0.75	1	0.5	133
Vacuum Pump	380	1	1	0.75	1	1	285
Low pressure drain Pump	280	2	1	0.75	1	1	210
CCCW pump	500	2	1	0.75	0.7	1	263
Low temperature Economizer Pump	355	2	1	0.75	1	1	266
Ship Unloading Machine	2300	3	3	0	1	0.5	0
Conveyor	2570	2	1	0.12	1	0.5	155
C14 Belt Conveyor	315	1	1	0.12	1	0.5	19
Stacker and reclaimer	600	1	1	0.12	1	0.5	36
Coal Crusher	630	2	1	0.12	1	0.5	38
Screwed Air compressor	350	7	6	0.75	1	0.5	788
$\sum K_{L1}K_bP$			(Including FGD)				27467

Table 5. Low Voltage Motor Calculation Sheet (One Unit)

Equpment	Rated Capacity(kVA)	SET	Set in Operation	Load factor	$\cos\varphi_{av}$	Shared	Calculated Load (kVA)
Steam Turbine Transformer	2000	2	2	0.5	0.8	0.5	800
Boiler Transformer	2500	2	2	0.5	0.8	0.5	1000
ESP Transformer	2500	3	2	0.5	0.8	1	2000
Lighting Transformer	500	1	1	0	0.8	1	0
Maintenance Transformer	630	1	1	0	0.8	1	0
Plasma Ignition Transformer	1600	2	2	0	0.8	1	0
FGD transformer	2500	2	1	0.5	0.8	0.5	500
Coal transportation Transformer	2500	2	1	0.2	0.8	0.5	200
	$\sum K_{L2}S_{db}COS\varphi_{av}$						4500

So the plant power rate could be calculated as:

$$e_r = \frac{\sum K_{L1}K_bP_d + \sum K_{L2}S_{db}COS\varphi_{av}}{P_e} \times 100\%$$

$$= \frac{27467 + 4500}{1000 \times 1000} \times 100\% = 3.19\%$$

5. Conclusion

This paper introduced measures to low down the plant power rate and improve the electric efficiency including close cooperation with equipment manufaturer and optimization during the design stage as well as the adoption of VFDs. The methods of plant power rate calculation is also introduced. For a typical 1000MW thermal plant, the main high volatage and low voltage motor power consumption are provided and the plant power rate could be lowed down to 3.2% after mearsures are taken.

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