Experimental Investigation of Performance Optimization of Direct air-cooling system

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1、Summary

As a result of excellent water-saving property, the direct air-cooling units have been applied widely where is lack of water but rich in coal and the installed capacity increases continuously. Optimizing the operation parameters of the direct air-cooling system will both enhance the economic benefit of the air-cooling power plant and conform to the " energy conservation and environmental protection " policy, which has a remarkable economic value and social significance.

At a fixed load and environmental temperature, the increment difference of air-cooling fan power consumption and the turbine power output (which is called as increment of net output) will change with the fan frequency varying. When the fan frequency achieves a certain value, the net turbine power output reached its maximum, In this condition, the fan frequency obtained is known as the optimum frequency. The experimental investigation of optimization of direct air-cooling system was carried out relying on a 200MW direct air-cooling power plant, from which the optimum frequency is acquired at the different load and the deferent ambient temperature. The experiment result indicates that after air-cooling optimization, an evident energy-consumption benefit is obtained.

2、The method and calculation of the experiment

1 The relationship between unit output and unit outlet pressure

under a certain load ,from the electrical power of the unit under different outlet pressure obtained from test, the relationship between unit output and unit outlet pressure could be derivate.

$$\Delta N_T = f_1(N, P_k)$$

ΔN_T —unit output change，MW

N —unit load，MW

P_k —unit back pressure，kPa

2 Air cooling system characteristic under varying conditions

the relationship between turbine outlet pressure and air cooling fan operating frequency under current load and environment temperature ,once the environment temperature changes ,this could be corrected by characteristic of air cooling condenser under varying condition.

$$P_k = f_2(N, T, f)$$

式中*T*—environment temperature，℃

f —air cooling fan's operating frequency，Hz

3 Air cooling fan power consumption

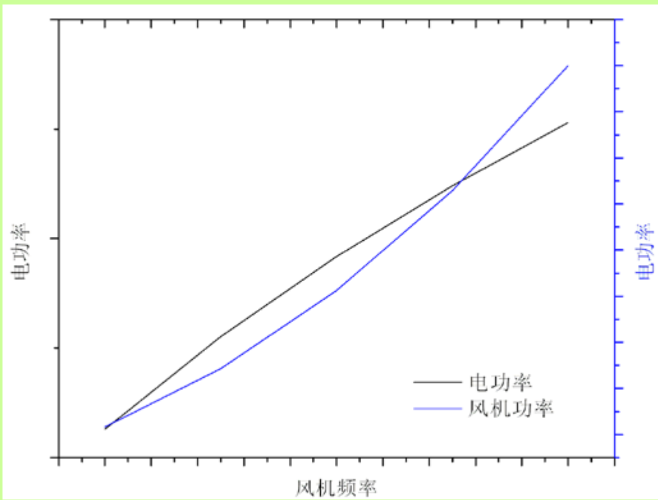
By altering the air cooling fan's operating mode ,the relationship between fan's power consumption and fan's operating frequency：

$$N_p = f_3(f, T)$$

N_p —Air cooling fan power consumption，kW。

4 The best air cooling fan operation frequency

- when unit steam inlet flow rate maintains, under certain environment temperature ,the fan's power consumption increases when air cooling fan's operating frequency increases, the turbine outlet vacuum degree increases, turbine's output increases;
- Both from theory facet and practical facet indicates that ,fan's power consumption increment increases when fan's operating frequency increases, the unit power output decreases, as shown in fig.1
- differential between increment of turbine power output and increment of air cooling fan power consumption changes when air cooling fan operating frequency changes ,when the frequency adjusts to a certain value ,the differential reaches maximal value ,thus ,the air cooling fan's operating frequency and outlet pressure could be set as the optimal fan's operating frequency and unit economical operating back pressure, as shown in fig.2



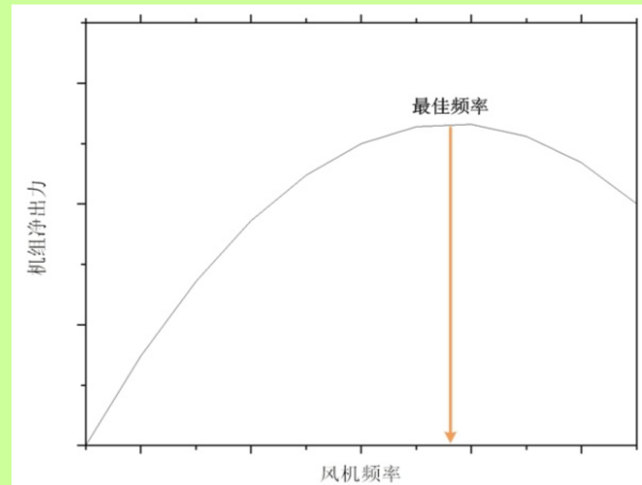


Fig1 the relationship between the power and the fan frequency

Fig2 determination of optimal frequency

- During the test ,main steam flow rate is stabilized by fixed valve position. Main steam pressure ,temperature ,reheat pressure and reheat pressure loss are hardly to be constant ,however ,this parameters have impacts on electrical power output .hence ,the influence of boundary parameter on electrical power output must be eliminated via correct method .the cooling water supply cut and the thermal system isolated during the test ,the outlet pressure's influence factor on the electrical power has been obtained ,test accuracy has been increased as well

3、 Experimental investigation of performance optimization of air-cooling system

the turbine unit investigated on is 200MW-lever ultra high pressure, once reheat unit, which model is CZK185/N200-12.75/535/535/0.245. The air-cooling condenser designed and manufactured by GEA contains 4×4 units, where 16 air-cooling axial-flow fans is configured. The total heat radiating area of the air-cooling condenser is $525205m^{2.}$.

test of air-cooling fan power consumption

The relationship is obtained by measuring the fan power consumption on different temperature and frequency, which serves as the basis of the air-cooling optimization. The rest result is shown in Table 1:

Table 1 test data of air-cooling fans

Fan frequency	ambient temperature 5℃	ambient temperature 12℃	ambient temperature 18.5℃	ambient temperature 26℃
Hz	kW	kW	kW	kW
49.79	2134.59	2086.416	2041.66	1990.04
47.69	1864.67	1815.67	1769.5	1717
43.88	1451.33	1404.67	1360.697	1310.71
38.12	991.67	976	960.597	943.812
33.14	665	662.67	660.458	657.968

- the relationship about fan power, fan frequency and ambient temperature is shown in Fig 3

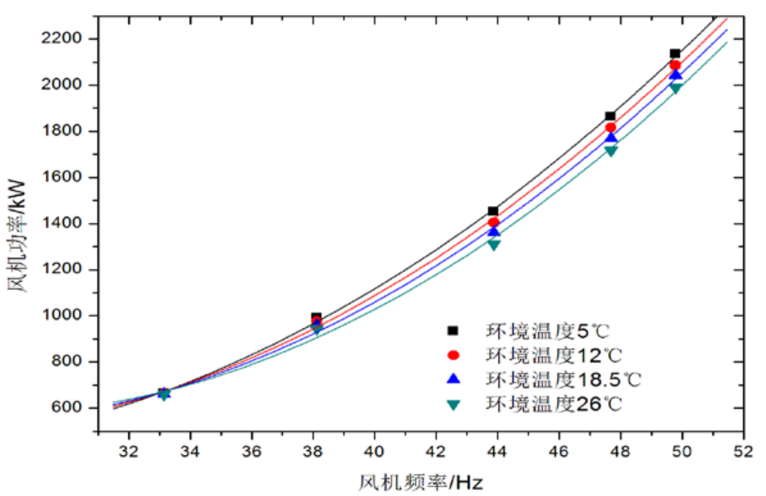


Fig3 the relationship about fan power, fan frequency and ambient temperature

The law between fan power and frequency closely approximates cubic function and fan power decreases linearly with ambient temperature raising. In the optimization of air-cooling experiment, the value of fan power is get by interpolation using fan frequency and ambient temperature.

optimization of air-cooling system

- The optimization test is conducted when the ambient temperature keeps steady, for minimizing the impact of test accuracy in varying environmental temperature. Due to the limited space, only the optimized result is listed in table 2 to table 6 when ambient temperature maintains 12℃.

Tab2 the calculation result of optimization test of 120MW load

Fan frequency	Fan power	Back pressure	Turbine power	ΔN_p	ΔN_T	ΔN_T-ΔN_p
Hz	MW	kPa	MW	MW	MW	MW
47.69	1.815	8.065	119.082	1.335	2.164	0.829
43.88	1.404	8.342	119.02	0.924	2.102	1.178
38.12	0.976	9.097	118.871	0.496	1.953	1.457
33.14	0.662	10.274	118.125	0.182	1.207	1.025
28.31	0.48	11.611	116.918	0	0	0

Tab3 the calculation result of optimization test of 140MW load

Fan frequency	Fan power	Back pressure	Turbine power	ΔN_p	ΔN_T	ΔN_T-ΔN_p
Hz	MW	kPa	MW	MW	MW	MW
47.69	1.816	8.424	140.311	1.153	2.505	1.352
43.88	1.405	8.863	140.099	0.742	2.293	1.551
38.12	0.976	9.834	139.388	0.313	1.582	1.269
33.14	0.663	10.988	137.806	0	0	0

Tab4 the calculation result of optimization test of 160MW load

Fan frequency	Fan power	Back pressure	Turbine power	ΔN_p	ΔN_T	ΔN_T-ΔN_p
Hz	MW	kPa	MW	MW	MW	MW
47.69	1.816	9.601	161.311	1.153	3.428	2.275
43.88	1.405	10.17	160.812	0.43	2.929	2.499
38.12	0.976	11.66	159.868	0.31	1.985	1.675
33.14	0.663	12.9	157.883	0	0	0

Tab5 the calculation result of optimization test of 180MW load

Fan frequency	Fan power	Back pressure	Turbine power	ΔN_p	ΔN_T	ΔN_T-ΔN_p
Hz	MW	kPa	MW	MW	MW	MW
47.69	1.816	10.533	179.481	1.153	4.15	2.997
43.88	1.405	11.47	179.081	0.742	3.75	3.008
38.12	0.976	12.76	177.428	0.313	2.098	1.784
33.14	0.663	15.1	175.331	0	0	0

Tab6 the calculation result of optimization test of 200MW load

Fan frequency	Fan power	Back pressure	Turbine power	ΔN_p	ΔN_T	ΔN_T-ΔN_p
Hz	MW	kPa	MW	MW	MW	MW
47.69	1.816	11.533	199.359	1.153	8.375	7.222
43.88	1.405	13.07	198.229	0.742	7.245	6.503
38.12	0.976	15.26	194.641	0.313	3.657	3.343
33.14	0.663	17.91	190.984	0	0	0

- the relationship between the increment (ΔN_T-ΔN_p) and fan frequency (f) is shown in Fig4 to Fig6. The climax of the curve corresponds to the optimal frequency in a certain turbine load and ambient temperature.

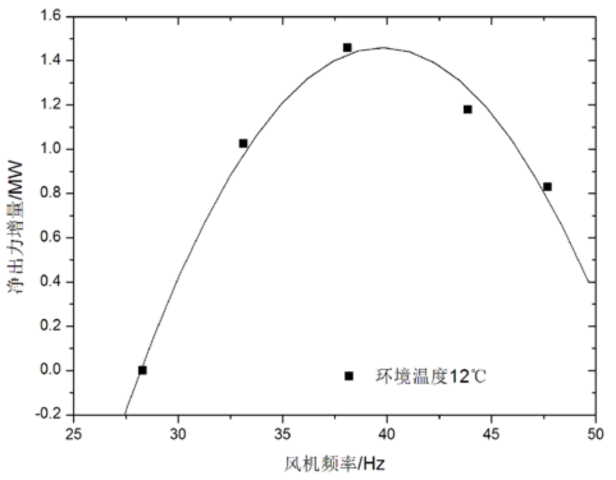


Fig4 calculation of optimal frequency on 120MW load

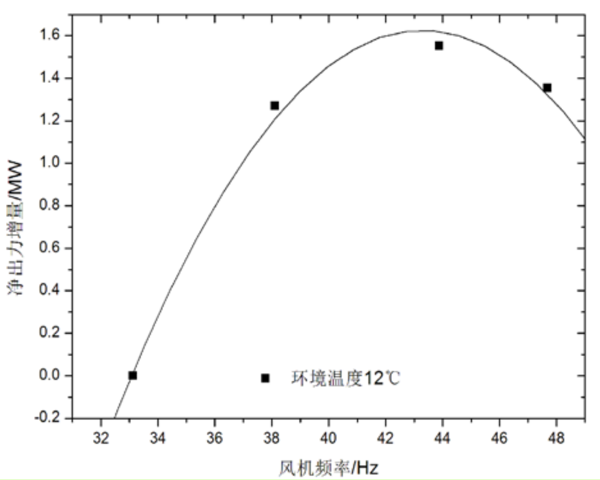


Fig 5 calculation of optimal frequency on 140MW load

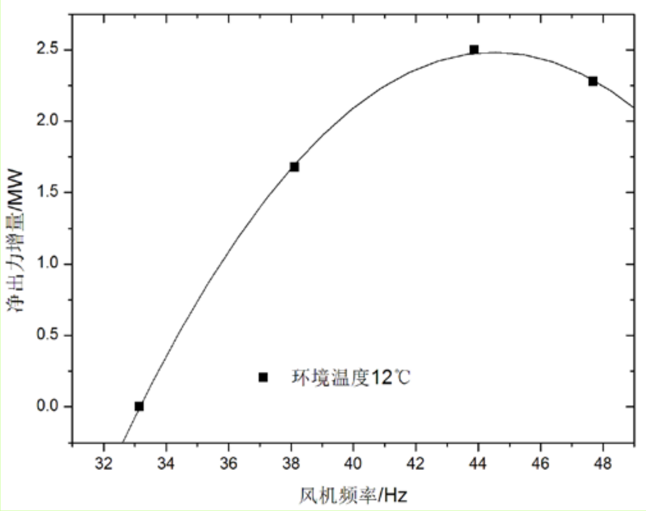


Fig 6 calculation of optimal frequency on 160MW load

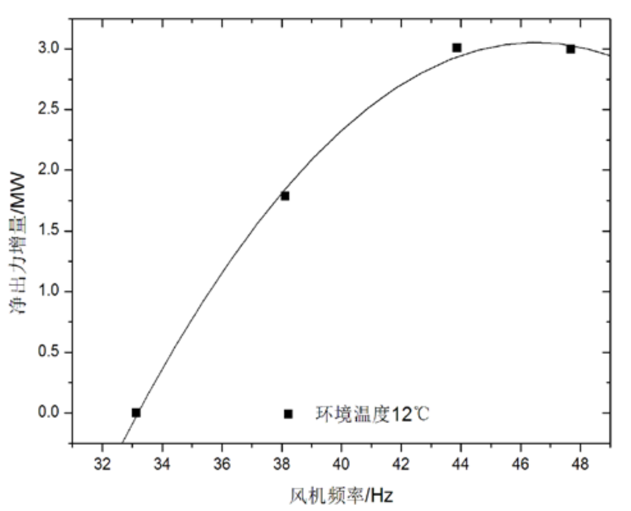


Fig 7calculation of optimal frequency on 180MW load

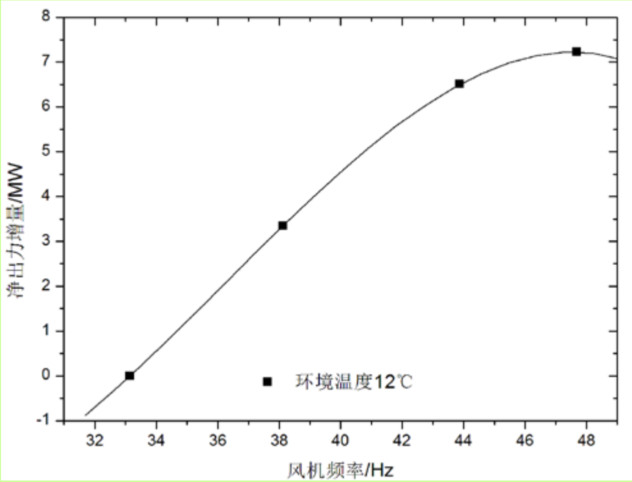


Fig 8 calculation of optimal frequency on 200MW load

The air-cooling optimized curve

The optimization test was conducted in a load range from 60% rated load to 100% rated load and in a ambient temperature range from 7℃ to 19℃, from which the optimum frequency is acquired at the different load and the deferent ambient temperature. By the way, some optimized results are gotten via the curve fitting. The relation of optimum frequency-unit loud-ambient temperature is shown in Table 7

Tab7 calculating table of optimum fan frequency

load	ambient temperature 7℃	ambient temperature 12℃	ambient temperature 15℃	ambient temperature 19℃
MW	optimum frequency /Hz	optimum frequency /Hz	optimum frequency /Hz	optimum frequency /Hz
120	34	38.5	42.3	46
140	37	41.5	44.5	47.5
160	39.3	43.5	46.7	49.6
180	42	45.6	48.9	52.2
200	44.1	48	51	54

the air-cooling optimization curve is shown in Fig9:

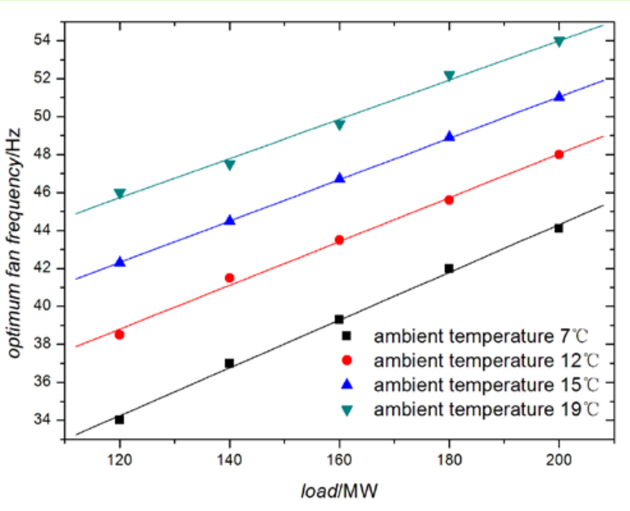


Fig 9 the air-cooling optimization curve

The linear fitting formulas are listed below, which provides a convenience for the operator to adjust the fan frequency according to the load and the ambient temperature. (satisfying the limits of current of the fan and the demand of freeze-proofing of the air-cooling condenser)

200MW： $f_{opt}=38.20456+0.83554T$

180MW： $f_{opt}=35.74202+0.86287T$

160MW： $f_{opt}=33.22117+0.87199T$

140MW： $f_{opt}=30.90717+0.88436T$

120MW： $f_{opt}=26.75147+1.01498T$

where f_{opt} is abbreviation for the optimum frequency, and T for the ambient temperature.

the calculation of energy-saving

- The energy-consumption comparison between the usual operating method and optimized operating strategy is listed in Table 8. After air-cooling optimization, the net turbine power output always has a increment on the different load, which is an evident energy-consumption benefit. According to estimation, the optimization will save coal consumption by 0.65 *g/(kW·h).*
- Tab8 comparison of the energy saving quantity

Load	ambient temperature	usual frequency	Optimized frequency	Net output increment	Ave. Net output increment
MW	℃	Hz	Hz	MW	MW
120	7	38	34	0.11	0.1025
	12	44	38.5	0.19	
	15	45	42.3	0.11	
	19	45	46	0	
140	12	44	41.5	0.45	0.225
	15	45	44.5	0	
160	7	38	39.3	0.09	0.185
	12	44	43.5	0	
	15	45	46.7	0.26	
	19	45	49.6	0.39	
180	12	44	45.6	0.11	0.43
	19	48	52.2	0.75	
200	7	44	44.1	0	0.66
	12	44	51	0.68	
	19	48	54	1.3	

4、conclusion

1) The experimental investigation of performance optimization is carried on by calculating the increment of net output. The relationship about optimal fan frequency, turbine load and ambient temperature is obtained, which will be a guideline for the power plant.

2) After air-cooling optimization, the optimization will save coal consumption by 0.65 *g/(kW·h).* which is an evident energy-consumption benefit. According to estimation,

3) Experimental investigation of performance optimization of direct air-cooling system can be popularized to direct air-cooling power plant with all capacity, which has a remarkable economic value and social significance.

Thanks！！