

Inclusion of absorption heat pumps into heat power plant scheme for stage heating efficiency increase of delivery water

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Abstract. Design analysis of absorption heat pumps use for delivery water stage heating levelling-off at ambient air temperature decrease has been reported in the present paper.

1 Introduction

Two stage heating of delivery water at heat power plant in comparison with one stage heating allows to increase electric energy generation at heat consumption. In modern heating turbines there is no opportunity to maintain equal distribution of delivery water heating within the whole heating season, which leads to decrease of efficiency of heating generation of electric energy [1].

Design research of work modes in two stage network installation in turbines of type T-110-130 and T-250-240 in respect to climate conditions in Tomsk for temperature chart of heat supply system 150/70 and extraction ratio=0.6 [2] shows that dispatch of heat enormously depends on ambient air temperature. During turbine plants work on heat graph share of water heating in low heating of water in lower line heater at decrease of ambient air temperature increases from (30–40) % to (65–75) % with corresponding decrease of heating in upper heater (fig. 1). All other conditions being equal inequality of network heating increases with decrease of delivery water discharge rate and increase of its temperature in return line [3].

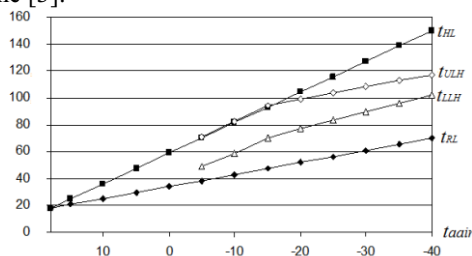


Fig. 1. Temperature chart of heat supply system (HL – heating line, RL – return line, ULH – upper line heater, LLH – lower line heater, air – ambient air).

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2 Statement of problem and limitations

Variant of absorption heat pumps (AHP) use for delivery water stage heating levelling-off at ambient air temperature decrease has been considered in the present paper [4]. Inclusion of absorption heat pumps into delivery water two stage heating scheme at heat power plant has been presented in fig.2. In evaporator of absorption heat pumps return wire temperature decreases due to use of heat of high-potential vapor extraction from turbine. Transmission of heat to delivery water in condenser of absorption heat pumps leads to decrease of delivery water temperature for upper line heater with corresponding decrease of vapor pressure in the upper controlled selection.

Simultaneous decrease of return wire temperature and vapor pressure in upper line heater causes redistribution of heating between upper and lower heaters and allows to approximate work mode of network installation to design mode with equal heating of delivery water. Pressure in work selection and its corresponding delivery water temperature for lower line heater are set on the base of coordinated solution of the Stodola-Flugel formula for interstage section of turbine and heat-balance equation of lower line heater.

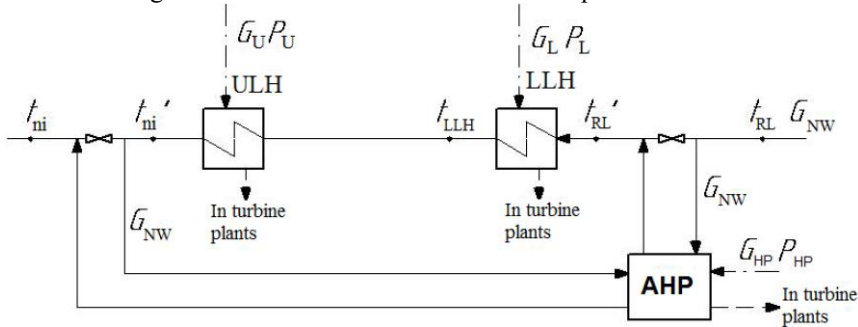


Fig. 2. Inclusion of absorption heat pumps into two-stage network installation of heating turbine scheme.

Initial data for design are presented in table 1. Design mode of heating turbine corresponds to equal heating of delivery water. It is close to the temperature of inclusion of Peak Water Boiler and it was accepted as equal to $t_{air} = -15$ for Tomsk. The design shows that at minimal ambient air temperature a share of heating in the lower stage of network installation increases to 70 % of overall heating of delivery water in lower line heater and upper line heater.

Table 1. Initial data for the task.

Specifications	Value
Common specifications for all modes	
Turbine plant prototype	T-110-130
Heat supply system temperature chart $t_{hl}/t_{rl}, ^\circ\text{C}$	150/70
Extraction factor $\alpha_{\text{heat power plant}}$	0.6
Minimum design temperature of ambient air $t_{air}, ^\circ\text{C}$	-40
Thermal capacity of system Q_t, MW	200
Working vapor pressure P_0, MPa	13
Working vapor temperature $t_0, ^\circ\text{C}$	540
Efficiency ratio of turbine η_{oi}	0.87
Product of mechanical efficiency and generation efficiency $\eta_m * \eta_g$	0.995
Design mode ($t_{air} = -15 ^\circ\text{C}$)	
Temperature of delivery water behind network installation $t_{ni}, ^\circ\text{C}$	95
Return wire temperature $t_{rw}, ^\circ\text{C}$	47

Share of heating in the lower stage of network installation (NI)	0.5
Minimal design ambient air temperature mode without absorption heat pumps ($t_{\text{air}} = -40 \text{ }^{\circ}\text{C}$)	
Temperature of delivery water behind network installation t_{ni} , $^{\circ}\text{C}$	118
Return wire temperature t_{rw} , $^{\circ}\text{C}$	70
Minimal design ambient air temperature mode with absorption heat pumps ($t_{\text{air}} = -40 \text{ }^{\circ}\text{C}$)	
Delivery water temperature behind condenser of absorption heat pumps t_{ni} , $^{\circ}\text{C}$	118
Return wire temperature t_{rw} , $^{\circ}\text{C}$	70
Coefficient of performance of absorption heat pumps ϕ	1.7
Vapor pressure of selection on absorption heat pumps P_{hp} , MPa	0.5

3 Analysis results

Analysis results are presented in Table 2.

Table 2. Analysis results.

Specification	Value		
	95/47 without absorption heat pumps	118/70 without absorption heat pumps	118/70 with absorption heat pumps
Delivery water discharge G_{dw} , kg/s	992.1		
Vapor pressure of selection on upper line heater P_{u} , MPa	0.1065	0.2292	0.1065
Vapor pressure of selection on lower line heater P_{l} , MPa	0.0422	0.1436	0.0635
Vapor feed rate of selection on upper line heater G_{u} , kg/s	47.07	28.15	27.19
Vapor feed rate of selection on lower line heater G_{l} , kg/s	47.38	65.8	41.45
Vapor feed rate of selection on absorption heat pumps G_{hp} , kg/s	-	-	26.55
Delivery water heating in condenser of absorption heat pumps Δt_{heat} , $^{\circ}\text{C}$	-	-	23
Delivery water cooling in evaporator of absorption heat pumps Δt_{cool} , $^{\circ}\text{C}$	-	-	9.47
Delivery water temperature behind network installation t'_{ni} , $^{\circ}\text{C}$	-	-	95
Delivery water temperature after evaporator of absorption heat pumps t'_{rw} , $^{\circ}\text{C}$	-	-	60.53
Delivery water temperature of lower line heater t_{lh} , $^{\circ}\text{C}$	71	103.6	81.14
Vapor feed rate on turbine G_0 , kg/s	94.45	93.95	95.19
Generated electric power N_{e} , MW	92.6	81.24	84.77
Specific vapor consumption on turbine d_0 , kg/MJ	1.02	1.156	1.123
Specific electric energy production on heat consumption e	0.463	0.406	0.424

Design results of turbine plant efficiency at different modes of network installation are presented in fig. 3,4.

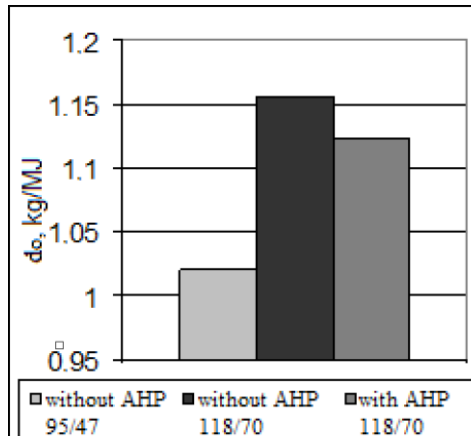


Fig. 3. Inclusion of specific vapor consumption on turbine for different modes of network installation efficiency.

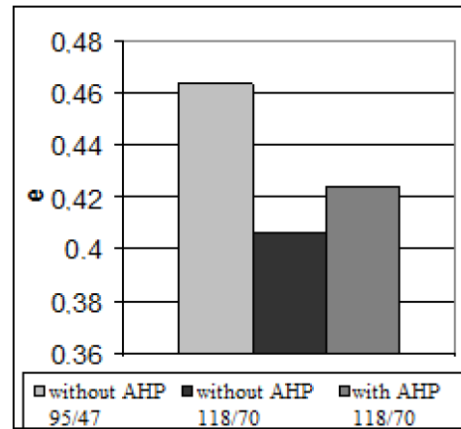


Fig. 4. Specific electric energy production at heat consumption for different modes of network installation efficiency.

4 Conclusion

To sum up:

- Delivery water heating in lower and upper heaters of two-stage network installation during heating season greatly differs from equal one. During ambient air temperature decrease thermal load of lower heat extraction and share of water heating in lower line heater grows. During delivery water discharge decrease and increase of temperature in return line at other equal conditions inequality of heating increases.
- Use of absorption heat pumps in stage heating increase of delivery water scheme of stage heating delivery water at low temperatures of ambient air allows to decrease return wire temperature at the input into lower line heater and at the output of upper line heater and approximate off-design conditions of network installation to equal one.
- Efficiency of inclusion of absorption heat pumps into two-stage network installation scheme of heating turbine without interstage interval with initial characteristics $P_0=13$ MPa, $t_0=550$ °C for mode with minimum temperature of ambient air is evaluated by increase of electric energy generation at heat consumption 2–3 % in reference to initial model.

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