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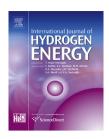
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## Use of heat pumps in turbogenerator hydrogen cooling systems at thermal power plant<sup>★</sup>

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#### ABSTRACT

The possible increase in heat power generation efficiency was evaluated through this paper via installation of heat pumps for cooling hydrogen in generator of steam turbine.

Using the heat pumps, the biggest part of waste heat from turbogenerator hydrogen cooling systems can be transferred to heat supply system. They are used for heat supply inhouse load of a power plant or for any other goal of heat supply as well.

All calculations were made for thermal power plant at the branch "Nevsky" "TGC-1" company — CHP-21. The analysis was made for heat pumps with heat capacities of 2 MW and 3 MW. The application of such analysis on CHP was applied by the method of detailed settlement estimation of the impact on CHP operating mode with synchronous calculation of characteristics of heat pump. The analysis was made for different operating mode of CHP. A low potential heat source is the water from hydrogen cooling systems of steam turbine generator.

The use of heat pumps for steam turbine generator hydrogen cooling system waste heat salvaging is innovation solution to increase TPP cost-performance ratio. On implementing cycle arrangement with heat pump used for sanitary and service makeup water warming, fuel saving is up to 700 toe/year while heat pump system specified heat power is 3 MW.

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#### Introduction

Strategic target of Russian state energy policy is the utmost rational use of energy resources, based on consumers' concern in energy saving, in proper energy efficiency increase and in investing into this sector [1].

On using primary fuel cells in technological cycle, thermal power plants (TPP) have large stock of reclaimable resources

which are little used, and they also have a negative impact on the environment. Heat output from turbogenerator hydrogen cooling system should be considered as such resource. One of the possible solutions to the problem of turbogenerator hydrogen cooling system's closed-loop system heat saving is the use of heat pumps (HP).

The use of HP at TPP could have the following effects:

- to save low grade heat;

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#### Nomenclature

G consumption, t/h
h heat content, kJ/kg
Q heat production, MW
t temperature, °C

#### Greek letters

χ steam dryness factor

Superscripts and subscripts

CBC continuous blowdown coolants
CBF continuous blowdown flash tank

RWW raw water warmers WT water treatment bw blowdown water

in inlet out outlet rw raw water

s parameters in saturation line at pressure in CBF

st steam

ww warming water

w water

#### Acronyms/abbreviations

ARR Average rate of return

BIB built-in bundle of condenser CAD computer-aided design

CBC continuous blowdown coolants
CBF continuous blowdown flash tank
CHP combined heat and power plant

CPR cost-performance ratio

DPB Discounted payback period

EFSF equivalent fuel specific flow
goe gram of coal equivalent

HP heat pump

HPS heat pumping system
IRR Internal rate of return
JSC Open Joint Stock Company
LGHS low-grade heat source

MW megawatt NPV Net present value PB Payback period ΡI Profitability index Ps saturated pressure  $Q_{HPS}$ HPS specified heat power  $Q_{RWW}$ RWW thermal load value RD regulatory document

RWW raw water warmers
TGC Territorial Generating Company

TPP thermal power plant toe ton of coal equivalent

TVF type turbogenerators with hydrogen cooling WEM wholesale electric energy/power market

WT water treatment

- to improve TPP environmental factors;
- to provide in part or total TPP auxiliary heat requirements;
- to increase heat supply;
- to decrease firing rate (by peaking hot water heater load decrease);

- to increase TPP output power (by steam turbine heat extraction load decreases) [2,3];
- to decrease technological minimum value of steam turbine plant.

Several HP arranged as heat pumping system (HPS) could be used to increase reclaimable resources' saving adjustment range.

#### Research technique

Performance analysis of HPS use in TPP cycle arrangement has been carried out by means of detailed assessment calculation of the system effect on TPP operating mode. At the same time energy efficiency rate, as well as approximate consumption for compressor drive in various TPP operating modes required for heat and electricity supply has been calculated.

Elementary scheme of one-stage heat pump, operating on Freon R134a which is widely used and is considered to be ozone-friendly coolant, has been selected for analytical model. CoolPack software has been used to evaluate the heat pump performance. Working fluid (or working medium) of vapor compression heat pump should meet the following requirements:

- 1. It should have high heat capacity and high density.
- 2. It should have stay-put feature and low cost [4].

In order to decrease compression work, it is necessary to fulfill the following conditions: working medium saturated pressure  $(P_s)$  in evaporator should be close to atmospheric pressure; working medium saturated pressure  $(P_s)$  in capacitor shouldn't be too high. The selection of heat pump elementary scheme is caused by the fact that it is the least favorable modification with ultimate consumption for compressor drive. So, one may conclude in accordance with this modification calculation that engineering development of the scheme could improve heat pump thermodynamic cycle and decrease thereafter consumption for compressor drive.

Statistical data along with cycle arrangement mathematical model approach has been used to evaluate reclaimable resources effect on TPP operating modes and to estimate its key technical-and-economic indexes. Russian United Cycle software has been used to develop mathematical models. United Cycle package is a new version of "Cycle arrangement" CAD system and is designed for solving problems of heat and power facility optimal structure and configuration, as well as for calculating of TPP steady states of operation [5].

#### Subject of research

Thermal power plant of Severnaya CHHP JSC TGC-1has been selected for HPS performance analysis in operating TPP. Five turbine generators TVF-120-2UZ have been installed at TPP. The TVF-type turbogenerators with hydrogen cooling have direct forced hydrogen cooling of rotor winding and indirect hydrogen cooling of stator winding. Hydrogen is cooled by gas condensers, embedded in stator frame horizontally.

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