ARTICLE IN PRESS

INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2016) 1–7

Available online at www.sciencedirect.com

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Use of heat pumps in turbogenerator hydrogen cooling systems at thermal power plant☆

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ARTICLE INFO

Article history:
Received 21 April 2016
Accepted 29 April 2016
Available online xxx

Keywords:
Heat pump
Turbogenerator
Hydrogen cooling
Thermal power plant
Technological cycle
Technical-and-economic indexes

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 in-house 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.

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;

☆ This paper is the English version of the paper reviewed and published in Russian in **International Scientific Journal for Alternative Energy and Ecology “ISJAEE” issue 191–192, number 03–04, date 29.02.2016**.

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http://dx.doi.org/10.1016/j.ijhydene.2016.04.256
0360-3199/

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
PI	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.