Available online at www.sciencedirect.com
ScienceDirect
Applied Thermal Engineering 28 (2008) 1865–1874
APPLIED THERMAL ENGINEERING
www.elsevier.com/locate/apthermeng

Sensitivity analysis for the capacity improvement of a combined cycle power plant (100–600 MW)

S. Boonnasa [a,*], P. Namprakai [b]

[a] Department of Power Engineering Technology, College of Industrial Technology, King Mongkut's Institute of Technology North Bangkok, Bangkok 10800, Thailand

[b] Division of Energy Technology, School of Energy Environment and Materials, King Mongkut's University of Technology Thonburi, Thungkhru, Bangkok 10140, Thailand

Received 16 May 2007; accepted 23 November 2007
Available online 3 December 2007

Abstract

Power improvement of a combined cycle power plant using inlet air cooling was analyzed in this paper. The corresponding CC capacities in a range of 100–600 MW were examined. The CC performance can be improved by decreasing an inlet air temperature and humidity to 15 °C (ISO) and 100% RH before entering air compressor of a gas turbine (GT). All year ambient temperature in Bangkok is normally higher than 15 °C. This research used a steam absorption chiller (AC) to cool intake air to the desired temperature level and no storage unit was needed. The CC uses a cooling tower (CT) for cooling purpose. In the 400 MW power plant as an example, it could increase the power output of the GT by 9.32% and the CC by 5.8%, while the ST power decreased by 3.42% annually, as some steam was supplied to the AC. In the economical analysis, the payback period (PB) will be in the range of 0.68–0.94 years, internal rate of return (IRR) 29–176%, and net present value (NPV) 116.5–154.63 MUS$. Additionally, sensitivity analysis concerning economic performance and environmental impact of the plants were also studied.

Keywords: Performance; Capacity improvement; Economics; Monthly analysis; Uncertainty

1. Introduction

Boonnasa et al. [1] analytically demonstrated an improvement of the CC (336 MW) of the Electricity Generating Authority of Thailand (EGAT, south Bangkok) by cooling the inlet compressor air of a GT using an AC with a chilled water storage. Cooling inlet air will increase air mass flow rate then increase the power output. It could increase the power output of a GT by about 10.6% and the CC 6.24% annually. Furthermore, Ameri et al. [2] could improve power of the new GT plant (16.6 MW) by about 11.3%. Mohanty et al. [3] observed 11% increases in power of the GT in Bangkok. Both used an AC without cooling water storage to solve their problem. Their systems had no ST unit. Recently Thailand produced 134,826.72 MW h of electrical energy of which 69,937.09 MW h was produced by private enterprises in 2005 [4]. The energy production will be increased gradually each year. Nowadays, the Thai government wants to promote small and medium enterprises (SMEs) which need electricity for their business. Moreover, it is a state policy to purchase the access electricity from private power producers [5].

In order to assist many independent power producers (IPPs) in Thailand and those having a similar climate to improve their existing power units, we simulated the CC improvement with various capacities: 100, 200, 300, 400, 500 and 600 MW using AC as in [1] but no cooling water storage was included. The analysis investigated both techniques and economics which can provide an appropriate

* Corresponding author. Tel.: +66 2 02 913 2500x6442; fax: +66 2 02 587 4356.
E-mail address: skbn@kmitnb.ac.th (S. Boonnasa).

1359-4311/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2007.11.021

Nomenclature

E_1	energy cost during on peak (9:00–22:00), US$/kW h
E_2	energy cost during off peak (22:00–9:00), US$/kW h
dP_{ST}	decrease in ST power, MW
h	specific enthalpy, kJ/kg
IRR	internal rate of return
i	interest rate, %
h_{fg}	latent heat of vaporization of water, kJ/kg
m	mass flow rate, kg/s
m_{st}	steam supplied to power the AC, kg/s
NPV	net resent worth, MUS$
P	present value of the total capital cost, US$
P_1	maximum power demand cost, US$/kW
PB	payback period, year
Q_{CL}	total cooling load, kW
T	temperature, °C
x_1	NG cost, US$/kg
x_2	plant capacity, MW
y	IRR, %
y	NPV, MUS$
%GT	GT output, %
%ST	ST output, %
%m	air mass flow rate, %

Greek symbols

η	efficiency, %
ω	humidity ratio, kg of moisture/kg of dry air

Subscripts

a, b, c, d	state points
amb	ambient
CHWR	chilled water return
CHWS	chilled water supply
CL	cooling load
CWR	cooling tower water return
CWS	cooling tower water supply
e	electrical
ISO	international standards organization
ST	steam turbine
th	thermal

Acronyms

AC	absorption chiller
CC	combined cycle
CD	condensate water
CDW	condensate water
Comp	air compressor
CT	cooling tower
ECON	economizer
EVAP	evaporator
GT	gas turbine
HE	heat exchanger
HP	high pressure
HRSG	heat recovery steam generator
LP	low pressure
NG	natural gas
RT	ton-refrigeration
ST	steam turbine
STB	standby unit

solution for a business people. Environmental impacts as well as the influence of an interest rate, NG cost on economical performances were also investigated. Statistical data of hourly ambient temperature and relative humidity in 2005 were used in this study.

2. Description of an air cooling system for the power plant and climatic data

2.1. A schematic diagram of the proposed system

The system schematic diagram is shown in Fig. 1 and the parameters used for simulation is shown in Tables 1 and 2. The studied system is a new power plant. However the analysis presented here can be applied for the older plant as well. It is composed of 1 GT and 1 ST. A GT to ST power ratio is 2:1. The GT is fueled by natural gas (NG) which is more attractive due to its clean burning and low cost. A 76.5% load factor of the power plant is assumed.

The modification was done by adding AC units and a compact heat exchanger (HE). Both units were used to cool the inlet air of the GT in order to increase power output. A temperature control for controlling the mass flow rate of the chilled water from the AC using a control valve (3-way valve) was installed at the heat exchanger.

The AC has no compressor hence consumes less electrical energy. So avoidance of the on-peak period is not necessary. As a consequence chilled water storage was not needed then the cost can decrease as compared with Boonnasa et al.'s [1]. The selected AC is a lithium-bromide cooler (double effect) which uses 0.8 MPa steam from the heat recovery steam generator (HRSG) and its COP is assumed to be independent of size.

Condensate tanks and various pumps also were included. The cooling tower (CT) is used for a condenser.

The cooling capacity of chilled water supplied to the HE can sustain the condition of compressor air intake at 15 °C (ISO condition). The designed inlet and outlet water temperatures in the HE are shown in Fig. 1. Cold and clean