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A new cogeneration targeting procedure for total site utility system

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HIGHLIGHTS

- ► New cogeneration targeting method for estimation of cogeneration potential.
- ► This algorithm is simple, clear to understand with high computational efficiency.
- ► More accuracy and reliable than the other methods.

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ABSTRACT

As a head of design, the cogeneration targeting is necessary to optimal design of site utility in the process industries to estimate fuel demand, steam generation, steam used as well as production of heat and power.

A new cogeneration targeting model that has been developed to estimate the cogeneration potential of site utility systems. The new procedure has been proposed here provides a consistent, general procedure for determining the mass flow rates and the efficiencies of the turbines used. This algorithm utilizes the relationship of the entropy with the enthalpy and the isentropic efficiency. Finally the new model allows targeting shaft work production and degree of superheat at steam boiler with high accuracy. It is superior to previous works in that it does not require cumbersome simulation for initiation and accurate. Also, this algorithm is simple, clear to understand with high computational efficiency and could be easily to provide computer code rather than simulation programs. Three case studies are used to illustrate the usefulness of the new cogeneration targeting method.

1. Introduction

The chemical process usually requires steam at different pressure and temperature values for heating and non-heating purposes. In order to provide steam at the required condition, the designer has to decide whether to provide steam at the extreme condition and then let it down to the different levels or produce steams separately at different boilers. Many industrial processes operate within Total Sites [1,2], where they are serviced and linked through a common central utility system. This utility system meets the demands for heat and power of the individual process units by their indirect heat integration. However, greater benefits in terms of energy and capital cost can be obtained by looking at the entire site. Total site integration addresses the task of optimizing each process and the utility system in the context of the overall site [3]. One of the important tasks for the utility systems design is targeting fuel consumption and shaft work production ahead of design. In this regard, a number of models have been proposed for estimation of cogeneration potential in site utility of process industries.

Dhole and Linnhoff [1] proposed developed the site profiles and Site Composite Curve (SCC) and Total Site Pinch. The application of this concept resulted in both a considerable reduction of energy use in processes and preservation or enhancement of the internal production of power.

Raissi [2] used the Salisbury approximation to estimate the power. Salisbury approximation indicated the power can be estimated by linearly proportional to difference between the inlet and outlet saturation temperatures [3]. This method is not accurate.

The Turbine Hardware Model (THM) based on the principle of the Willan's line demonstrates the variation of efficiency with turbine size and operating load. Mavromatis and Kokossis [4] proposed the THM to estimate the power based on Willan's line concept. It does not estimate shaft work very well.

Harell [5] proposed concept of extractable power and header efficiency to establish cogeneration potential. This method is based

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Nomenclature

h	specific enthalpy (kJ/kg)
$\dot{m}$	mass flow rate, kg/s
P	pressure, bar
$\dot{Q}$	heat load, MW
s	specific entropy, kJ/kgK
T	temperature, °C
W	shaft work, electricity (MW)
VHP	very high pressure
HP	high pressure
MP	medium pressure
LP	low pressure
Z	expansion zone
SUGCC	site utility grand composite curve
GCC	grand composite curve
TSP	total site profiles
SCC	site composite curve
A	constant coefficient to calculate W
B	constant coefficient to calculate W
a_0	constant coefficient to calculate A
a_1	constant coefficient to calculate A
a_2	constant coefficient to calculate B
a_3	constant coefficient to calculate B
THM	Turbine Hardware Model
IBTM	iterative bottom-to-top model

Greek symbol

η	isentropic efficiency
ε	limitation of error

Subscripts

is	isentropic
Sat	saturated conditions
1	state 1
2	state 2
z	expansion zone
act	actual condition
f	saturated liquid
net	net heat or mass load
max	maximum
init	initial state
new	new

Superscripts

DEM	process steam demand
GEN	process steam generation
i	steam main
net	net heat or mass load
$'$	isentropic state

on graphical representation. Varbanov et al. [6] introduced the improved THM method. This model had better results than THM model. However, it has not enough accuracy.

Sorin and Hammache [7] proposed a targeting model based on a new thermodynamic insight on cogeneration in general and Rankine cycle in particular. This method is based on the ideal shaft work of a cogeneration unit through the outlet heat load and the difference in Carnot factors between the heat source and heat sink for the given inlet temperature of the heat source [6]. This model allows targeting fuel consumption, cooling requirement and shaft work production and visualizing them directly as special segments on the T–H diagram. This method has not good accuracy.

Mohan and El-Halwagi [8] proposed the concept of extractable power. It has been used as a basis of constructing this linear algebraic cogeneration targeting approach for effective utilization of biomass in combined heat and power systems through process integration.

Medina-Flores and Picón-Núñez [9] presented a thermodynamic model for the prediction of the operating performance of back pressure steam turbines with single and multiple extractions. This approach takes the advantage of THM and incorporates some improvements that allow for the prediction of the shaft work under changes in the operating conditions such as steam flow rate and pressure of each of the extractions. In this model, the correlations of Varbanov et al. [6] have been modified to obtain the regression parameters as a function of inlet pressure.

Bandyopadhyay et al. [10] proposed a methodology based on simple and linear as well as utilizes the rigorous energy balance at each steam header to estimate the cogeneration potential. This model doesn't consider superheat degree of each main and the results.

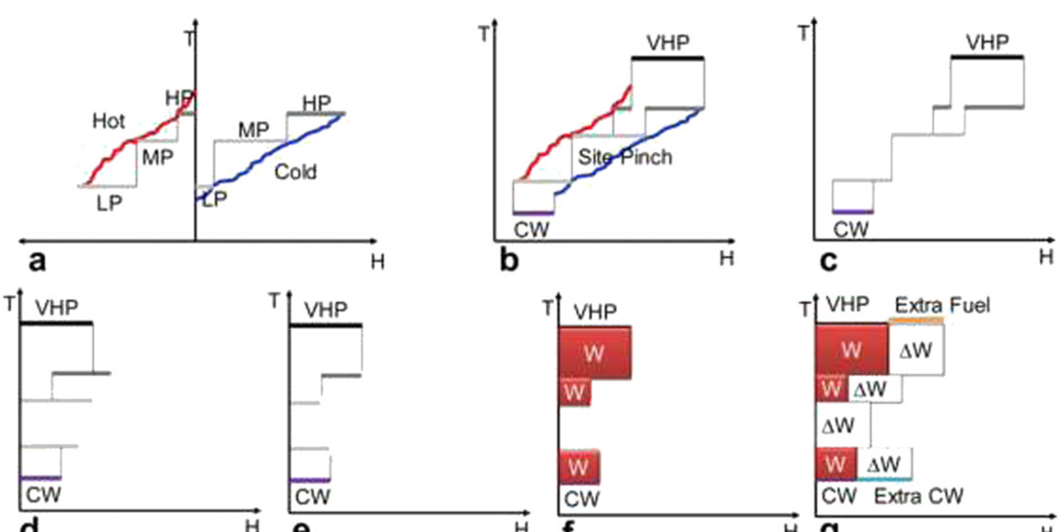

Fig. 1. (a) TSP, (b) SCC, (c) Steam profile, (d) SGCC, (e) SUGCC, (f) cogeneration potential for a pinched site, (g) cogeneration potential for a site violating the minimum targets [12].