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PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Abstract

EFENIS-Site is a software package for the design of site utility and cogeneration systems. The interactions between the processes on the site and the steam system, steam turbines, gas turbines (with auxiliary firing options), boiler house, local fired heaters and cooling systems are all analysed using EFENIS-Site.

There are some issues addressed by EFENIS-Site:

1) Utility System Optimization

EFENIS-Site has a utility system optimisation facility that allows existing utility systems to be optimised. It can also be used to plan infrastructure debottlenecking and investment.

2) Top Level Analysis

When studying existing sites it is important to understand the way in which the existing site infrastructure influences the degrees of freedom to make changes and the economic consequences of any changes. This is provided by EFENIS-Site in its Top Level Analysis such that the designer does not waste time pursuing changes which will neither be viable nor economic in the context of the overall site.

3) Process Energy Targets

Even though the prime function of EFENIS-Site is the analysis of utility systems, it has tools available to set energy targets and select utilities for individual processes. These tools include the composite curves, the grand composite curve, and the problem table, that enable the engineer to predict hot and cold utility targets for individual processes.

4) Total Sites

EFENIS-Site can produce total site profiles representing the heating and cooling requirements of the site. This allows targets to be set for fuel consumption in the boilers, cogeneration potential and energy costs. Profiles can be based on either the full heat recovery data or more simply from the data for the utility exchangers only. Cogeneration potential can be targeted.

5) Boiler Systems

EFENIS-Site is able to optimally target the amount of steam generated for process use by boilers and gas turbines (with auxiliary firing options). A gas turbine model allows different gas turbine arrangements to be studied.

6) Steam Turbine Systems

EFENIS-Site incorporates tools for the design of steam turbine networks and analysis of their operability.

7) Emissions

By relating the energy requirements of the processes to the supply of utilities, it is possible to target for the amount of fuel required for the utility system. These targets can be combined with information on the fuel and type of combustion device to provide targets for CO_2, SOx, NOx and particulates. The various options to reduce emissions can then be explored using EFENIS-Site.

New methodologies developed on total site targeting and optimization has been implemented in the 'EFENIS-Site', and has been applied to EFENIS demonstration projects.

1 Introduction

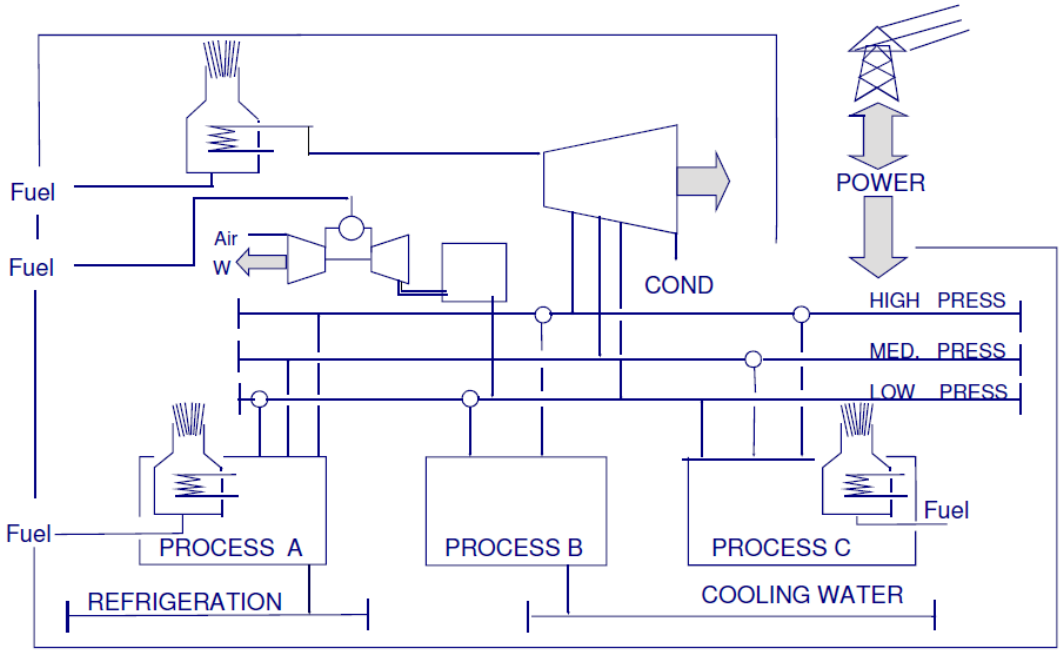

Figure 1 A Total Site Utility System

Various processes operate on the site and are connected to a common utility system. A typical site utility system is shown in Figure 1. The source of utility very high pressure (VHP) steam is fuel combustion in boilers and gas turbines heat recovery steam generators, and VHP steam distribute to lower pressure steam mains to satisfy process heating demand. Steam cascade in the utility system is determined by utility VHP steam from boilers, process heating and cooling demands, and process indirect heat recovery through the utility medium. Utility power is generated by fuel combustion in gas turbines and steam expansion or condensation in steam turbines. Cogeneration means both heat and power production simultaneously. The deficit or excess power is imported from or exported to the grid.

The software 'EFENIS- Site' has been developed by the Centre for Process Integration, The University of Manchester, for the simulation and optimization on the site utility systems. Issues involved in the 'EFENIS- Site' include fuel combustion and emissions, boiler feed water treatment, gas turbines and heat recovery, steam mains selection (number, temperature, and pressure), steam distribution in the system, steam use for process heating and power generation. It can present provision of heat and power to site processes, steam use/generation

in processes, interaction between processes and utility system, interaction between processes through steam mains, and cogeneration. It can solve complex problems of fuel choice and emissions, steam production mechanisms, steam available at different levels, water/cooling system, potential power production.

The 'EFENIS- Site' is a quantitative tool used for site system simulation, optimization, and the integration of utility system with processes.

New methodologies developed on total site targeting and optimization has been implemented in the 'EFENIS-Site', and has been applied to EFENIS demonstration projects.

New site profiles and new power models

A number of practical issues have been addressed for the steam profiles:

1) Boiler feedwater (BFW) preheating. BFW is fed to process steam generation at the deaeration temperature, which will be below saturation temperature. Preheating of the BFW prior to vaporisation can be carried out by recovery from the site hot composite curve.

2) Steam superheating. Steam fed to the steam mains from process steam generation should be superheated and this can also be carried out by heat recovery from the site hot composite curve.

3) Steam desuperheating. Steam fed to process steam heaters, if superheated, involves a poor heat transfer coefficient until saturation conditions are attained. The design of steam heaters benefits from the desuperheating of steam prior to use. If this is carried out, BFW from the deaerator is injected into the steam under temperature control to typically bring it within 3°C of saturation. The benefit is smaller and cheaper heat exchangers and in some cases less damage to sensitive process fluids. However, for the same process heating load, the mass flowrate of steam increases and additional boiler fuel is required to compensate for the desuperheating.

4) Condensate heat recovery. After condensation of the steam in process steam heaters, additional heat can be extracted from the condensate before returning the condensate to the boiler. This has drawbacks for the design of the heat transfer equipment, reducing overall heat transfer coefficients. However, less energy is lost in the condensate system, which possibly reduces boiler fuel.

These options need to be included in the targets so that they can be screened as to the benefit or penalty of different options.

Discrete Process site profiles

Whilst the targets developed so far are thermodynamically feasible, they might be difficult to achieve in practice because of the resulting design complexity. For example, the BFW recovers heat from the site hot composite curve might require the BFW to be circulated around a number of processes to achieve the required temperature, because a number of different processes are brought together in the construction of the Site Source Profile. Also, the superheating of the steam might require the steam to be circulated around a number of processes. Circulating steam in this way is even more problematic than circulating BFW. Thus, although the targets set based on the site profiles and site composite curves are thermodynamically feasible, they might involve significant undesirable design complexity.

This problem can be overcome by decomposing the site data. The hot and cold composite curves for the individual processes on the site are constructed firstly with steam profile targets matched against the individual processes. And then, the steam profiles of the individual processes are combined to give steam profiles for the whole site. The minimise utility boiler demand is obtained by the same profiles but overlapped the maximise heat recovery through the steam system.

EFENIS-site application

The ‘EFENIS-site’ can be used for system simulation.

The ‘EFENIS-site’ can be used for site system optimization to accounts for: the cost of fuel for steam and power generation; costs for running the steam and power generation, other than fuel costs; power generation; imported or exported power; and the cost of demineralized water or cooling water.

It has been implemented in EFENIS demonstration projects.

Conclusions

In general, the soft tool ‘EFENIS-Site’ can be used for understanding site utility infrastructures, optimizing existing utility system configurations, targeting cogeneration potential, choosing the most appropriate cogeneration system, optimizing site steam pressures

and loads, design and operation of steam turbine networks, minimizing energy costs for the site, and reducing flue gas emissions from the site.

The 'EFENIS-Site' has been applied to EFENIS demonstration projects.

References

Dhole VR, Linnhoff B. Total site targets for fuel, co-generation, emissions and cooling. Computers & Chemical Engineering 1993; 17(Suppl.):101-109.

Raissi K. Total site integration. PhD Thesis, UMIST, UK; 1994.

Klemeš J, Dhole VR, Raissi K, Perry SJ, Puigjaner L. Targeting and design methodology for reduction of fuel, power and CO2 on total sites. Applied Thermal Engineering 1997; 7: 993-1003.

Sun L, Doyle S, Smith R. Graphical cogeneration analysis for site utility systems, Clean Technologies and Environmental Policy, 2014,16: 1235-1243

Sun L, Doyle S, Smith R. Cogeneration Improvement based on Steam Cascade Analysis, Chemical Engineering Transactions, 2013, 35, 13-18

Li Sun, Robin Smith, Performance Modelling of New and Existing Steam Turbines, Industrial & Engineering Chemistry Research (DOI:10.1021/ie503230910.1021/ie5032309)

Li Sun, Liuchang, Reliable and flexible steam and power system design, Applied thermal engineering, 2015, 79: 184-191

Li Sun, Steve Doyle, Robin Smith. Heat Recovery and Power Targeting in Utility Systems, Energy (accepted)