Development and optimization of power plant concepts for local wet fuels

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This paper explores the role of optimization in different power plant design phases. It provides an overview on the systematic power plant design and descripes a new process analysis procedure called CATTHER (**C**onsept **A**nalysis **T**ool/**Ther**mal). As an example preliminary desing and optimization of local wet fuel based power plant is presented.

Preplanning or pre-engineering differs from detailed design in several ways, including rapid and simplified evaluation of competing processes along with identifying potential problems. The goal of these preliminary studies is to find out the most favourable process alternatives for additional study. By contrast the goal of detailed design is complete and accurate specification of final design and operation parameters. In preliminary desing cycle configuration itself is the major design variable defining significantly fortcoming economy of the power plant.

There has been published several methods feasible for different optimization tasks of thermal systems (Linnhoff, Bejan, Press, Rao). The nature of optimization is present in all basic design tasks, which should be seen as a process mixed with both detailed and comprehensive design tasks. This design process varies by companies, by projects and the amount and the quality of expertness used.

The biggest difficulty of power plant optimization is caused by the process nature of design work. In the starting point of design process most comprehensive optimizations should be done but the lack of needed dimensioning work weakens the accuracy of it. If high accuracy is targeted in comprehensive optimization tasks then iterative designing is dimensioning and costing should be done. In practise many dimensioning routines have been adopted to control the predimensioning in optimization phase. Typically process component costing information is described as simple scaling exponent functions of production capasities, sizes, etc.

The first optimization phase is power process generation phase and it is based on several thermal rules and it is realised in research phase or in expert design phase in starting point of energy concept development. The aim of process generation phase is identify and thermally optimize all concept alternatives for energy investment. The optimization can be done experienced thermal experts but the use of knowledge based design system helps to systemize this design phase. Design rules for generation process connections and optimal energy regeneration can be identified. So thermodynamic optimum of each power process can be determined. The used knowledge includes information from both thermal expertise and basic designing of power plants.

The objects of optimization can be determined for each design phase. For the preplanning phase of energy investment project the optimization objects include the size of production capacities of the power plant and its equipment, the specifications of fuels and the technical and operational concepts. This design phase can be controlled by a group of optimisation methods called mathematical programming. Mathematical programming includes mathematical model of the optimization task as a mathematical objective function and its constraints. Objective functions and constraints can be linear or nonlinear called linear programming (LP) or nonlinear programming (NLP). If the part of design variables can have only integer values, then the problem is called an mixed integer programming problem. Mixed integer programming can be adopt with linear (MILP) or nonlinear functions (MINLP). NLP is probably the most feasible optimisation method for concept development phase. Integer parameters are not meaningful in energy concept optimisation and they can be eliminated by preceeding process generation phase.

The systematisation of the development work in a power plant investment project can be improved in many different ways and in many separate sectors. In this study the focus of the systematisation is on

thermodynamic expert work. The main target of experts' work is not the basic or detailed designing of a power plant but developing of power plant concept alternatives and the directing of the selection process. No matter how sophisticated computer models are, they cannot generate a single new idea. This creative process is difficult to automize and therefore more interactive process between models and designer is required. To systematize experts work CATTHER procedure is used. It defines the tasks for the thermodynamic expert in the development of power plant concepts.

The name CATTHER takes into consideration the fact that the development work on the power plant concept is only partly thermodynamic development. Comprehensive development expertise is connected with the fuel selections. Expertise of combustion chemistry can be considered to be as important as thermodynamics. By combustion development expertise is meant expertise in fuel prehandling and feeding systems, combustion systems, boilers, flue gas treatment, fly ash systems etc. Other expertise areas relevant in concept development are the reliability expertise connected with the specifications of reliability criteria for automation, maintenance and process equipment and the energy production expertise connected with the operation modes of the plant. They are all excluded from this study. However, they can be developed parallel to thermodynamic development in the same design process.

Wet fuel driven power plants are well suited for the analysis of power plant planning since number of connection possibilities increases considerably because the drying of the fuel forms its own subprocess which has to be integrated in the power production. This analysis concentrates on three connection alternatives containing a similar steam power process:

A. No fuel drying, preheating of combustion air is done by flue gases (by luvo).

B. No fuel drying, combustion air is preheated with extraction steam airheaters.

C. Fuel is dried in the mixing dryer and preheating of combustion air is done by steam airheaters. The energy for drying is taken from the combustion process and dryer produces steam for district heating process.

Profitability model of different process alternatives include fuel acquisition costs (harvesting, transpotation), investment costs (described using simple correlations for main components), and operational costs. Since the purpose is to demonstrate pre-engineering phase optimization fast problem setup is done using Excel spreadsheets. Excel includes optimization tool called Sorver, which can be easily used for solution of constrained optimization problems.

References

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