A NOVEL METHODOLOGY FOR IMPROVING THE DESIGN OF COMMUNITY SCALE ENERGY SYSTEMS

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Overview

The initial choice of the energy system components and the way they should interact are crucial decision which the outcome of the design heavily relies on. The most popular practiced approach for deciding the synthesis of large scale energy systems (such as communities like cities, regions or countries) are based on engineering experience and judgment. The outcome of this approach depends mainly on the individials' background and experiences. Consensus could be reached when a widely accepted principal has been used together with engineering judgment for choosing the components and their interactions within the system. The purpose of the research is to present an improved methodology for a design of integrated energy systems. The proposed methodology makes use of a thermodynamic concept (namely exergy matching) in addition to engineering judgment to assist in the choice of the system components and the way they should interact. The advantage of the methodology is demonstrated by implimention for design of district heating system for a district.

Methods

The methodology uses three main tools: In the initial stages of the design of the energy system, a thermodynamic concept is used through a tool called Exergy Matching Diagram (EMD) for defining the design cases by choosing the components of the energy system and the way they should interact. Moreover the exergy flow modeling is also performed in order to have a more realistic evaluation of the technical performance of various design cases. Together with the previous tools the Generalized Reduced Gradient (GRG) nonlinear optimization algorithm is also used for identifying the optimum level of interaction between components and also the suitable design case for each condition. The main criterion for optimization is minimization of the annual energy related costs subject to operational and demand constraints.

Results

Some of the results could be summarized as below:
First: Optimum design of district heating system was found subject to variations in energy prices and heating devices' efficiencies.
Second: Contrary to energy efficiency, exergy efficiency clearly points out the design with best energetic performance.
Third: Exergy optimum design becomes the most economically feasible option as the energy prices tend to rise towards the international prices. The technical performance of this system is demonstrated in Figure 1. The optimum design obtained displays 17% improvement in exergy efficiency, 10.8% reduction in CO_2 production per capita and 2% reduction in overall energy related costs.
The results are sensitive to energy prices. Therefore the sensitivity analysis has been also performed to demonstrate the optimum economic design case in each situation. A sample result is demonstrated in Figure 2. Were Case 1 is district heating without additional electricity generation, Case 2 is additional electricity generation through steam turbine but no district heating, in Case 3 the output heat from steam turbine is used for district heating, finally Case 4 is similar to Case 3 but additional heat is directly extracted from HRSG for district heating.

Conclusions

The effectiveness of the proposed methodology is shown in this study. In addition, it was shown that design improvement opportunities could be realized more easily through use of the proposed methodology.
There is agreement between numerical results and qualitative analysis of different cases using EMD.

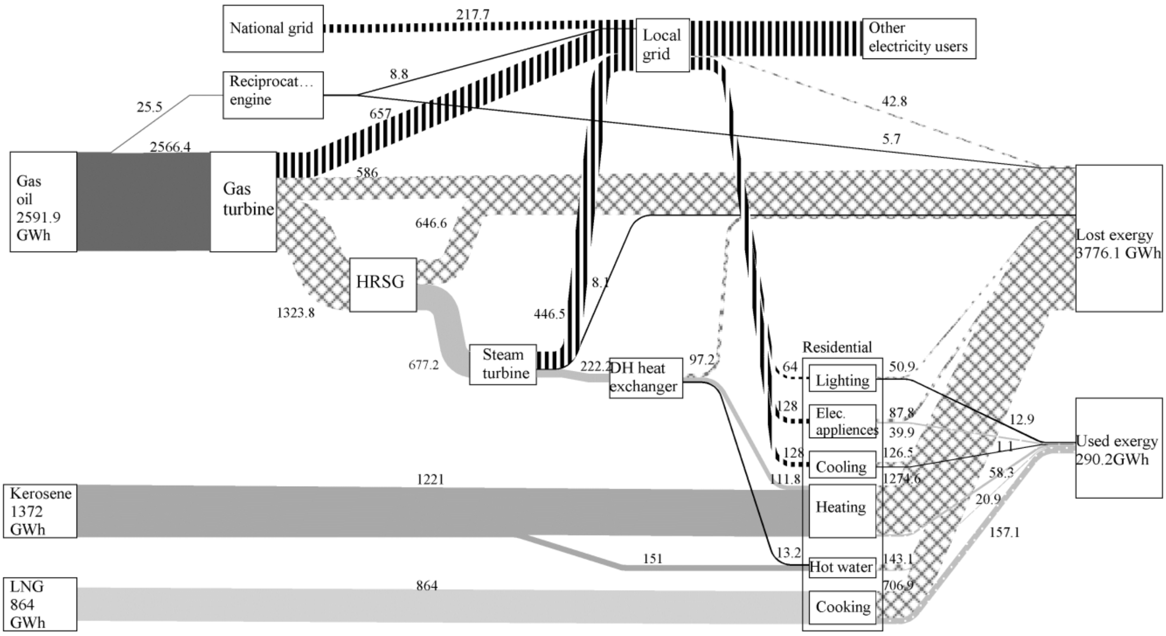

Figure 1 Exergy flow for the energy optimum design.

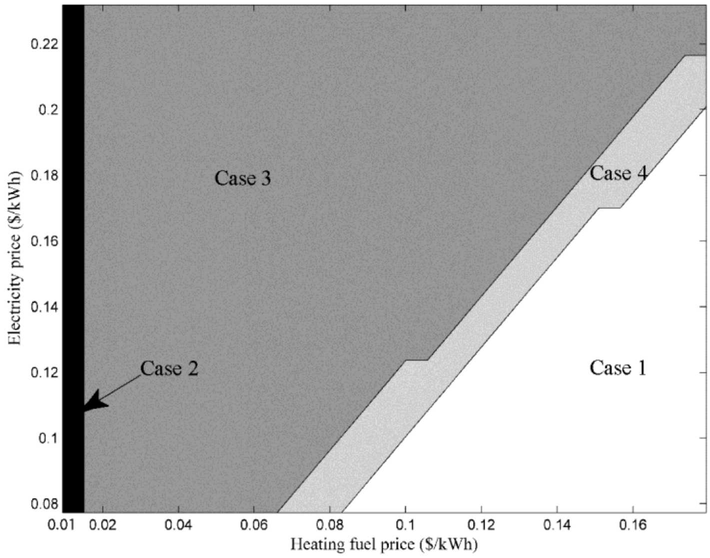

Figure 2 The optimum design case changes as the electricity and heating fuel prices change

The agreement of the optimum economic and environmental design with the exergy optimum design suggest considering optimum exergetic performance as a suitable criteria for arriving at long-term sustainable design. Moreover the results indicate the importance of using exergy for understanding the technical merit of each design case. The methodology presented in this research could be used for defining sustainable design options for community scale energy systems. Appropriateness of each option could be found subject to important environmental parameters (as shown in Figure 2) assisting policy makers in their decision making.

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