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Simulation programme for Part Load Operating Analysis of Total Energy Units with Diesel Engines

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Abstract: - Total Energy Units with combustion engines are generally planned for the coverage of the base load and usually work with constant power. Still there are more and more application areas in which Cogeneration Units are supposed to work with variable power and accordingly it is required to calculate and analyse the Part Load Operation. The Cogeneration Units have to be treated as complex, several componential energetic systems. The interaction of the multiple varying parameters is the subject of this elaboration. On fond of some chosen Combine Heat and Power Units, methods of calculation and simulation programmes have been elaborated, to enable the analysis of the Part Load Operation and to consider most of the parameters. Thus, the optimum dimensioning of energetic systems with Block Heat and Power Plants, in which the variable operating parameters are considerable and predictable, becomes possible. The analysis concerned, contains the heat transfer calculation as well as the combustion calculation at variable operating conditions.

Key-Words: - Total Energy Units, Part Load Operation, Energy and Combustion Calculation, Simulation of Operating Conditions

1 Introduction

The Total Energy Units working with combustion engines are nowadays used in different objects as local Cogeneration Energy Supply Systems. The common philosophy at the dimensioning of these installations is their use for covering the base load, though in the more and more complex systems, this condition can only be fulfilled with limitations. By this means it becomes necessary to analyse and optimise the Part Load Operation of total Energy Units.

This problem was investigated in many practical applications, but there is a low theoretical found of systematic analysis. Although different authors have published the results of their practical and theoretical researches [1, 3, 5, 6] there was no theoretical basis of the considered case as a complex solution.

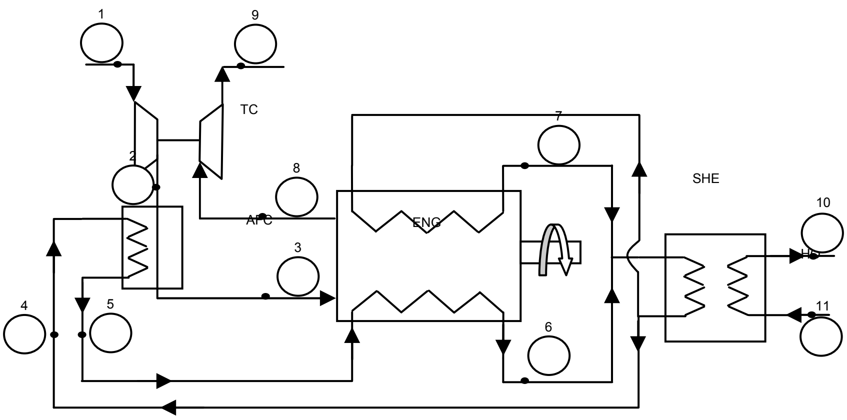
The intention of the accomplished investigation was the elaboration of a simulation programme to analyse the variable operating conditions. With this tool, it is possible to operate the optimum energy management at the application of Total Energy Units in dynamic systems. However, the particular analysis steps are made iterative, which means that the quasi-steady model is applied in the system analysis.

2 Representative Total Energy Unit with Diesel Engine

On the basis of the accomplished investigations, analyses and simulation programmes for different types of Total Energy Unit systems were elaborated. The differences between the various systems exist in the circuit of the heat exchanger (use of waste heat) as well as in the dimensioning of the components (e.g. with or without turbo charging, air-fuel ratio cooling and others).

Figures 1 and 2 show two typical possible circuits.

Moreover, the points in the illustrations, in which mass flow rates and thermal parameters are given as base and are calculated respectively, were numbered.



Abbreviations:
AFC - air-fuel ratio cooling unit
EG - exhaust gas
EGHE - exhaust gas heat exchanger
ENG - engine
HO - heat output
SHE - system heat exchanger
TC - turbo charger

Fig. 1: Circuit diagram – option 1

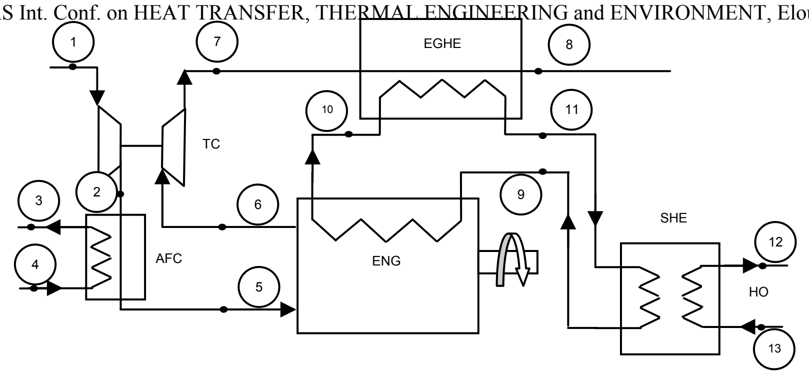


Fig. 2: Circuit diagram – option 2

3 Algorithm

In Fig. 3, the common schema of the analysis and the programme algorithm are represented. The method is suitable for both the calculative simulation of existent objects and as a dimensioning tool for newly designed systems.

In the following, the modules will be characterised:

- **Input module 1:**
- Fuel data from databank or new designation,
- Engine and generator data,
- Circuit diagram selection,
- Boundary conditions; especially ambient parameters and prescribed temperature of heating and cooling circuits;

- **Calculation module 1:**

Complete combustion calculation [2, 4, 9] for gaseous and fluid fuels, including incomplete combustion and influence of the combustion-air temperature and humidity;

- **Module 1:**

Combustion calculation for gaseous fuel;

- **Module 2:**

Combustion calculation for fluid fuel;

- **Module 3**

Calculation of heat capacity of the air-fuel mixture cooler;

- **Module 4**

The energy flows (on the basis of the results of the combustion calculation) and the total energy balance;

- **Module 5**

Heat Transfer calculations for circuit diagram 1;

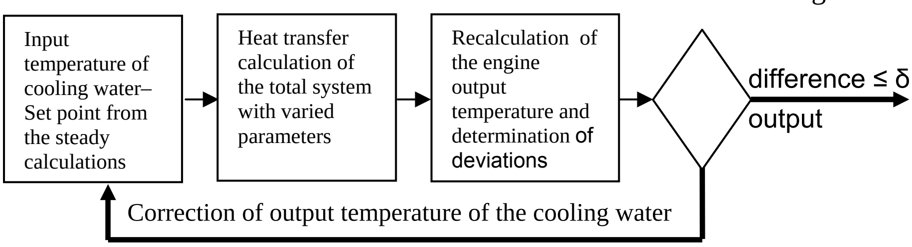


Fig. 3: Method of iteration to determine the quasi-steady operating conditions

- **Module 6**

Heat Transfer calculation for circuit diagram 2;

- **Output module 1:**
- Heat Transfer Units,
- Power balance, energy and mass flow rates;

- **Input module 2:**
- Data about the system- , waste gas- and auxiliary-heat exchangers,
- Hydraulic data (diameter, hydraulic characteristics and the like);

- **Calculation module 2:**

Iterative calculation (quasi-steady process) of the mass and energy flows and hydraulic calculations on the basis of the data from input module 1 and 2;

- **Module 7:**

Execution of the calculations (calculation module 2) for circuit diagram 1;

- **Module 8:**

Execution of the calculations (calculation module 2) for circuit diagram 2;

- **Output module 2:**
- Energy flows and energy balance,
- Fuel data, amount of combustion air,
- Consistence of waste gas,
- mass and energy flow rates,
- efficiency,
- Leakage of pressure and hydraulic dimensioning respectively;

The quasi-steady analysis [7] consists of the iterative calculation of the heat transfer at the operating conditions' variation. The output temperature of the cooling water was chosen as the knot-point of the iteration. The general proceeding is illustrated schematic in figure 4.

The analysis was programmed in VisualBasic and the mathematic modules were run in MatLab. In the context of the presentation, the possibilities of the programmes will be displayed.

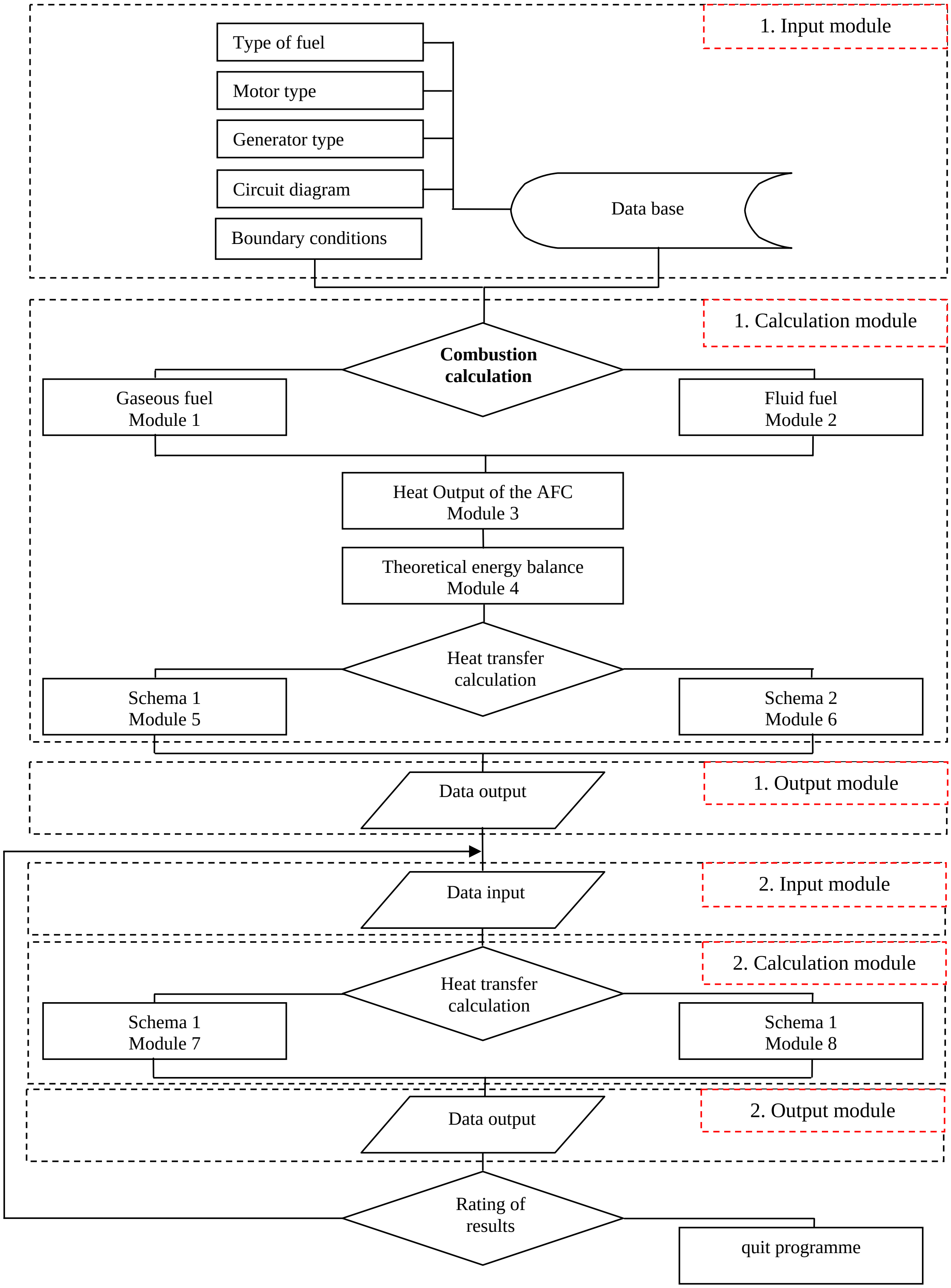


Fig. 4: Algorithm for calculation and modelling of Total Energy Units

4 Additional calculations and results

Asides to the fundamental modules mentioned under point 3, additional technical issues of optimisation were examined. As example are shown the results from the investigation of the influence of connecting tube's diameters on the complete system efficiency. From the given system data, the tube diameter of nominal 65 mm was minimised to 50 mm and maximised to 80 mm. The energetic and exergetic variation of efficiency and relative cost analysis are illustrated in figure 5 and table 1.

Moreover, other operating optimisation issues were investigated, e.g. influence of the fouling in the heat exchangers on the heat transfer and operating parameters of the system, just as aspects of efficiency and cost optimisation [8, 10].

5 Conclusion

The worked out procedures of calculation and optimisation give the possibility to simulate and investigate the operation of Total Energy Units on Part Load. In this way, numerous optimisation issues of the energy management can be simulated and treated calculative. Furthermore, selected operating and profitability aspects, such as the influence of different constructive and system modifications, were analysed. By such complex analysis, the Part Load Operation of Total Energy Units can be forecasted and accordingly be adjusted to the standards of varying application possibilities.

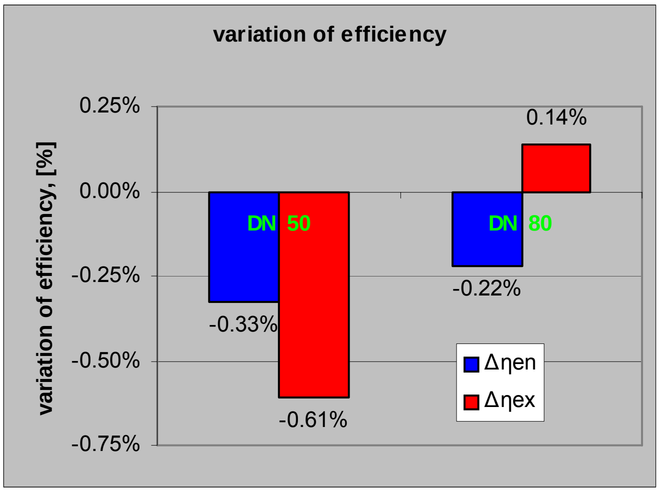


Fig. 5: Influence of the connection pipeline's tube diameter on the energetic and exergetic total efficiency (nominal diameter 65 mm)

Diameter nominal DN 65	Relative changing of operating costs %		
	Pump efficiency	Heat loss	Variation of total costs
50	0,43	-0,05	0,42
80	-0,12	0,04	-0,08

Table 1: Relative changing of operating costs at a variation of the diameter of connecting tubing.

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