Establishing a trigeneration solution to increase the operational efficiency of a heat engine plant

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Trigeneration is a method of increasing global energy efficiency, which is based on the use of residual heat that is otherwise discharged into the atmosphere. The purpose of this article is to identify a method of increasing the efficiency of a plant by implementing a trigeneration solution. In this paper, compressor and absorption refrigeration installations were analyzed. Considering the main objective of the power plant, to produce and sell the electric energy produced by the two thermal motors and to utilize the thermal energy, the implementation of a solution of trigeneration with absorption has proved viable. As a result of the analysis of the operating curves of the plant, a thermal potential resulted, which could be used in an absorption plant for the production of about 2.9 MW of cold. The amount of cold produced will be used to maintain a refrigeration temperature in a fruit and vegetable store near the power plant.

Key words: Tri-generation, CHP, district heating, heat losses

1. Introduction

Operating in cogeneration is a method of increasing the overall efficiency of a plant, through total or partial use of residual heat, otherwise lost to the atmosphere.

In this paper, the authors analyze the solutions which can be developed in case of a combined heat and power producer which aims to sell the most possible quantity of the electrical energy produced by the heat engines and at the same time, to make use of the available excess heat occurring as a result of lower demand, through implementing a trigeneration solution. There are various types of consumers who have a cooling demand, such as city halls, hospitals, fruit warehouses [1] and [2].

The combined heat and power plant is equipped with:

- Two heat engines by Rolls-Royce, with 6800 kWel power output and the electrical efficiency of 47.22%;

- The flow of flue gases at the outlet of the turbocharger is 39500 kg/h, with a temperature of 350 °C.

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• A hot water boiler of 58 MWt (50 Gcal/h) and a steam boiler of 10 t/h, which produces steam, p=10 bar, t=176°C, to cover the internal steam demand and for the preparation of added water for the heating circuit of the plant.

A problem that the plant faces with is that, although there are periods of time when selling the electricity is profitable, due to the decreasing of heat demand, there is excess heat which appears when operating the engines at nominal parameters. In these circumstances, during the summer time, one of the two heat engines is stopped. A solution to this problem entails the implementation of a trigeneration application in accordance with the available heat potential.

2. Process description

There have been analyzed two refrigeration technologies: compression and absorption.

Compression refrigeration system

In a trigeneration plant equipped with a compressor refrigeration plant, the compressor of the refrigeration plant can be directly connected to the engine or can use the electric power produced by the engine to drive it. The variant of the direct connection to the engine implies the exclusion of energy losses in the case of an electric generator, instead requires the operation of the refrigeration system throughout the engine operation. The complete separation of the refrigeration system from the thermal engine has the disadvantage of energy loss in the electric generator. Instead it is completely autonomous and can function independently.

This solution has a disadvantage related to the consumption of electricity for the production of cold, but the amount of cooling agent of the refrigeration plant is lower than that of the absorption refrigeration plant and the average cooling coefficient is around 5.

Absorption refrigeration system

Another solution of the internal combustion engine based triggering plant is the one that uses the cooling system with absorption to produce the cold. Absorption refrigeration facilities represent about 10% of all cooling technologies, with a very high potential for growth in the future. In this case the cold is produced using a part of the thermal energy produced in the power plant [3].

The main advantage of this technology comes from the fact that any residual heat that may come from: cogeneration, waste incineration plants, etc. can be used as a source. The average coefficient refrigerant is around 1.

3. Methodology

The proposed solution is to integrate an absorption cooling system, which uses the heat potential of the flue gases, as can be seen in Figure 1. Operating the absorption cooling system implies the thermochemical compression of the refrigerant, by using a binary mixture, which requires heat consumption [4] and [5].
Where: $W$ - electrical energy; $Q_{PT}$ - heat for the heating substation; $Q_{G}$ - heat for a cooling system; $Q_{inc}$ - heat for the heating water circuit; $Q_{ACC}$ - heat for the domestic warm water circuit; $Q_{Ev}$ - cold produced.

In Figure 1, the electrical energy production is noted as $W$, while the heat production is noted as $Q_{th\_rec}$. The heat recovered from the engines during winter time $Q_{PT}$ is transported to a heating substation for the preparation of the heating agent and the domestic warm water. During summer, $Q_{G}$ is transported towards the generator of an, where $Q_{Ev}$ cooling is produced.

![Figure 1: Integrated diagram of the system](image)

In case of the trigeneration solution, there has been determined the amount of cold $Q_{Ev}$ which can be produced, considering the available heat potential $Q_{G}$, the energy consumption for pumping $P$ and the coefficient of performance $COP$ of the absorption cooling equipment as shown in equation 1.

$$COP = \frac{Q_{Ev}}{Q_{G} + P}$$  \hspace{1cm} (1)

4. Results and discussion

Following the analysis of the plant operation, the thermal load duration curves were drawn, as can be seen in Fig. 2, showing an important potential for thermal energy that could be used in the trigeneration plant during the summer.
The trigeneration solution entails that one of the engines, which is otherwise off due to low heat consumption, will be operating during the summer. The thermal potential which could be used in an absorption cooling system is approx. 2.9 MW.

If the coefficient of performance of the cold production plant increases from 0.2 to 1.2, a significant amount of cold production can be achieved, from 0.5 MW to 3.5 MW, as shown in table 1.

<table>
<thead>
<tr>
<th>COP</th>
<th>Q cold</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>588.33</td>
</tr>
<tr>
<td>0.4</td>
<td>1176.66</td>
</tr>
<tr>
<td>0.6</td>
<td>1764.99</td>
</tr>
<tr>
<td>0.8</td>
<td>2353.32</td>
</tr>
<tr>
<td>1</td>
<td>2941.65</td>
</tr>
<tr>
<td>1.2</td>
<td>3529.98</td>
</tr>
</tbody>
</table>

In this case, there will be analyzed the possibility of producing the cold close by the plant by supplying it to a warehouse/storage facility for fruits and vegetables. A remote consumer would imply analyzing the transport system, which would allow the circulation of the high temperature agent.

5. Conclusions

The proposed trigeneration solution allows for the plant to operate both of the engines during summer, thus producing electricity in a profitable way and making use of the heat potential by harnessing it in an absorption equipment to produce a significant amount of cold (approx. 1.7 MW), to be consumed.

REFERENCES


