An investigation of a household size trigeneration running with hydrogen

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Presentation Outline

• Introduction
• The design of the trigeneration
• Simulation Software
• Results and Discussions
• Conclusions
1. Introduction
The objective of the study

- To investigate the performance, efficiency and emissions of a micro-scale trigeneration based on a diesel engine genset using hydrogen as the fuel in a domestic application
- To compare with that of single generation & cogeneration, fuelled with hydrogen
- To compare the performances of the above 3 generations when using original diesel fuel
2. The design of the trigeneration
Background:

Sources of CO$_2$ gas emissions
**Background:** The design of the system

- The design of the system is based on the energy (including electricity and heat) consumptions in the households in the UK [References 19 – 27].

- A diesel engine genset (6.5 kW) is selected for the generation of electrical power;
- A heat recovery system is designed and used for heat recovery and storage;
- an absorption refrigerator is selected for the household refrigeration requirements.
Schematic diagram of the 6.5kWe diesel engine Trigeneration
Schematic diagram of the 6.5kWe diesel single generation
Schematic diagram of the diesel engine cogeneration
The Yanmar Engine used in the study
3. Simulation Software
Simulation software

ECLIPSE developed by Ulster University and used for techno-economic analysis of power systems.

Uses generic chemical engineering equations and a capital costing program with over 100 equipment types.

Chemical compound properties and plant cost database can be modified to allow new or conceptual processes to be evaluated.

Techno-economic assessment studies are carried out in stages; initially a process flow diagram is prepared, technical design data can then be added and a mass and energy balance completed.
Simulation software
4. Results and Discussion
Generations flow diagram in ECLIPSE

(a) Single generation.
Generations flow diagram in ECLIPSE

(b) Cogeneration
Generations flow diagram in ECLIPSE

(c) Trigeneration
Table 2: Technical and Emission Results at Engine Full Load (6.5 kW electricity output)

<table>
<thead>
<tr>
<th>Fuel used</th>
<th>Diesel</th>
<th>Hydrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>S_gen*</td>
<td>Cogen</td>
</tr>
<tr>
<td>Fuel input (kg/s) x 10^{-3}</td>
<td>0.498</td>
<td>0.498</td>
</tr>
<tr>
<td>LHV (MJ/kg)</td>
<td>42.893</td>
<td>42.893</td>
</tr>
<tr>
<td>Total thermal input (kW_{th})</td>
<td>21.36</td>
<td>21.36</td>
</tr>
<tr>
<td>Electrical output (kWe)</td>
<td>6.53</td>
<td>6.53</td>
</tr>
<tr>
<td>Electrical efficiency (%)</td>
<td>31%</td>
<td>31%</td>
</tr>
<tr>
<td>Engine exhaust temperature (°C)</td>
<td>557</td>
<td>557</td>
</tr>
<tr>
<td>Carbon Dioxide emissions (kg/kWh)</td>
<td>0.855</td>
<td>0.324</td>
</tr>
<tr>
<td>Exhaust gas mass flow (kg/min)</td>
<td>0.7650</td>
<td>0.7650</td>
</tr>
<tr>
<td>Heat recovered from cooling system and exhaust (kW_{th})</td>
<td>10.7</td>
<td>10.06</td>
</tr>
<tr>
<td>Total useful energy output (kW) (Electricity + Heat + Refrigeration)</td>
<td>6.53</td>
<td>17.23</td>
</tr>
</tbody>
</table>
Table 2: Technical and Emission Results at Engine Full Load (continued)

<table>
<thead>
<tr>
<th>Fuel used</th>
<th>Diesel</th>
<th>Hydrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>S_gen*</td>
<td>Cogen</td>
</tr>
<tr>
<td>Exhaust temperature at exit of the system (°C)</td>
<td>(450)</td>
<td>150</td>
</tr>
<tr>
<td>Heat consumption of refrigeration (kW)</td>
<td>0.61</td>
<td>0.61</td>
</tr>
<tr>
<td>Refrigeration effect at – 10 °C (kW)</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>Refrigeration effect at +5 °C (kW)</td>
<td>0.29</td>
<td>0.29</td>
</tr>
<tr>
<td>COP</td>
<td>0.66</td>
<td>0.66</td>
</tr>
<tr>
<td>Overall efficiency</td>
<td>31%</td>
<td>81%</td>
</tr>
</tbody>
</table>

* Singlegen – Single generation, Cogen - Congeneration, Trigen - Trigeneration
Results (Overall efficiency)

[Graph showing overall efficiency vs. engine load for different types of generation: Single generation, Cogeneration, Trigeneration.]
Results (Overall efficiency)
Results (Useful energy output)
Results (Useful energy output)

(b) Hydrogen
Results (Brake Specific Fuel Consumption)
Results (Brake Specific Fuel Consumption)
Results (CO₂ Emissions)

- **Single Generation**
- **Cogeneration**
- **Trigeneration**

The graph shows the CO₂ emissions (kg/kWh) as a function of engine load. The emissions decrease significantly with increasing engine load, with trigeneration having the lowest emissions at all load levels.
Conclusions

From the above results and discussions, conclusions can be drawn:

- It is feasible to use hydrogen as the fuel to run the domestic micro-trigeneration based on a diesel engine genset.

- The efficiencies of the single generation, trigeneration and cogeneration run by hydrogen are comparable to those run by diesel, respectively.

- The micro-trigeneration has much higher overall efficiency and higher useful energy output than that of single generation.
Conclusions

- The trigeneration produces zero CO\textsubscript{2} emissions when fuelled with hydrogen. This means, if the hydrogen used is from renewable resources, the hydrogen fuelled trigeneration will be a net-zero energy system for the application in households. It has also much lower CO\textsubscript{2} emissions than that of single generation when fuelled with diesel.

- Although the trigeneration has a lower overall efficiency and lower useful energy output than that of cogeneration, it has one more useful refrigeration output using a small part of waste heat from the genset.
Thank you!

Questions?
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