Optimisation of water and energy consumption in industrial water circuits: a case study.

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ABOUT SIC

SUSTAINABLE INNOVATION CENTRE

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TECHNICAL EXCELLENCE

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PROJECT COORDINATION

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ABOUT SIC

ISQ’s Sustainable Innovation Centre provide technical and scientific support to Industry within a large range of multisectorial competences aiming to achieve improved industrial competitiveness and sustainability.
Motivation for WaterWatt project

Industrial Water Circuits (IWC):

- Water Consumption
- Energy Consumption

- 40% of the total water consumption in Europe
- Frequently neglected streams (secondary to the production process)

- Industrial Sector – 25.3% of Final end use of Energy

- Electric Motors – 65% of Electric Energy Consumption

- Pumping Systems – 21% of Electric Motors Energy Consumption

Energy Efficiency Improvement

Europe 2020 Strategy

Development and Application of alternative strategies

Development of tools and guidelines to decrease energy consumption in IWC
Aims and objectives of the present work

Remove market barriers for energy efficient solutions in industrial water circuits, through:

• Case studies in relevant industries;
• Development of improvement measures for energy efficiency in industrial water circuits;
• Market studies;
• Capacity building activities;
• Dissemination in workshops and by e-learning

➢ The present work presents a model that has been developed in OpenModelica Software in order to analyse the energy consumption of an IWC case study of the project.

➢ Different improvement measures are proposed and energy savings and payback are estimated.
## Summary of Case Studies

<table>
<thead>
<tr>
<th>Industry</th>
<th>Case study</th>
<th>Country</th>
<th>Representative circuits</th>
<th>Nr*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal</td>
<td>Stainless wire processing</td>
<td>DE</td>
<td>Open cooling circuit (rolling mill) with sand filtration</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Closed cooling circuit (inductive furnace)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Carbon steel production</td>
<td>UK</td>
<td>Closed cooling circuit (blast furnace)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE</td>
<td>Open gas washing circuit (basic oxygen furnace)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO</td>
<td>Open cooling/quenching of rebar rods and wire coils</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Manganese production</td>
<td>NO</td>
<td>Closed cooling circuit</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Open gas washing circuit</td>
<td>7</td>
</tr>
<tr>
<td>Chemical</td>
<td>Pharmaceuticals</td>
<td>DE</td>
<td>Open cooling circuit</td>
<td>8</td>
</tr>
<tr>
<td>Paper</td>
<td>Pulp transportation and pressing</td>
<td>PT</td>
<td>Fiber transportation circuit</td>
<td>9</td>
</tr>
<tr>
<td>Food and beverage</td>
<td>Sugar production</td>
<td>PT</td>
<td>Water treatment (filtration)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Open cooling circuit</td>
<td>11</td>
</tr>
</tbody>
</table>

**Electric Energy Consumption:** 2327 ktoe/year in the Iron and Steel Industry (about 12% of the total energy consumption of the industrial sector)

**Water Consumption:** About 581 $hm^3$ in the production of basic metals in the manufacturing industry (85% corresponding to cooling water)
Case study: Cooling Circuit of a Hot Rolling Mill

Water cooling circuit of a steel wire processing plant in Germany in which steel billets are transformed into wire.

1. The billets are previously heated in an inductive furnace and sent through a series of rolls (rolling mill). The rolls and the rolled material need to be continuously cooled with water to prevent equipment damage and to reach required material quality.

2. The water is treated through oil separator, cyclone and afterwards water is treated in sand filters.

3. Treated water is pumped to the cooling tower where it is cooled down.
Modelling in OpenModelica software

Input: Equipments parameters and operation conditions
## Operation Conditions

### Pump Groups Specifications

<table>
<thead>
<tr>
<th></th>
<th>Pump Group 1</th>
<th>Pump Group 2</th>
<th>Pump Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power</strong></td>
<td>82 kW</td>
<td></td>
<td>92 kW</td>
</tr>
<tr>
<td><strong>Volumetric flow rate</strong></td>
<td>500 m3/h</td>
<td></td>
<td>600 m3/h</td>
</tr>
<tr>
<td><strong>Static Head</strong></td>
<td>48,0 m</td>
<td></td>
<td>47,5 m</td>
</tr>
<tr>
<td><strong>Pump rotational speed</strong></td>
<td>1450 rpm</td>
<td></td>
<td>1450 rpm</td>
</tr>
<tr>
<td><strong>Motor Efficiency</strong></td>
<td></td>
<td></td>
<td>90 %</td>
</tr>
</tbody>
</table>

### Cooling Tower Fans Specifications

<table>
<thead>
<tr>
<th>Power</th>
<th>22 kW</th>
</tr>
</thead>
</table>

### Circuit Specifications

| Operational Time       | 6600 h (per year) |
Optimisation Measures - Application of Variable Speed Drives in Pumps

Why?

- Provides the automatic flow adjustment to the process needs
- Allows the dynamic adjustment of the pump rotation frequency to the optimal efficiency point
- In pump groups, the replacement of the on/off cycle to the continuous operation allows significant energy savings

Applied into the circuit

- For this circuit, the initial rotational speed of the pump motors of 1450 rpm was decreased to 1350 rpm

Pump curves observation; flowrate; pressure drop.
## Optimisation Measures - Application of Variable Speed Drives in Pumps

### Results

<table>
<thead>
<tr>
<th>Measure</th>
<th>Annual energy savings (MWh)</th>
<th>Investment cost (€)</th>
<th>Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Couple VSD in pump group 1</td>
<td>231,74 (19%)</td>
<td>21.62</td>
<td>1.0</td>
</tr>
<tr>
<td>Couple VSD in pump group 2</td>
<td>231,05 (19%)</td>
<td>21.62</td>
<td>1.0</td>
</tr>
<tr>
<td>Couple VSD in pump group 3</td>
<td>266,24 (20%)</td>
<td>21.62</td>
<td>0.9</td>
</tr>
</tbody>
</table>

- Typical values of energy savings with such application (20%) are reached.
- It reveals as a favorable measure due to its low payback time (11 months to 12 months) for all pump groups.
Why?

- Corresponds to the mechanical cleaning and overhaul of a pump to restore its initial functioning, namely its energy efficiency.
- It is known that pumps without maintenance over the years generate a lower flow.

Applied into the circuit

- The optimisation measure for the pumping system of this circuit considered the refurbishment of all pumps.
- An improvement of 10% in the hydraulic efficiency of the pump (value set in IMechE)
## Results

<table>
<thead>
<tr>
<th>Measure</th>
<th>Annual energy savings (MWh)</th>
<th>Investment cost (€)</th>
<th>Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refurbishment of the pumps</td>
<td>524,175 (12%)</td>
<td>436</td>
<td>0.01</td>
</tr>
</tbody>
</table>

- Allows reasonable energy savings
- It is a peculiarly advantageous measure because presents a low payback time, due to the low investment cost for the implementation of such measure
Optimisation Measures – Change of electric motors

Why?

- The change from standard motors to IE3 Premium Efficiency motors allow considerably energy savings
- An higher efficiency motor is more expensive than a conventional motor
- An higher efficiency motor lifespan is much longer, as it operates at a lower temperature and hence heat losses are lower

Applied into the circuit

- In this circuit, the pump motors with an initial mechanical efficiency of 90% were exchanged to IE3 electric motors with a mechanical efficiency of 95.4%
Optimisation Measures – Change of electric motors

Results

<table>
<thead>
<tr>
<th>Measure</th>
<th>Annual energy savings (MWh)</th>
<th>Investment cost (€)</th>
<th>Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change motors to high-efficiency ones (IE3)</td>
<td>212,46 (6%)</td>
<td>134.92</td>
<td>6.9</td>
</tr>
</tbody>
</table>

- The measure has not the same propitiousness as the aforementioned ones (produces less energy savings and presents a longer payback period)
- The pump motors are changed at the end of their lifecycle, and, as such, savings can be expected at that time
Optimisation Measures – Variable Speed Drives (VSD) in Cooling Tower Fans

Why?

- Allow a dynamic adjustment of the airflow respecting the required temperature values in the circuit.
- Adjustments by decreasing the fan speed allow high energy savings (energy consumption is directly associated to the operation of the fan).

Applied into the circuit

- In this circuit, the initial speed of the four cooling towers fans of 1450 rpm was decreased to the optimal value of 1350 rpm.

Fan curves observation; flowrate; pressure drop.
Results

<table>
<thead>
<tr>
<th>Measures</th>
<th>Annual energy savings (MWh)</th>
<th>Investment cost (€)</th>
<th>Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Couple VSD in fans</td>
<td>157,39 (27%)</td>
<td>14872</td>
<td>1,0</td>
</tr>
</tbody>
</table>

- This measure is quite propitious, with high energy savings and a relatively low payback period
Why?

- In water treatment process, sand filters present considerable impact on energy efficiency due to lower pressure drop induced into the water.

Applied into the circuit

- The optimisation measure for the treatment section was to replace the two sand filters with a pressure drop of 1.3 bar to new ones with a pressure drop of 0.5 bar.
## Optimisation Measures – Change of water filters

### Results

<table>
<thead>
<tr>
<th>Measures</th>
<th>Annual energy savings (MWh)</th>
<th>Investment cost (€)</th>
<th>Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>iii) Change filters (dp: 1.3 bar to 0.5 bar)</td>
<td>146.67 (4%)</td>
<td>42.19</td>
<td>3.1</td>
</tr>
</tbody>
</table>

- The measure has not the same propitiousness as the aforementioned ones (produces less energy savings and presents a longer payback period)

- Similarly to the pump motors, filters are changed at the end of their lifecycle, and, as such, savings can be expected at that time
Combination of measures
Optimisation Measures – Application of VSD in Pump Motors + Refurbishment

Results

<table>
<thead>
<tr>
<th>Measures</th>
<th>Annual energy savings (MWh)</th>
<th>Investment cost (€)</th>
<th>Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coupling VSD and Refurbishment in pump group 1</td>
<td>400,60 (29%)</td>
<td>21.79</td>
<td>0,6</td>
</tr>
<tr>
<td>Coupling VSD and Refurbishment in pump group 2</td>
<td>399,83 (29%)</td>
<td>21.79</td>
<td>0,6</td>
</tr>
<tr>
<td>Coupling VSD and Refurbishment in pump group 3</td>
<td>452,77 (29%)</td>
<td>21.79</td>
<td>0,5</td>
</tr>
</tbody>
</table>

- Reveals as the most propitious arrangement, since it produces the larger reduction in energy consumption associated to an acceptable payback period
### Optimisation Measures – Application of VSD in Pump Motors + change of motors

#### Results

<table>
<thead>
<tr>
<th>Measures</th>
<th>Annual energy savings (MWh)</th>
<th>Investment cost (€)</th>
<th>Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coupling of VSD and Change motors to high efficiency ones in pump group 1</td>
<td>286.57 (24%)</td>
<td>66.59</td>
<td>2.5</td>
</tr>
<tr>
<td>Coupling of VSD and Change motors to high efficiency ones in pump group 2</td>
<td>285.84 (24%)</td>
<td>66.59</td>
<td>2.5</td>
</tr>
<tr>
<td>Coupling of VSD and Change motors to high efficiency ones in pump group 3</td>
<td>327.86 (24%)</td>
<td>66.59</td>
<td>2.2</td>
</tr>
</tbody>
</table>

- It reveals as a very attractive measure presenting, with high energy savings and relatively low payback times
- It is beneficial on a technical point of view, as the application of VSD reduces of the motors lifetime and replacing to a high efficiency motor enables to overcome such limitation
Conclusions

- The analysis of the presented case study shows that indeed there is a large potential for energy savings and improvement of the efficiency in industrial water circuits (IWC).

- The results show that was possible to achieve up to 29% of energy savings.

- The simulation tool allows a prior analysis of efficiency measures to be implemented in the IWC, avoiding extra costs with technical work (being IWC frequently auxiliary circuits of the industrial process, such analysis still presents a significant impact, which can be of great value for small and medium-sized companies where profit margins are tighter)

- This simulation tool also has the potential to design a circuit at a planning stage, making possible to analyse the implementation of energy efficiency measures from the scratch, namely at the design stage (for example, the diameter of pipework) which for instance reduces pressure drop and consequently the energy demand of the equipment (also reduce additional costs at the operation stage, promoting more competitiveness in industries)
THANK YOU

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