Development of Dalälven Hydropower Scheme in Sweden

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Fortum Hydro Power & Technology
Fortum – a Power and Heat company in the Nordic countries, Russia, Poland and the Baltics
Fortum briefly - Key figures 2013

Nordic countries (Fortum’s share)
- Power generation: 46.5 TWh
- Heat sales: 13.9 TWh
- Distribution customers: 1.6 mn
- Electricity customers: 1.2 mn

Great Britain
- Power generation: 1.0 TWh
- Heat sales: 1.8 TWh

Poland
- Power generation: 0.6 TWh
- Heat sales: 4.0 TWh

Baltic countries
- Power generation: 0.5 TWh
- Heat sales: 1.1 TWh

Russia
OAO Fortum
- Power generation: 20.0 TWh
- Heat sales: 24.2 TWh

TGC-1 (~25%)
- Power generation: ~7 TWh
- Heat sales: ~8 TWh

Financials
- Sales: EUR 6.1 bn
- Operating profit: EUR 1.7 bn
- Balance sheet: EUR 24 bn
- Personnel: 9 900

Next generation energy company
Fortum briefly

Fortum’s Hydropower (excl Kemijoki):
• 139 HPPs in Sweden and Finland
• 257 units
• 250 hydro reservoirs
• Annual production 18 600 GWh (~80 000)
• Installed power 4 275 MW (~19 300)

The Nordic Power System is de-regulated and a totally open market.

Market place Nord Pool established 1996: Sweden, Norway, Finland, Denmark, Estonia, Latvia and Lithuania.

Market penetration turnover 2012 = 334 TWh electricity (77% of the Nordic system electricity utilization)
Dalälven river Scheme

In Dalälven river Fortum owns 35 hydropower plants (of totally 38)

- 57 units
- 50 hydro reservoirs
- Normal production 4 000 GWh/a
- Installed capacity 970 MW
Development of the Dalälven Hydropower Scheme

- Utilisation dates back to 1288 when Stora Kopparbergs Bergslags AB was established for copper mining.
- Industrial scale usage of Dalälven from 1872:
  - In Domnarvet the first complete cut off of a river 1875
  - Kvarnsveden first era 1897-1900
  - Bullerforsen 1907-1910
  - Forshuvudforsen 1917-1922
- General expansion of hydropower production in Dalälven from 1930 to 1970

<table>
<thead>
<tr>
<th>Power plant</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tängen</td>
<td>1931</td>
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<tr>
<td>Avesta</td>
<td>1931</td>
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<tr>
<td>Eldforsen</td>
<td>1935</td>
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<tr>
<td>Långhag</td>
<td>1938</td>
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<tr>
<td>Domnarvet, stage 2</td>
<td>1945</td>
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<tr>
<td>Skedvi</td>
<td>1949</td>
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<tr>
<td>Gråda</td>
<td>1951</td>
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<tr>
<td>Lindbyn</td>
<td>1953</td>
</tr>
<tr>
<td>Gävunda</td>
<td>1954</td>
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<tr>
<td>Båluströmmen</td>
<td>1956</td>
</tr>
<tr>
<td>Lima</td>
<td>1958</td>
</tr>
<tr>
<td>Trängslet</td>
<td>1960</td>
</tr>
<tr>
<td>Åsen</td>
<td>1963</td>
</tr>
<tr>
<td>Väsa</td>
<td>1965</td>
</tr>
<tr>
<td>Blyberg</td>
<td>1967</td>
</tr>
<tr>
<td>Spjutmo</td>
<td>1969</td>
</tr>
<tr>
<td>Kvarnsveden, stage 2</td>
<td>1974</td>
</tr>
</tbody>
</table>
Construction of Trängslet Dam and Power Plant 1955-1960

- Located in main tributary Österdalälven, Trängslet lake is the largest artificial lake in Sweden.
- Constructed between 1955-1960, facilitating the development of a number of plants downstream.
- The highest earth-fill dam in Sweden (850 m long and 126 m high)
- Reservoir capacity of 880 million m³
- Three Francis units, totalling 330 MW, 651 GWh/a.
- Most important plant in the scheme, operated as a peak load power plant and regulating the whole river’s production.
In 1990 started the ongoing rehabilitation program for Dalälven:

- Increased economic benefit due to increase in energy production and flexibility,
  - 11 hpps upgraded so far. Total capacity increase 57 % => +125 MW
  - Annual production up 28 % => +378 GWh/a.
  - Energy production entitled to Swedish green certificates (from 2003) = 247 GWh/a.
- De-regulation of the energy market in 1996 and EU environmental targets in the 2000s have increased demand for renewable production.
- A strong growth of wind power has pushed for more regulating power, i.e. hydropower. (Wind power up 53 % between 2011 and 2013, 6,2 to 9,5 TWh/a, and growing. Target 25 TWh/a).
## Hydropower plants renovated/upgraded since 1990

(updated after article)

<table>
<thead>
<tr>
<th>Plant</th>
<th>Orig. year</th>
<th>Orig data (MW)</th>
<th>Orig data (GWh)</th>
<th>Renov. year</th>
<th>Data after (MW)</th>
<th>Data after (GWh)</th>
<th>G.C. 1) (GWh)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forshuvudforsen</td>
<td>1922</td>
<td>18</td>
<td>145</td>
<td>1990, 1998</td>
<td>47</td>
<td>209</td>
<td></td>
<td>2 units in new building</td>
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<tr>
<td>Långhag</td>
<td>1938</td>
<td>46</td>
<td>270</td>
<td>1992, 1993</td>
<td>54</td>
<td>280</td>
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<td>Upgrade</td>
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<tr>
<td>Domnarvet</td>
<td>1945</td>
<td>16</td>
<td>121</td>
<td>1994, 1995</td>
<td>22</td>
<td>132</td>
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<td>Upgrade</td>
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<tr>
<td>Kvarnsveden</td>
<td>1975</td>
<td>29</td>
<td>133</td>
<td>1996</td>
<td>60</td>
<td>275</td>
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<td>Extended, new p.h.</td>
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<td>Tänger</td>
<td>1931</td>
<td>3.2</td>
<td>19</td>
<td>2005</td>
<td>4.6</td>
<td>23</td>
<td>23</td>
<td>1 unit in new building</td>
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<tr>
<td>Avestaforsen</td>
<td>1931</td>
<td>30</td>
<td>171</td>
<td>2007</td>
<td>43</td>
<td>206</td>
<td>171</td>
<td>1 unit in new building</td>
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<tr>
<td>Eldforsen</td>
<td>1935</td>
<td>3.5</td>
<td>19</td>
<td>2010</td>
<td>8.5</td>
<td>41</td>
<td>41</td>
<td>1 unit in new building</td>
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<tr>
<td>Skedvi (ongoing)</td>
<td>1949</td>
<td>38</td>
<td>213</td>
<td>2013, 2014</td>
<td>40</td>
<td>223</td>
<td>10</td>
<td>Efficiency increase</td>
</tr>
<tr>
<td>Väsa</td>
<td>1965</td>
<td>7</td>
<td>59</td>
<td>2013</td>
<td>7.5</td>
<td>60</td>
<td>1.2</td>
<td>Turbine renewed</td>
</tr>
<tr>
<td>Gävunda (ongoing)</td>
<td>1954</td>
<td>7.5</td>
<td>32</td>
<td>2014</td>
<td>8</td>
<td>33</td>
<td>1</td>
<td>Efficiency increase</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>217</strong></td>
<td><strong>1330</strong></td>
<td></td>
<td><strong>342</strong></td>
<td><strong>1708</strong></td>
<td></td>
<td><strong>247</strong></td>
<td></td>
</tr>
</tbody>
</table>

1) G.C. = Green certificates
Case: Avestaforsen rehabilitation project

- Originally Månsbo hpp with five Horizontal Francis turbines, 12 MW.
- Replaced by Avestaforsen hpp 2007, one Kaplan unit 25 MW.
- Total output including sister plant 43 MW (30 MW), 206 GWh/a (171 GWh/a).
- The new power house allowed development of layout and technology of civil structures and mechanical equipment.
- Active project planning and continuous contact with authorities were important for the permission process.
Case: Avestaforsen rehabilitation project

- Old chemical industrial area => major decontamination actions.
- The turbidity during excavation works successfully handled. (Fish spawning, steel works and paper mill issues.)
- Dam safety considered throughout the project. (Water management, bypass, and cofferdams.)
- High degree of pre-fabricated concrete structures, a high level of quality assurance and a high standard worker’s environment, made the 28 month’s short project time without accidents.
- Keeping the same project management staff from project to project was a very important success factor.
Case: **Eldforsen** rehabilitation project

- Original Eldforsen hpp, one Kaplan unit 3.5 MW, 19 GWh/a
- New power house 2010, one Kaplan unit 8.5 MW, H =10 m, 41 GWh/a.
- Raise of dam.
- Increased HWL 2.33 m.
- New waterways. Dredging downstream not needed.
Case: *Eldforsen* rehabilitation project

Project success factors:

- Local authorities and locals were positive to the project.
- Losses from the generator are recycled for heating of the power house, spillway gates and regulation dam. Gain ~250 MWh/a.
- Same concept of power plant layout, as developed in projects during the latest 20 years.
- Focus on high technical standards, environmental friendliness, long technical lifetime and low operational costs.
- As compensation for increased HWL, a fishway “Eldbäcken” was constructed.
Feedback and lessons learned in terms of good practice

Environmental permits for rehabilitation projects

• New law, Environmental Code (Miljöbalken), was introduced 1999.
• Now much more complicated and time consuming to get new permits, especially after ~2007. To be considered when planning new projects.

Green certificates

• Change of regime for green certificates 2012. Now granted only for additional production.

Design of power house buildings

• Architectural appearance is becoming more and more important.
• Indoor design is focused on good and safe access for operating personnel and for transportation of equipment.
• Using pre-fabricated concrete elements save both money and time.
• Improved attachment system for intake trash racks – allowing divers to work safe and fast.
Feedback and lessons learned in terms of good practice

State-of-art designs in equipment

- State-of-the-art turbine technology => increased efficiency and upgrades.
- Environmentally friendly runner hub type for Kaplan turbines.
- High pressure turbine governor systems => small amount of oil in the regulation systems.
- High performing Kaplan runner blade bearings! Today our units are subject of more frequent regulation. With bad bearing materials we have experienced need of change of runners within ten years.
- New generator design materials => higher efficiency, less ageing due to start-stop and regulation.
- Better generator insulation materials => Removal of CO₂ fire extinguishing systems => lower maintenance costs and improved personnel safety.
- Reduced risk of leaks in hydraulic systems for spillway and intake gates, e.g. by stainless steel pipes instead of hoses.
Future development plan for Dalälven Scheme

Dam Safety actions:

- New guidelines => rehabilitation of several dams, including increase in spillway capacities.
- The ongoing feasibility study for Trängslet dam contains increased spillway capacity from 1 200 m³/s to 1 500 m³/s.

Preliminary plan for future power plant rehabilitations in Dalälven:

<table>
<thead>
<tr>
<th>Hydro Power Plant</th>
<th>Construction year</th>
<th>Data before</th>
<th>Data after</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Power (MW)</td>
<td>Production (GWh)</td>
<td>Power (MW)</td>
</tr>
<tr>
<td>Hummelforsen</td>
<td>1955</td>
<td>10,7</td>
<td>66</td>
<td>13,2</td>
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<tr>
<td>Lindbyn</td>
<td>1953</td>
<td>11,0</td>
<td>60,0</td>
<td>14,6</td>
</tr>
<tr>
<td>Lima</td>
<td>1959</td>
<td>13,4</td>
<td>60,0</td>
<td>15,4</td>
</tr>
<tr>
<td>Untra</td>
<td>1918</td>
<td>44,0</td>
<td>270,0</td>
<td>45</td>
</tr>
</tbody>
</table>
Conclusions

• Replacing old power houses by new, facilitate the layout and technology of civil structures, and utilisation of state-of-the-art production equipment.

• The opposition against hydropower has increased during the last years. Earlier it was rather easy to obtain a water rights permit for a new power plant even with increased turbine discharge. Not anymore.

• The green certificate system has improved the profitability of rehabilitation projects. The system gives good money for the power plant owner to a low cost for the society.

• There are always environmental benefits in a hydropower rehabilitation project!
Thank you for your attention!
Merci pour votre attention!

Eldforsen hpp