Repowering of Steam Power Plants (STPP)

Seminář Energetika

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Most, 09 června 2011
Agenda

Steam Power Plant Life Cycle

Modernisation of a Steam Plant → Repowering

Repowering with Alstom Technology

Benefits of Repowering

Alstom Experience

The Value of Alstom Repowering Solutions
Typically the lifecycle of a STPP is around 40 years
Consequences of Aging
STPP Performance Without Modernizing

The gap between the existing plant and the actual technology getting bigger.
Consequences of Aging

- Decreasing efficiency
  - unrecoverable wear of components
- Decreasing reliability and availability
  - Forced outages
  - Increasing maintenance costs
  - Decreasing availability $\rightarrow$ lower operating profitability
- Environmental impact issues and operability at risk
  - Increasing emission levels (CO$_2$/kWh)
  - Emissions far above the level from state of art technology
    $\rightarrow$ operating consent at risk

Aging of the plant has a remarkable economical impact
Drivers for Repowering
The Main Solutions of the Plant Owner

A. Keep operating the existing plant (+ modernization)
B. Repowering
C. New plant construction (brown field)

The 3 fork way of the plant owner:
Analysis for a way out of this multilemma
Agenda

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Plant Modernization Alternatives

A variety of solutions (increasing scope A to D) to mitigate aging effects

A) Retrofit
B) Rehabilitation
C) Repowering
D) Brown/Greenfield CCPP

existing Steam Plant (coal, oil, gas)
Drivers for Repowering

What is it a STPP REPOWERING?

Senoko, Singapore

Repowering is a scope intensive solution with its peculiar advantages compared to a new replacement plant (brown field)
Repowering raises your plant performances into an order of magnitude much higher than Rehabilitation.
**Repowering Concept**

**Full Repowering**
- **NEW**
- **Existing**
- **Back-up or retired**

**Hybrid Repowering**
- **NEW**
- **Existing**
- **GT - Gas Turbine**
- **ST - Steam Turbine**

Hybrid repowering is often the preferred choice when:
- STPP is a coal fired plant
- ST is oversized respect to the GT capacity (supplementary fire capacity is provided by the existing boiler)

**Different Repowering variants for different drivers**
Repowering Concept Existing Plant

Typical schematic of an existing STPP

- HP HTR
- LP HTR
- FWT
- IP/LP
- G
- Boiler
- Condenser

G - Generator
HTR - Heater
HP - High Pressure
IP/LP - Intermediate Pressure / High Pressure
FWT - Feed water Tank
Full Repowering Concept

Typical schematic of a full repowering STPP

HRSG - Heat Recovery Steam Generator
Typical schematic of a hybrid repowered STPP
Drivers for Repowering
Technical Feasibility Needs Careful Assessment

Preconditional requirements for Repowering

- Gas turbine fuel availability (gas/oil)
- Grid capacity to dispatch extra power
- Space for new equipment
- Residual life of existing equipment
- Capacity and size of existing equipment (steam turbine, cooling system, generator...)

Criteria of eligibility of a steam power plant for Repowering

Bayside, Canada
Drivers for Repowering

When to consider a REPOWERING?

Boundary conditions and economical analysis allow a proper choice

Senoko, Singapore
Drivers for Repowering
Economic Analysis

….when the operability and profitability of the plant are at risk:

• Future variable costs and repair investments needed to retain present plant in operation.
• Future costs needed to meet environmental regulations with the present plant (e.g. addition of Scrubbers, FGD*, SCRs**) which could be eliminated or reduced through Repowering
• Present value of the future profit of the existing plant (if any)
• Costs for plant decommissioning which could be eliminated through Repowering

* FGD - Flue Gas Desulphurisation
** SCR - Selective Catalytic Reactor

Evaluation of these parameters will define the best solution
Drivers for Repowering

Why REPOWERING instead of a new plant as replacement?

Boundary conditions and economical analysis allow a proper choice
Drivers for Repowering
Economical Analysis: Existing Plants

- Permission to produce electricity
- Existing equipment, buildings and infrastructure
- Located at a node point for electricity distribution
- Location in areas of strict building regulations
- Reduced permitting procedure
- Supply access of fuel
- Cooling water infrastructure
- Trained operation and maintenance personnel

The value of an existing plant can be much higher than the residual book value
Repowering: Economical Choice

The boundary conditions and the electricity market parameters (the most important being the spark spread) of the business model are deeply influencing the profitability of repowering (RP) and its advantages over a brown/green field (BF/GF) solutions.

Repowering needs lower investment than a new CCPP and offers shorter payback and higher NPV within the middle term.
Repowering: Economical Choice

Alstom capability to design a RP plant performing very close to a BF/GF is the key factor to make it more profitable on the middle term: the graph shows the benefit on NPV of a 2x GT26 repowering a 300 MW ST (solution at 56% and 57% Eff.) vs. a KA26-2 (GF). Calculations done assuming electricity price of 60 €/MWh and fuel cost of 6 €/GJ.

Repowering needs lower investment than a new CCPP and offers shorter payback and higher NPV within the middle term.
### Repowering Technical Options Choice

#### Full Repowering
**Single Fuel Concept**
- To provide the most efficient combined cycle solution utilizing present equipment
- For certain ranges of steam turbines that fit the GT portfolio providing a technical and economical competitive solutions
- The best option for boilers presently running on gas. Also advantageous for plants with existing oil or coal boilers

#### Hybrid Repowering
**Dual Fuel Concept**
- To provide the most flexible operating solution both in terms of power output and fuel arbitrage
- For all sizes of steam turbines
- An option optimized for boilers presently using coal or oil
- An option for the true merchant power plant

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**Solutions for max efficiency or max flexibility**
Steam Power Plant Life Cycle

Modernisation of a Steam Plant → Repowering

Repowering with Alstom Technology

Benefits of Repowering

Alstom Experience

The Value of Alstom Repowering Solutions
Alstom Repowering Technology
Core Components of Repowering

GT26
Gas Turbine

TOPAIR Generator

HRSG: different configurations are possible

Proven and state-of-the-art components for Repowering
GT characteristics to match specific requirements of the Repowering project and existing plant
**POWER ISLAND** is composed by **GT+Generator+HRSG** and all necessary auxiliary components.

<table>
<thead>
<tr>
<th>Model</th>
<th>Total Length [m]</th>
<th>Total Width [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>GT8C2</td>
<td>65</td>
<td>25</td>
</tr>
<tr>
<td>GT11N2</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>GT13E2</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>GT24</td>
<td>85</td>
<td>40</td>
</tr>
<tr>
<td>GT26</td>
<td>90</td>
<td>40</td>
</tr>
</tbody>
</table>
Alstom Repowering Technology
Plant Integrator Approach

Claus-C Repowering: plant arrangement simulation

ST type 13K215 LP on LMZ licence: retrofitted for performance increase

Repowered STPP into CCPP

Alstom capabilities maximize the value of a repowering
Alstom is in the unique position to be able to provide a turnkey EPC Repowering fully customized and optimized

**Advantages:**

- Single contract negotiation and single procurement contact point
- Customer relieved from the complexity of optimizing and matching the design of differently sourced components like the GT, HRSG and ST retrofit
- Customer receives a “matched” set of gas/steam cycle equipment therefore is assured that the highest performance and integration is achieved
- Customer receives state of the art harmonized set of controllers and optimized plant operating instructions
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Steam Power Plant Life Cycle

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Benefits of Repowering

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The Value of Alstom Repowering Solutions
Benefits of Repowering Efficiency Increase

Improve the existing steam turbine power plant efficiency from ~35% to ~57% or more
Benefits of Repowering Performance Impact of Full and Hybrid Modes

(Production Cost and Efficiency are not directly proportional for Hybrid Repowering Modes - price for the two different fuels, coal and gas, as well as output determine the most profitable mode)

Solutions for max efficiency or max flexibility
Installation in parallel with the existing plant → Short Power Production Interruption
Benefits of Repowering
Parameters Beneficially Affected by Repowering

- Power output ↑
- Efficiency ↑ → fuel gas saving
- Emissions: CO₂/kWh, NOₓ, SOₓ ↓ → CO₂ trading
- Production costs through higher efficiency → CoE ↓
- Operation flexibility ↑
- **Fuel Management Independence** (Hybrid mode) ↑
- Reduced investments → NPV ↑
- Lifetime of existing plant ↑
- Limited loss of power generation during installation
- Optimization of Fuel Economics e.g. District Heating
- Implementation **time of new generation capacity** ↓
- Permitting complexity (compared to green/brown field) ↓

Repowering can be a better choice than a new CCPP
Agenda

Steam Power Plant Life Cycle

Modernisation of a Steam Plant → Repowering

Repowering with Alstom technology

Benefits of Repowering

Alstom Experience

The Value of Alstom Repowering Solutions
Rheinhafen RDK4 – Germany Full Repowering (50Hz)

- Conversion of one 100MW coal-fired unit to one 360MW gas-fired CCPP

- New Equipment
  - GT26
  - Alstom Dual Pressure Reheat HRSG
  - Alstom Air cooled generator
  - Feedwater tank, bypass stations, etc.

- Modernisation
  - Retrofit of Steam turbine internals
  - Condenser re-tubing for increased cooling water mass flow
  - Refurbishment of W/S-cycle pumps

- Re-use of Existing Equipment
  - Steam turbine casings, bearings and foundations
  - Water treatment plant
  - Main cooling water system

Efficiency increase by 17% additive, 260% more power
Valle de Mexico – Mexico Hybrid Repowering (60Hz)

- Conversion of one 300MW gas fired unit to 550MW in hybrid operation mode, (in combined cycle operation 372MW)
- Increased efficiency from 36.8% to 43.8%, (in combined cycle operation to 48.2%)
- New equipment
  - KA11N2 – 3x package (GT11N2, HRSG and generator)
  - Auxiliaries
  - Electrical and control systems
  - Switchyard
  - Civil works, engineering, erection and commissioning
- Re-use of Existing Equipment
  - Steam turbine
  - Boiler

Efficiency increase by 7%-11.5% additive, 80% more power
Senoko – Singapore
Full Repowering (50Hz)

- Conversion of three 120MW oil-fired units to three 360MW gas-fired Combined Cycle Power Plants

- New Equipment
  - GT26 gas turbine
  - Triple Pressure Reheat HRSG

- Modernisation
  - Retrofit of Steam turbine internal
  - Retrofit of Steam turbine generator
  - Condenser re-tubing for increased cooling water mass flow

- Re-use of Existing Equipment
  - Steam turbine casings, bearings and foundations
  - Main cooling water system

Efficiency increase by 14% additive, 200% more power
Claus C – Netherlands Full Repowering (50Hz)

- Conversion of one 640 MW steam turbine unit with gas-fired Boiler into KA26-3

- New Equipment, main components
  - 3x GT26 + 3x Generators
  - Triple Pressure Reheat 3x HRSG

- Modernisation
  - Retrofit of Steam turbine bundle
  - Direct cooling, switch over to cooling tower

- Re-use of Existing Equipment
  - Main Cooling water systems
  - Civil in brown field
  - ST Generator with auxiliaries
  - Demineralization Plant
  - C&I existing

**Efficiency** after repowering *58.5%* (+20%),

**CO₂ decrease of 40%**
<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Output</th>
<th>GT</th>
<th>Country</th>
<th>PAC</th>
<th>Application</th>
<th>Original Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNA MK 10</td>
<td>100 MW</td>
<td>2 x GT9D1</td>
<td>NL</td>
<td>1978</td>
<td>Full Combined Cycle</td>
<td>Coal</td>
</tr>
<tr>
<td>Lage Weide 5</td>
<td>271 MW</td>
<td>1 x GT11D5</td>
<td>NL</td>
<td>1986</td>
<td>Combined Cycle / Cogen</td>
<td>Coal</td>
</tr>
<tr>
<td>Hemweg</td>
<td>635 MW</td>
<td>1 x GT13E</td>
<td>NL</td>
<td>1987</td>
<td>Hot Windbox / Cogen</td>
<td>Gas</td>
</tr>
<tr>
<td>Midland</td>
<td>1370 MW</td>
<td>12 x GT11N</td>
<td>USA</td>
<td>1989</td>
<td>Full Combined Cycle</td>
<td>(Uranium)</td>
</tr>
<tr>
<td>Martinlaakso</td>
<td>200 MW</td>
<td>1 x GT8C</td>
<td>FI</td>
<td>1994</td>
<td>Combined Cycle / Cogen</td>
<td>Oil/Coal</td>
</tr>
<tr>
<td>Rheinhafen</td>
<td>361 MW</td>
<td>1 x GT26</td>
<td>GE</td>
<td>1998</td>
<td>Full Combined Cycle</td>
<td>Coal</td>
</tr>
<tr>
<td>Gorzow</td>
<td>65 MW</td>
<td>1 x GT8C</td>
<td>PL</td>
<td>1998</td>
<td>Full C.C. / Cogen / Distr. Heat</td>
<td>Coal</td>
</tr>
<tr>
<td>Senoko I, Phase 1</td>
<td>360 MW</td>
<td>1 x GT26</td>
<td>SG</td>
<td>2001</td>
<td>Full Combined Cycle</td>
<td>Oil</td>
</tr>
<tr>
<td>Bayside</td>
<td>265 MW</td>
<td>1 x GT24</td>
<td>CA</td>
<td>2001</td>
<td>Full Combined Cycle</td>
<td>Oil</td>
</tr>
<tr>
<td>Valle de Mexico</td>
<td>552 MW</td>
<td>3 x GT11N2</td>
<td>MX</td>
<td>2002</td>
<td>Combined Cycle / Hybrid Mode</td>
<td>Gas</td>
</tr>
<tr>
<td>Senoko I, Phase 2</td>
<td>740 MW</td>
<td>2 x GT26</td>
<td>SG</td>
<td>2004</td>
<td>Full Combined Cycle</td>
<td>Oil</td>
</tr>
<tr>
<td>Claus C</td>
<td>1280 MW</td>
<td>3 x GT26</td>
<td>NL</td>
<td>2008</td>
<td>Full Combined Cycle</td>
<td>Gas</td>
</tr>
</tbody>
</table>

Long time and wide span of technology in Repowering: last 12 projects successfully completed
Steam Turbine Retrofit Experience

Turbine Retrofitting – Experience since 1984

<table>
<thead>
<tr>
<th>Type</th>
<th>Own Fleet</th>
<th>3rd Party</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP</td>
<td>183</td>
<td>87</td>
<td>270</td>
</tr>
<tr>
<td>HP/IP</td>
<td>3</td>
<td>43</td>
<td>46</td>
</tr>
<tr>
<td>IP</td>
<td>61</td>
<td>29</td>
<td>90</td>
</tr>
<tr>
<td>LP</td>
<td>228</td>
<td>199</td>
<td>427</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>475</strong></td>
<td><strong>358</strong></td>
<td><strong>833</strong></td>
</tr>
</tbody>
</table>

Including: GE, Siemens, Westinghouse, Parsons, MHI, Hitachi, Toshiba, Zamech, LMZ, Escher Wyss, Franco Tosi, Ansaldo and Skoda

Alstom Experience in ST retrofits spans through all the world and all the main OEM
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Steam Power Plant Life Cycle

Modernisation of a Steam Plant

Repowering with Alstom technology

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The Value of Alstom Repowering Solutions
Repowering with Alstom

Why Alstom?

- Number 1 world EPC and full chain OEM of Turnkey Power Plant provider
- More than 40 years of experience in retrofitting/upgrading existing steam turbines plants from all OEM
- More than 40 years of experience in the maintenance and modernization of every type of power plants world wide, including repowering
- Tailor-made to customer requirement through unique Plant Integration concept to fit at best demanding operational features (modern control concepts, load flexibility, frequency response,....)

EPC - Engineering, Procurement and Construction
OEM - Original Equipment Manufacturer

Alstom is unique
The economical drivers of Repowering are:
• Reduced investment → reduced capital costs
• Better NPV and shorter payback
• Reduced permitting time and efforts
• Carbon fees reduction/credits on CO₂ emissions

Profitability of repowering projects depend, for every electricity market characteristic, on:
• balance between new performance achieved vs. investment
• capacity to maximize performance increase for the chosen retrofit set-up

Alstom confirmed to be the partner capable to optimize both points with a customer specific solution
Claus C proves the values of Alstom as Plant Integrator
Claus C Repowering
Repowering Performance Overview

A quantum leap into a different class of performance level

Power: +100% add.
Eff.: + 19% add.
CO₂: - 40%
NOx: - 73%
Claus C Repowering
Repowering Performance Overview

Every retrofit with performance improvements brings a clearly related economical benefit. For Claus C project we want to highlight the benefit coming from a reduction of fuel consumption and a reduction of CO₂ tax.

OPERATING COST BENEFITS

- 19.5 % Efficiency increase → 33% fuel consumption reduction
- 1.773.000 tons/year less CO₂ emissions

<table>
<thead>
<tr>
<th></th>
<th>Claus B 2x 640</th>
<th>Claus C 3x GT26 with ST retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power - net</td>
<td>MW</td>
<td>1280</td>
</tr>
<tr>
<td>Efficiency - net</td>
<td>%</td>
<td>39%</td>
</tr>
<tr>
<td>Heat Rate</td>
<td>kJ/kWh</td>
<td>9'231</td>
</tr>
<tr>
<td>Service Factor</td>
<td></td>
<td>90%</td>
</tr>
<tr>
<td>Power production</td>
<td>MW/yr</td>
<td>10'091'520</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>1000 m³/yr</td>
<td>2'425'846</td>
</tr>
<tr>
<td>DELTA Fuel consumed</td>
<td>1000 m³/yr</td>
<td>-307'509</td>
</tr>
<tr>
<td>Gas specific cost</td>
<td>EUR/GJ</td>
<td>6.0</td>
</tr>
<tr>
<td>Gas Cost</td>
<td>MEUR/yr</td>
<td>553</td>
</tr>
<tr>
<td>Gas Saving</td>
<td>MEUR/yr</td>
<td></td>
</tr>
</tbody>
</table>

186 MEUR/year of gas saving
(gas price = 6 €/GJ)

17.7 MEUR/year of CO2 tax saving
(CO2 tax = 10 €/ton)

Repowering brings an old STPP into another magnitude of profitability
GT26 has an intrinsic advantage in part load maximizing the efficiency in CCPP mode Claus C unique configuration (3 on 1) enlarges further the performance and flexibility envelope with a turn-down capability from 100% down to 30%

**In Figures:**
- 100% CCPP load → 58.5% eff.
- 60% CCPP load → 58.2% eff. !!!
(2x GT @ 90% load)

GT26 repowering (3-on-1) for outstanding efficiency at full and part load and maximum operational flexibility
Repowering
Project Economics: The “Russian” Case

A business case (the “Russian” case) has been developed: 3x 300 MW block of a gas fired STPP to be repowered with 2x GT26. Target is to keep roughly the same capacity while increasing massively the efficiency. Summarized below are the schematic and the performance increase.

Repowering Project Economics: The “Russian” Case

<table>
<thead>
<tr>
<th>BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>20% Efficiency increase → -35% fuel consumption</td>
</tr>
<tr>
<td>Fuel gas saving = 580 Mm³/year</td>
</tr>
<tr>
<td>70% of NOx emissions reduction</td>
</tr>
<tr>
<td>1.400.000 tons/year less CO₂ emissions → 28 MEUR/year of CO₂ credits (20 €/ton), or 14 MEUR/year of CO₂ tax reduction (10 €/ton)</td>
</tr>
</tbody>
</table>

Repowering much better profit out of “old” technology
Repowering: an excellent business case on the base of gas savings

Based on this repowering configuration, it is interesting to analyze, for different fuel gas prices, the magnitude of savings achievable due to the shown increase of efficiency:

<table>
<thead>
<tr>
<th>Power - net</th>
<th>MW</th>
<th>3 x 300 MW</th>
<th>2 x GT26 on 300 MW with ST retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency - net</td>
<td>%</td>
<td>37%</td>
<td>57.0%</td>
</tr>
<tr>
<td>Heat Rate</td>
<td>kJ/kWh</td>
<td>9730</td>
<td>8316</td>
</tr>
<tr>
<td>Service Factor</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>Power production</td>
<td>MWh/y</td>
<td>6543720</td>
<td>6543720</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>1000 m3/y</td>
<td>1858037</td>
<td>1076270</td>
</tr>
<tr>
<td>DELTA Fuel consumed</td>
<td>1000 m3/y</td>
<td>-561757</td>
<td></td>
</tr>
</tbody>
</table>

A repowering project based on the scheme above and with a market price of gas of 6 EUR/GJ (e.g. Europe) would show a simple payback in the range of 5 years based only on the fuel economics.
Repowering: Conclusions

The **VALUES** of **REPOWERING**

Repowering is a retrofit solution applicable to existing STPP and particularly suitable to plants entering their 2\textsuperscript{nd} half life period. The main values of repowering are:

- Increase the efficiency of the plant in the range of 20% additive
- Decrease the fuel costs in the range of 35% (in case of gas fired boilers)
- Decrease emissions of NO\textsubscript{x}, and CO\textsubscript{2} in the range of 40%.
- Increase the flexibility of operation due to the characteristic of the GT compared to the ST, and the fuel arbitrage capacity in case of hybrid repowering
- Increase the reliability and lifetime of the existing plant with the use of state of art technology
- Reduce the investment compared to a brown/green field solution
- Reduce the time to market due to easier permitting and re-use of existing equipment
- Easiness of financing due to the saved gas value and to the carbon credits eligibility (where applicable)