Usage of existing power plants as synchronous condenser
Conversion of existing power plants to synchronous condenser units

Increased need of reactive power

Available solutions

Electrical and mechanical works;
examples Biblis and Ensted

Your advantage
New challenges for power plants and power grids by a steady increase in renewable power

Reduction of nuclear and fossil power is causing stability problems in the HV-grid (Reduction of short circuit power and voltage dips stability)

Increase of renewable energy (wind parks in the north / PV in the south) means stress to power grid

International transit trade of electricity causes additional stress to transmission network
New challenges for power plants and power grids by a steady decrease of fossil power generation. Synchronous condensers as solution.

**Impacts on the grid:**

- Lack of short circuit power capacity in the grid
- Voltage and frequency swings in the grid
- Grid capacity has reached its limit due to increased power transport from one side of a country to the other side of the country
- Lack of generators for reactive power
- Power factor ($\cos \varphi$) difficult to control
New business model: profitable growth by generation or reactive power
Conversion of existing power plants to synchronous condenser units

Increased need of reactive power

Available solutions

Electrical and mechanical works to be done; examples Biblis and Ensted

Your advantage
Synchronous generator as optimal solution for synchronous condenser

Synchronous generator working as synchronous condenser
5…1.500 MVAr (+/-)

Transformer combination working as phase shifter
up to 1.000 MVAr (+/-)

Capacitor banks working as condenser
Continuous MVAr-regulation
up to 200 MVAr (+/-)
Synchronous generator working as synchronous condenser

New built synchronous condensers

or

Conversion of power plants to synchronous condenser units
# Synchronous generator as optimal solution for synchronous condenser

<table>
<thead>
<tr>
<th></th>
<th>Synchronous generator working as synchronous condenser</th>
<th>Transformer combination working as phase shifter</th>
<th>Capacitor bank working as synchronous condenser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment cost per MVAr</td>
<td>low</td>
<td>mid.</td>
<td>high</td>
</tr>
<tr>
<td>Additional short circuit current (rotating mass)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Short delivery time</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Re-use of existing components</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Optimal solution</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Charges for reactive energy*

Two charging schemes for reactive energy exist:

- **Reactive Tariff**: A regular tariff rate is applied to each MVArh of reactive energy produced and/or consumed.
- **Penalty**: Reactive energy produced and/or consumed is charged only if some pre-defined conditions are met. Examples can be excesses of energy off-taken/fed-in during a given period or excess levels of $\cos \varphi$ or $\tan \varphi$.

<table>
<thead>
<tr>
<th>Country</th>
<th>Reactive Tariff (Y/N)</th>
<th>Penalty (Y/N)</th>
<th>Tariff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bosnia and Herzegovina</td>
<td>Y</td>
<td>N</td>
<td>5,56€ / MVArh</td>
</tr>
<tr>
<td>Croatia</td>
<td>Y</td>
<td>N</td>
<td>20,90€ / MVArh</td>
</tr>
<tr>
<td>France</td>
<td>N</td>
<td>Y</td>
<td>13,3€ / MVArh</td>
</tr>
<tr>
<td>Germany</td>
<td>Y/N</td>
<td>Y/N</td>
<td>8,70€ / MVArh</td>
</tr>
<tr>
<td>Serbia</td>
<td>Y</td>
<td>Y</td>
<td>1,22€ / MVArh</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Y</td>
<td>N</td>
<td>7,80€ / MVArh</td>
</tr>
</tbody>
</table>

* ENTSO-E Overview of transmission tariffs in Europe Synthesis June 2014
Example amortization time for synchronous condenser

<table>
<thead>
<tr>
<th>Owner</th>
<th>max. reactive power (MVAr)</th>
<th>Tariff</th>
<th>Project cost</th>
<th>Amortization time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>800MVAr</td>
<td>8,70€ / MVArh</td>
<td>5,5M€</td>
<td>&lt;24 month</td>
</tr>
<tr>
<td>RWE</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

**Investment**

**Profit**
New tasks for old power plants means advantages for all involved parties

Minimum costs due to use of existing plants. Written-off assets will be reactivated!

Extended lifetime of a power plant generates additional income

Grid is in an optimum range of operation due to improved $\cos \varphi$ and increase of short circuit capability; Decreased danger for blackouts
Conversion of existing power plants to synchronous condenser units

Increased need of reactive power

Solutions

Electrical and mechanical works to be done; examples Biblis and Ensted

Your advantage
NPP Biblis: Generator in use for power-factor correction

Generator: 1500 MVA, 27 kV, 1500 rpm
Reactive Power: -450 ... +850 MVAr
Start operation: 2012
Conversion to synchronous condenser in few steps
Example: NPP Biblis

Mechanical Works:

• Check and recalculiation of generator design (electrical and mechanical)
• Decoupling of generator and turbine and dismantling of low pressure turbine part
• Modification and extension of generator shaft
• New / additional axial bearing
• New hydraulic motor (in case of brushless excitation)
• New oil pumps and piping
Conversion to synchronous condenser in few steps
Example: NPP Biblis

Electrical Works:

• Installation of start-up frequency converter for start-up
• Modification of generator protection system and synchronizer
• Modification of excitation equipment
• Modification / connection to the generator bus duct
• Installation of Is-limiter
• Electrical installation, cabling
Residual works:

Mechanical / hydraulic works:
- Blocking Generator / Turbine Springs
- Check of hydraulic oil pumps
- Modification of hydraulic pipes

I&C / DCS works:
- Installation of new probes and sensors
- Modification of DCS and turbine controller
- Connection to Control Room

Erection Supervision
Commissioning
Training

Conversion to synchronous condenser in few steps
Example: NPP Biblis
Conversion to synchronous condenser in few steps
Example: NPP Biblis

Overview of the electrical parts in Biblis

View of the

- Generator

- new electrical components on top of the low pressure turbine housing

- and the remaining high pressure turbines
Power Plant Ensted: Converted to Synchronous Condenser Operation

Generator: 850 MVA, 21 kV, 3000 rpm
Reactive Power: -350 … +800 MVAr
Start operation: 2013
Other references in 2013....

<table>
<thead>
<tr>
<th>Project Location</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>GKM, Germany</td>
<td>Study (2013)</td>
</tr>
<tr>
<td>Huntington Beach, USA</td>
<td>4x 128 MW (2013)</td>
</tr>
<tr>
<td>Bjaerveskov, Denmark</td>
<td>270 MVA (2013)</td>
</tr>
<tr>
<td>DK1 &amp; DK2, Denmark</td>
<td>2x 150 MW (2013)</td>
</tr>
</tbody>
</table>
Main differences between Gas-Turbine and Steam-Turbine adaptation

For a conversion from power shaft to synchronous condenser, there is NO difference!
There is always a direct connection to the Generator which has to be removed.
SPPA-E3000 Electrical Solutions
Conversion of existing power plants to synchronous condenser units
Possible disconnection ways

Disconnecting the generator by moving the turbine [2” (5cm) needed]

Disconnecting the generator by removing the distance ring between generator and turbine

Disconnecting the generator by complete removal of the LP-turbine (compressor)
Conversion of existing power plants to synchronous condenser units

Increased need of reactive power

Solutions

Electrical and mechanical works to be done; examples Biblis and Ensted

Your advantage
### Your advantages:

- Increased controlled reactive power in the grid
- Increased short circuit capacity of the grid
- Stability of the grid
- Stability of the grid voltage
- To settle grid system incidents
- Increased capacity (load flow) of the HV power grid
- To keep old power plants alive
- To earn money
Thank you!
To obtain further information, please contact:

SPPA-E3000.energy@siemens.com

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