ERCOT Stakeholder Meeting, 15th November 2013

Synchronous Condenser Solutions

Brian Gemmell – Transmission Solutions Sales, USA
Kai-Uwe Paeselt – Generator Sales, Germany
Agenda

SynCon Solutions

Reference – Bjaeverskov

Reference – Georgia Black Sea

Reference – Huntington Beach

Other SynCond Topics for ERCOT
Agenda

SynCon Solutions

Reference – Bjaeverskov
Reference – Georgia Black Sea
Reference – Huntington Beach
Other SynCond Topics for ERCOT
Turnkey Synchronous Condenser Solutions
Scope and main components

- Synchronous Condenser
- Generator Step-up Transformer
- Static / Brushless excitation
- Pony Motor / Starting Frequency Converter
- Isolated Phase Busduct
- Control and Protection system
- Auxiliary Transformer
- Generator Circuit Breaker
- External Coolers (option)
- Complete Civil and Construction works

Siemens combines proven in-house Equipment with Technical & Project Management know-how to offer tailor-made turnkey SynCon solutions
## Generator Product Portfolio

<table>
<thead>
<tr>
<th>Cooling</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H₂O</strong></td>
<td>25/30 Hz 1000-2235 MVA (4-pole)</td>
</tr>
<tr>
<td></td>
<td>50 Hz 550-1300 MVA</td>
</tr>
<tr>
<td></td>
<td>60 Hz 799-1066 MVA</td>
</tr>
<tr>
<td><strong>H₂</strong></td>
<td>50 Hz 350-570 MVA</td>
</tr>
<tr>
<td></td>
<td>60 Hz 310-513 MVA</td>
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<tr>
<td><strong>Air</strong></td>
<td>50 Hz 165-370 MVA</td>
</tr>
<tr>
<td></td>
<td>60 Hz 165-310 MVA</td>
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<tr>
<td></td>
<td>50/60 Hz 25-300 MVA</td>
</tr>
<tr>
<td></td>
<td>25/30 Hz 25-65 MVA (4-pole)</td>
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</tbody>
</table>

Siemens SynCon Solutions based on standard horizontal Generators
# Advantages of 2-pole over 4-pole Generators

1. Very lower mass moment of inertia with the same power (appr. 1:4)
   This results in a smaller starting motor

2. Higher rotational energy due to the double speed, more stable in the grid

3. Higher thermal time constants. This results in a higher over load capability

4. Higher unbalance load capability due to the damper winding, which is composed of rotor wedges and retaining ring

5. Modern reliable Generators

Siemens offers both 2 pole & 4 pole Generators basing on Customer’s preference
Start-up / Braking System

Variable Frequency Drive

SINAMICS GL 150

<table>
<thead>
<tr>
<th>Supplier</th>
<th>SIEMENS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Power</td>
<td>12 MW</td>
</tr>
<tr>
<td>Rated input voltage</td>
<td>2x 2,8 kV</td>
</tr>
<tr>
<td>DC-link voltage</td>
<td>6.3 kV</td>
</tr>
<tr>
<td>DC-link current</td>
<td>2000 A</td>
</tr>
<tr>
<td>Type of the SFC</td>
<td>SINAMICS GL 150</td>
</tr>
</tbody>
</table>

Frequency drive controlled Pony Motor

10 kV / 690 V - SINAMICS S120

Geafol transformer
Cast resin

Voltage-source DC ink Converter
4Q operation air cooled

Start Motor
Sleeve Bearings

LV induction machine

Siemens offers both solutions from own portfolio basing Customer’s requirement
## Brushless / Static Excitation

<table>
<thead>
<tr>
<th>Schematic</th>
<th>Pros</th>
<th>Cons (Relative)</th>
</tr>
</thead>
</table>
| ![Brushless Schematic](image1) | - Lesser maintenance  
- Support during close-in system faults  
- Simpler robust design  
- No carbon dust  
- Insensitive to system fluctuations  
- No high power DC connections  
- Simpler station layout, no excitation skid | - Slower response time  
- No active de-excitation possible |

<table>
<thead>
<tr>
<th>Static Schematic</th>
<th>Pros</th>
<th>Cons (Relative)</th>
</tr>
</thead>
</table>
| ![Static Schematic](image2) | - Faster response due to few electromechanical components  
- Requires only little room on shaft  
- Better accessibility  
- Some protective functions are simpler to realize  
- Faster de-excitation possible | - Higher maintenance  
- Carbon dust contamination  
- Periodic inspection of collector and collector ring assemblies  
- Shorted turns possible without proper maintenance  
- Requires high power DC connection to generator or local power system |

Siemens offers both solutions from our own portfolio based upon Customer’s request.
Siemens Synchronous Condenser Solution
DAC unit, Pony Motor & Frequency Converter for Start-up
# Siemens SynCon Solutions References

<table>
<thead>
<tr>
<th>Frame</th>
<th>Operation</th>
<th>Country</th>
<th>Customer</th>
<th>Station/Unit</th>
<th>Drive</th>
<th>Rated Voltage / kV</th>
<th>Rated Power Sn / MVA or Qn / Mvar</th>
<th>Frequency / Hz</th>
<th>Power Factor</th>
<th>Cold Gas Temperature °C</th>
<th>Cooling Type OAC or TEWAC</th>
<th>Delivery Plant</th>
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</thead>
<tbody>
<tr>
<td>SGen5-100A</td>
<td>Aug 2013</td>
<td>Denmark</td>
<td>Engerinet.dk</td>
<td>Bjaeverskov</td>
<td>SynCon*</td>
<td>15,75</td>
<td>270 Mvar</td>
<td>50</td>
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<td>30</td>
<td>DAC</td>
<td>Erfurt</td>
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* Synchronous Condenser Application

* Designed to operate in Synchronous Condenser mode

DAC: Direct Air Cooled

TEWAC: Totally Enclosed Water to Air Cooled
 Agenda

SynCon Solutions

Reference – Bjæverskov
Reference – Georgia Black Sea
Reference – Huntington Beach
Other SynCond Topics for ERCOT
Back ground for installing new synchronous condensers in Denmark

Power systems requires balance in every second and must also be given special system-supporting services such as:

- Short-circuit Power
- Voltage regulation
- Inertia
- Exact 50 Hz frequency control

So far, these "invisible" services in the power system was supplied from central power plants, when they delivered energy (MWh) and power (MW).

In Denmark the TSO requires:

2-3 central power plants to be in operation in the Western and Eastern part of the power system.
Denmark's plans for fulfilling the EU targets
50% Wind Power in 2020

What are the needs for system-supporting services in a power system, where half of the energy comes from wind?

- Wind turbines will **not** provide the necessary short circuit power and inertia to the power system
- Central Danish Power Plants are aging and shot down due to low earnings or new environmental requirements
Synchronous Condenser Solution Reference
Bjæverskov, Denmark

Bjæverskov, Denmark

- Customer: Energinet.dk
- Siemens Scope: Turnkey incl. Civil
- Number of SynCons: 1
- SynCon terminal voltage: 15.75 kV
- Power (at PF=0), over / under excited: 250 / 150 MVAr
- Short-Circuit Power (Sk): 800 MVA
- Impedence SynCon, unsaturated (Xd’’): 0.16 pu
- Step-up Transformer: 250 MVA, Uk = 14%
  400 / 15.75 kV, OLTC

Specific Project Features

- SynCon cooling: Direct Air Cooled
- Excitation: Brushless
- Starting System: Frequency drive controlled Pony Motor
- Specials: Civil works matching the existing HVDC

Design / Engineering
Award Jan’12

Site works start June’12

Civil works
Kai-Uwe Päsalt

Major equipment on site Feb’13
ERCOT SynCon Siemens

Erection / Commissioning
Energy Sector
PAC July’13

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Distance required by the Danish authorities, due to fire protection.
First Synchronous Condenser in Denmark for 40 Years
Key components
Synchronous Generator

2 pole Synchronous Generator

SGen5-100A-2P 118/46

Power: 270 MVAr
Voltage: 15,75 kV ± 5%
Power Factor: \( \cos \phi = 0 \)
Speed: 3000 rpm
Frequency: 50 Hz ± 5%

Design according to IEC 34

Different cooling types:
- DAC (Direct Air Cooling)
- TEWAC (Totally Enclosed Water to Air Cooled)
Key components
Generator Step-Up Transformer

- Rated Power: 250 MVA
- Rated Voltage: 15.75/420 kV
- Rated impedance: 14% @ 250MVA
- Frequency: 50 Hz
- Tap changer: +/- 10 taps
- Cooling: ONAF
Closed loop voltage step
Brushless excitation

Reactive power response caused by a +10% step of the PCC voltage from 1 pu to 1.1 pu

Reactive power response caused by a -10% step of the PCC voltage from 1 pu down to 0.9 pu
Open loop voltage step
Brushless excitation

Open-loop voltage step from 0.95 pu to 1.05 pu
Less than 500 ms

Open-loop voltage step from 1.05 pu to 0.95 pu
Less than 850 ms
Agenda

SynCon Solutions
Reference – Bjaeverskov
Reference – Black Sea
Reference – Huntington Beach
Other SynCond Topics for ERCOT
Synchronous Condenser Solution References
Black Sea Transmission Network, Georgia

Customer: Energotrans Ltd.
Siemens Scope: Turnkey (HVDC)
Number of SynCons: 2+1
SynCon terminal voltage: 11 kV
Power /Syncon, over / under excited: 60 / 39 MVar (@ PF=0)
Short-Circuit Power (Sk): 300 MVA
Impedence SynCon, unsaturated (Xd”):0.12 pu
Step-up Transformer: 60 MVA, 400 / 11 / 10 kV, OLTC

Specific Project Features
- SynCon cooling: Direct Air Cooled
- Excitation: Brushless
- Starting System: Frequency drive controlled Pony Motor
- Specials: Close operation with HVDC BtB system

Award: Dec’10
Site works start: June’11
Major equipment on site: Jan’12
Trial operation: Oct’12
PAC*: Dec’12

Design / Engineering
Civil works
Erection / Commissioning

* PAC depends on power availability for HVDC
Black Sea
Synchronous Condenser Building
Black Sea Design
Main Terminal Box - Line Side – IPB’s cast resin isolated
Black Sea
Generator Step Up Unit Transformers
Agenda

SynCon Solutions
Reference – Bjaeverskov
Reference – Black Sea
Reference – Huntington Beach
Other SynCond Topics for ERCOT
Huntington Beach, CA
Synchronous Condenser Conversion

Siemens Energy converts U.S. steam turbine generators to synchronous condensers

Siemens Energy converted the units 3 and 4 steam turbine generators at the Huntington Beach Generating Station, in California, USA, to synchronous condensers. Both natural gas-fired steam units at Huntington Beach are currently owned by AES, but had been retired since 1995. By converting the two generators to synchronous condensers, AES and Siemens made a significant contribution to ensuring grid stability in Southern California.

Siemens' scope of supply included the turnkey conversion of both cross-compound steam turbine generators to synchronous condensers. One of the steam turbine generators was originally supplied by the Westinghouse Electric Co., and the other from General Electric. Siemens supplied various solutions from the SPPA- E3000 electrical systems portfolio, and was responsible for integrating the acceleration system and the auxiliary systems into the power plant's existing control and protection systems.

Due to the shutdown and subsequent closure of the San Onofre nuclear power plant in Southern California, the Californian grid operator, CA ISO, faced the challenge of ensuring the supply of power to 400,000 homes in the region. The grid's stability was a critical point. The solution installed by Siemens uses "pony motors" and variable frequency drives to accelerate the generators to synchronous speed.

"By partnering with Siemens to develop and construct this important project, we supported much needed grid stability", said Weikko Wirta, AES Southland Operations and Maintenance Manager. "This was a major undertaking, but well worth the effort to help keep the lights on and air conditioners blowing without interruption – especially during heat waves."
Agenda

SynCon Solutions

Reference – Bjaeverskov

Reference – Black Sea

Reference – Huntington Beach

Other SynCond Topics for ERCOT
## Brownfield vs Greenfield Installations

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons (Relative)</th>
</tr>
</thead>
</table>
| • Lesser maintenance  
• Guaranteed performance  
• Guaranteed availability  
• Customized solution  
• Minimum O&M cost  
• High efficiency solution  
• State of the art technology | • Possible higher investment |

### GREENFIELD
- Reuse of existing equipment

### BROWNFIELD
- Lower possible investment  
- Utilization of existing asset

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Siemens offers both solutions from own portfolio based upon Customer’s requirement
Remaining topics for ERCOT Stakeholder Meeting

- O&M – see mainenance document
- Reliability
- Losses

- Any other topics?
Many Thanks for Your Attention

CONTACT:
Dr. Brian Gemmell
Cell: (407) 280-4153