SIEMENS

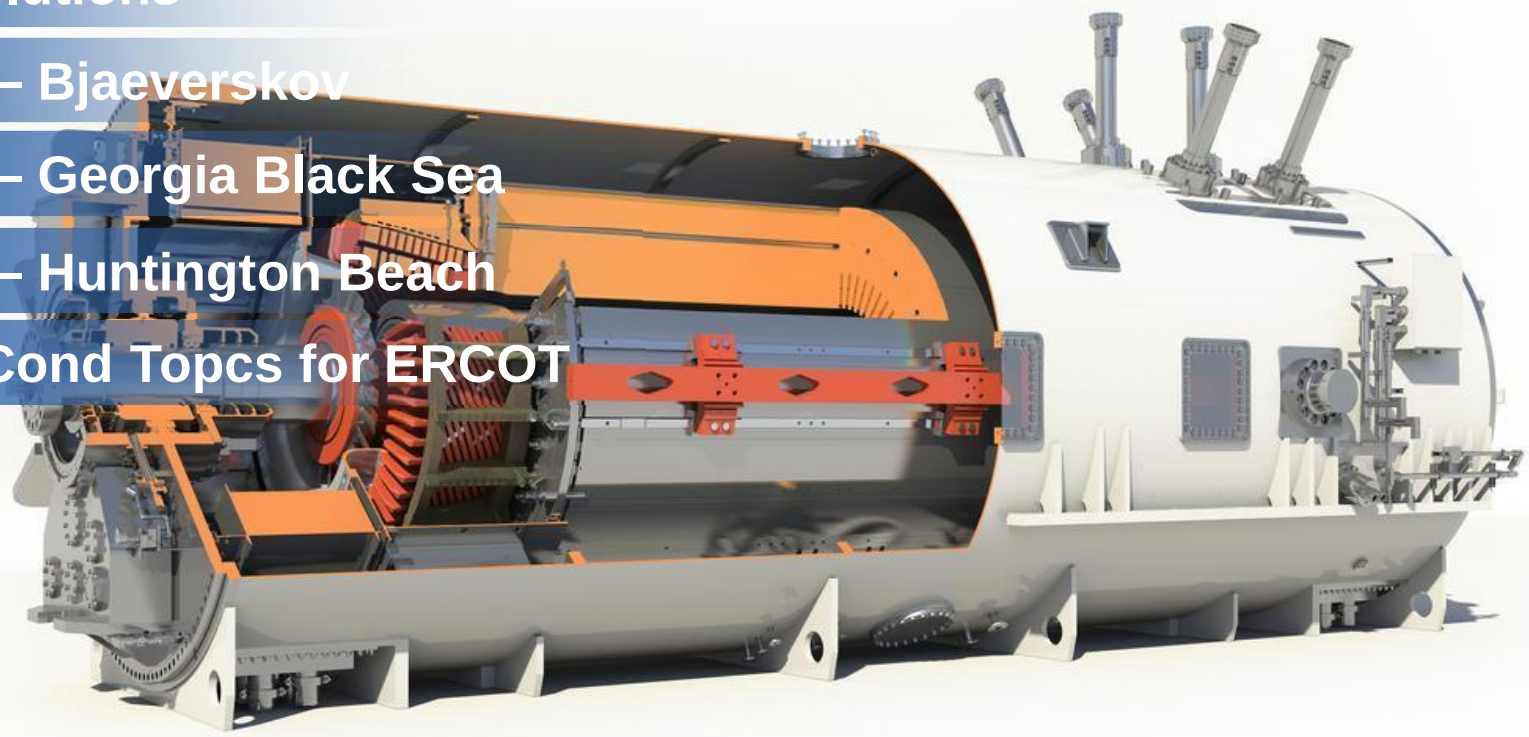
ERCOT Stakeholder Meeting,15th November 2013

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 Topcs for ERCOT



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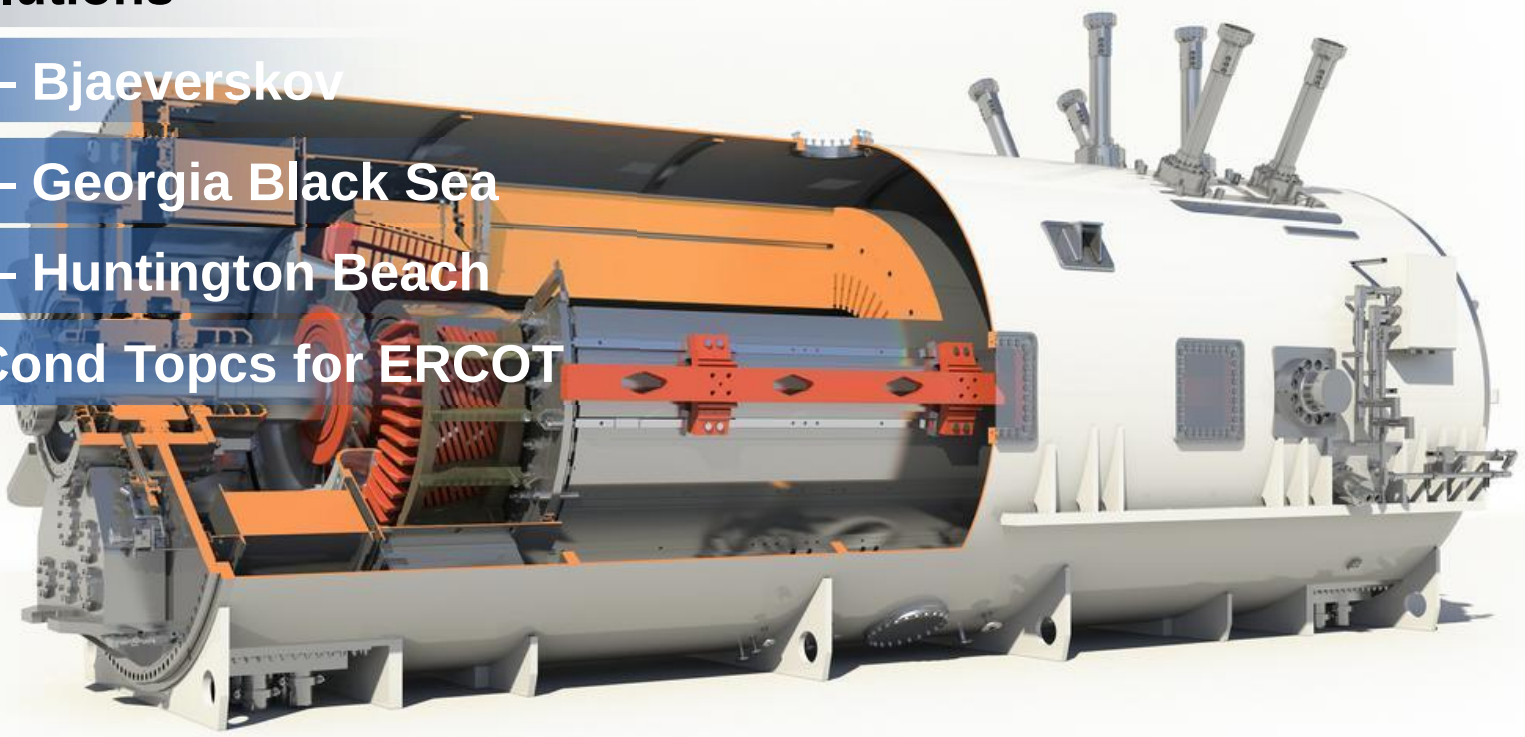

Turnkey Synchronous Condenser Solutions
Scope and main components

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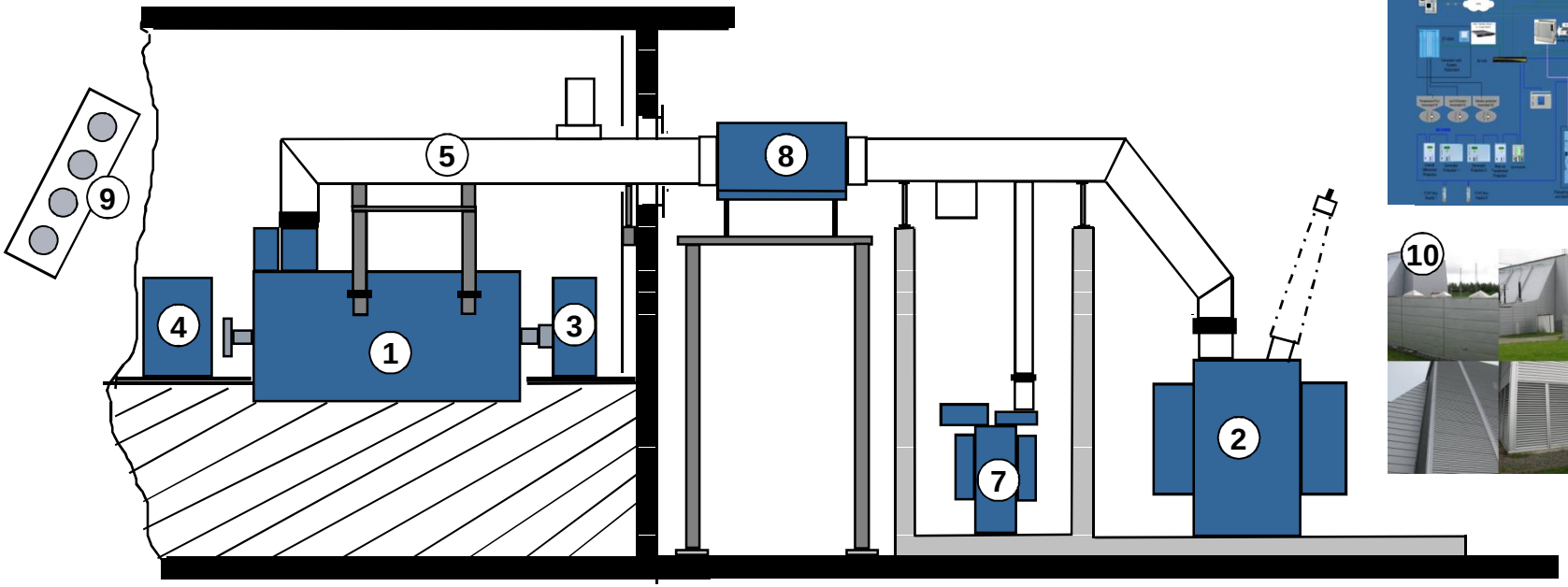

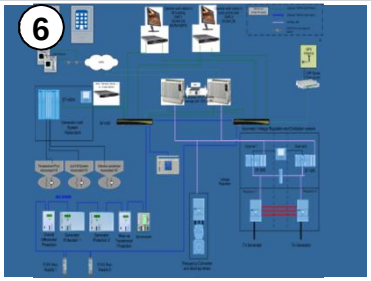

① Synchronous Condenser
② Generator Step-up Transformer
③ Static / Brushless excitation
④ Pony Motor / Starting Frequency Converter
⑤ Isolated Phase Busduct
⑥ Control and Protection system
⑦ Auxiliary Transformer
⑧ Generator Circuit Breaker
⑨ External Coolers (option)
⑩ Complete Civil and Construction works

Siemens in-house Equipment

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

Generator Product Portfolio

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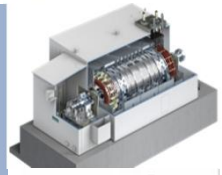
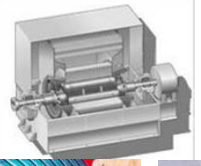
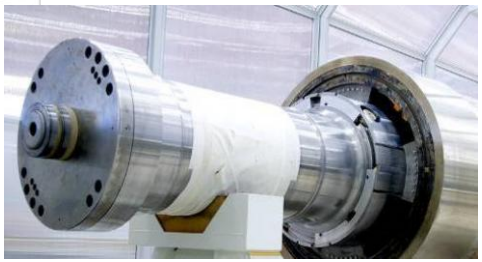
Cooling		Size
H_2O		25/30 Hz 1000-2235 MVA (4-pole)
		50 Hz 550-1300 MVA
		60 Hz 799-1066 MVA
H_2		50 Hz 350-570 MVA
		60 Hz 310-513 MVA
Air		50 Hz 165-370 MVA
		60 Hz 165-310 MVA
		50/60Hz 25-300 MVA
		25/30 Hz 25-65 MVA (4-pole)

Siemens SynCon Solutions based on standard horizontal Generators

Advantages of 2-pole over 4-pole Generators

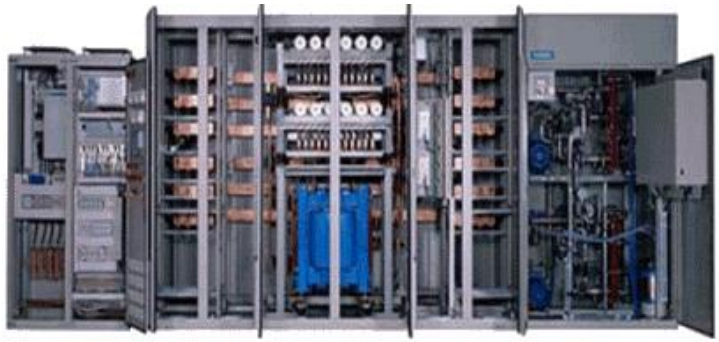
1. Very lower mass moment of inertia with the same power (appr.1:4)
   This results in a smaller starting motor
2. Higher rotational energy due to the double speed, more stable in the grid
3. Higher thermal time constants. This results in a higher over load capability
4. Higher unbalance load capability 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

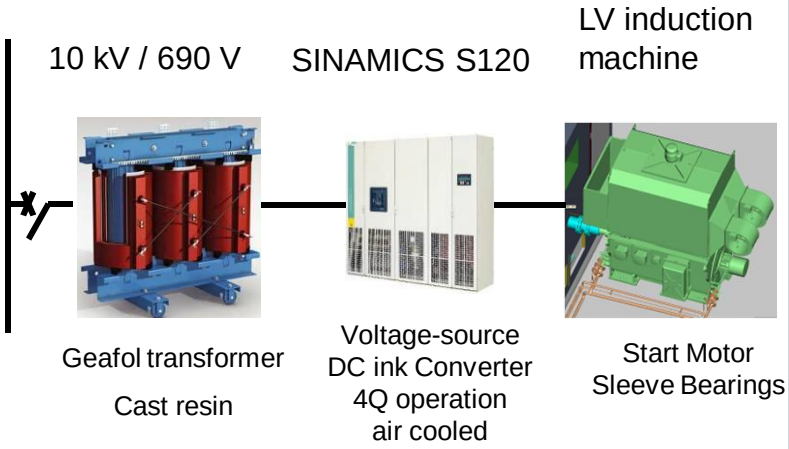
Variable Frequency Drive

SINAMICS GL 150



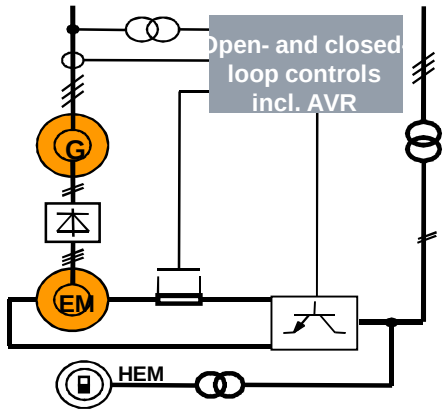
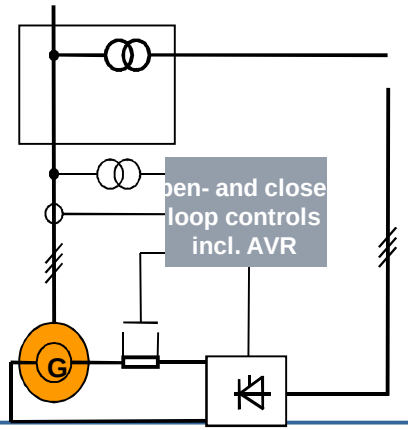
Supplier	SIEMENS
Rated Power	12 MW
Rated input voltage	2x 2,8 kV
DC-link voltage	6.3 kV
DC-link current	2000 A
Type of the SFC	SINAMICS GL 150

Frequency drive controlled Pony Motor



Siemens offers both solutions from own portfolio basing Customer's requirement

Brushless / Static Excitation

	Schematic	Pros	Cons (Relative)
Brushless		• 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
Static		• 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 own portfolio based upon Customer's request

Siemens Synchronous Condenser Solution
DAC unit, Pony Motor & Freqeuncy Converter for Start-up

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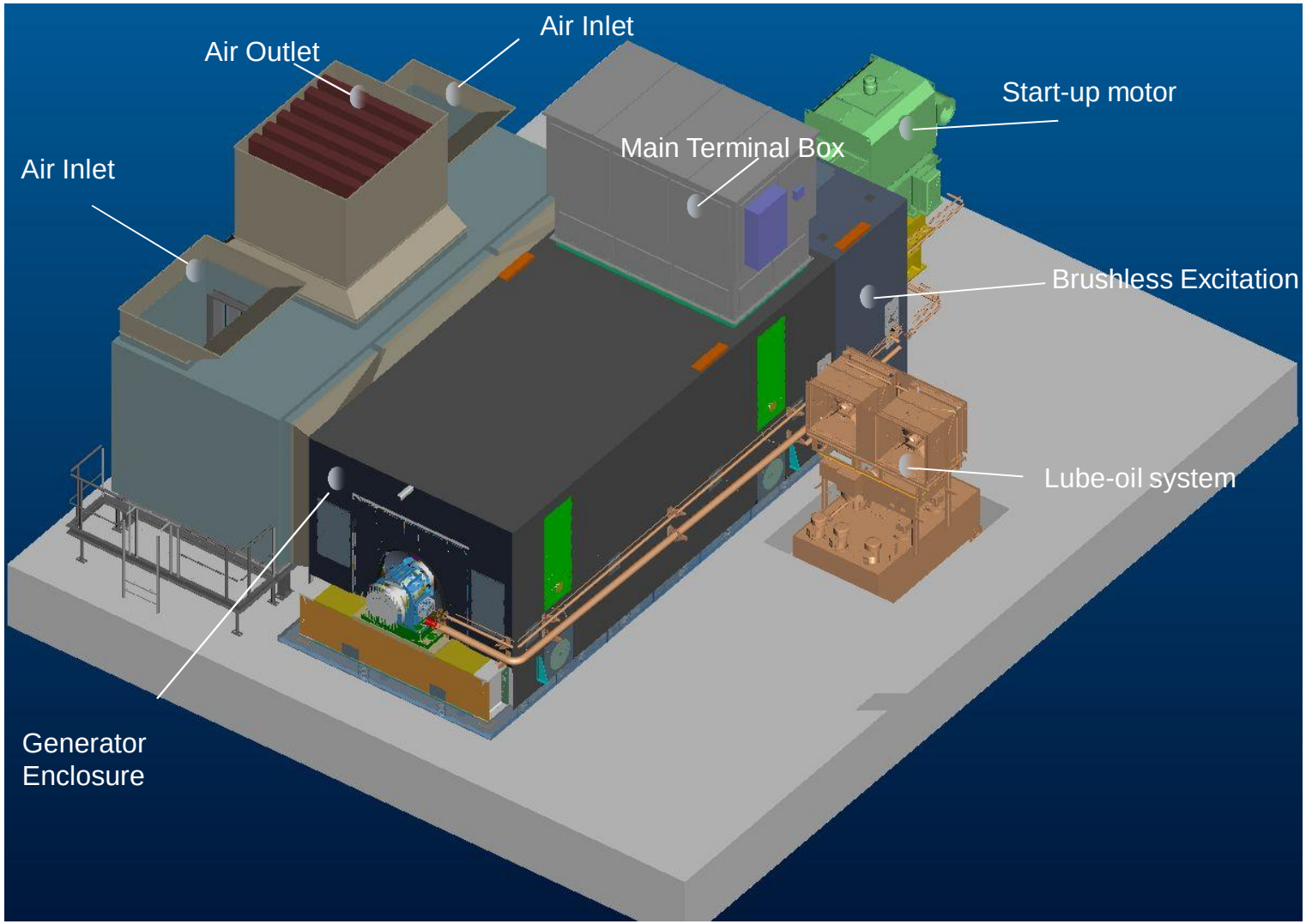

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Siemens SynCon Solutions References

Frame	Operation	Country	Customer	Station/Unit	Drive	Rated Voltage / kV	Rated Power Sn / MVA or Qn / Mvar	Frequency / Hz	Power Factor	Cold Gas Temperature / °C	Cooling Type OAC or TEWAC	Delivery Plant
SGen5-100A	Aug 2013	Denmark	Engerinet.dk	Bjaeverskov	SynCon*	15,75	270 Mvar	50	0	30	DAC	Erfurt
SGen5-100A	Dez 2012	Georgia	Energotrans Ltd.	Georgia Black Sea 1	SynCon*	11	60 Mvar	50	0	35	DAC	Erfurt
SGen5-100A	Dez 2012	Georgia	Energotrans Ltd.	Georgia Black Sea 2	SynCon*	11	60 Mvar	50	0	35	DAC	Erfurt
SGen5-100A	Dez 2012	Georgia	Energotrans Ltd.	Georgia Black Sea 3	SynCon*	11	60 Mvar	50	0	35	DAC	Erfurt
SGen5-100A	Jul 2007	South Africa	ESKOM Ltd.	Atlantis 11	GT²	15,75	186 MVA	50	0,8	28	TEWAC	Erfurt
SGen5-100A	Jul 2007	South Africa	ESKOM Ltd.	Atlantis 12	GT²	15,75	186 MVA	50	0,8	28	TEWAC	Erfurt
SGen5-100A	Jul 2013	South Africa	ESKOM Ltd.	Atlantis 21	GT²	15,75	186 MVA	50	0,8	28	TEWAC	Erfurt
SGen5-100A	Okt 2007	South Africa	ESKOM Ltd.	Atlantis 22	GT²	15,75	186 MVA	50	0,8	28	TEWAC	Erfurt
SGen5-100A	Nov 2008	South Africa	ESKOM Ltd.	Atlantis 31	GT²	15,75	186 MVA	50	0,8	28	TEWAC	Erfurt
SGen5-100A	Nov 2008	South Africa	ESKOM Ltd.	Atlantis 32	GT²	15,75	186 MVA	50	0,8	28	TEWAC	Erfurt
SGen5-100A	Dez 2008	South Africa	ESKOM Ltd.	Atlantis 41	GT²	15,75	186 MVA	50	0,8	28	TEWAC	Erfurt
SGen5-100A	Dez 2008	South Africa	ESKOM Ltd.	Atlantis 42	GT²	15,75	186 MVA	50	0,8	28	TEWAC	Erfurt
SGen5-100A	Dez 2009	South Africa	ESKOM Ltd.	Atlantis 43	GT²	15,75	186 MVA	50	0,8	28	TEWAC	Erfurt
SGen5-100A	Sep 2007	South Africa	ESKOM Ltd.	Mossel Bay 21	GT²	15,75	186 MVA	50	0,8	28	TEWAC	Erfurt
SGen5-100A	Sep 2007	South Africa	ESKOM Ltd.	Mossel Bay 22	GT²	15,75	186 MVA	50	0,8	28	TEWAC	Erfurt

* Synchronous Condenser Application
² Designed to operate in Synchronous Condenser mode

DAC Direct Air Cooled
TEWAC Totally Enclosed Water to Air Cooled

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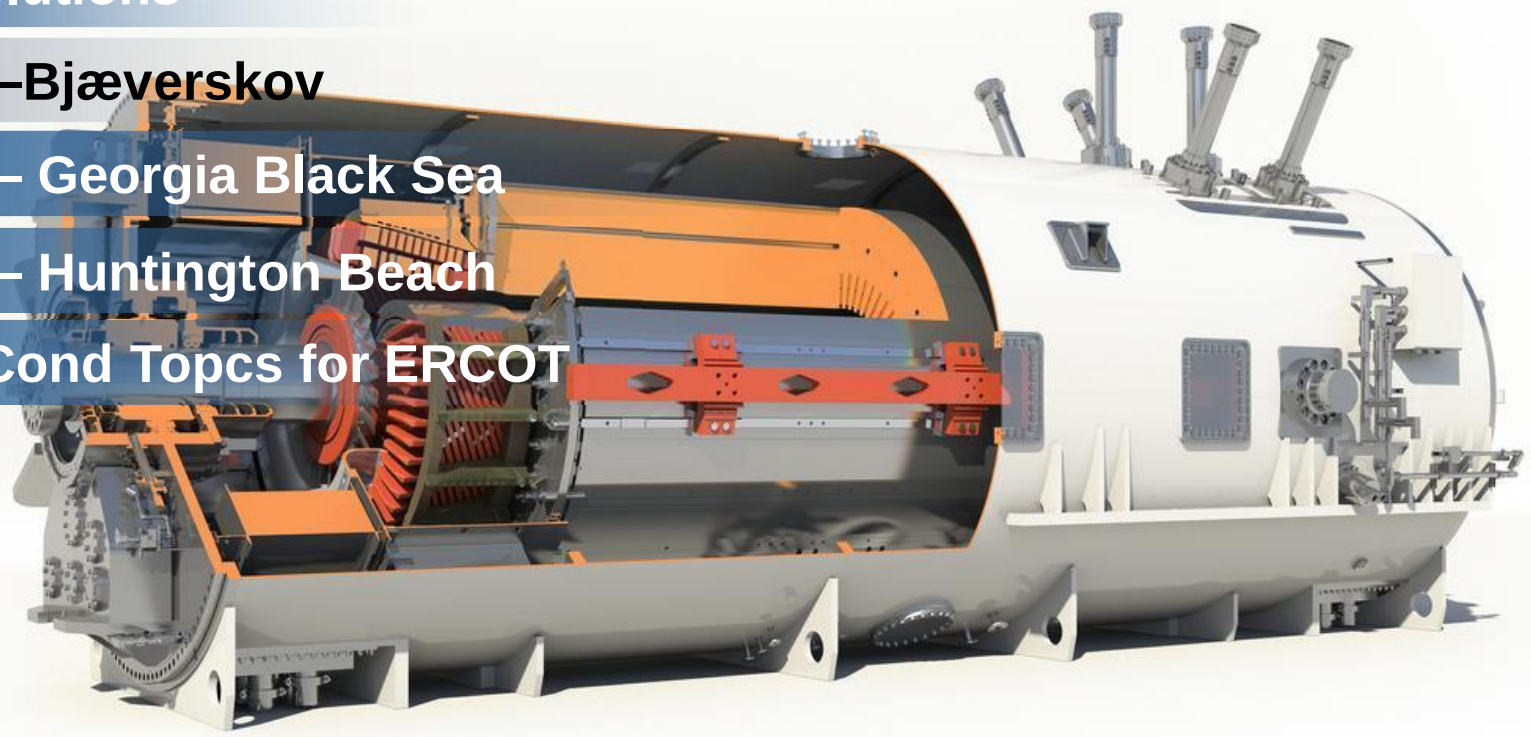

Back ground for installing new synchronous condensers in Denmark

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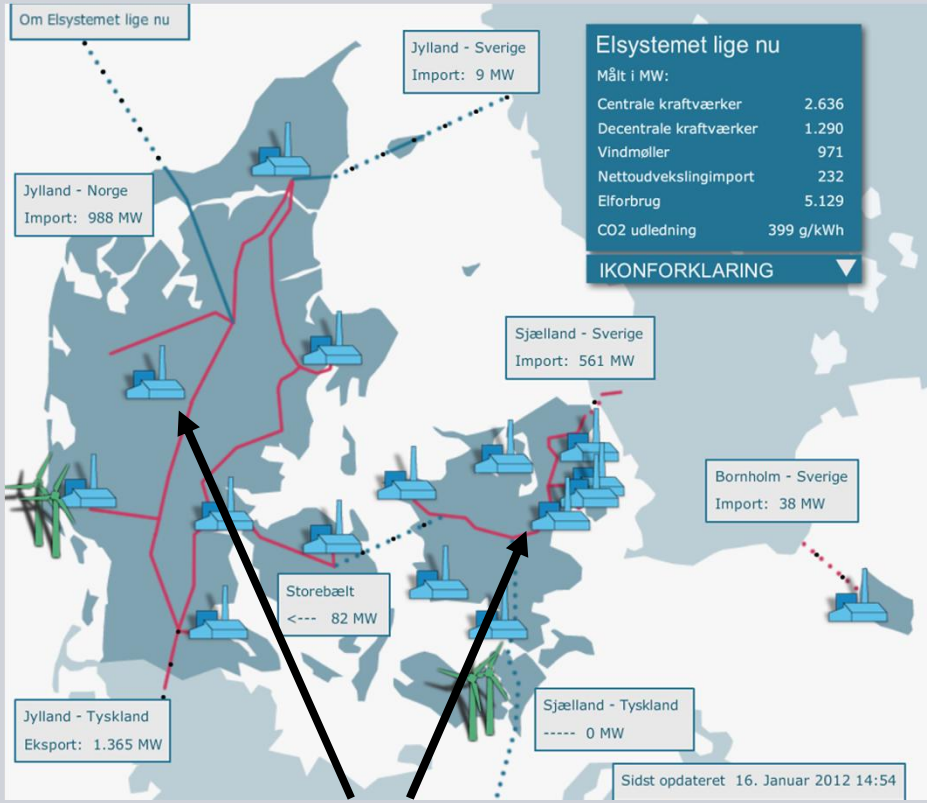
Power systems requires balance in every second and must also be given special system-supporting services such as:

- 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

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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

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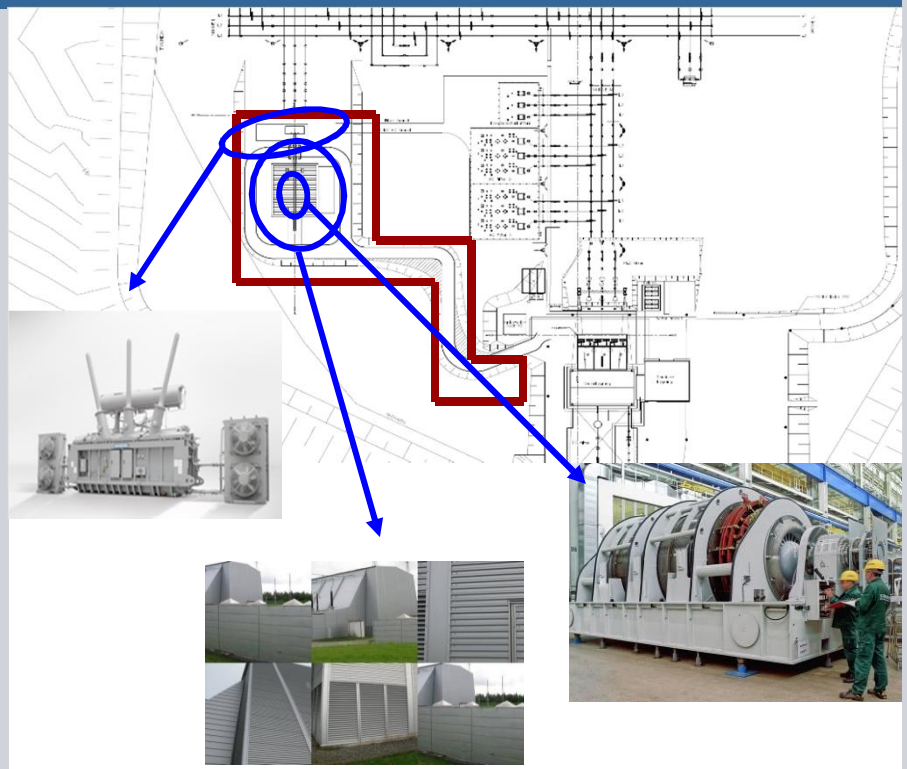
Bjæverskov, Denmark

- 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

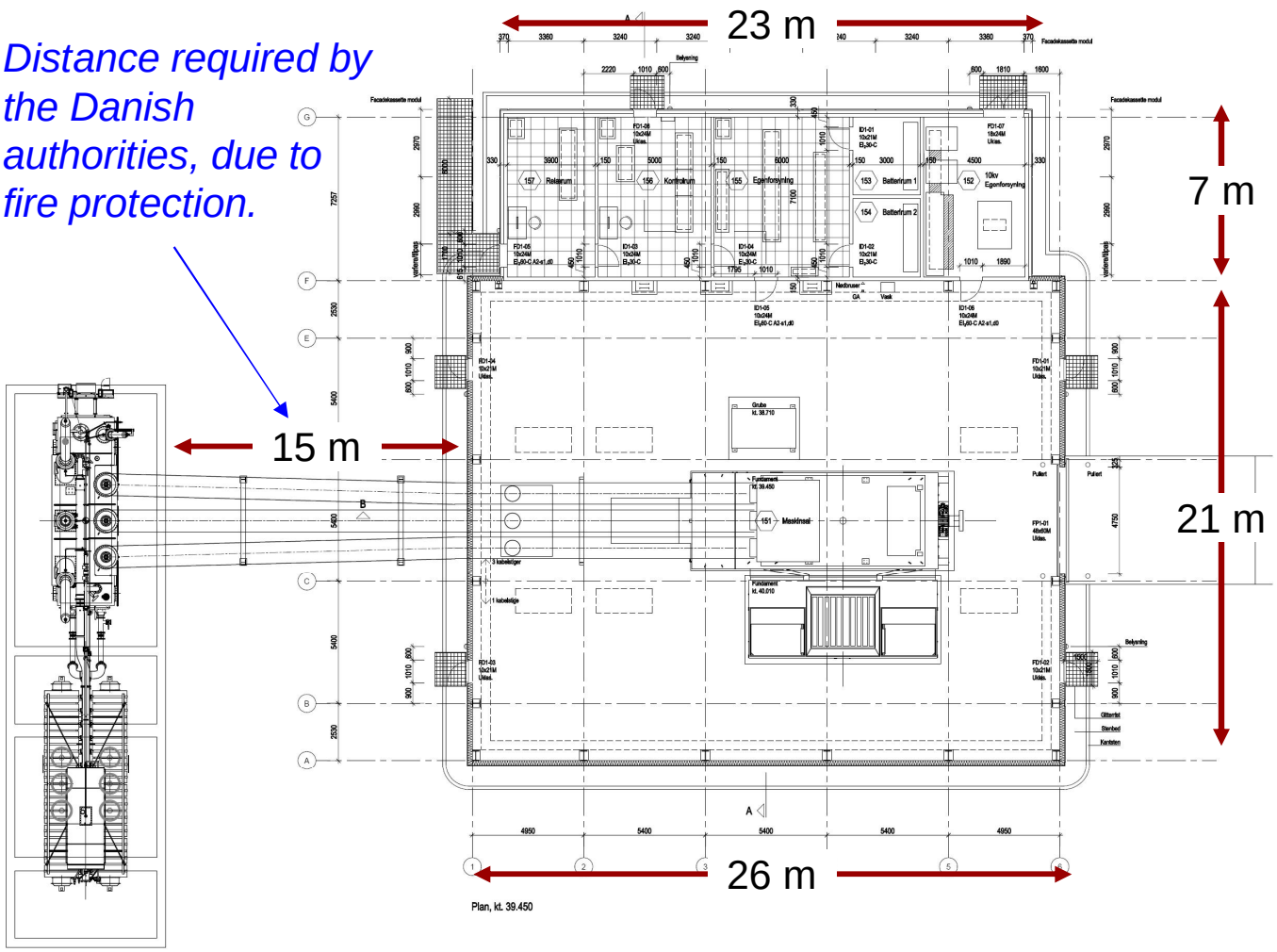
- SynCon cooling: Direct Air Cooled
- Excitation: Brushless
- Starting System: Frequency drive controlled Pony Motor
- Specials: Civil works matching the existing HVDC



Award Jan'12 | **Site works start June'12** | **Major equipment on site Feb'13** | **Trial operation June'13** | **PAC July'13**

Design / Engineering | Civil works | Erection / Commissioning

Building layout - Bjæverskov



First Syncronous Condenser in Denmark for 40 Years

Key components
Synchronous Generator

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2 pole Synchronous Generator

SGen5-100A-2P 118/46

Power:	270 MVAr
Voltage:	15,75 kV ± 5%
Power Factor:	cosφ =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

SIEMENS

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

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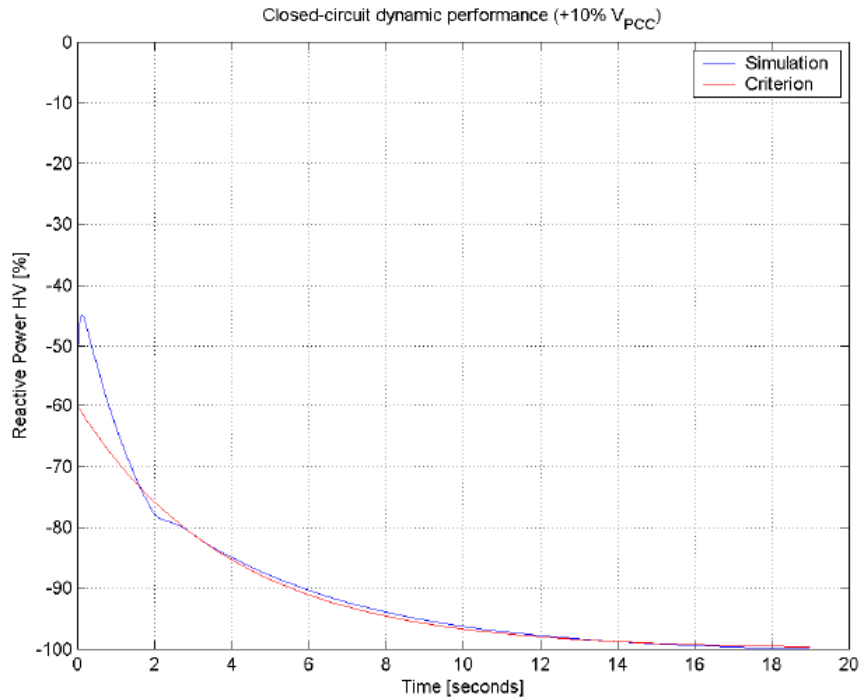

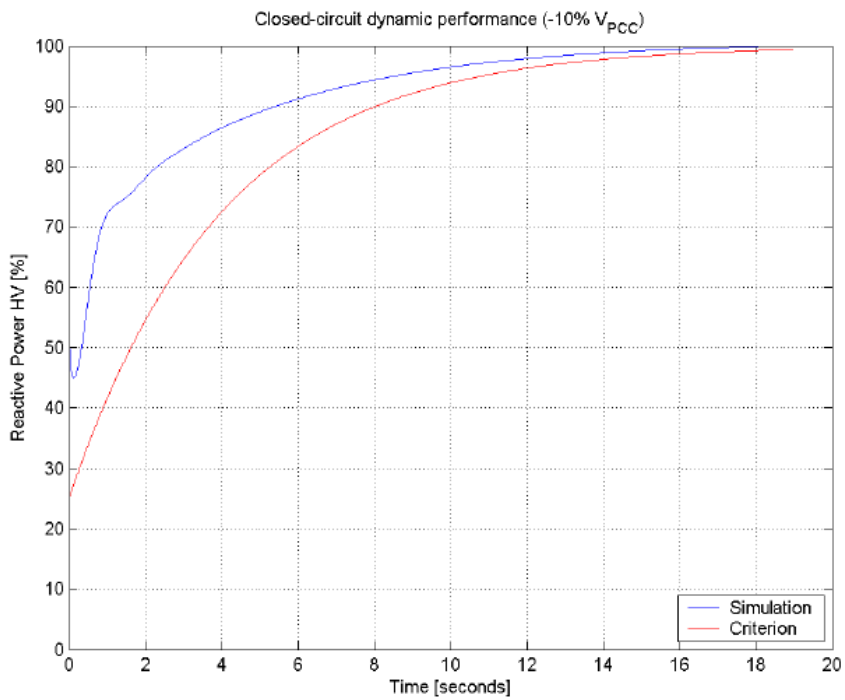

Reactive power response caused by a +10% step of the PCC voltage from 1 pu to 1.1 pu

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

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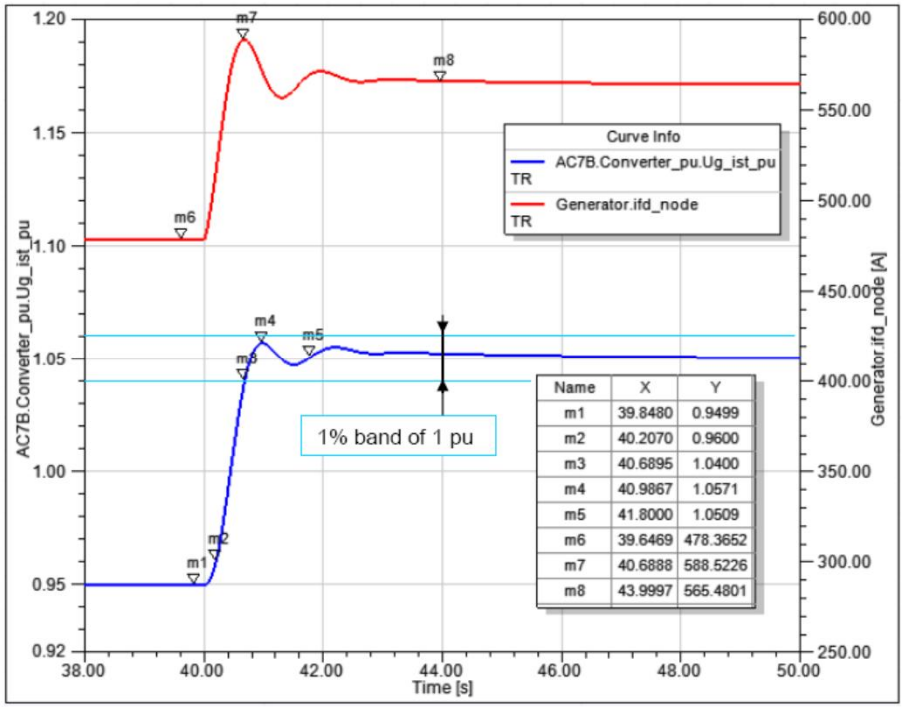

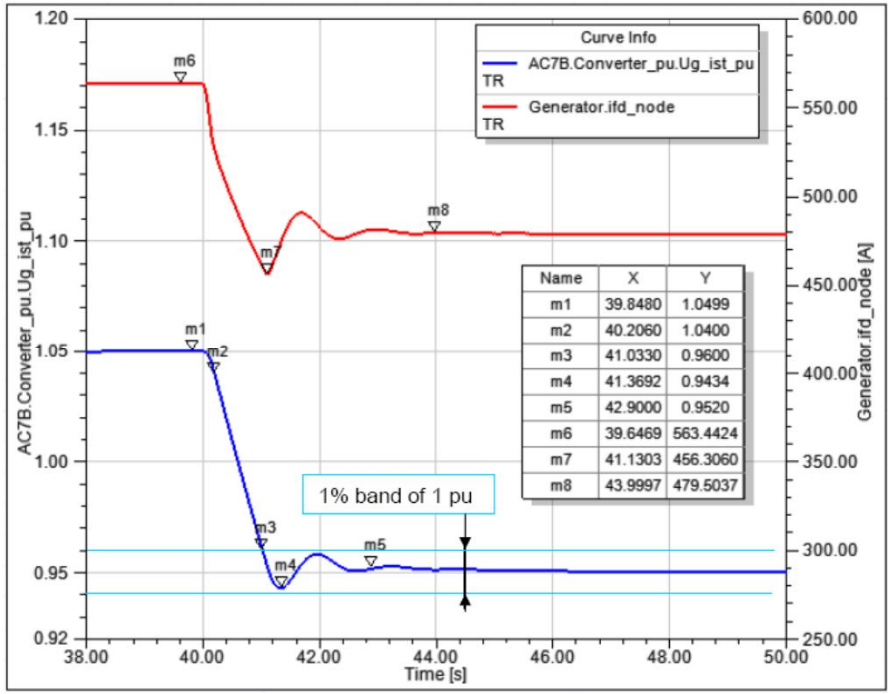

Open-loop voltage step from 0.95 pu to 1.05 pu

Less than 500 ms

Open-loop voltage step from 1.05 pu to 0.95 pu

Less than 850 ms

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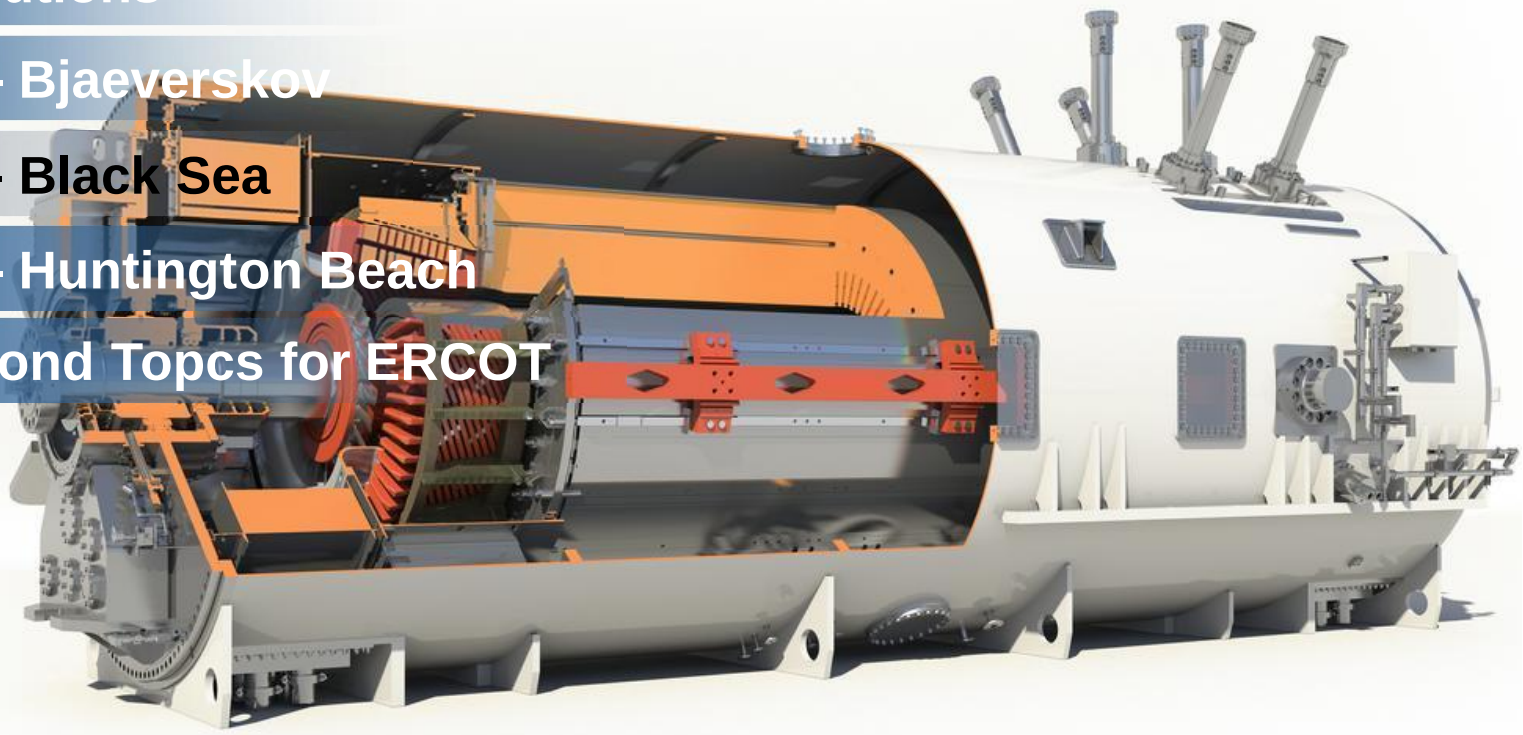

Synchronous Condenser Solution References
Black Sea Transmission Network, Georgia

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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

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Black Sea Design
Main Terminal Box - Line Side – IPB's cast resin isolated

Black Sea
Generator Step Up Unit Transformers

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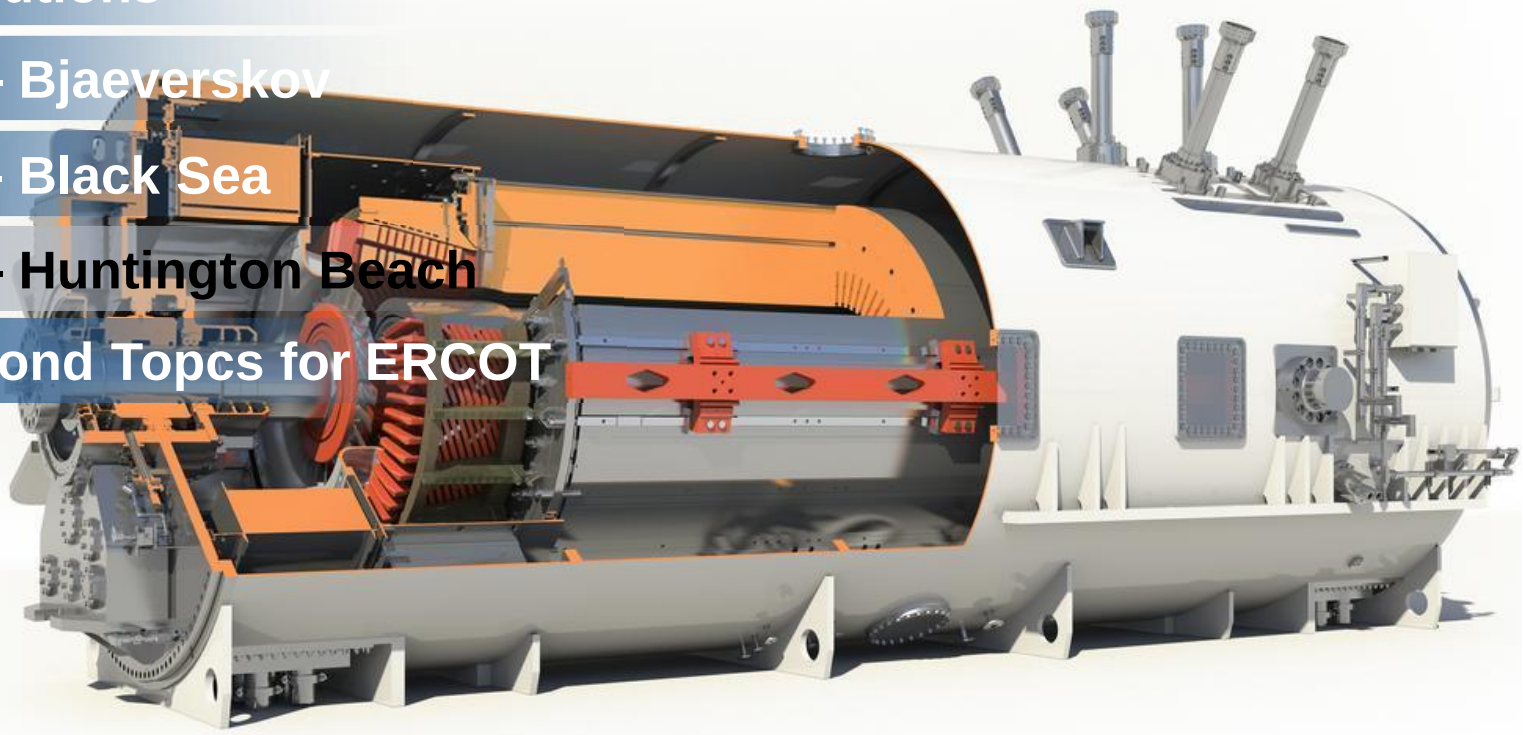

Huntington Beach, CA
Synchronous Condenser Conversion

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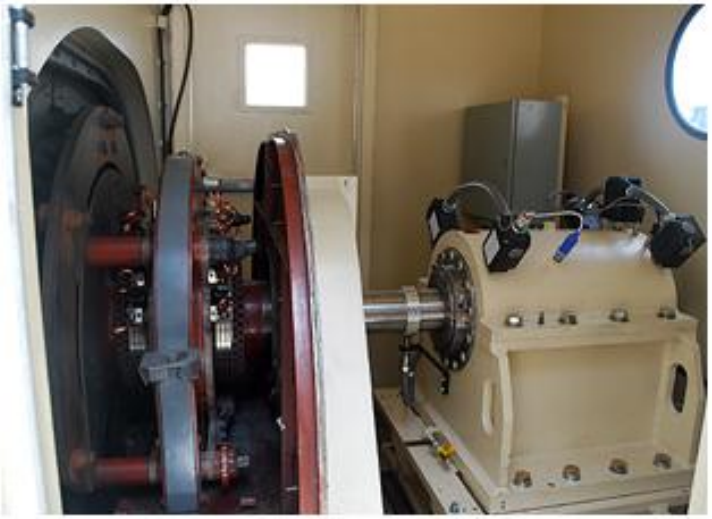
siemens.com/press

Information for the press

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."

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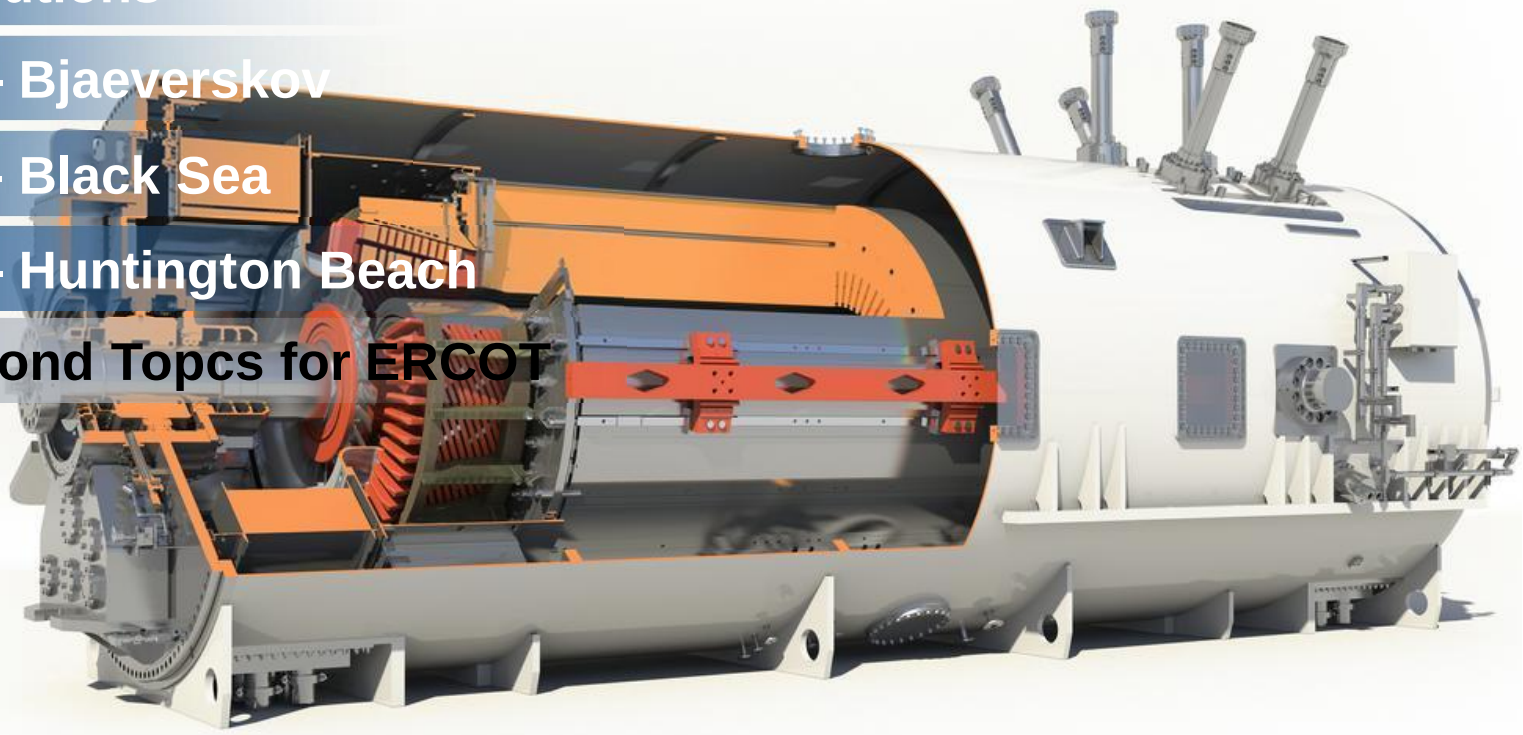

Brownfield vs Greenfield Installations

	Pros	Cons (Relative)
GREENFIELD	• Lesser maintenance • Guaranteed performance • Guaranteed availability • Customized solution • Minimum O&M cost • High efficiency solution • State of the art technology	• Possible higher investment
BROWNFIELD - Reuse of exsisting equipment	• Lower possible investment • Utilization of existing asset	• Uncertain reliability • Less possible customization • Eventual lower efficiency • Uncertain maintenance costs • Limits in capabilities

Siemens offers both solutions from own portfolio based upon Customer's requirement

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Remaining topics for ERCOT Stakeholder Meeting

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

- *Any other topics ?*


Many Thanks for Your Attention
CONTACT:
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Cell: (407) 280-4153