Synchronous Condensers for Transmission Systems

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imagination at work

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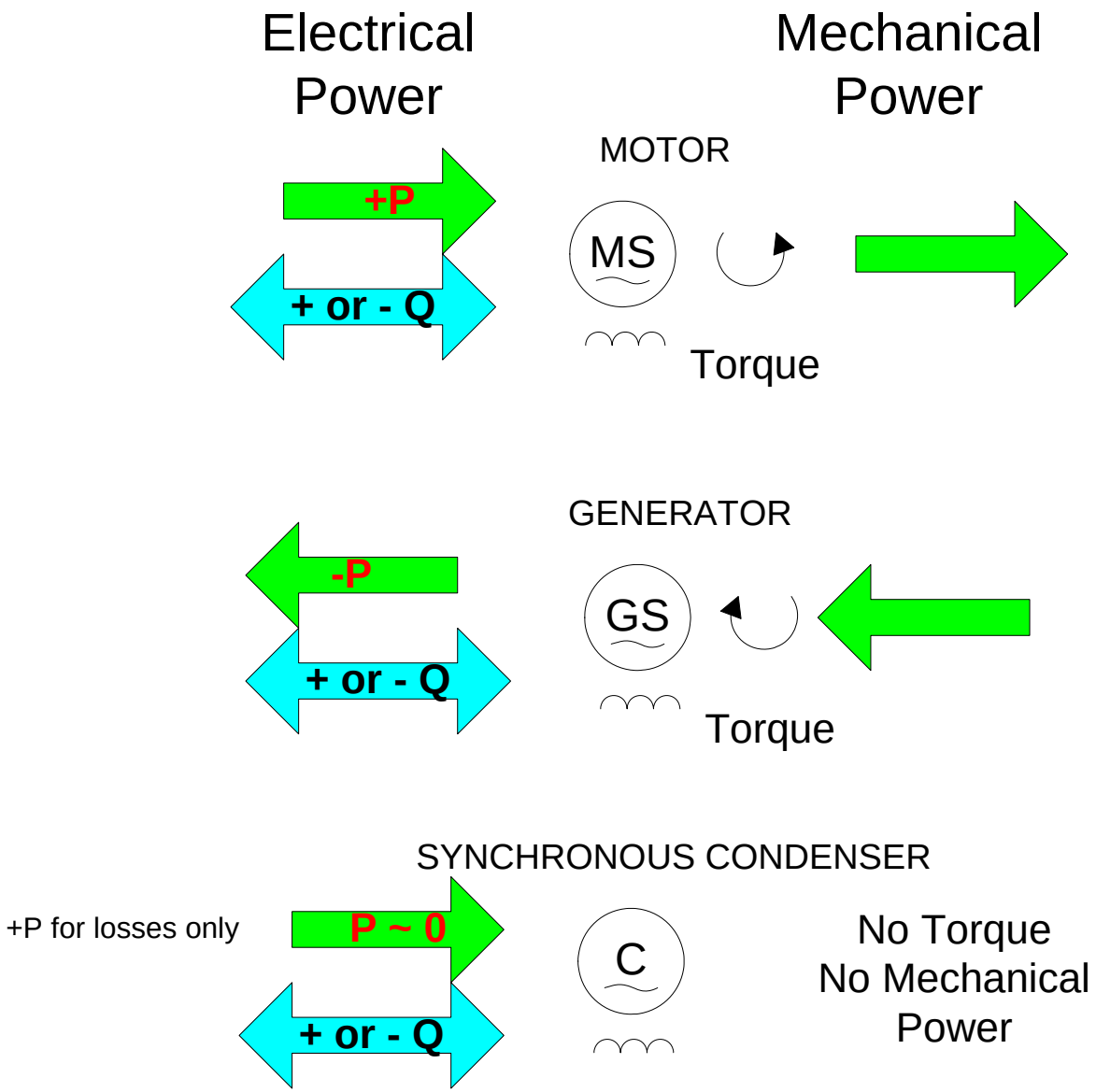
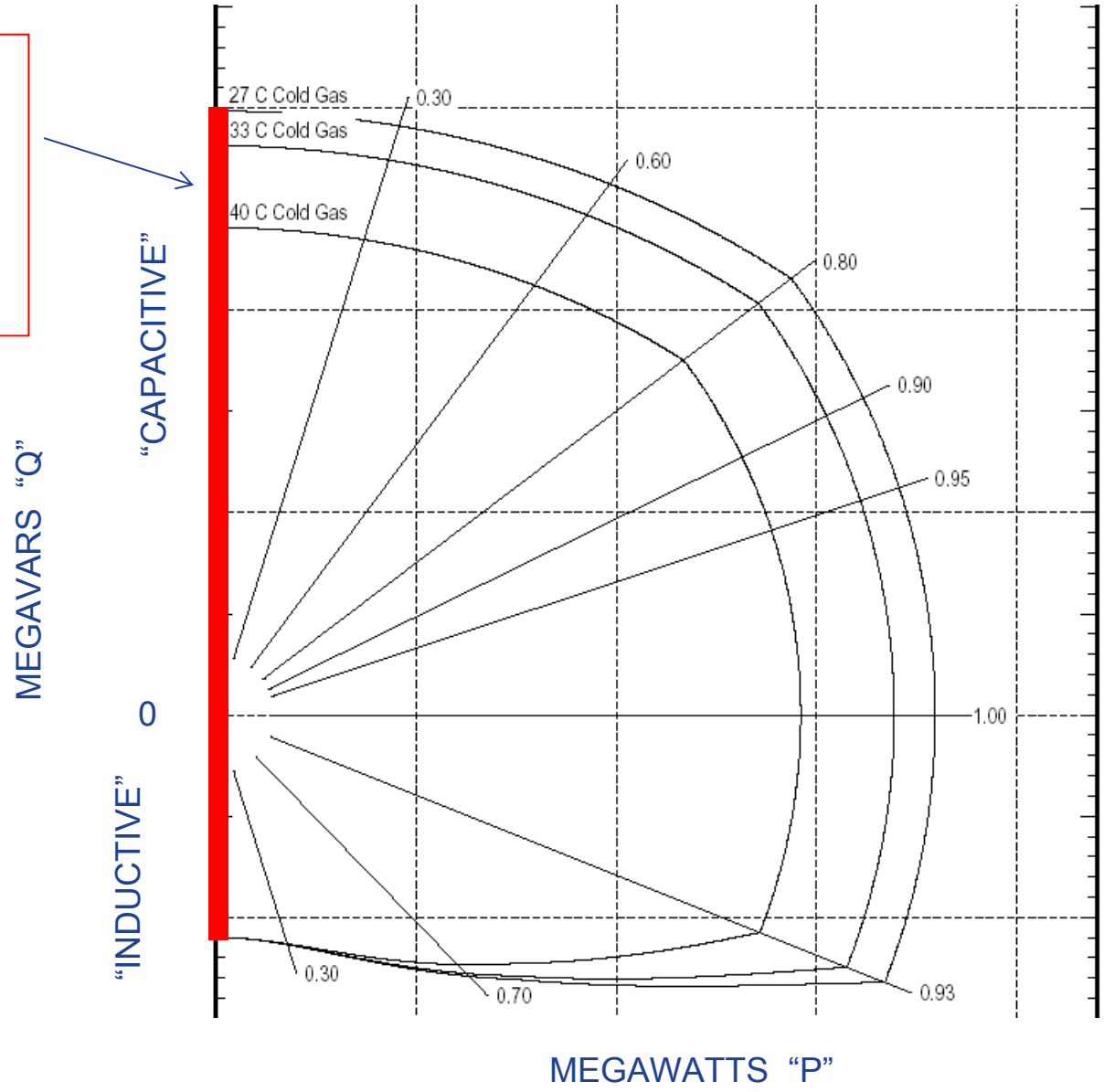
Outline

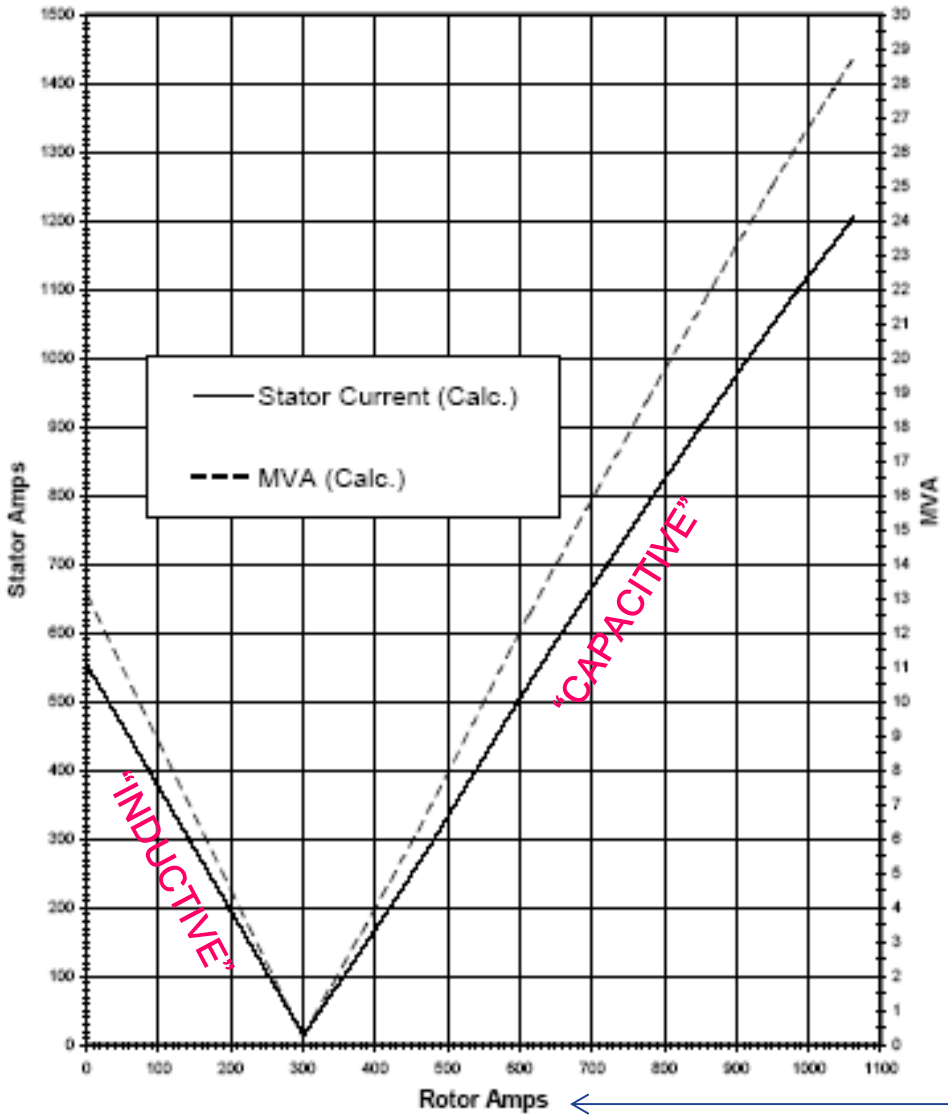
1. Synchronous Condenser Basics
2. GE Condenser Product Overview
3. ERCOT Concerns
4. Summary

1. Synchronous Condenser Basics


Electrical Power
Mechanical Power
MOTOR
+P
+ or - Q
MS
Torque
GENERATOR
-P
+ or - Q
GS
Torque
SYNCHRONOUS CONDENSER
+P for losses only
P ~ 0
+ or - Q
C
No Torque
No Mechanical Power

SYNCHONOUS CONDENSER CAN ONLY OPERATE ALONG THE VERTICAL “Q” AXIS AS P~0.





Synchronous Condenser V- Curves

Inductive VAR requirement will determine size of the machine

The ROTOR is the machine FIELD. Adjustment of the FIELD Amps result in change in REACTIVE POWER "Q" on the ARMATURE or STATOR.

2. GE Condenser Product Overview

2. GE Condenser Product Overview

	Peterborough Factory	Schenectady Factory
Ratings	≤ 100 MVArs	52 – 478+ MVArs
Rotor	Salient pole	Round rotor
Poles	4 or 6	2
Excitation	Brushless, static	Brushless, static
Starting	Full V, Reduced V, Reactor start, Capacitor assist, Motor	LCI
Cooling	Air	Air, H2

2. Sample GE Machine Ratings

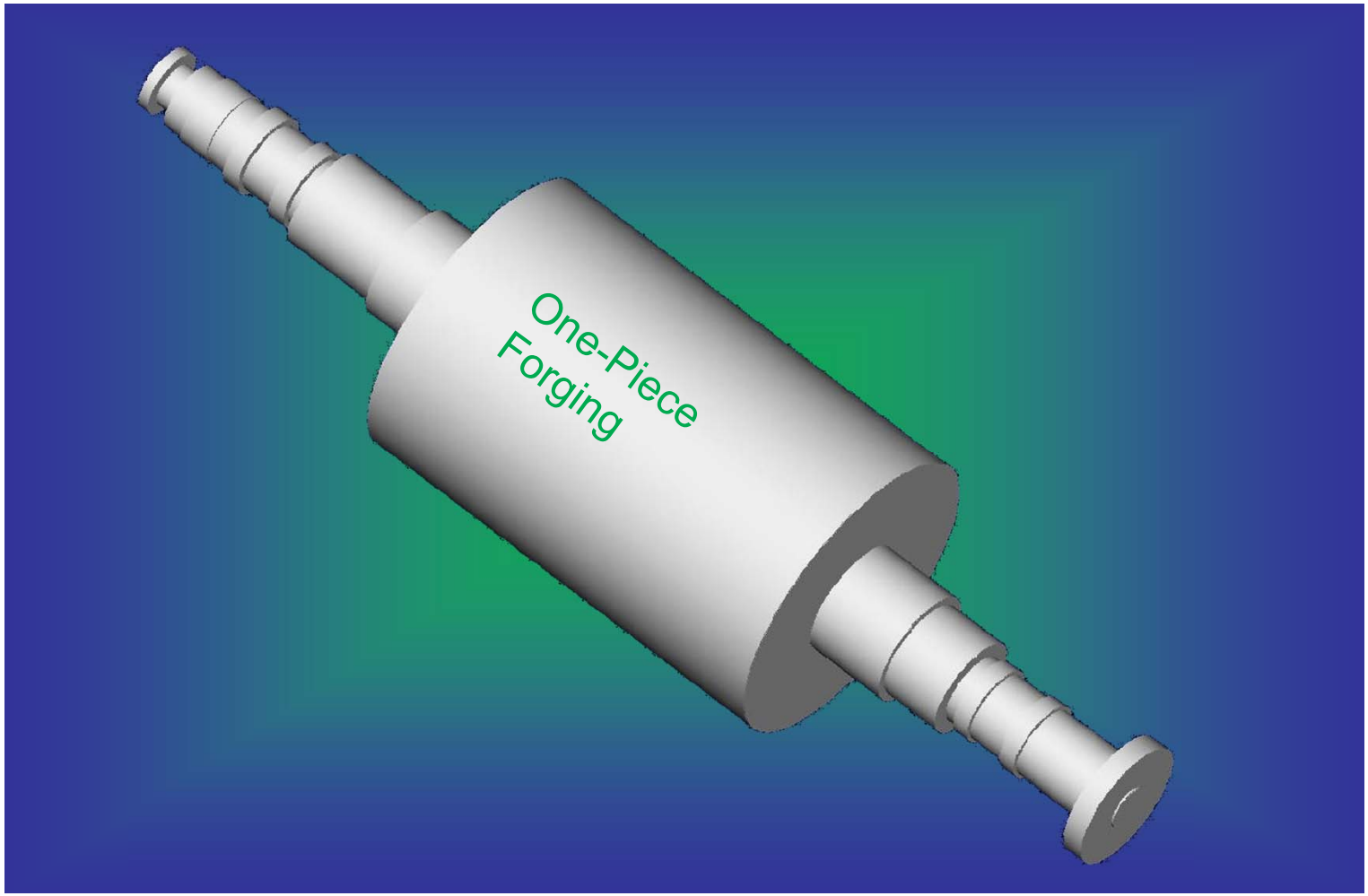
Frame	Cooling	Condenser Ratings	H	kV	Hz	Comments
Large Motor	Air	+25/-12.5	~2	12.47-13.8	60	
Large Motor	Air	+50/-25	~2	12.47-13.8	60	
Large Motor	Air	+100/-45	~2	12.47-13.8	60	
6A8	Air	+52/-26.5	2.13	13.8	60	
7A6	Air	+91.8/-38.2	2.21	13.8	60	
9A4+	Air	+125/-67	2.10	13.8	60	
170A	Air	+175 / -85	1.72	13.8	60	
7FH2	H2	+198 / -86	1.27	18	60	
7FH2B	H2	+237 / -94	1.2	18	60	
324	H2	+332 / -128	0.96	18	60	

2. Peterborough Factory: Reliability

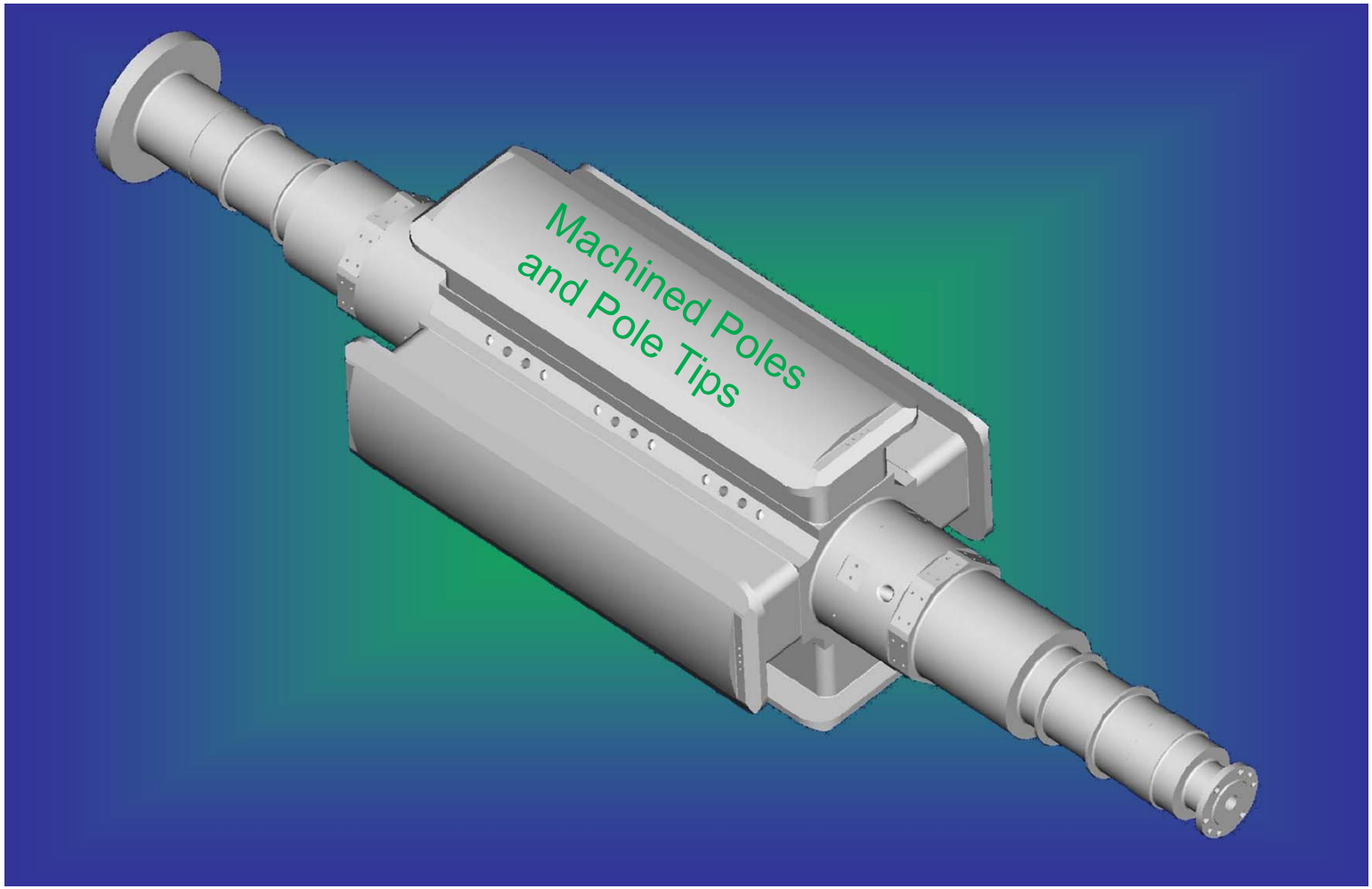
Series 9000 Salient Pole Machines

- 5MVA – 100MVA
- Up to 13.8kV 50/60Hz
- Advantages
- Integral rotor pole tips
- Minimize rotating components
- Highest efficiency - best in class

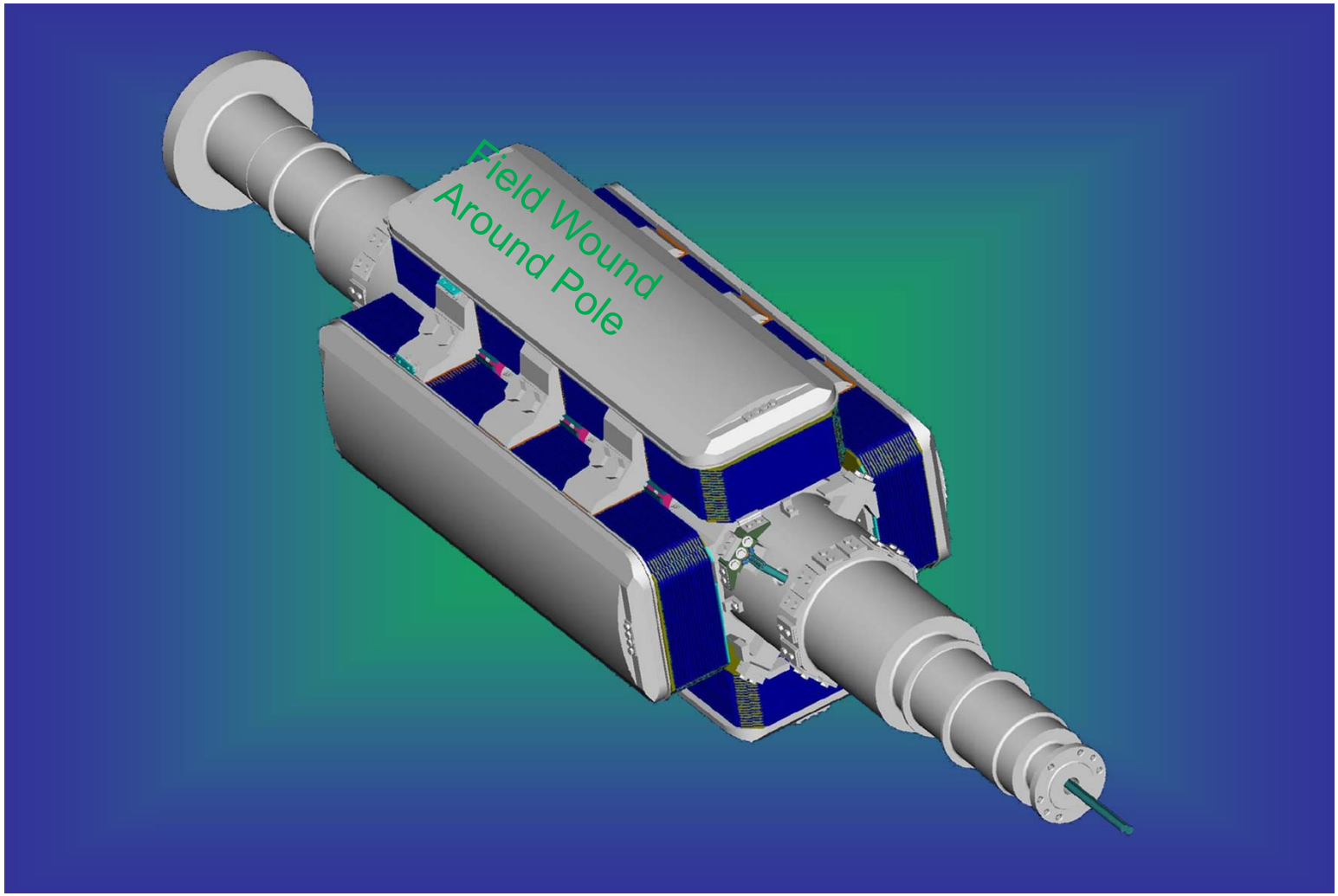
Cylindrical Forging



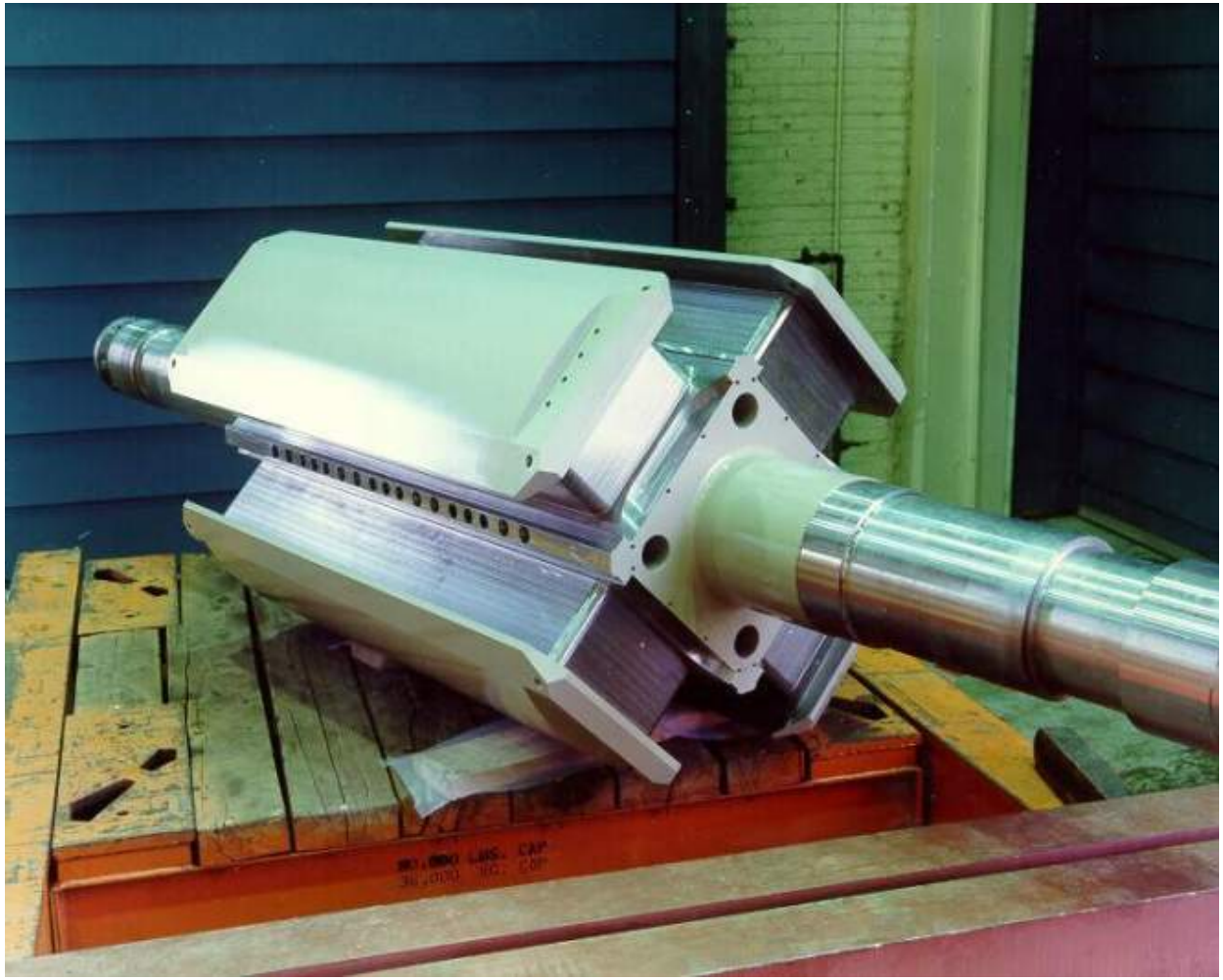
Integral Pole Tips



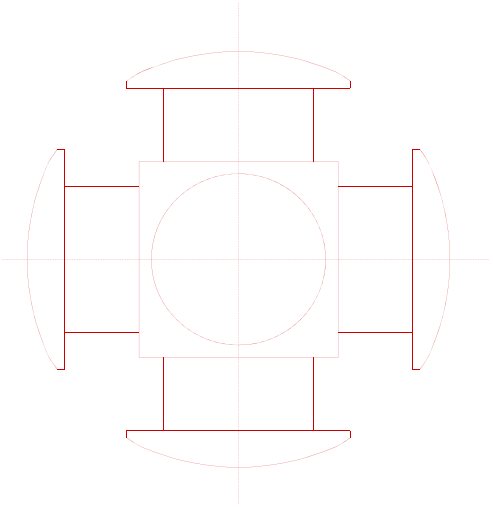
Completed Rotor



Integral Pole Tips

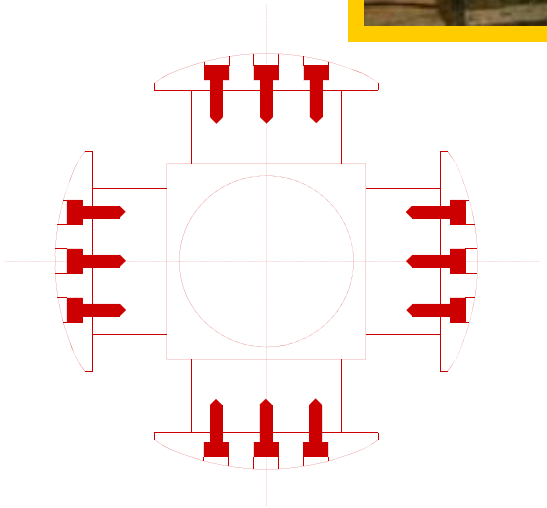


Integral Pole Tips



GE's Design

Competition



2. Peterborough Factory: Reliability

Series 9000 Installed Base

Over 400 units installed in 30 years

- Meets stringent American Petroleum Institute (API) standards:
  - Minimum 25 years of service life
  - Minimum 5 years of uninterrupted continuous operation
- Proven reliability in O&G industry as process critical equipment in large refineries

2. Peterborough Factory: Reliability
Recommended Maintenance

- Monthly:
- Listen for any unusual noise
- Clean surfaces as required
- Check oil flow and filters
- Annual:
  - Test bearing oil

- Extended Outage (or every 5 years):
  - Inspect stator and rotor winding
  - Inspect brushless exciter
  - Measure insulation resistances (stator, rotor and exciter windings)
  - Estimated outage length: 1-2 days
  - Estimated cost: $15,000 per outage

- Condenser protective equipment (RTD's, vibration sensors, cooler leak detector, differential protection CT's) is monitored continuously.

3. ERCOT Concerns

3a. New vs. Re-Purpose Existing Machine

Existing

What is the right size?

- Existing machine is often a compromise in size
- Location – is it in the right place? Moving can be costly
- Condition / age. Reliability covers a wide range depending on machine used
- Starting/clutch can be costly

New Machines

- Size and number of machines desired
- Located where most effective
- All new components (bearings, windings, pumps, fans)

Re-purposing an existing machine is usually a compromise. But sometimes is attractive because the savings are worth the compromised performance.

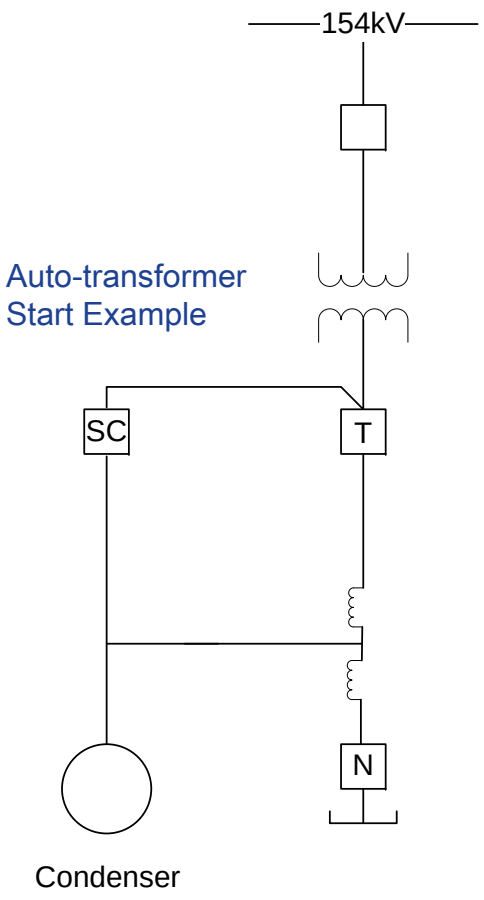
3b. Performance

Starting / Stopping

Many starting methods exist

- Across the line
- Reduced voltage (Reactor, Auto-transfomer)
- Pony motor
- LCI

Coast stop

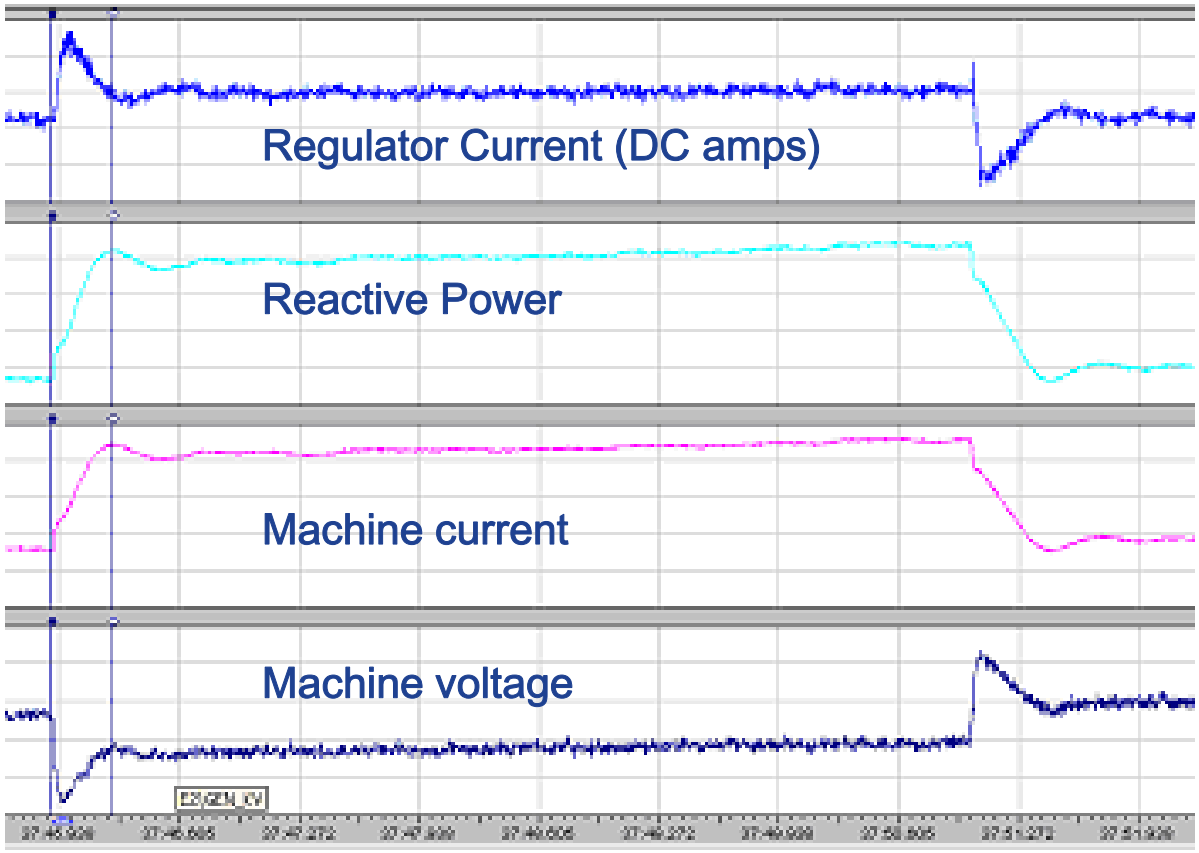


Grid strength and tolerance of voltage dip will influence recommended starting method

3b. Performance
Dynamic Response

Response to a 25 MVAr shunt bank tripped off line and then placed back into service.

- Long tail-in is the master controller slowly raising the system voltage.
- Voltage dips to 98.8% at 0.059 seconds.
- Voltage returns to 99.5% at 0.271 seconds.



Response time to reactive power peak is 0.339 seconds.

3b. Performance

Power Consumption / Losses

Performance Criteria	Synchronous Condenser	Static Var Compensator	STATCOM or DVAR
Losses (Device Base)	~0.94% at idle ~ 1.6% full on	~0.16% at idle ~0.27% TSC only ~0.80+% with TCR	~0.17% idle ~1.0% full on
Losses (SVC Base)	~0.47% at idle ~0.80% full on	~0.16% at idle ~0.27% TSC only ~0.80+% with TCR	~0.14% idle ~1.0% full on

3c. SSR Concerns

Sub-Synchronous Resonance

Likelihood is Lower than with a generator

(But is still possible)

GE can do screening studies and check for issues

Possible mitigations include:

- Multiple smaller machines vs. one large machine or vice-versa
- Blocking filters on transformer neutral can mitigate
- A filter can be added to the series bank

GE has done all the above and is qualified to handle SSR concerns

GE Summary

- Recently, GE has supplied highly reliable and proven systems (VELCO and KEPCO)
- GE can study, design, engineer and install modern Synch Condenser systems for any grid application need, without concern for control interactions
- GE's 4-pole technology utilizes superior design, allowing for a robust, efficient and reliable solution
- 100+ years of experience and continuous improvements – modern controls and excitation
    - With brushless excitation, operated continuously for years with no outages
    - Expect decades of operation without major maintenance
    - Superior insulation systems – extremely long life