



GTEN 2019 Symposium

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19-GTEN-101

EVOLUTIONARY IMPROVEMENTS OF SIEMENS SGT-A35 GAS TURBINE (INDUSTRIAL RB211)

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**Presented at the Gas Turbines Energy Network (GTEN) 2019 Symposium
Banff, Alberta, Canada - October 2019**

The GTEN Committee shall not be responsible for statements or opinions advanced in technical papers or in symposium or meeting discussions.



GTEN 2019 Symposium

Agenda



- **SGT-A35 Product & Applications**
- Evolutionary enhancements
- Using disruptive technologies
...wisely



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SGT-A35 (Industrial RB211)

Trusted power, everywhere



- ✓ Over 43 million service hours across wide application range
- ✓ Continuously improved to achieve class-leading reliability
- ✓ Aero lineage provides high efficiency and operational agility
- ✓ Low emission dry / wet options
- ✓ Fast engine exchange to maximize uptime and availability
- ✓ No “hot lockout” by inherent design

Proven in mission-critical service to support Customer operations worldwide

Mechanical Drive

Pipeline compression



Power Generation

Floating offshore



Fixed offshore



Industrial Power





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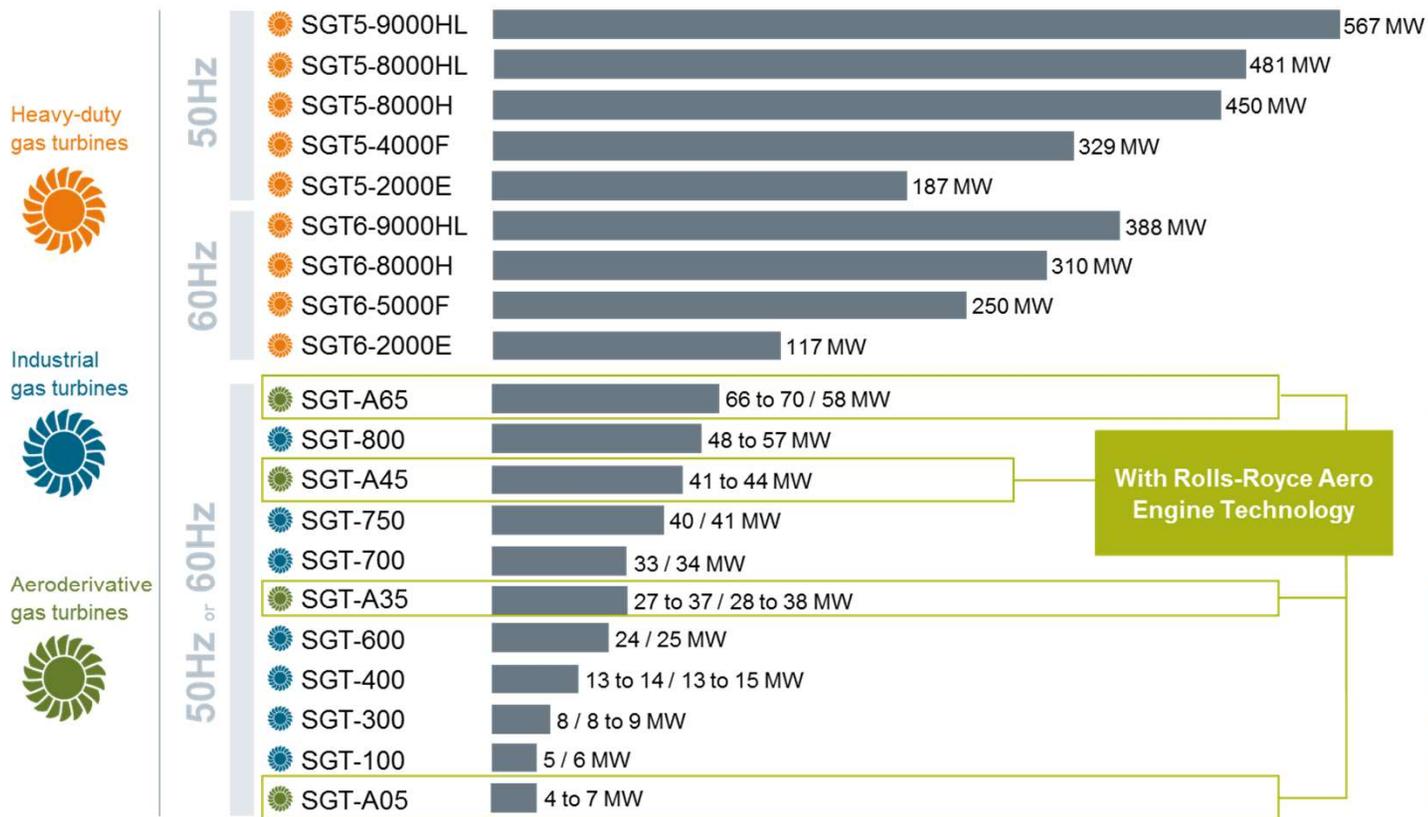
Siemens Aeroderivative Gas Turbines

	Rolls-Royce name	Siemens name
	Industrial 501-K	SGT-A05
	Industrial Avon 200	SGT-A20
	Industrial RB211	SGT-A35
	Industrial Trent 60	SGT-A65



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Siemens Gas Turbine Portfolio



Power Generation / Mechanical Drive ISO ratings

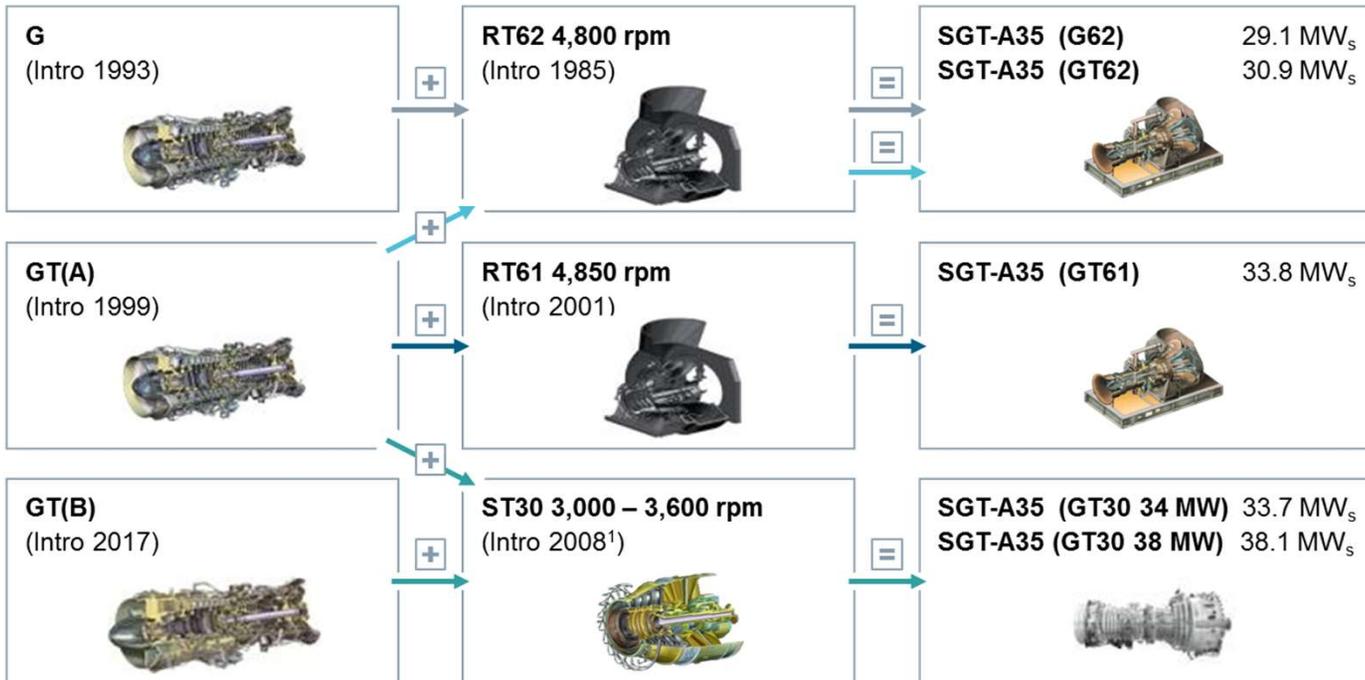


SGT-A35 Portfolio

Gas generator

Power turbine

Gas turbine



Focus applications

Pipeline compression
(Mechanical drive)

Offshore
mechanical drive/
power generation

Offshore
mechanical drive/
power generation

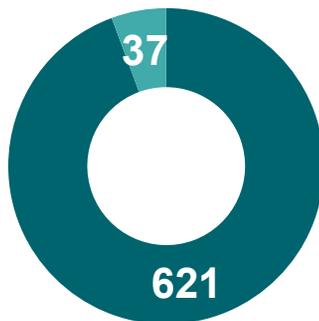
¹ ST30 Power Turbine Entry Into Service with Rolls-Royce MT30 Marine gas turbine

Modular variants for an ideal application fit

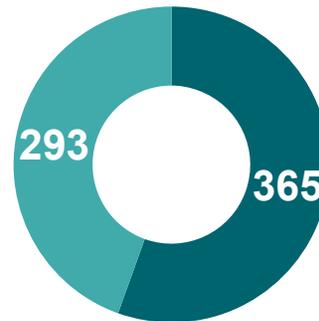


SGT-A35 (Industrial RB211) Fleet statistics

over **650 units**

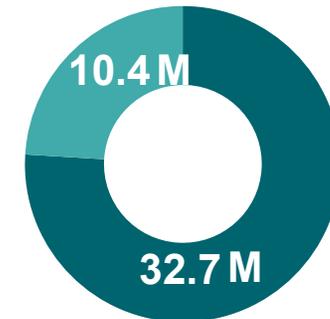


■ Oil & Gas



■ Onshore ■ Offshore

over **43M hrs**



■ Mechanical Drive

Lead unit hours

>206,000

Fleet in Canada

> 90 units and > 9M hrs

Last update: September 2019



SGT-A35 recent orders

**Offshore
Production
(Generation +
Compression)**

23x SGT-A35 units of which:

- 17x SGT-A35 (GT30)
- 4x SGT-A35 (GT61)
- 2x SGT-A35 (G62)



**Pipeline
Compression**

**8x SGT-A35 (GT61) DLE units
with Siemens RFBB 36 pipeline
compressor**



Strong position in fast-growing Oil & Gas markets



A consistent product strategy

- Focus on core applications
- Incremental enhancements to a proven and reliable product
- Technology “download” from Siemens, Rolls-Royce, Dresser-Rand

Pipeline Compression



- ❑ OPEX improvements: heat rate, service cycle
- ❑ Power Turbine incremental improvements (RT62, RT61)
- ❑ DLE emissions – NO_x and CO capability

Roadmap supported by Siemens leadership in Additive Manufacturing



Offshore O&G



- ❑ Intro GT30 variant – compact package, 34 MW and 38 MW
- ❑ Incremental Reliability, Availability & Maintainability
- ❑ Improvements of Dual Fuel DLE capability

Sustained R&D investment in a product line of strategic importance to Siemens



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RT62X Power Turbine enhancement

Benefits – configured to suit

- Power Turbine Time Between Overhauls up to 132k hrs
- Heat rate improvement up to 2.5%
- Power increase up to 6%
- Flexible offerings to optimize power or life enhancement
- Available for aftermarket and new unit

Scope – applying proven technology

- 1st and 2nd stage nozzle guide vanes
- 1st and 2nd stage blades
- Honeycomb tip seals
- Casing insulation
- GT operating limits
- No change to: Gas Generator, PT casing, disc interface

Applicability			
SGT-A35	G56 / C56	DLE	non-DLE
	G62 / C62		
	GT62		
	GT61		
	GT30		

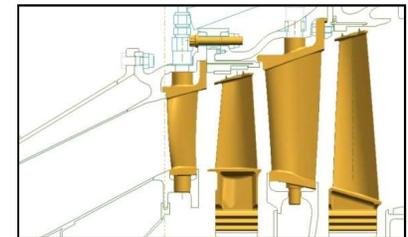


Incremental benefits, tailored to Operator requirements



Key parameters – RT62X Upgrade

RT62 Current				RT62X Upgrade		
SGT-A35 Variant	Gas Generator	MTBO	Power Turbine Entry Temp. (PTET)	Power gain (ISO)	Heat Rate gain (ISO)	MTBO
C62 *	- C *	Case-by-case	750 °C	2%	2.7%	Case-by-case
G62	- G	100k hrs	780 °C	2%	2.5%	132k hrs
			785 °C	3%	2.7%	100k hrs
GT62	- GT	100k hrs	780 °C	2%	2.4%	132k hrs
		50k hrs	790 °C	3%	2.5%	100k hrs
			800 °C	6%	2.6%	50k hrs



Applies 3D vortex design and materials proven in RT61



(*) Aftermarket only

Flexible offerings to optimize for life or power enhancement



RT61 Time Between Overhauls 100k hrs

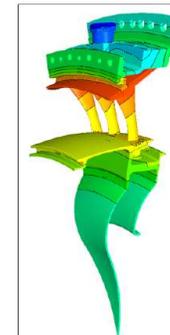
Benefits

- Double Time Between Overhauls (TBO) 50k hrs to 100k hrs
- Increased availability
- OPEX savings
- No interim inspection up to 100,000 hours
- Now standard for new units
- Drop-in upgrade for existing units

Scope

- Application of Siemens proprietary coating, a proven technology, to life limited components of the power turbine:
 - 1st stage vanes
 - Blade tip seals
- Improved corrosion and oxidation protection
- No change in geometry and performance

Applicability			
SGT-A35	G56 / C56	DLE	non-DLE
	G62 / C62		
	GT62		
	GT61		
	GT30		





RT61 “Cold Match” 1st stage Optimized performance in cold climates

Applicability			
SGT-A35	G56 / C56	DLE	non-DLE
	G62 / C62		
	GT62		
	GT61		
	GT30		

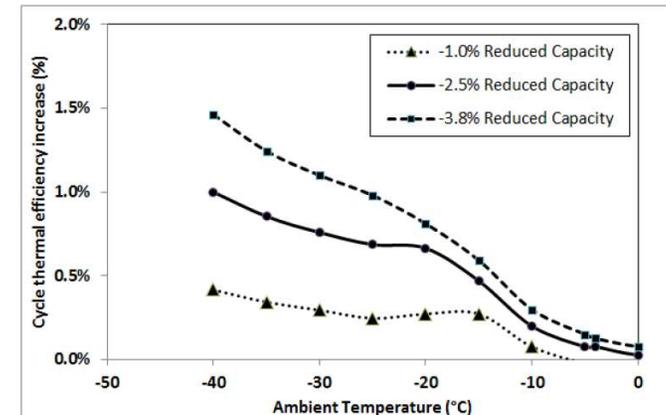
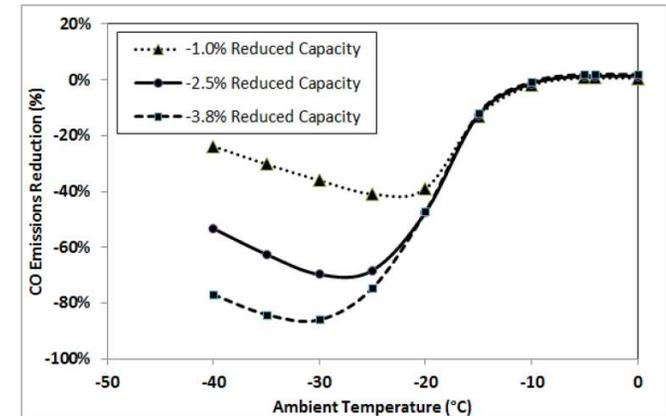
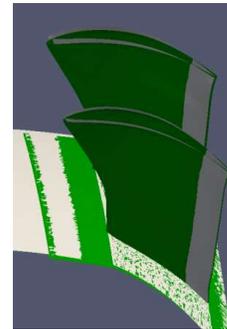
Benefits

- ❑ Enhanced performance in cold ambient and part power conditions (ref. pipeline stations in Western Canada):
 - ❑ Improved heat rate (up to ~ 1%)
 - ❑ Reduced CO emissions – up to ~ 40%
- ❑ Power Turbine overall design unchanged

Scope

- ❑ “Skewed” close stage 1 vane (reduced effective area)
- ❑ No change to RT61X 100k mean-time to overhaul
- ❑ New vane fast-tracked via 3D printed wax pattern casting

7x units ordered for pipeline compression stations in Western Canada





SGT-A35 Core Engine up-rate

- **SGT-A35 (GT30) available in two variants: 34 MW and 38 MW**
- **10% more power** – highest in its class
- Based on proven **compressor upgrade**
- **Same firing temperature**
- **Same package interfaces**



Upgraded compressor

Existing hot end



Same Power Turbine

Nominal ISO rating	34 MW	38 MW
Mechanical Drive (3,429 rpm)		
Shaft power output	33.7 MW	38.1 MW
Shaft thermal efficiency	39.1 %	40.3 %
60 Hz electrical generation		
Power output A/C	33.2 MW	37.4 MW
Simple-Cycle Efficiency	38.5 %	39.7 %

Significant performance gain through evolutionary upgrade



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...wisely**



The disruption: Additive Manufacturing (AM)



Siemens is a world leader in applied AM

120,000 operating hours on Siemens turbines

40 3D printing machines operational worldwide

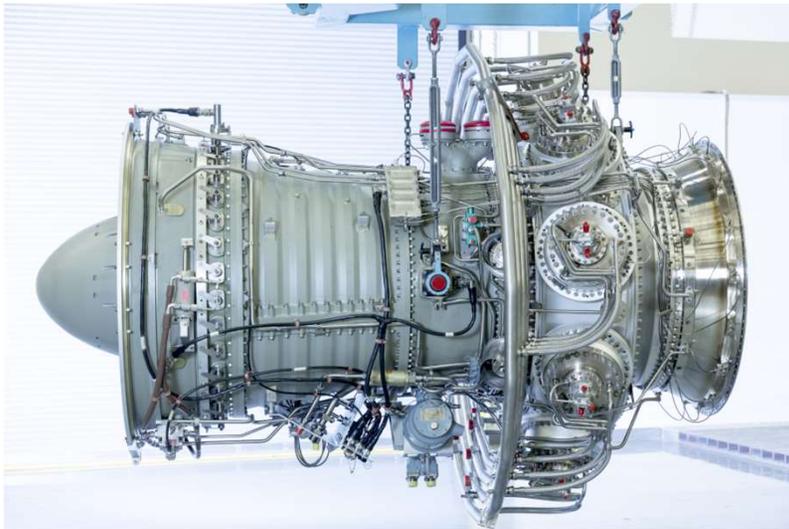
100 specialized engineers

200 components identified for AM until 2025

15 components already commercially implemented



Application case: SGT-A35 DLE



200+

Engine fleet
SGT-A35 DLE

7 Million

Combined
fleet hours

3+ Million*

DLE fleet in
Canada

- Air & fuel pre-mixed for low NO_x and CO
- Two pre-mixed stages for flexible operation
- Dual Fuel option



150,000 hrs*

Fleet leader

* Last update: September 2019

AM provides ideal optimization opportunity for 3D flow passages



Case Study: Dual Fuel DLE injector

Utilizing Additive Manufacturing to enhance capability

Background

- ❑ Existing DF DLE injector based on proven Gas-Only design, with slight differences in some features
- ❑ Non-optimal noise signature when running at very low-power
- ❑ Root Cause: positioning of gas fuel injection holes (constrained by manufacturing process)

Solution

- ✓ **Additive Manufacturing** of Central Fuel Injector – benchmarked to **proven gas-only design**
- ✓ Fuel passages optimized in ways **not viable with conventional manufacturing**
- ✓ Robust validation – **4x iterations in ~ 7 months**
- ✓ Released to production with **much shorter development cycle time**
- ✓ **Low-power noise anomaly now eliminated**



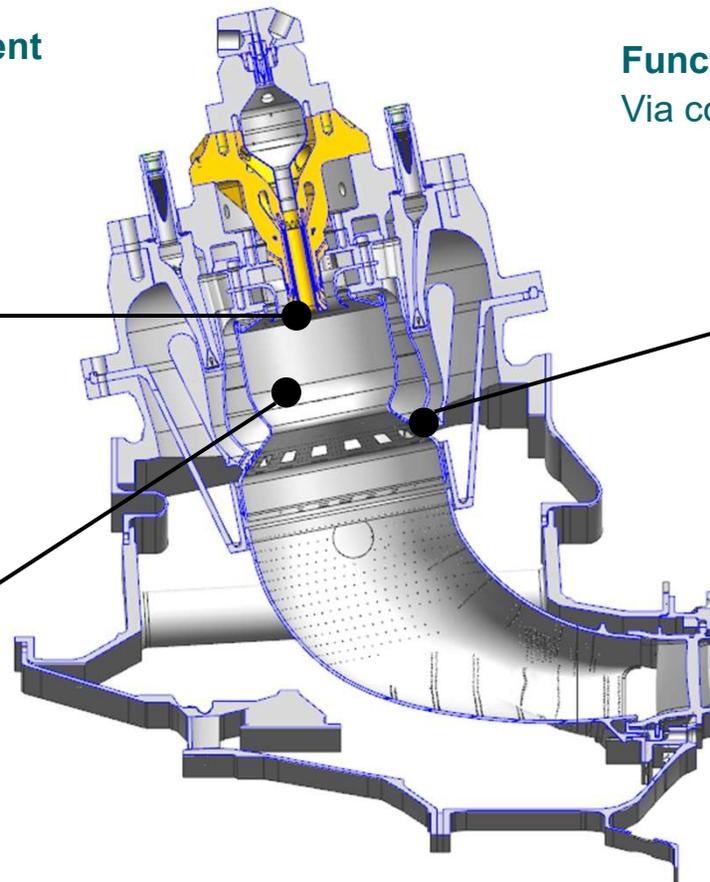
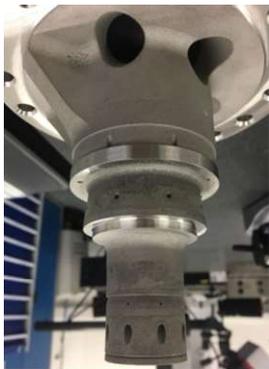
AM extends design space with game-changing speed of iterations



SGT-A35 DLE enhancement

Incremental improvements to a proven architecture

AM Component development
Rigorous qualification



Functional validation & optimization
Via combustion rig & engine testing



- ❑ AM enables agile & robust iterative development
- ❑ Combined with experience on known systems, Customer input & rigorous validation
- ❑ Only use AM where it makes sense to enhance the overall product functionality



Conclusions

- The SGT-A35 remains strategic to Siemens**
- Strong position in core applications: Offshore Oil & Gas and Pipeline Compression**
- Sustained R&D investment with a consistent product strategy**
- Several life cycle enhancements recently released**
- Applying latest advancements like AM selectively to enhance specific features**

Incremental improvements – stay true to a trusted legacy