9TH INTERNATIONAL GAS TURBINE CONFERENCE

TECHNOLOGY DEVELOPMENT NEEDS & REQUIREMENTS FOR OIL & GAS OPERATORS TODAY AND IN THE FUTURE

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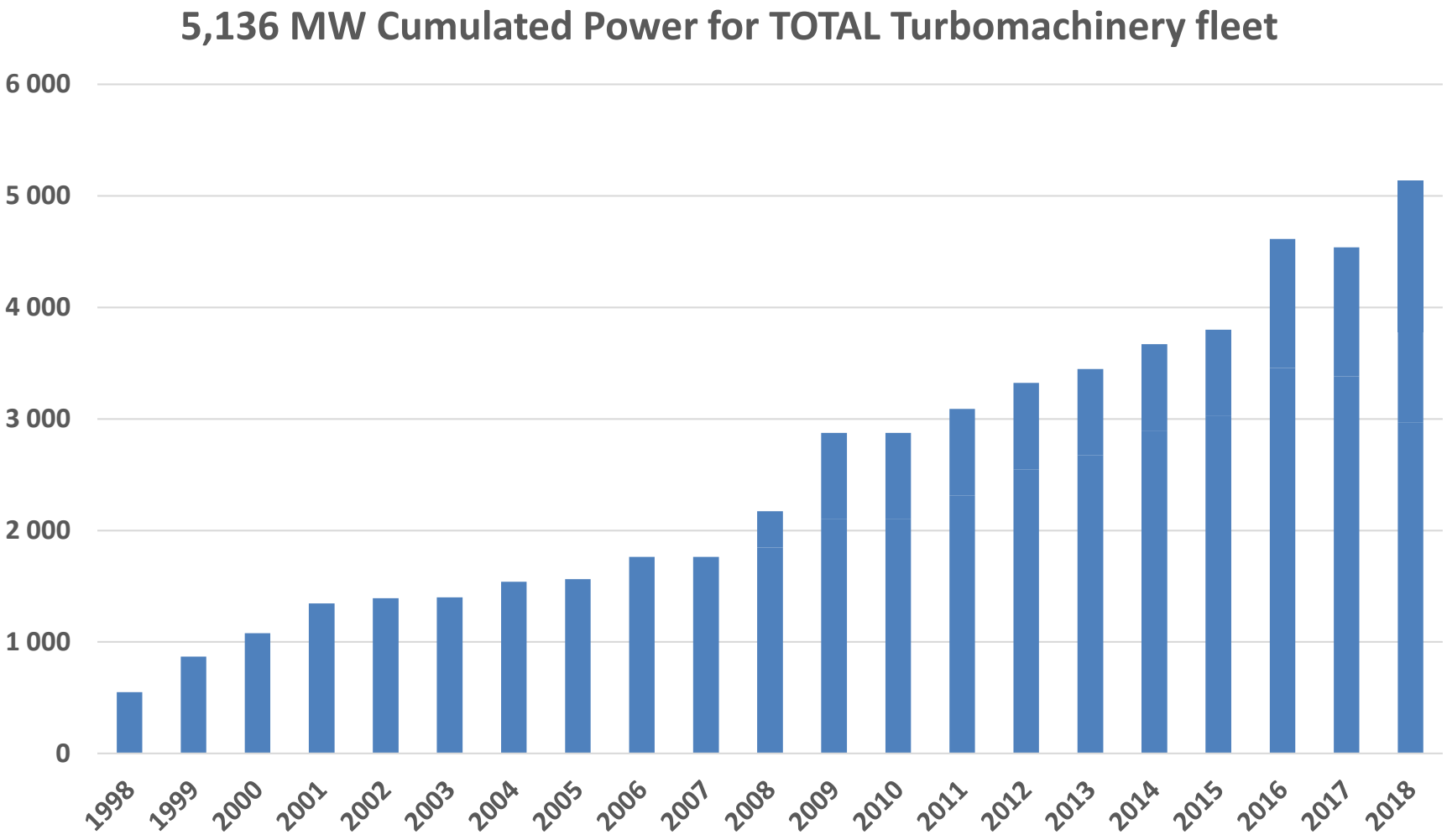
Increased operational complexity in the Oil & Gas industry

- Increasing demand for Energy
- Climate change and international climate agreements
- Remoteness of sites and harsh operating conditions
- Water depth
- Ultra-high gas reinjection pressure
- More installed power requirement

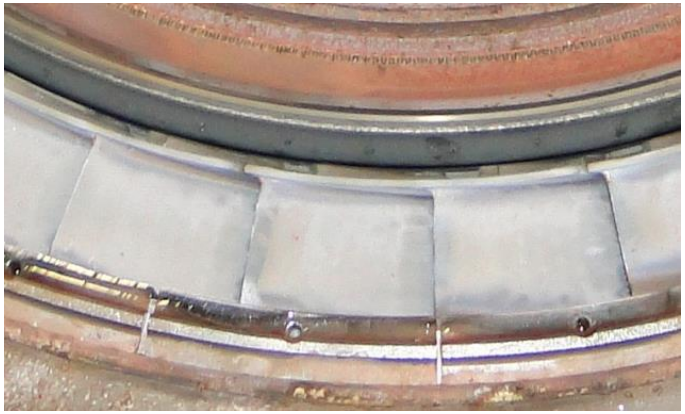
Reduce OPEX and our emission footprint without compromising safety

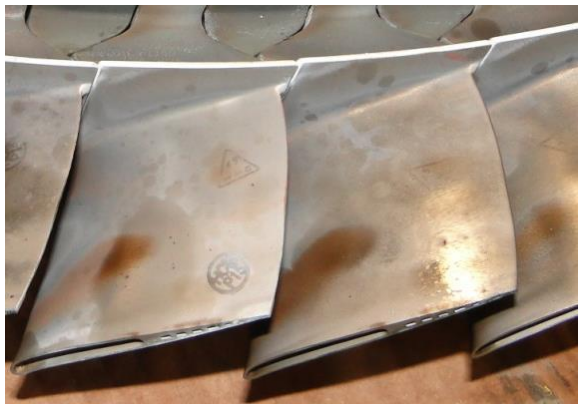
TOTAL EP TURBOMACHINERY FLEET CUMULATED POWER (MW) VERSUS TIME



CREEP EXAMPLE

Environment	Tropical
Offshore/onshore	Offshore
Fuel gas quality	Within OEM standards
Operating regime	Continuous operation
Running hours	TBO + 10%
Starts between overhauls	215
Driven Load	Compressor at process capacity limit
Driver Load	~ 80%





Lifetime extension of 30%

Parameters	Operating average value	Base load engine test value
T5 temperature	710°C	776°C
GG speed	96%	99.67%
Starts	215	

CUMULATIVE DAMAGE EXAMPLE

Environment	Tropical
Offshore/onshore	Offshore
Fuel gas quality	Within OEM standards
Operating regime	Operational redundancy
Running hours	TBO
Starts between overhauls	287
Driven Load	Electric generator at Partial load
Driver Load	~65%

Parameter	Operating average value	Base load engine test value
T5 temperature	750°C	852°C
GG speed	9 550 rpm	9 660 rpm
Starts	287	

- Required start frequency
  < 1/200 running hours
- Actual start frequency
  = 1/87 running hours

Running conditions versus start frequency
=> double the TBO

FATIGUE EXAMPLE

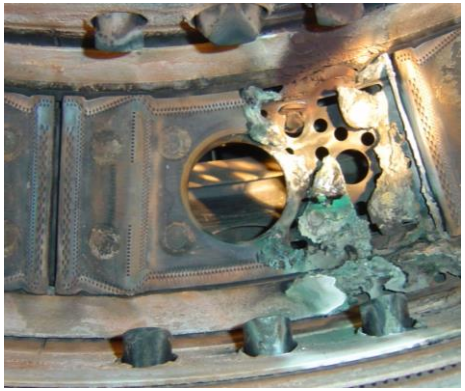
Running hours	24506
Starts	935
Driven Load	Full load
Driver Load	~95% in average

- Restart every 26 hours
- Impact of each start in addition to the cumulating running hours
- Engine should have a reduced Time Between Overhaul (TBO) of 43%

Operational TBO as per standard OEM cycle

HOT CORROSION

Environment	Subtropical
Offshore/onshore	Offshore
Fuel gas quality	Out of OEM standards 1,4% of H2S



REDUCE CAPEX & OPEX OF ROTATING MACHINES IN O&G INDUSTRY

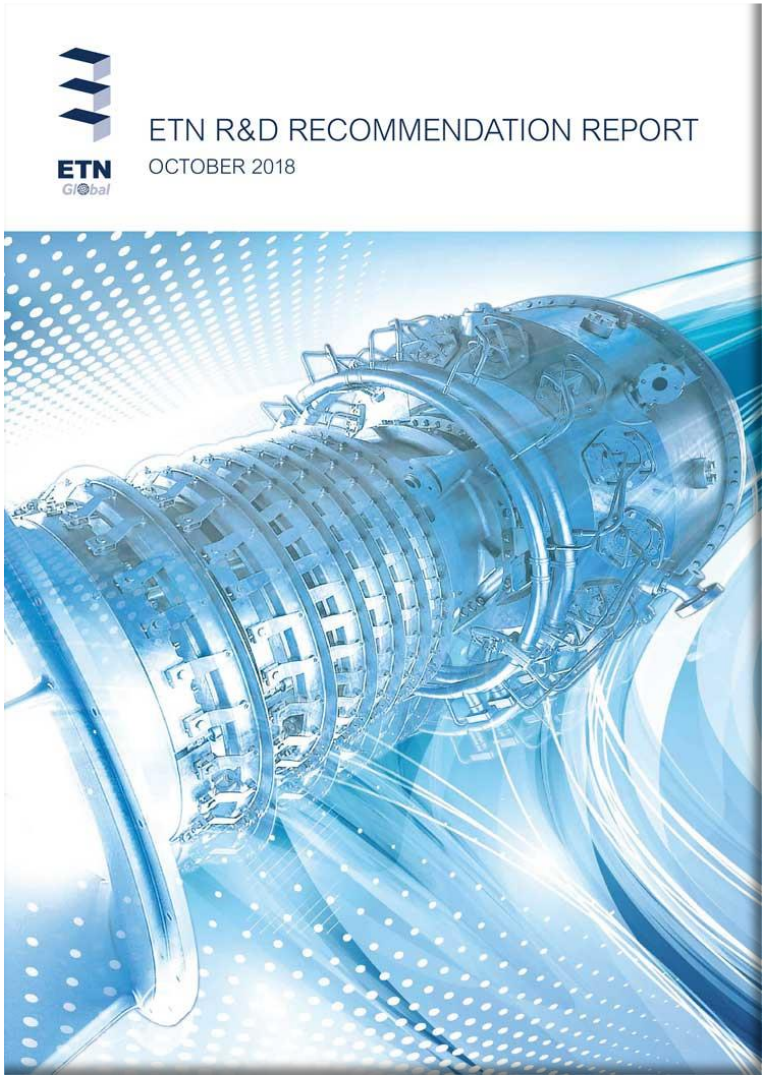
- Optimization of the rotating machinery architecture
- Preventive, Conditional Based Maintenance
- Tracking and analyzing each breakdown
- Digital Technology for Remote Follow-up

Need to take cooperation to a new level

R&D Interests and needs

- Development of high power gas turbines for LNG applications with free Power Turbine
- Development of Mini Modular LNG trains
- Efficiency increase, reduction of methane leakage, CO2 and NOX emissions
- Hot Corrosion Materials Resistance
- High Speed and Pressure Ratio Integrated Compressors
- Turbomachinery Modularization
- Close collaboration with Suppliers is required

ETN R&D RECOMMENDATION REPORT



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