DEEP OFF-SHORE COMBUSTION AIR FILTERING SYSTEM ANALYSIS
OFF-SHORE FILTER SYSTEMS ANALYSIS TO PEAK GTG AVAILABILITY AND RELIABILITY IN HARSH CONDITION
Fernando Markovits is Project Engineer with Petrobras and Turbo Lecturer since 2004, being part of E&P and Refinery Projects; Experienced in Heavy Projects such as Power Plants, Military Projects, Energy and O&G for nearly 20 years. He has a bachelor’s of mechanical engineering and Graduate of Production Engineer.

Orlando Guerreiro is Senior Engineer, Turbomachinery Advisor and Lecturer at Petrobras Brazil. He is part of the Design Team of Off-Shore Units. Provides a large Internacional Background with key suppliers to O&G Business. He has a bachelor’s of Mechanical Engineering and MBA in Project Management.

Francisco Carlos is Senior Engineer and Turbomachinery Advisor at Petrobras Brazil. He has over 30 years of strong background in Filter Systems Design, being responsible for the GTG Filter Systems Operation at Campos Basin Off-Shore Units. He has a bachelor's of Mechanical Engineering.

Jim Benson is a senior product engineer with Camfil Farr Power Systems, North America. He has over 30 years of filtration experience, in the areas of product development, filter media and applications. This experience has covered multiple of markets including military vehicles, industrial dust collection and gas turbine systems. He has a bachelor’s of mechanical engineering from the University of Minnesota.

Joshua Kohn is an junior application engineer with Camfil Farr Power Systems, North America. He has four years of experience related to filtration for gas turbine systems, specializing in optimizing filtration applications for various environments, as well as product development. He has a bachelor’s of mechanical engineering from McGill University.
Greater off shore distance

- Increases need for high reliability power systems
- Logistic challenges
  - Transportation Cost
  - Uncertainty [weather, storage, lead time]
Deeper water location increases the challenges

- Power systems fundamental to off-shore facilities [Reliability & Availability]
- Filters MTTF:
  - Improve from 6k to 12k hours Prefilter
  - Improve from 10-12k to 24k hours Final Filter
- Reduce Life Cycle Cost by 20%

Salty environment increases risk of Thermal Corrosion

- Improve filter salt efficiency by > 50%

Inertial Separation Philosophy x Filtration Grade

- Size Really Matters?

Challenge

✓ Which driver to consider to select the optimum combustion air filtration system for gas turbines installed on deep off-shore platforms??
PETROBRAS EXPERIENCE

FLEET MAKEUP

• OVER 250 GTGs
• 100+ PLATFORMS
• PRE SALT APPLICATIONS:
  • 31 MW ISO GTGs

OPERATION ISSUES

• THERMAL CORROSION
• SHORT FILTER LIFE / PRESSURE DROP
• POOR FILTER PERFORMANCE
  • DRAINAGE
  • DURABILITY
  • COMPRESSOR FOULING
  • DOMESTIC OBJECT DAMAGE
KEY PARAMETERS FOR SYSTEM SELECTION

A

Reliability
Availability
• MTTF Increase
• Less Downtime

B

Long Service Life
• Prevention of Thermal Corrosion
• Less Filter Stress

C

Life Cycle Cost
• Balance Factors [Technic/Economic]
• Max. $$$$$ Savings
• Minimize Turbine Fouling
Two main sources of particles:

- Airborne salt / sea spray
- Platform generated particles such as hydrocarbons

Location – Deeper Off-Shore

- Amplifies critical importance of gas turbine performance
- Logistic challenges:
  - Availability of parts
  - Response time for repairs
  - Cost of transporting parts
  - Weather
INLET FILTRATION OPTIONS

**High Velocity**
- 4500 cfm
- 1.5 filters / MW
- 0.5 m² / MW
- Inertial Separation Required
- Optimized to filter wet salt particles

**Medium velocity**
- 2500 cfm
- 2 to 3 filters / MW
- 0.75 – 1 m² / MW
- More Filtration Area [Less Stress]
- Optimized to filter particles of all types
TYPICAL OFF-SHORE SYSTEM EFFICIENCY

Compressor Fouling & Thermal Corrosion Zone

Compressor Erosion Zone

Particle Size [µm]

Eff.%

Ref.: EN-779:2012
Multi Stage Filtration System allows operators to Change Filters on-line

- Increase Availability

Filter Life directly related to Airflow per Filter Element and dust caught by filter

- Less Air Flow Ratio means Less Filter Stress = Long Filter Life

Filter Integrity Critical:

- High (wet) burst strength
- Water resistance / drainage
- Salt removal efficiency

Air Flow Ratio [Filter Stress]
FACTORS IN LIFE CYCLE COST

Capital Investment: [CAPEX]
- Cost of filter housing [inc. platform m² value]

Direct Filter costs: [OPEX]
- Cost of replacement filter elements
- Transportation to site, installation and disposal
- Downtime for filter replacement

Indirect Filter costs: [OPEX]
- Output lost due to pressure drop

Fouling and thermal corrosion cost: [OPEX]
- Reduced power output
- Increased heat rate / fuel consumption
- Water wash consumable cost and downtime
- Turbine Parts replacement / Refurbishment
LCC PREMISSES

ASSUMPTIONS

- LOGISTIC COST [Transport, Install, Storage, Disposal]
  - $270 / Rigid Filter [Final Filter]
  - $140 / Bag Filter [Prefilter]
- Heat Rate: $7.3 / MM BTU
- MW Value: $95 / MW-hr
- 6,000 Operation Hours / Year
- Air Compressor Efficiency < 0.80 – Dirt Filter
- 100mm H2O [10mbar] inlet drop means:
  - 1.42% Power Output Loss
  - 0.45% Heat Rate Increase

PRESSURE DROP

- <100 MM H2O [10 mbar] as per API 616 for all system calculated

CURRENT PETROBRAS EXPERIENCE

- PREFILTER: 6,000 hours [G4]
- FINAL FILTER: 12,000 hours [F7]
True value of high quality air intake: maintaining turbine in peak performance

- More $$$ configuration means $$$$$ saving along life cycle.
- The more cost configuration the more saving along life cycle.

**LIFE CYCLE COST ASSESSMENTS**

- Optimal air intake will balance many factors to minimize overall Life Cycle Cost (LCC) [$$$$$]

**Increasing Filtration Efficiency leads to:**

- Minimize performance loss due to fouling and thermal corrosion [+]  
- Increased intake pressure drop and direct and indirect filtration costs [$$] [-]
LIFE CYCLE COST ASSESSMENTS

High Quality Air Intake

Keep Turbine in Peak Performance

More Filter Config. Cost

Higher Pressure Drop

Power Loss due to Fouling & Thermal Corrosion

Costs Savings $$$$

LCC Balance = Optimal System

Don’t FORGET!
LIFE CYCLE COST RESULTS

Cost Ratio

Performance Ratio

Thermal Corrosion Risk

F7 - 4500 CFM
F9 - 3000 CFM
E10 - 2500 CFM
E12 - 2500 CFM
H14 - 2500 CFM

Worst config. Means...

Path Ahead

USING F9 IN 1ST STG...

Cost Ratio

Life Cycle Cost (LCC)

Fouling
Pressure Drop
Filter
Housing - CAPEX

LIFE CYCLE COST RESULTS

Cost Ratio

F7 - 4500 CFM
F9 - 3000 CFM
E10 - 2500 CFM
E12 - 2500 CFM
H14 - 2500 CFM

Thermal Corrosion Risk

F7 - 4500 CFM
F9 - 3000 CFM
E10 - 2500 CFM
E12 - 2500 CFM
H14 - 2500 CFM

116 kg/year
31 kg/year
4 kg/year
0.6 kg/year
0.06 kg/year

Worst config. Means...

Path Ahead

USING F9 IN 1ST STG...
LCC Recommendations

OPEX main cost driver
• Turbine fouling and Filter pressure drop

Main cost of Filters Systems is Filtration Grade
• Filter House Size, Purchase, Transport, Installation, Storage and disposal costs are secondary

Fouling / Thermal Corrosion costs can be dramatically reduced with good filtration;
• E12 minimizes LCC;
• E10 minimum recommended [Assuming some Fouling]

Multiple filter stages (different grades) increase availability and efficiency;

Increased Filter Houses (MID velocity / 2500-3000 CFM):
• Reduced pressure drop
• Increased filter life
• Minimize difference in filter class between stages [Máx 3]

Salt Removal Efficiency (coalescing effect)
• Ability to remove aerosol particles
Filter Integrity Critical:
- High (wet) burst strength
- Water resistance / drainage
- Salt removal efficiency – including aerosol particles

Focus on Filtration Efficiency to enhance Gas Turbine Availability and Reliability

Filter House CAPEX is secondary when approaching the air intake from an LCC perspective

Best Life Cycle Cost for offshore is achieved with mid velocity, multiple stages with different grades and salt removal efficient.