F-technology Gas Turbine Retrofit with EPA Filters (Case Study)

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Site environment and contaminants

Environment
- Mediterranean sea coast
- Nearby sea port with trucks traffic
- Nearby city
- Industry
- Temperature 0 – 40°C; Relative humidity 20 – 100%
- Khamsins - hot desert winds with high atmospheric dustiness (similar to Sirocco)

Air contaminants
- Atmospheric dust, sea salts, soot, oil vapors

Gas turbine unit
- 250-MW class gas turbine in a two-shaft Combined Cycle
- Operation mode – BASE
- Operation start – July, 2004

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Air cleaning: usual approach

Requirements
- Full filtration of erosion-risk particles (> 5 µm)
- Good filtration of particles in the fouling range (<5 µm)
- Pulse-cleaning provides low pressure loss on the filter
- Performance degradation caused by fouling is restored by periodical compressor washings

Result
- No blade erosion
- Low filter pressure loss
- Acceptable filter life-time – two-three years of GT operation

Typical Particles Size Distribution for Erosion and Fouling Range

IEC had good long-term experience with 16 E-technology type turbines (120-150 MW class)

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Filter system arrangement

The system comprises

- Filter house
- Inlet weather hoods with moisture separators
- Single filtering stage F9 class
- Horizontally arranged filter cartridges
- Cone-cylinder filter pairs (700 pairs)
- Pulse air system – cleaning with air blasts
- Dimensions: H12 m * W15.8 m * D7.6 m
Usual approach: field experience

- Ineffective pulse-cleaning that resulted in the fast increase of the filter pressure drop and shortened life-time of the filter
- Strong performance degradation due to compressor fouling (up to 15 MW loss)

Inlet pressure drop versus Operating Hours.

- Soot and sea salt ingestion through the filter. This could initiate corrosion of the compressor blades.
- Compressor stator blades failure and cracks as a result of pitting corrosion

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Filter upgrade: main goals

- Prevent or substantially decrease sea salt ingestion into compressor
- Minimize ingestion of dust, oil, soot
- Avoid or minimize a filter house reconstruction required for the upgrade
- Increase actual life-time of the filter for up to two years or more

These goals could be met by usage of high efficiency filters with hydrophobic media.
Possible solutions and the final decision

Proposals:
1. Retrofit of the whole filter house to three-stage F9-class filter with combined pulse-cleaning/static filtration stages, with the hydrophobic last stage (OEM’s proposal).
2. Upgrade filters to hydrophobic F9-class static filters with no filter house retrofit (IEC’s proposal).
3. Move to EPA static hydrophobic filter with no changes of the filter house arrangement (third party proposal).

The third option was finally chosen as providing an achievement of all goals of the upgrade at a reasonable cost.
Initial stage: EPA-1 filter system

**Main filter: EPA E11**
Fine F8

**Pre-filter: M5 Hoods**
(Socks)

**Socks:**
- Cheap
- Simple to replace
- Too low filtering area

**Maintenance plan:**
During a year operation of the main filter, one or two replacements of the pre-filters.
The replacements were planned with the main filter in place and probably on operated GT unit. This was not achieved in actual operation.

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Initial stage: Performance data

Compressor adiabatic efficiency
- Compressor efficiency does not degrade that points on virtual absence of fouling
- On-line washings were totally eliminated
- Off-line washing were not required (performed due to regular maintenance plan)

Filter performance
- On average, EPA filter $\Delta p$ was lower than that of the previous conventional filter
- Pre-filter hoods (socks) feature very fast increase of $\Delta p$ in dusty atmosphere
- Hoods replacement is too time-consuming
Initial stage: Summary of Results

✓ The EPA-1 system was replaced after about 9800 operational hours of the main filter and two replacements of the pre-filter hoods. The replacement was not forced by the filter differential pressure limitations.

✓ The pressure drop of the main filter (F8/E11) remained almost unchanged that pointed out on much longer life-time of the main filter.

✓ The EPA filter has a lower average pressure loss than the previous conventional F8 filter.

✓ Turbine Power Output and Heat Rate were remarkably better with EPA filter. This provided a returned investment of the EPA filter within the first year of the filter operation.

✓ The pre-filter hoods should be replaced with the pre-filter panels, in order to increase the life time of the pre-filter.
Second stage: EPA-2 filter system

Improvements of EPA-1 system

- Pre-filter hoods were replaced with panels (G4-class) installed in the weather hoods instead of the moisture separator.
- Cone-cylinder pairs were implemented in 20% of cartridges
- Cartridges were upgraded with guiders providing better assembly
- Upgraded gaskets were implemented for better sealing of the main filter
- Pre-filter panels enforced with stiffening ribs (on the last stage of the project)
- Differential pressure measurements downstream of the pre-filter

With the these improvements, anticipated life-time of pre-filter was estimated as 5000-6000 hours and of the main filter as 16000 hours.
EPA-2 system: Performance results

- Operation - as was anticipated.
- Main filter: ~15200 hours in operation (27 months).
- Pre-filter: Two replacements.
- The system was replaced earlier than required maximum Δp.
- Compressor fouling virtually absent.
- Overall GT performance – good.
- Retrofit goals – achieved.

Compressor adiabatic efficiency

- Compressor efficiency does not degrade
- On-line washings were totally eliminated
- Off-line washings were reduced

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EPA-2 system: Filter data

Filter performance
- On average, EPA-2 filter Δp was about the same as that of the previous EPA-1 filter
- Two pre-filter replacements as was planned
- Life-time is estimated as ~16000 hours or higher
- Implemented RAB of the panels provides more operational flexibility and increases life-time by more than 1000 hours

Pre-filter and Main filter differential pressure (RAB – Reverse Air Blowing)

Peaks of the pre-filter Δp are results of the Khamsins

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Main conclusions

1. The final EPA filter version represents a three-stage static air filter with panel-type pre-filter of G4 class, and cartridge-type main filter of F8/E11 class. Pre-filter is mounted separately in the place of the original moisture separator.

2. Based on the collected experience, life time of the main filter has been estimated as 16000 hours and the average life time of the pre-filter panels as 5500 hours.

3. The EPA filter operation provided high profits on the fuel economy. Additional profits are: no on-line and less frequent off-line washings, less compressor corrosion, lower filter differential pressure drop, longer life time of the filter.

4. Each new type of EPA filter should be initially checked in actual or similar environment conditions for its performance and life time. Some non-standard tests are required for EPA filters evaluation.
The END