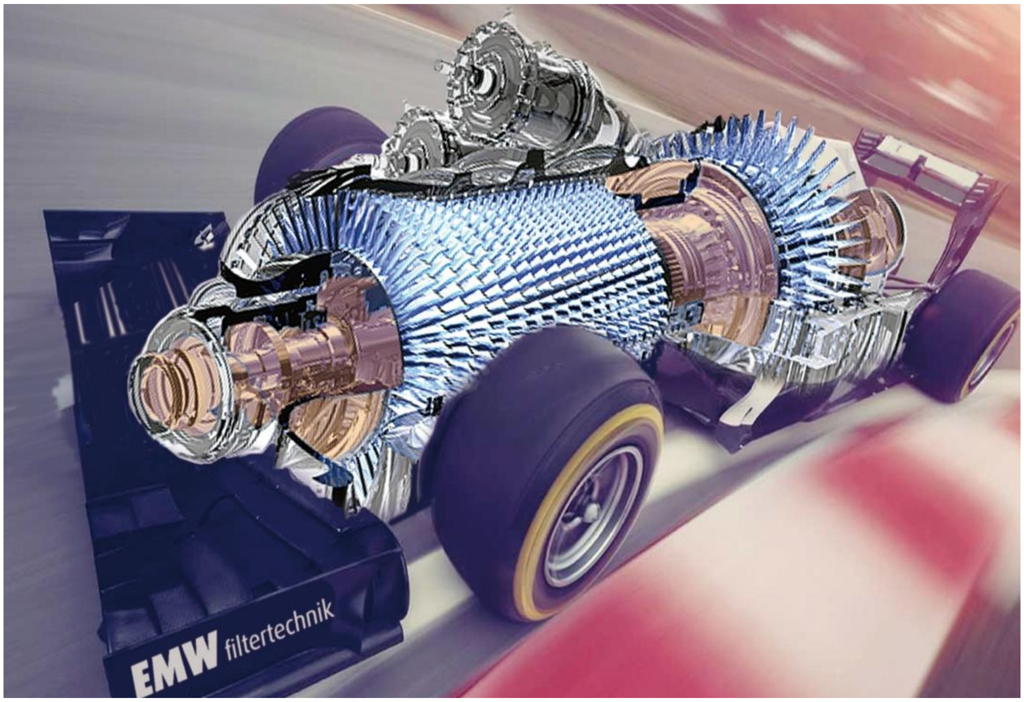

Case Study

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Capacity Loss in Gas Turbines

EMW® (H)EPA Filtration vs. Compressor Fouling

by Detlef Marx & Florian Winkler

The **power output capacity** of a gas turbine normally **declines** gradually over its service life. Part of that decline is caused by mechanical wear and other ageing processes that cannot be avoided. However there is another part of that decline, a very substantial part, that is preventable.

Surface deposits in compressors, better known as fouling, cause roughly **70 – 85%** of capacity loss in gas turbines. One method for removing fouling is on/offline washing, a method which provides only short-lived recovery of capacity. Fouling soon returns and with it: downtime, costly repairs or even the need to replace entire component systems.

The cause of the problem is poor air quality, i.e. particulates in the inlet air stream into the compressor. Conventional inlet air filter systems designed to remove these particulates normally incorporate F7-F9 class filters for final-stage filtration. These filter classes are however not efficient enough to prevent fouling in newest-generation gas turbines.

Important Factors
Configuring the best filter system for the job at hand is not a straightforward process. The **"wish list"** in selection basically comes down to three targets to be attained:

- high efficiency
- low pressure drop
- long service life

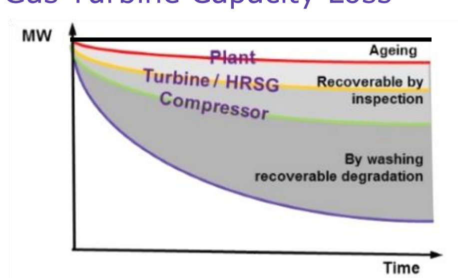
Higher-efficiency inlet air filtration is an obvious way to protect against compressor fouling. However, at second glance, questions come up in the minds of design engineers: Are the advantages provided by finer filtration a bad trade-off when weighed against the increased pressure drop it causes? Will increased filtration efficiency shorten the lifespan of the filters used? And what economic benefits are provided by increased filtration efficiency in general?

The EMW® Case Study
This study is intended to provide answers to the above questions from a EMW® reference project. All data given were gathered and evaluated by the company operating the power plant described.

Summary of Case Study

Experiencing declining capacity in their gas turbines, the operating company of a gas power station attempted to solve the problem with on/offline compressor washing. The washing caused substantial downtime and – on top of that – resolved the problem only temporarily. Asked to solve the problem, EMW® provided a permanent upgrade of the filter system without requiring modification of the filter house. The results: significant increase in capacity and reduced heat rate. The gas turbines have now been operated since 2012 without need for further washing to date.

Gas Turbine Capacity Loss



Compressor fouling causes roughly 70 – 85% of power capacity loss in gas turbines. This problem can be avoided by more efficient filtration providing a cleaner inlet air stream. EMW® can often upgrade users' filtration systems without need for replacement or modification of the filter house.

The Problem

Capacity decline in a Combined Cycle Power Plant with 2 SIEMENS SGT5-4000F gas turbines located in South-east Asia. Running in base-load operation, each turbine has a nominal electric power capacity of 244 MW.

Design of filter house

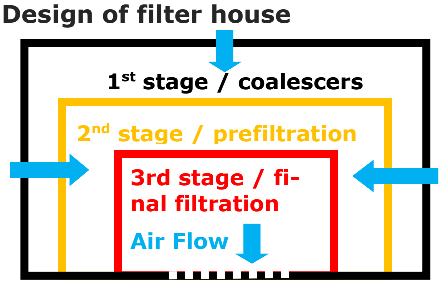


Figure 1.1

Entering the filter house from three sides, the inlet air stream passes through a 3-stage filtration system incorporating 540 filters in each stage. In the owner's existing configuration, the first filtration stage was equipped with Class G3 coalescers, the second stage with Class G4 Class prefilters and the third stage with Class F7 fine filters.

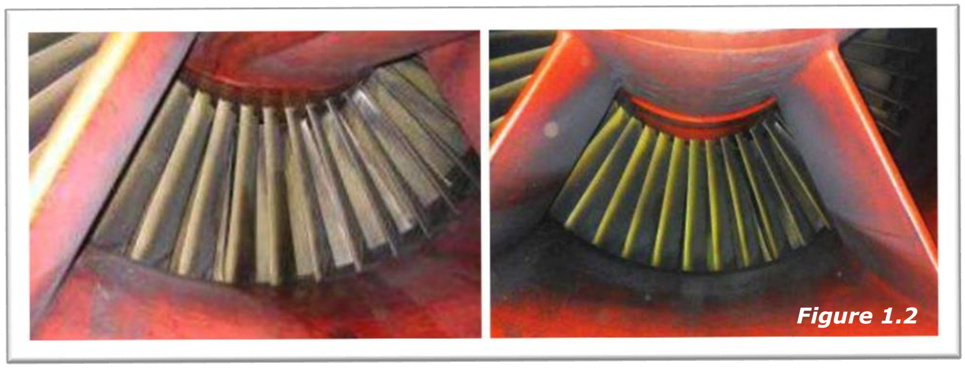


Figure 1.2

Figure 1.2 shows heavy fouling build-up in the compressor. The fouling was caused by insufficient inlet air filtration permitting particulate passage into the gas turbine.

Filter Life

In the existing configuration, the coalescers were changed every 4 months, the prefilters every 12 months and the fine filters every 3 years of operation. Although everything in the system seemed normal at first glance, a look behind the scenes at filtration efficiencies conveyed a totally different picture.

Filter Efficiency

The original system achieved an overall filtration efficiency of approx. 35%. Analysis of the filter house air showed an average particulate throughput of 750 kg (1650 lbm) per year with particle sizes primarily smaller than 0.4 microns.

Figure 1.2 shows the severe fouling build-up encountered with the existing filter configuration. The filter system did not provide the required efficiency, allowing fine particles to enter the gas turbines in large quantities.

In an effort to address the problem, the turbines were washed offline 3 times over a 120 day period. The washing provided no lasting benefit; fouling with the same severity as before returned shortly after each washing. This effect was mirrored by the turbines' power capacity, i.e. a temporary improvement in capacity which quickly disappeared.

Power Output of Gas Turbines Before (H)EPA Upgrade

Power Output and Heat Rate vs. Operating Time

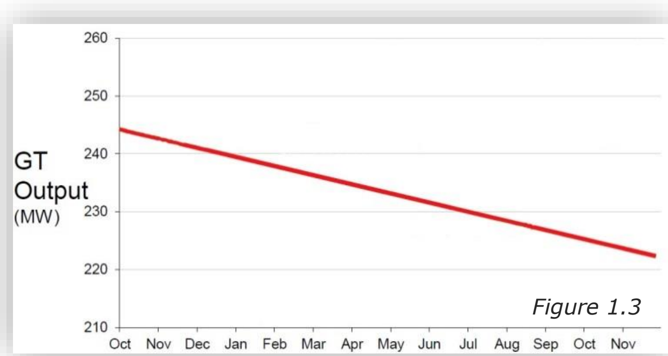


Figure 1.3

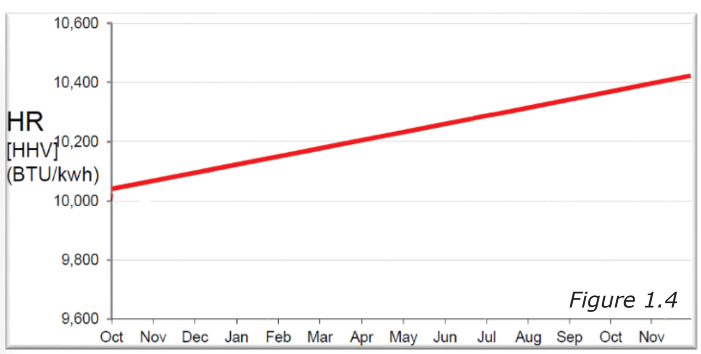


Figure 1.4

The above graphs show power output capacity and heat rate as functions of operating time (without taking compressor washing into account). Including the remediative effects of the washing, power output decreased by an average of 3 % and heat rate increased by 1.3 % over the 12 month period shown. *Factoring in the turbines' 6000 operating hours per year, the resulting power loss amounted to 22,320 MW. Adding in the effects of increased fuel consumption, the problem was costing the operator a grand total of € 925,000*($1 million) per year. All due to: compressor fouling.*

*electric power price €28/MWh ($30/MWh), fuel price €21/MWh ($23/MWh)

POWER OUTPUT & HEAT RATE

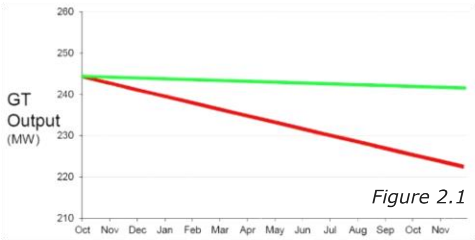


Figure 2.1

Capacity drop with old filter system 3%
and, after EMW® upgrade 0.8%
As shown by the photos at right (Figure 2.3), the filter upgrade virtually eliminated fouling. Power capacity of the gas turbines also got quite a boost. The upgrade restored power output of the gas turbines, reducing the average capacity loss over a 12 month period to only 0.8 % per year as opposed to 3.0 % with the old configuration.

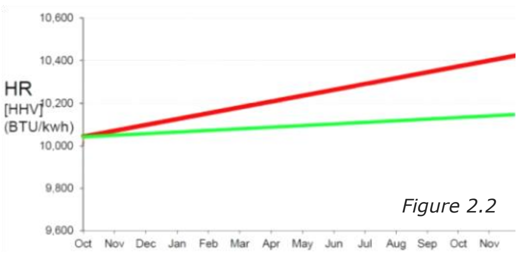


Figure 2.2

Increase in heat rate with old filter system 1.3%
and, after EMW® upgrade 0.6% The result of the upgrade: increased gas turbine power output, providing the power plant operator an additional profit contribution of € 695,000* ($760,000) annually.
**electric power price €28/MWh($30/MWh), fuel price €21/MWh ($23/MWh)*

EMW® MINIPLEAT COMPACT CASSETTES

The upgrade included a changeover from Class F7 fine filters to **EMW® (H)EPA** Class E12 fine filters. The EMW® filters provide convincing benefits by removing virtually 100% of even the finest-sized particles with only moderately increased pressure drop over the filter lifespan.

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Figure 2.3

Following the EMW® upgrade, compressor fouling is almost nonexistent. The gas turbines have been in operation since 2012 without need for on/offline washing to date.

Avoid Compressor Fouling!

Go with the EMW® filter upgrade!

The **capacity loss** observed in the gas turbines was due to dusty inlet air. The severe surface fouling on the turbines' inner surfaces was particulate matter which had settled and accumulated there.

The poor inlet air quality was the result of insufficient filtration efficiency in the final filter stage. Conventional filter systems use Class F7 to Class F9 filters in their final stage. In this particular application, the final stage was equipped with Class F7 filters. While well suited for retaining large particulates, this filter class allowed virtually unhindered passage of fine particulates into the gas turbine.

The EMW® Upgrade

The filtration performance in the inlet air system was improved by upgrading the filter class from F7 to (H)EPA E12, i.e. a jump upwards of 5 filter classes. The EMW® filter version used was MPK 4 12-31 GT.

The prefiltration stage was also enhanced. The Class G4 coarse dust filters previously in use here were replaced by EMW® Class F8 fine filters, selected specifically to best protect the (H)EPA final filters and prolong their service life. The coalescer stage for coarse dust removal remained unchanged at Class G3. The upgrade did not require any modification of the filter house structure.

Service Life

The (H)EPA E12 final filters in the upgraded system provide a useful service life of 1 year. The same filter life is attained by the the upgraded system's prefilters. The coalescer service life is the same as with the old system, i.e. 4 months.

Filter Efficiency

The EMW® upgrade increased filtration efficiency in the filter house from 35% to well over 99%. Fouling of the gas turbines in the owner's power plant is now virtually nonexistent. On/offline washing has not been required since implementation of the upgrade in the year 2012.

Conclusions

The EMW® upgrade significantly boosted power output, reducing the average capacity loss over 6000 operating hours to only 0.8% per year as opposed to 3.0% with the old configuration. As noted above, a certain amount of capacity drop is related to ageing as opposed to fouling. The other (and larger) part of capacity drop, i.e. that caused by compressor fouling, was virtually eliminated on a lasting basis by the upgrade. The upgrade also reduced the average heat rate increase over a 12 month period to only 0.6% per year as opposed to 1.3% with the old configuration.

Providing increased power capacity and reduced fuel consumption, an EMW® filter system upgrade typically pays for itself within a few months' time. Besides these economic advantages, the upgrade offers yet another benefit "on top": reduced CO_2 emissions.

Are you interested in getting more details? Pls. contact us via **mail@emw.de**.