

Innovative Technologies for Gas Turbine Air Filtration

This study will explain how the correct use of air filters can significantly improve the efficiency of gas turbines. Whilst the main focus will be filtration's role in the defense against contaminants that blunt performance, this paper will also examine the most effective methods of water removal and outline the key considerations when scheduling filter replacement.

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In the field of large power generation plants, even a small improvement in efficiency can have a dramatic effect on overall performance. Increasing the efficiency of the world's installed capacity of 2500 GW by as little as 1% would lead to a reduction of around 300 million tons of CO₂ per year and save 100 million tons of fossil fuels [1]. A considerable portion of the world's capacity utilizes gas turbine (GT) technology so it is clear that even a small improvement in GT efficiency can yield big benefits.

Improving the efficiency of energy production through retrofitting of existing plants would therefore generate substantial savings in emissions to the environment

According to a study of EU turbines within large central electricity production [2], it is estimated that in 2030, 60% of global emissions will come from power plants currently in service. According to the same study:

- an optimization of the system would lead to a reduction of 5% in CO₂;
- retrofit of turbines would lead to a reduction in CO₂ of 5%;
- retrofit of boilers would bring a further CO₂ reduction of 3%;
- Europe's combined cycle plants are currently working with an average efficiency of approximately 52%; existing best available technology (BAT) makes it possible to achieve a value greater than 58%.

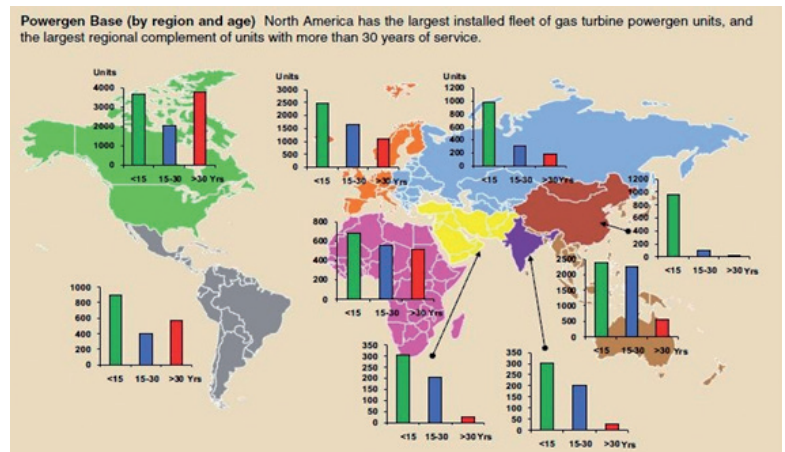
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Figure 1 powergen base (by region and age) [3] illustrates the average life of gas turbines across the globe using average data from various sizes of turbines.

As can be seen, many turbines installed around the world have been operating for a number of decades, often

with low efficiency due to outdated technology and worn machinery. The opportunity for improvements in gas turbine efficiency is therefore extensive. This study examines possible performance improvements to existing installations via the air filtration system.

Fig. 1 - Average life of gas turbines across the globe using average data from various sizes of turbines



Typical parameters of air filtration performance (EN 779:2012)

The benchmark standard for defining an air filter's performance is the recently updated EN 779:2012, which now considers minimum efficiency when awarding filter class. The parameters which characterize an air filters are:

- *Average Arrestance (Am)*: the ratio between the total amount of synthetic test dust retained by a filter and the amount injected. This parameter is used to classify coarse dust filters of class G;
- *Average Efficiency (Em)*: the ratio of the number of particles (average diameter of 0.4 µm) retained by the filter to the number entering it expressed in a percentage; this parameter is used to classify M and F class filters;
- *Dust Holding Capacity*: the amount of dust that a filter can retain until the final pressure (in grams);
- *Initial Pressure Drop*: the pressure drop (Pa) of a new filter operating at test air flow;
- *Minimum Efficiency*: the lowest value recorded during testing from the initial, discharged and loaded efficiencies.

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ignored from this example. Against external environmental condition of 50 µg/m³ of dust concentrations in a turbine of 250 MW come on average 13.1 kg/year of dust that cause the phenomena of fouling, corrosion and erosion. This system has an initial pressure drop of 145 Pa. The alternative to be analyzed is a pre-filter G4, a filter F9 and a final E11; in this case 26.8 g/year dust will enter in the gas turbine with an initial pressure drop of 360 Pa, considerably higher than the previous case.

Moving from two to three stages, there is the negative factor of the increase in pressure drop but a significant reduction of dust that reaches the turbine. To quantify this additional pressure drop, it is agreed within the power generation industry that an increase in pressure drop of 50 Pa causes a fall in efficiency of 0.1%.

Figure 2 shows the trend of the efficiency of the turbine as a function of time due to the effect of fouling [4].

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Group	Class	Final pressure drop Pa	Average arrestance (Am) of synthetic dust %	Average efficiency (Em) of 0,4 µm particles %	Minimum efficiency (a) of 0,4 µm particles %
Coarse	G1	250	50≤Am<65		
	G2	250	65≤Am<80		
	G3	250	80≤Am<90		
	G4	250	90≤Am		
Medium	M5	450		40≤Em<60	
	M6	450		60≤Em<80	
Fine	F7	450		80≤Em<90	35
	F8	450		90≤Em<95	55
	F9	450		Em≤ 95	70

Table 1 – Classification of filters

According to the new EN 779:2012 standard, filters are classified into coarse, medium and fine categories (**table 1**).

Improving efficiency through EPA filtration

Normally a gas turbine intake filtration system consists of a first stage of glass fiber coalescer pads, followed by G4 or M5 bag filters and a final stage of F8 or F9 filters. Now, high efficiency EPA filters are offering an alternative.

The coalescer stage will remain the same so will be

drop of 50 Pa causes a fall in efficiency of 0.1%.

For the maintenance of gas turbines, to bring the efficiency of the turbine to an optimal value, are used off- line washing, washing with water and detergents of the turbine's vane (considered hazardous waste once used). In **figure 3** are reported respectively developments due to fouling with the classical filtration and the one with the absolute filters, confirmed by [5]. As is illustrated above, with EPA filtration off line washing is not necessary for 9000 hours. Overlaying the two curves (**figure 4**), provides further demonstration that a turbine with EPA filtration has less fouling and less deterioration of the efficiency

than a traditional two-stage system.

Quantifying the benefit is a balance between reduced fouling and increased pressure drop. The increased pressure drop can be estimated to restrict performance by approximately 0.4%, while cutting fouling provides a 1.2% improvement in output (empirical average). Therefore, the overall result is a potential efficiency improvement of 0.8%. Other costs must also be considered in addition to the above. Investment is required in the retrofit of filter chambers, consisting of upgrades to the system housing (metal frames) to accommodate three stages of filters, for example. However, empirical research has shown that a 37 MW turbine operating continuously saved 2300 MWh in a year by changing from a two to a three-stage system incorporating EPA filters.

Improving efficiency with hydrophobic pre-filters

In the past, the simplest way to eliminate water at the first stage of the air intake was through the use of glass fiber coalescer panels or finned louvers. However, these systems come along with an inherent pressure loss, which is particularly high in coalescer panels as they become dirty. Hundreds of pascal of pressure is wasted in order to capture the water and prevent it from reaching the final filters or the turbine itself. The introduction of filters that combine the dual function of pre-filter and coalescer has therefore brought considerable benefits to gas turbine operators. Utilizing a hydrophobic media, these

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elements provide a low pressure drop whilst maintaining the ability to stop water and increase the performance of filtration overall (figure 5). In old filter chambers with coalescer panels and/or rain louvers as the first stage, the new combined filters simply replace the coalescers

without the need for structural work to the existing.

Table 2 demonstrates how a 250 MW gas turbine experienced a dramatic pressure drop enhancement by adopting Macrogen GT Duo™ combined filters unit and removing a separate coalescer stage.

Modifying the filter house to accommodate a new filter configuration requires both capital investment in new frames and significant downtime to conduct the work. To avoid this disruption and cost, Macrogen GT Duo™ can be easily integrated with Compatex TMP (figure 6) compact filters using Velcro strips to provide an all-in-one solution that is incredibly simple to deploy.

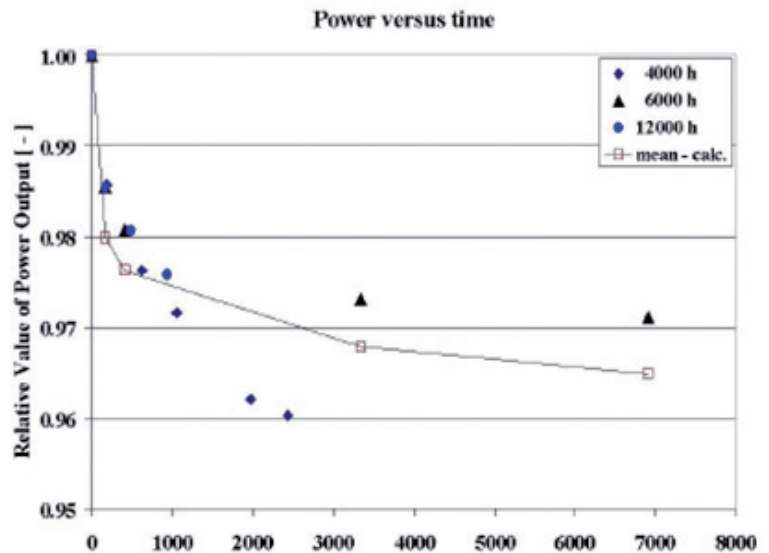


Fig 2 - Efficiency of a turbine over time due to the effect of fouling [4]

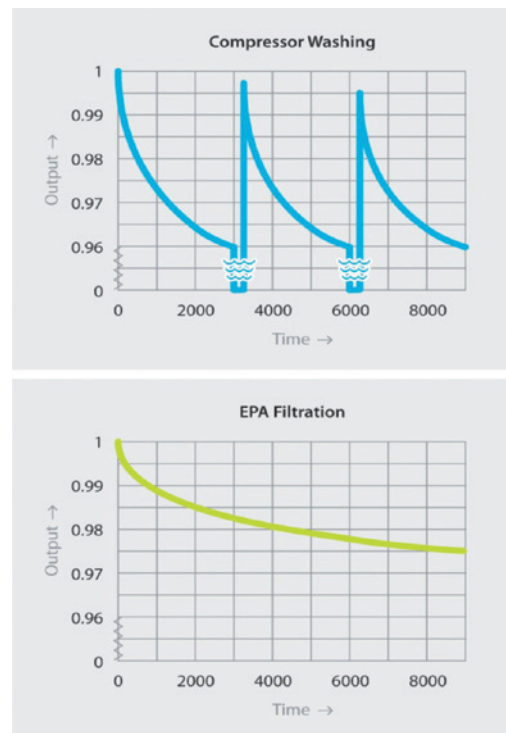


Fig. 3 - Traditional two-stage intake (top) vs EPA filtration

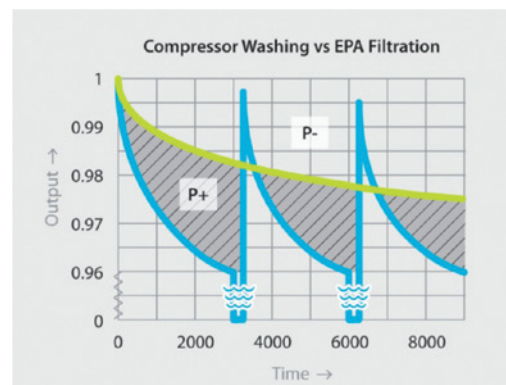


Fig. 4 - Compressor washing and EPA filtration compared

	Stage 1	Pre-Filter	Final Stage	Total PD
Initial Configuration	Coalescer G3	Bag Filter G4	Compact F9	275 Pa
Replacement	[None]	MacroGen GT Duo M5	Compact F9	162 Pa
			Delta P Reduction	113 Pa

Table 2 - Example of removing a dedicated coalescer stage(250 MW gas turbine, operating 4000 hours/p.a.); based on 90 €/MWh, the pressure drop reduction yielded an annual efficiency saving of 180,000 € per turbine



Fig. 5 - Water first coalesces then drains away from the downstream air flow

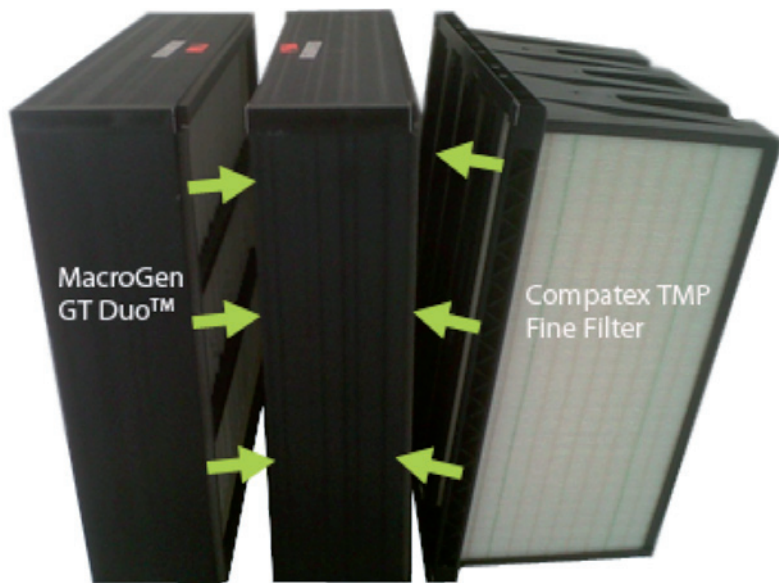


Fig. 6 - MacroGen GT Duo™ integrated with Compatex TMP compact filters

Improve efficiency through timely filter replacement
Quite often the policy of changing filters for each stage is driven not by the prescribed final pressure drop, but by other considerations such as scheduled shutdowns of the plant for maintenance. Bearing in mind the impact that just 50 Pa of additional pressure drop has on overall system efficiency, this should clearly not be the case. Even if the cost of the replacement filter is a factor in delaying, the purchase price of the new element is likely to be much less than the cost incurred through the loss of efficiency from an old, dirty filter.

With this in mind, there are clear areas for potential improvement through the management of filter changes and ensuring that these are completed at exactly the right time.

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Figure 7 shows the pressure drop of a pre-filter in an air intake of a turbine of 250 MW. This type of product has an average cost of 20 euros, with this size turbine typically requiring an average of 500 filters. Therefore, a set of pre-filters for this turbine would cost in the region of € 10,000. In November 2008 the new filter had an initial pressure drop of 50 Pa. By mid-May 2009 this figure had increased to 200 Pa and was begin to rise at a greater rate. The filter was finally replaced at 450 Pa in mid-June 2009. In that month of operation with a high load loss (mid-May to mid-June), the increased pressure drop had reduced the efficiency of the turbine by 0.5%. This equated to an economic loss estimated around €60,000 (assuming continuous operation and a price of 70 €/MWh).

It is therefore clear how the timely changing of pre-filters would have resulted in a considerable economic advantage.

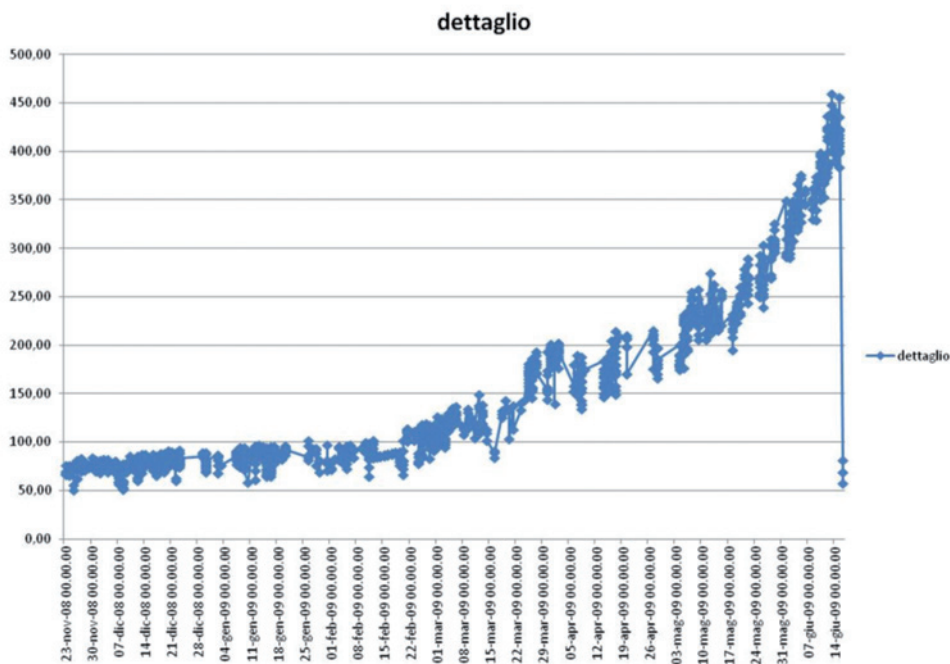


Fig. 7 - Pressure drop of pre-filters over time

Conclusion

Air filters are often neglected in the definition of a project in the field of power – filters are considered commodities or simply generators of pressure drop. This study has shown that proper selection and management of filters that considers environmental conditions and new technologies can lead to significant improvements in efficiency of the turbines themselves. ■

[3] Gas Turbine World, 2009

[4] Timot Veer, Klaus Haglerod, Olav Bolland (Norwegian University of Science and Technology): Measured data correction for improved fouling and degradation analysis of offshore gas turbine - **specificare anno** (pag. 6)

[5] Koji Watanabe, Hisato Arimura, Koichi Akagi, Hiroki Sakuma: Modernization and upgrade programs for Mitsubishi Heavy Duty Gas Turbines- **specificare anno** (pag. 5).

References

[1] EU Turbines, **specificare anno**

[2] EU Turbines - Position paper in energy efficiency from the supply side, 30 August 2010



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Carlo Coltri was born in Milan in 1970; he has a degree in Engineering at Politecnico di Milano.

His experience in Energy business started with KSB Italy (pumps and valves), as marketing manager and as a key account manager for the Business Unit Energy.

Currently holds the position of Country Sales Manager for Vokes Air in Italy, Swedish multinational manufacturer

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