Innovative technologies for gas turbine air filtration

Carlo Coltri – Vokes Air

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.

Introduction

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 CO_2 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.

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 CO_2
- Retrofit of turbines would lead to a reduction in CO_2 of 5%
- Retrofit of boilers would bring a further CO_2 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%.

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

Fig. 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many turbines installed around the world have been operating for a number of decades, often with low efficiency due to outdated technology and worn machinery.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.

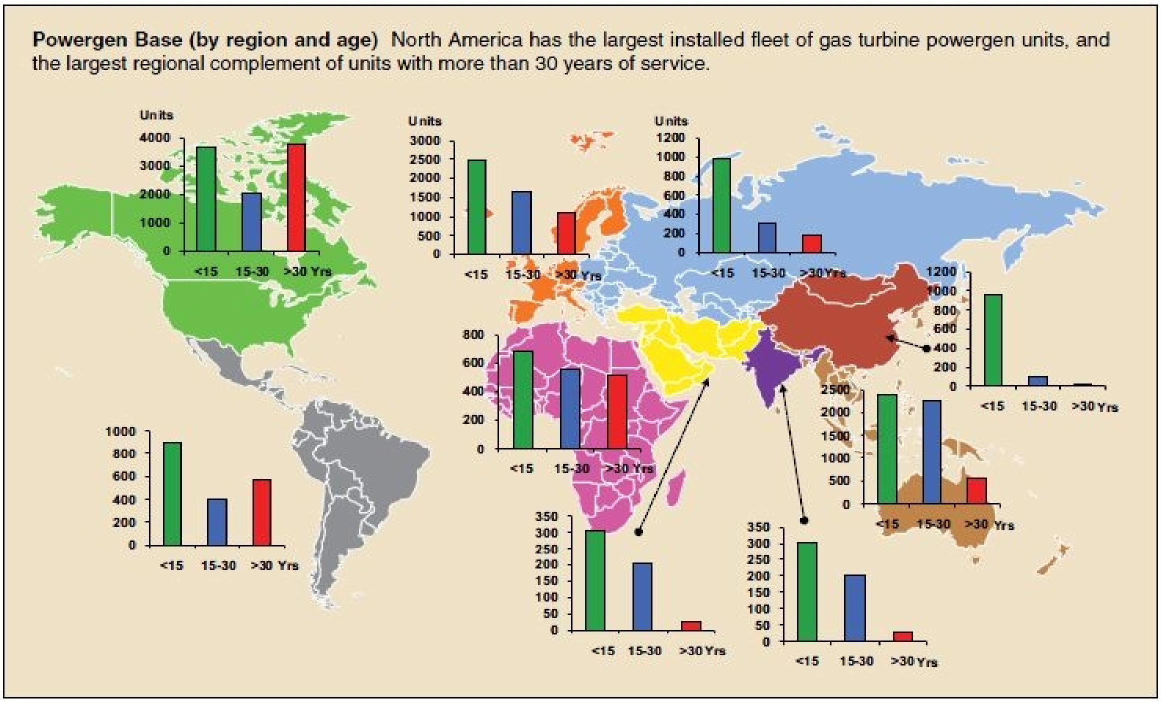

Fig. 1 Power generation base

1. 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 filter 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, 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.

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

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

2. 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 ignored from this example. For a 250 MW turbine operating in an environment with dust concentrations of 50 µg/m^3, the classical and new EPA approaches can be compared as below.

	Pre-Filter	Secondary Filter	Final Filter	Dust Entering Turbine	Total Pressure Drop
Classical	G4	-	F8	1310 g/p.a.	145 Pa
EPA	G4	F9	E11	26.8 g/p.a	360 Pa

Moving from two to three stages has significantly increased system pressure drop but simultaneously reduced the quantity of dust reaching the turbine by approximately 98%, lowering the chance of engine damage – fouling, corrosion and erosion. 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%.

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

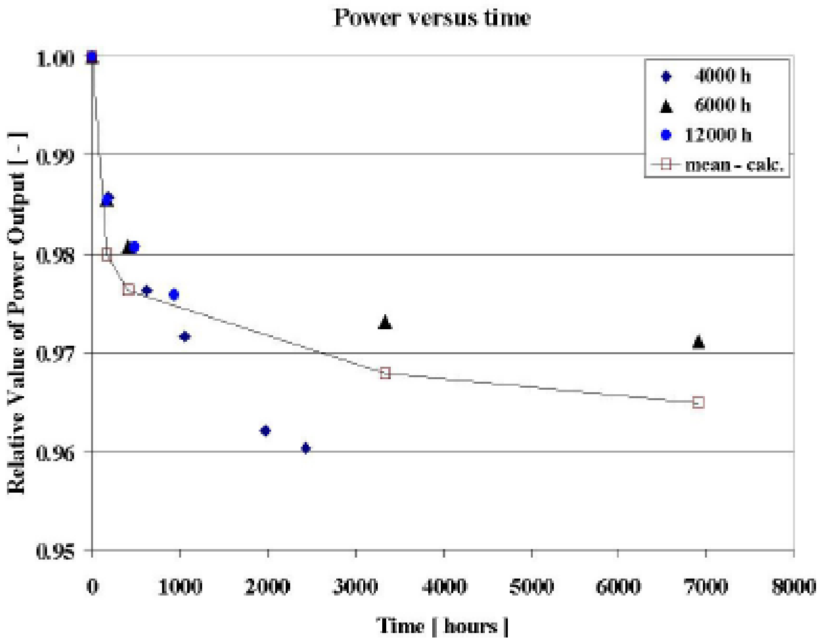

Fig. 2 The efficiency of a turbine over time due to the effect of fouling[4].

With the traditional air intake filtration arrangement, the turbine is taken off-line and washed to eliminate the performance-inhibiting effects of fouling to the engine blades. Not only does this process introduce downtime to the turbine schedule, the washing fluid – a mixture of water and detergents – is considered hazardous waste once used, bringing further complications to the process.

Fig. 3 demonstrates the key performance differences between classical filtration and absolute filters, further highlighted by Fig 4 and confirmed by note [5].

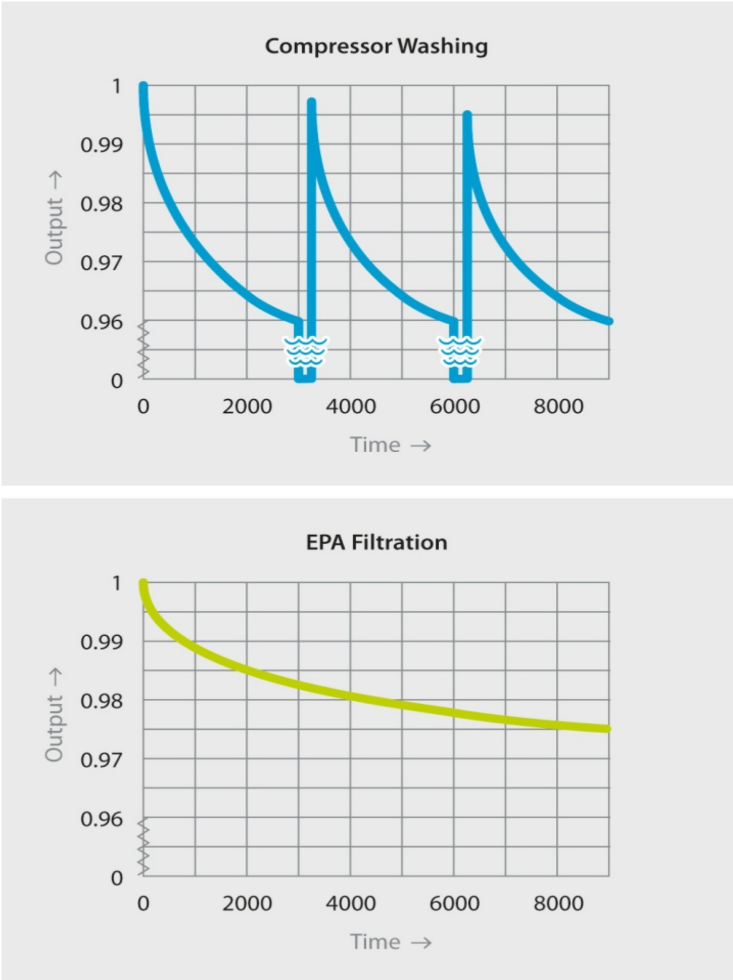

Fig. 3 Traditional two-stage intake (top) vs EPA filtration

As is illustrated above, with EPA filtration off line washing is not necessary for 9000 hours. Overlaying the two curves (Fig. 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.

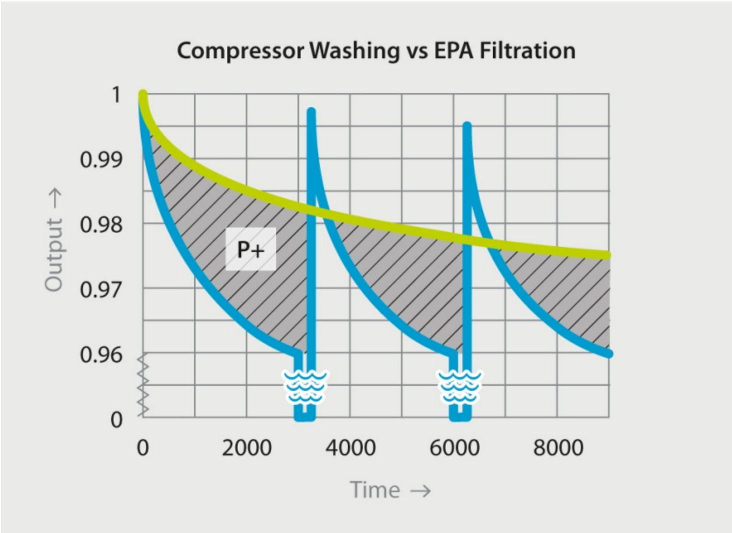

Fig. 4 Compressor washing and EPA filtration compared

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.

3. 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 elements provide a low pressure drop whilst maintaining the ability to stop water and increase the performance of filtration overall (Fig. 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 work to the existing structure.

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

Fig. 6 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.

Fig. 6 Example of removing a dedicated coalescer stage

250 MW gas turbine, operating 4000 hours/p.a.

	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**

Based on €90/MWh, the pressure drop reduction yielded an annual efficiency saving of €180,000 per turbine.

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 (Fig. 7) compact filters using Velcro strips to provide an all-in-one solution that is incredibly simple to deploy.

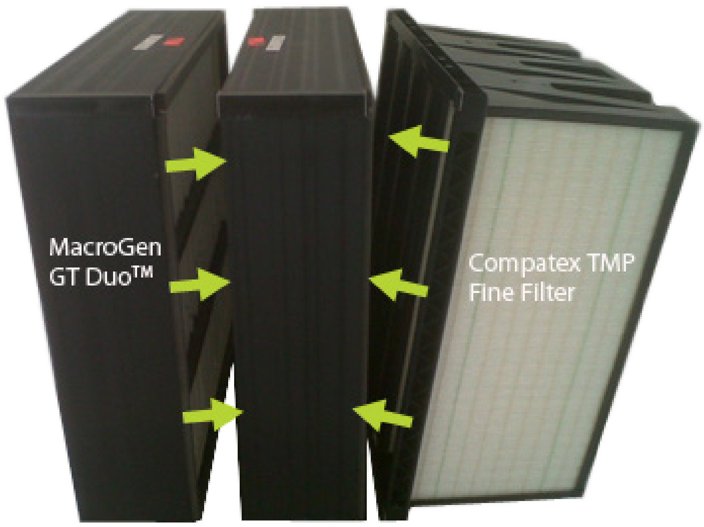

Fig. 7 Macrogen GT Duo™ integrated with Compatex TMP compact filters

4. 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. Fig. 8 shows the pressure drop of a pre-filter in an air intake of a 250 MW turbine. 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.

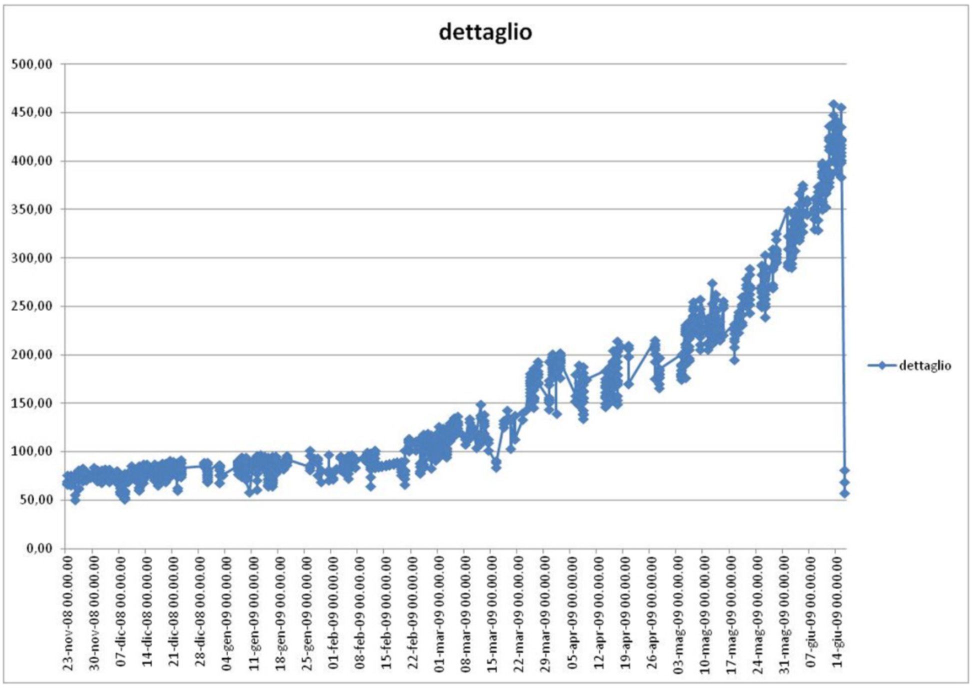

Fig. 8 Pressure drop of pre-filters over time

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.

References

(1) EU Turbines

(2) EU Turbines -Position paper in Energy efficiency from the supply side- 30 August 2010

(3) Gas Turbine World 2009

(4) Timot Veer, Klaus Haglerod, Olav Bolland, Norvegian Univerity of Science and Technology: “Measured data correction for improved fouling and degradation analysis of offshore gas turbine”-pag 6

(5) Koji WATANABE, Hisato ARIMURA, Koichi AKAGI, Hiroki SAKUMA: “Modernization and up grade programs for Mitsubishi Heavy Duty Gas Turbines” –pag 5