Dr. Födisch
Umweltmesstechnik AG
Zwenkauer Straße 159, D-04420 Markranstädt
T. +49-34205-755-0, F. +49-34205-755-40
www.foedisch.de

The application of triboelectric dust measuring technology in cement industries – solutions, application examples, challenges

Summary

Apart from electrostatic precipitators for de-dusting of oven and clinker coolers, lots of bag filters are installed in cement plants in order to reduce dust emissions of smaller emission sources. These are often distributed across the usually broad plant area. The big emission sources are mostly equipped with dust concentration measuring devices and so are under control. That's why, in fact, smaller emission sources are responsible for increased dust loads in the vicinity of a cement plant. In order to reduce the total dust emission of a plant, it is important to be able to monitor the single dust sources. Moreover the filter facilities of these smaller sources cause substantial costs. Therefore the aim is for monitoring to be efficient and optimised with regard to time expenditure and financial expenses.

1 Introduction

In recent years the application of so-called filter controllers has become accepted for the monitoring of clean gas dust contents behind de-dusting facilities. They are installed as in-situ devices in clean gas channels behind dust precipitators (**Fig. 1**), in order to continuously monitor the relative clean gas dust content of filters. Modern filter controllers work according to the triboelectric measuring principle, which means that the charge exchange between the measuring probe and the dust particles streaming nearby as well as the dust particles directly impacting on the probe is used (**Fig. 1**).

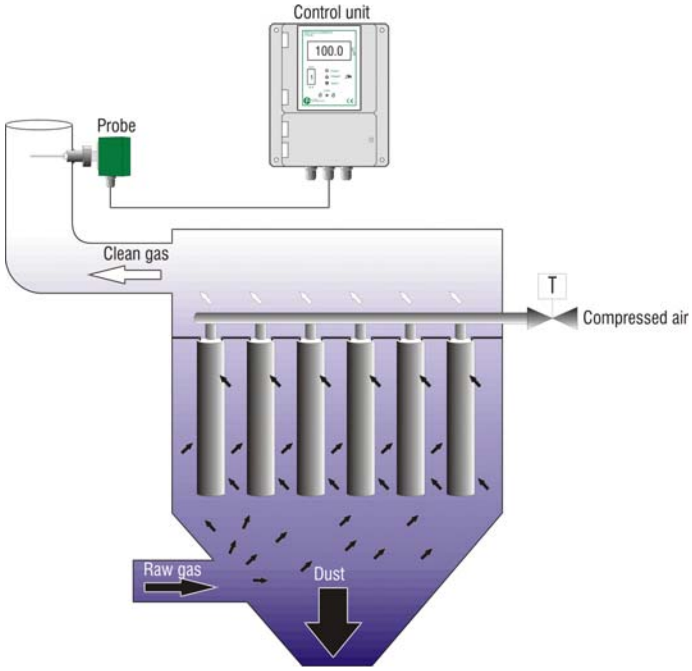

Figure 1: Principle of in-situ measurement after the triboelectric method for monitoring of bag filters

The measuring current arising is registered by the electronic circuit and amplified. The signal derived is a measure for the dust content portion in the exhaust gas, depending on the kind of dust and the gas velocity. Moreover it is possible to pre-select an upper and lower alarm value, which if exceeded causes potential-free contacts to be activated.

2 Continuous triboelectric filter monitoring

Until some years ago the measuring variable pressure loss over the filter was used for filter monitoring. This measurement is reasonable, as for bag filters an optimum range of pressure loss exists (approx. 800 to 1#400#Pa). If the filter works within this range, it is guaranteed that the filter cleaning system functions properly. Increasing pressure loss hints at malfunctions in this regard which have to be repaired in the short-term.

In order to estimate the passage of the dust through the filter, the differential pressure monitoring, however, is absolutely extraneous. So for example a hole in a needle-fleece filter bag which is as big as a fist (when all other filter elements are intact) causes a dramatic increase in dust emissions, the filter differential pressure, however, is not really substantially influenced. For an optimum estimation of the precipitator's efficiency, measurement of the filter differential pressure as well as the continuous monitoring of dust emissions by means of filter controllers are required.

The qualitative dust measurement not only ensures monitoring of the clean gas dust content behind de-dusting facilities but at the same time also allows the assessment of the state of the flue gas purification equipment. Besides the localisation of defective filter elements, determination of damaged parts i.e. membrane valves, flaps not tightly closed etc. are all part of an effective filter diagnosis.

2.1 Filter monitoring

The filter controllers of the Dr. Födisch Umweltmeßtechnik AG, Markranstädt, Germany, possess two different operational modes. In the operational mode "Integral Off" the signal is only slightly time-damped, whereas in the operational mode "Integral On" a notification with a time constant of approx. 30#s is carried out. So for the operator this results in the possibility of providing - at first in the standard mode ("Integral On") - an average emission value, which is close to the half-hourly average value relevant for authorities. Since the dust concentration slowly increases in case of incipient filter wear, an alarm can be provided if a fixed limit value is reached (**Fig. 2**).

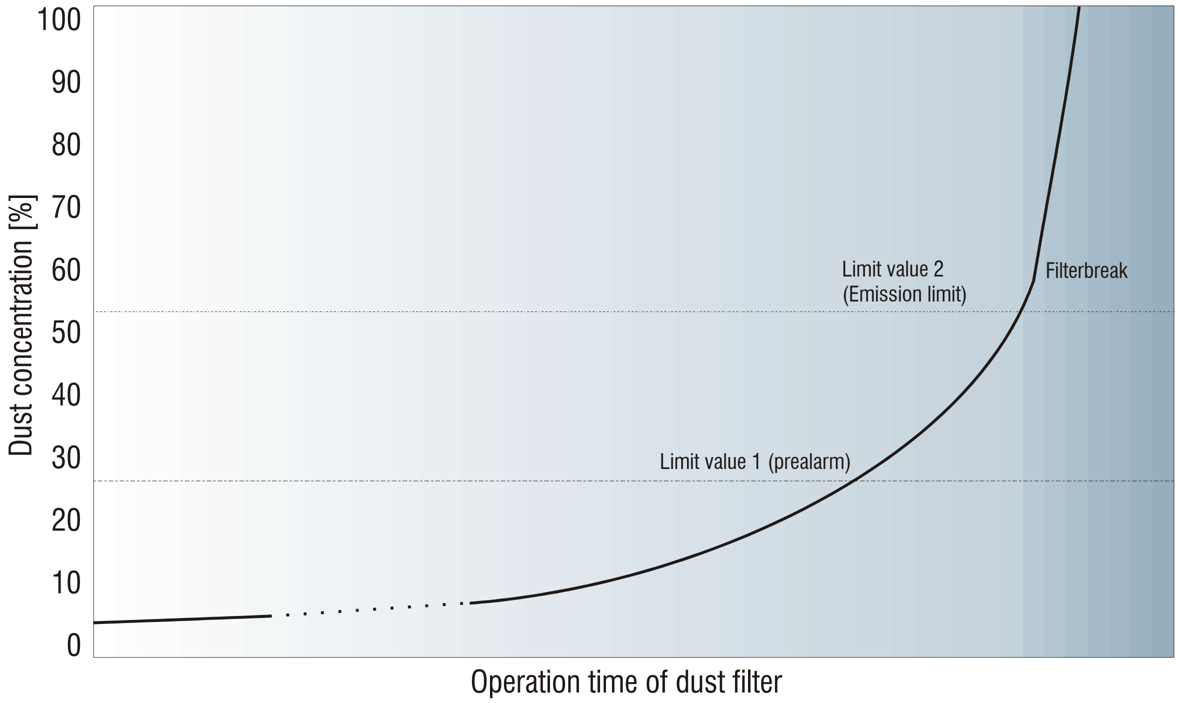

Figure 2: monitoring of a filter in operational mode „Integral on“

2.2 Filter diagnosis

Apart from the limit value monitoring of an emission limit value, there is the possibility of filter diagnosis. If the device is operated in the mode "Integral Off", quick changes of the dust content after cleaning processes - the so-called dust peaks - can be detected and assigned to the bag rows based on the cleaning impulses. The height of the triboelectric signal at the moment of the cleaning impulse is therefore not only the criteria for the limit value but also a degree for the quality of the bags. A typical example is shown in **Figs. 3 and 4.**

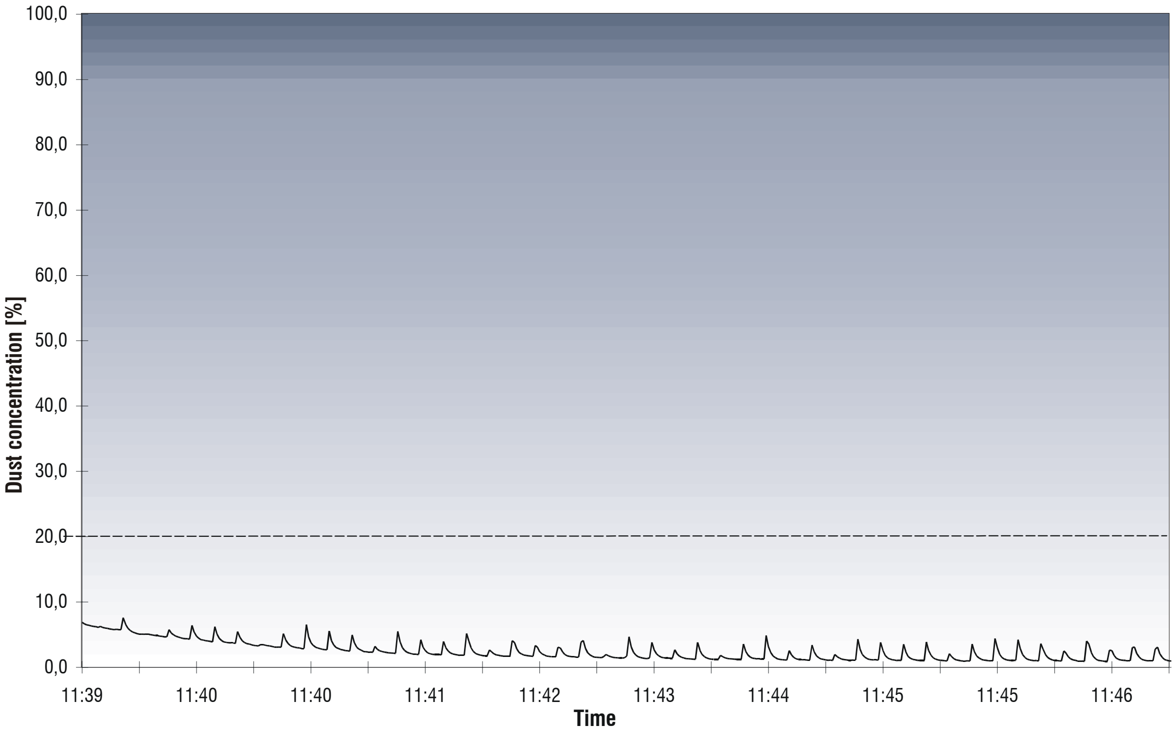

Figure 3: faultless filter elements

Contrary to **Fig. 2** here, in this mode, the momentary values of the respective bag row in the instant of cleaning are shown. The diagram in **Fig. 3** was obviously recorded at a faultless filter. Compared to **Fig. 4** it is significant that only some filter bags are functioning correctly. Whereas other rows hint at defective filter bags. These can be systematically changed based on the measuring results.

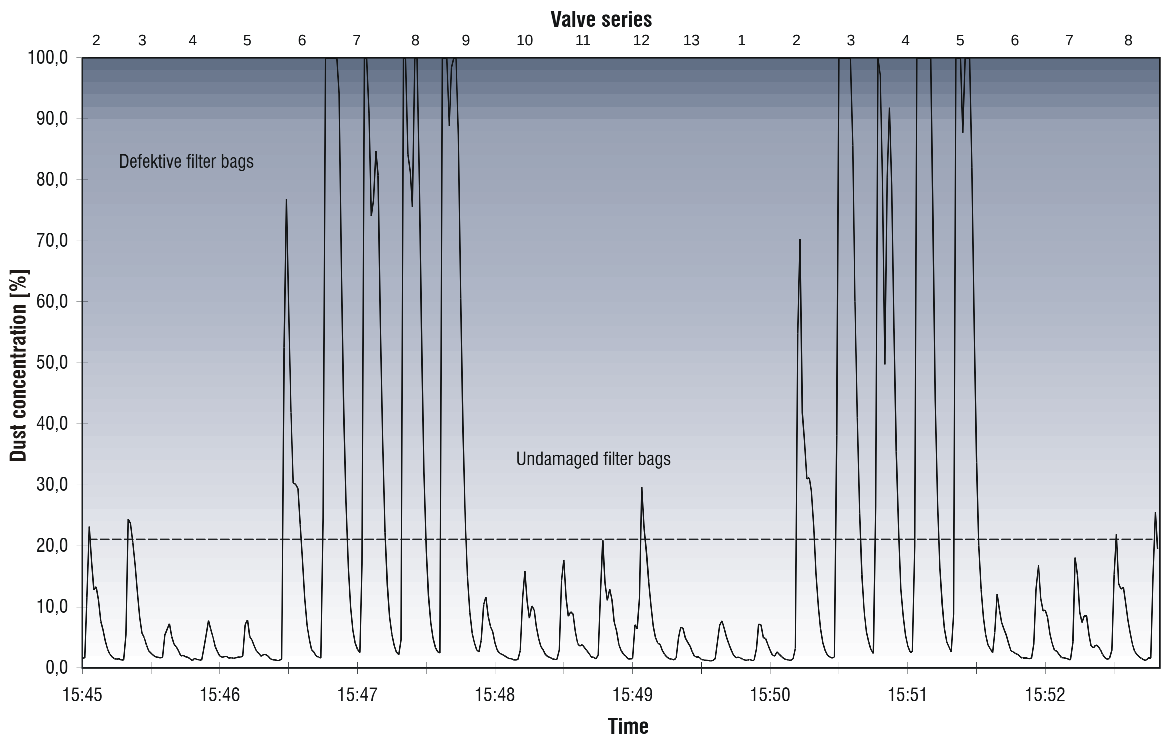

Figure 4: defective filter elements

The evaluation of the filter controllers' signals therefore allows identification of incipient wear of filter material at a very early stage, which means that emissions of these bag rows had not been visible or had hardly been visible so far. So the operator receives the warning about a deteriorating filter state in good time long before a dust plume can be seen or noticed by authorities and neighbours. Therefore extraordinary dust emissions and filter leakage can be avoided.

The new generation of filter controllers even possess a display at the probe head, so that it is possible directly on site to see the facility state either in mode "Integral On" or "Integral Off" and to react immediately to increased dust breakthroughs (**Fig. 5**).

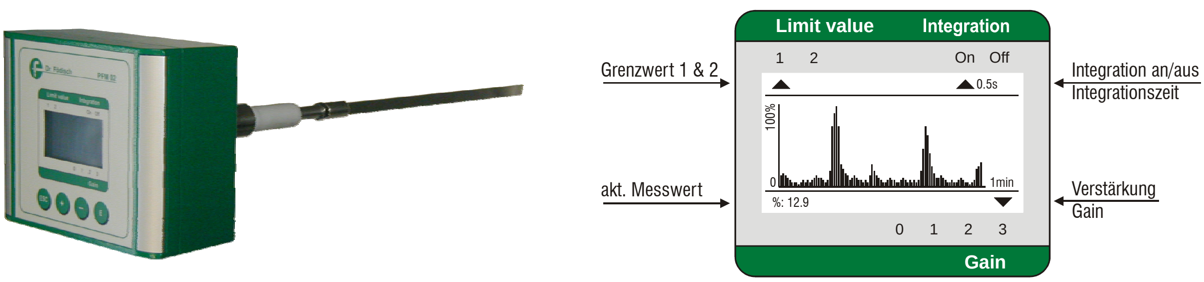

Figure 5: compact filter controller with on-line presentation

3 Application examples for triboelectric filter monitoring systems connected with automated filter control

The advantage of filter monitoring at single filters has long been undisputed. In addition, it is also possible to monitor effectively numerous de-dusting facilities by installing and linking several devices and their corresponding evaluation software. Especially for plants where 30, 60 or more filters distributed all over the plant have to be monitored or for plants with multi-chamber filters, where so far a control system - the place where all filter information is merged - has been missing. Therefore the aim has to be, on the one hand, by means of timely filter diagnosis and on the other by optimisation of filter cleaning, to keep the expenditure for maintenance and repair as well as for energy consumption as cost-effective as possible.

3.1 Example 1 - continuous filter monitoring of many individual filter facilities

In a selected cement plant, a filter monitoring system was installed which, on the one hand allows optimum operation of the filter but at the same time achieves continuous monitoring of the filter and therefore keeps the plant's dust emission permanently and safely at a very low level.

The filter monitoring system provides an overview of the state of all 30 filter facilities of the plant at any time. Per filter and in the case of bigger filter facilities per filter chamber, one triboelectric filter controller each was installed for the qualitative dust measurement as well as one pressure transmitter for the measurement of pressure loss of the filter. The dust signal as well as the differential pressure signal of each filter is connected with the common filter monitoring system. Therefore two new issues result:

The filter monitoring is not carried out as in the past exclusively by the pressure loss on the filter but also by detection of lowest dust contents in the clean gas channel. The timed filter control is replaced by one being controlled by differential pressure. That means the cleaning is no longer done in cycles but on demand. So the impulse for compressed air is provided when a certain dust load on the filter is reached.

The dust and differential pressure measuring devices are connected via five data registration systems installed at different places with the computer where SPS and visualisation are integrated. For that the filter facilities were combined in five groups where the group's assignment depends on the close location of the filters to each other. In order to reduce the wiring expenditure of the single devices to the evaluation system a combination of analogue and digital signal transfer was chosen. **Fig. 6** shows the wiring of the measuring system schematically.

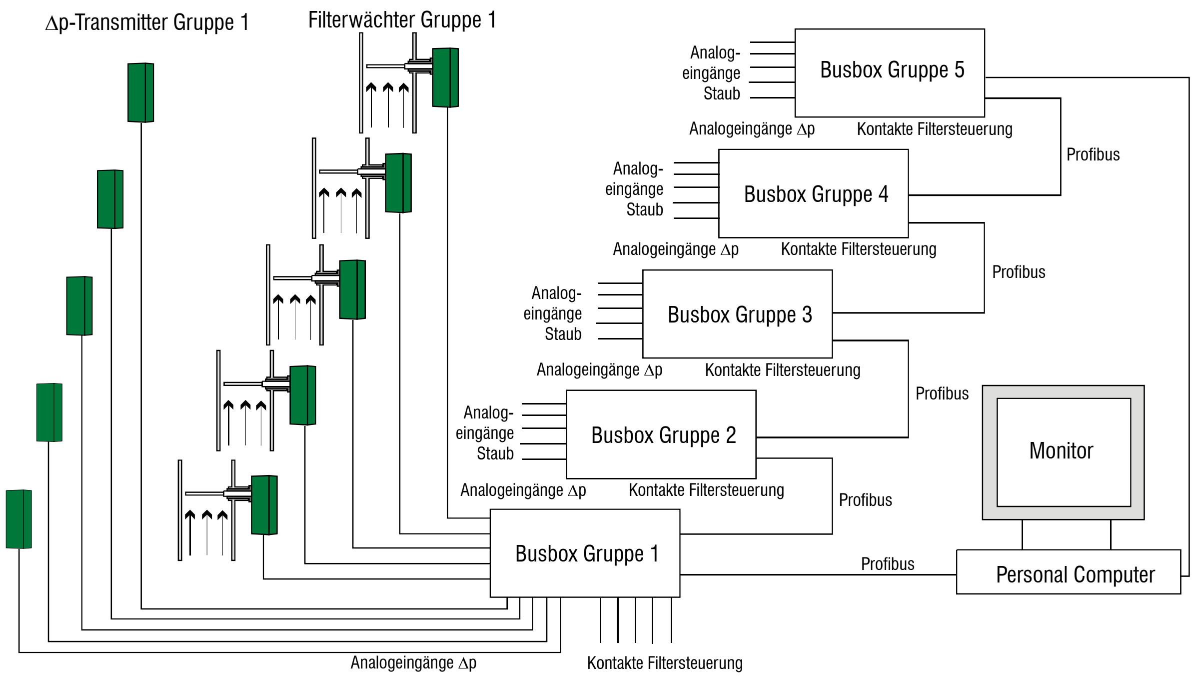

Figure 6: scheme of a filter monitoring system

The analogue output signals of each time up to six filter controllers and six pressure transmitters were wired to one common collecting point - the bus box of the respective filter group. All bus boxes of the five filter groups are then connected via profibus with the evaluation system. At **Fig. 6** it can be seen, that apart from the two times six analogue inputs per bus box also six status contacts can be operated. In this way the (already existing) filter control of each single filter can be started.

The number of devices which are combined in one group can be freely chosen depending on the plant. It is also possible to link all devices via bus. Thus bus boxes as given in this example can become unnecessary. The optimum solution depends on the local and plant-related conditions.

A huge amount of filter controllers whose output signals are recorded by a PC, however, do not result in a filter monitoring system. For that, a suitable software package is required which carries out activation of the single filters, the counting of the rows and the transfer of the analogue values. Data recording and evaluation are carried out on the PC.

If the computer boots up, SPS and visualisation system will be started automatically. The PC shows an overview window where all filter groups with the respectively assigned single filters are presented. For each filter the current value of dust and differential pressure measurement are shown. Filters highlighted with colours mean that an error or a limit value violation has occurred. A protocol generated after repeated occurrences of the failure allows a diagnosis of the type of error. Moreover it can be seen in the overview whether a filter is currently being cleaned or not (**Fig. 7**).

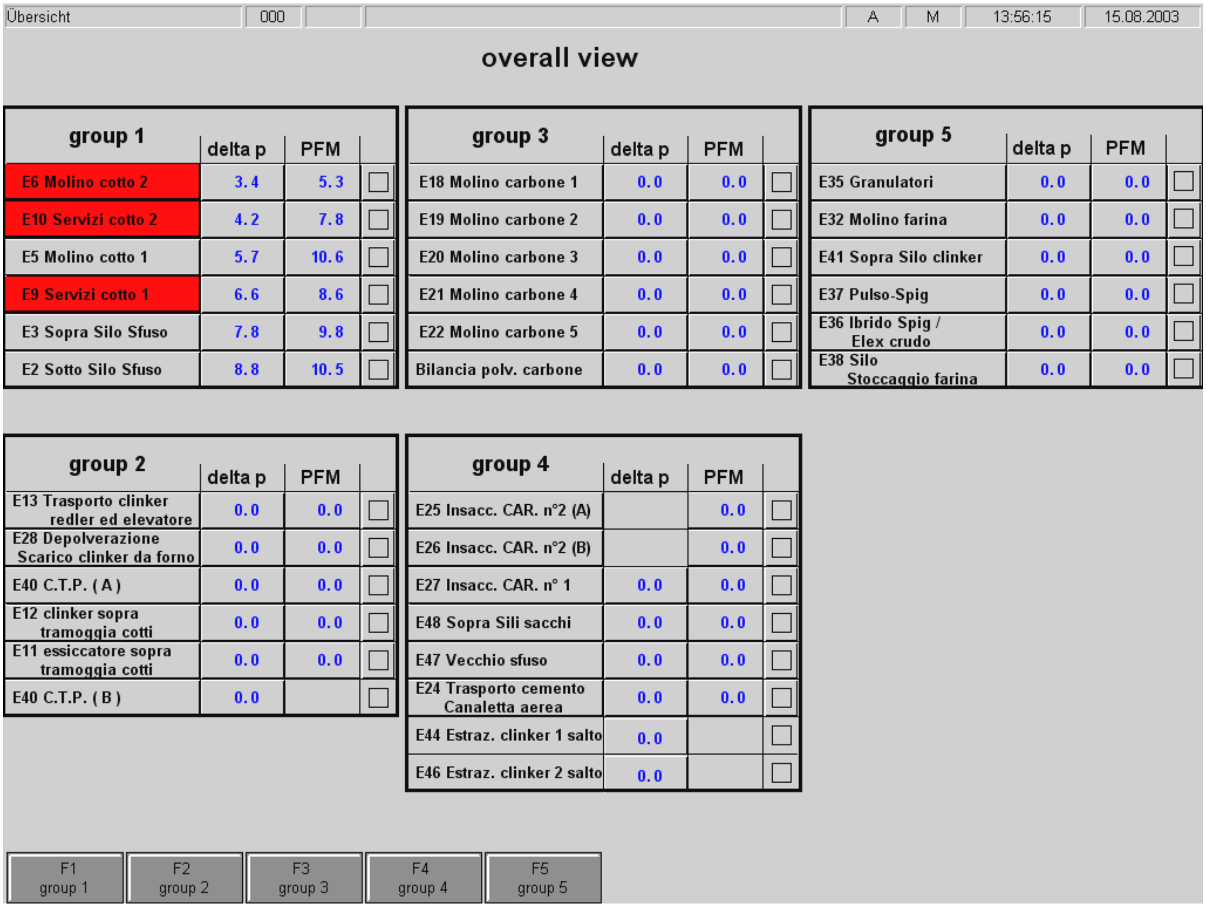

Figure 7: overview about all 5 filter groups with 30 single filters exemplary for a cement plant in Italy

In **Fig. 8** a single filter group is shown. In the upper part of the figure each single filter is recorded with the number of its bag rows. In the diagram section of the figure the online registered dust values of the single filters can be seen including their cleaning impulses. The diagram can be scaled further and allows provision of graphs of single filter controllers and pressure transmitters respectively both online as well as retrospectively.

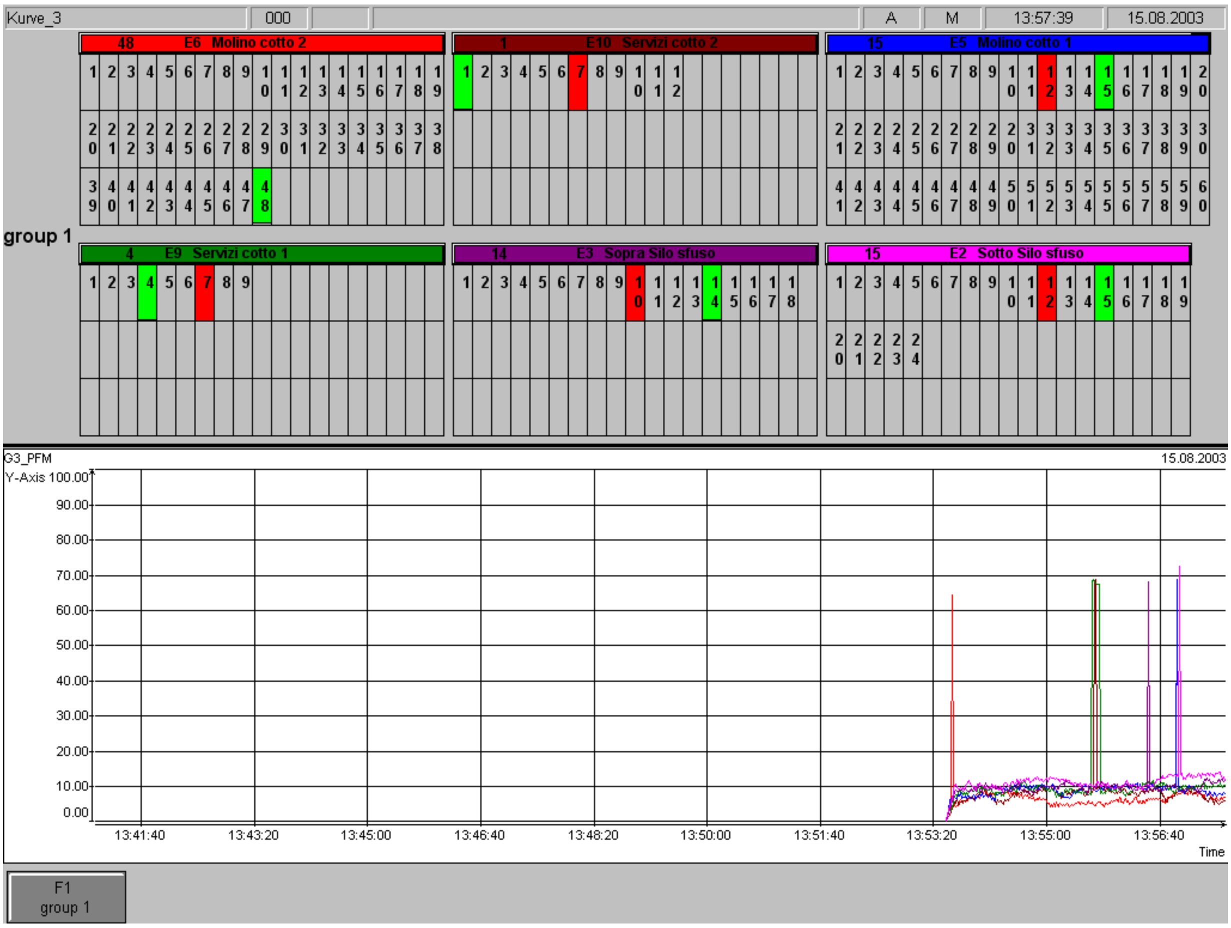

Figure 8: overview filter group 1 with 6 single filters exemplary for a cement plant in Italy

The filter diagnosis is done automatically. In the upper part of the figure a bag row highlighted in green can be seen. That means this bag row is currently being cleaned. The field will be coloured red if during the cleaning process a limit value violation occurs, which means that the cleaning peak of the respective bag row is too big. In case of a repetition the software provides an error message , like i.e. "Filter 1, Piati Granulatori, Row 23, Dust Alarm". Exceeding the limit value can be explained for example by wear of the filter material. If the peak is too small or does not occur, for example a breakdown of compressed air or a defective valve could be the reason. In this case the bag row is coloured blue. The system registers the errors and if they occur e.g. in 3 subsequent cleanings, an error protocol will be compiled.

In order to evaluate dust peaks occurring and to assign the bag rows to the cleaning impulse it is required to know or to determine and enter the following parameters of filter control. These are:

- the number of bag rows,
- the break time between the cleaning impulses,
- the delay time, that means the time until the dust peak arises at the filter controller depending on its place of installation and the flow velocity (**Fig. 9**).

G3_Par | 000 | A | M | 13:58:14 | 15.08.2003

parameter

	E6 Molino cotto 2	E10 Servizi cotto 2	E5 Molino cotto 1	E9 Servizi cotto 1	E3 Sopra Silo sfuso	E2 Sotto Silo sfuso
scan time [100 ms]	0	0	0	0	0	0
delay time [t]	2	12	12	12	12	12
assessment time [s]	2	6	4	7	5	4
alert threshold of dust	3	3	3	3	3	3
T.pause [s]	0	0	0	0	0	0
dust [%] Min	0.0	0.0	0.0	0.0	0.0	0.0
dust [%] Max	50.0	50.0	50.0	50.0	50.0	50.0
delta p [mbar] Min	0.0	0.0	0.0	0.0	0.0	0.0
delta p [mbar] Max 1	3.5	4.5	5.5	6.5	7.6	8.5
delta p [mbar] Max 2	4.5	5.5	6.5	7.5	8.5	9.5
alert threshold delta p	3	3	3	3	3	3

F1 group 1

Figure 9: surface for parameter input for a filter group exemplary for a cement plant in Italy

In general, filter cleaning in the project described will be started by the filter monitoring system, if the current value of the pressure loss Δp_i of the filter i exceeds the pressure loss limit value GW1 Δp_i.

At the start of the filter cleaning the system begins to assign the following dust peaks to the single bag rows by means of the parameters break time and delay time. The system of triboelectric filter monitoring and automated filter control shown has been working for some years now without any problems.

3.2 Example 2 - continuous filter monitoring for a multi-chamber filter

A further application example is filter monitoring for a multi-chamber filter. The plant consists of two filters each with six filter chambers where in each 13 rows with 14 bags are mounted. In the clean gas channels of each filter, four filter controllers were installed whose analogue signals together with those of the filter control are led to a central evaluation computer (**Fig. 10**). By connection via special software it is here also possible to view cleaning of the individual bag rows with a corresponding evaluation.

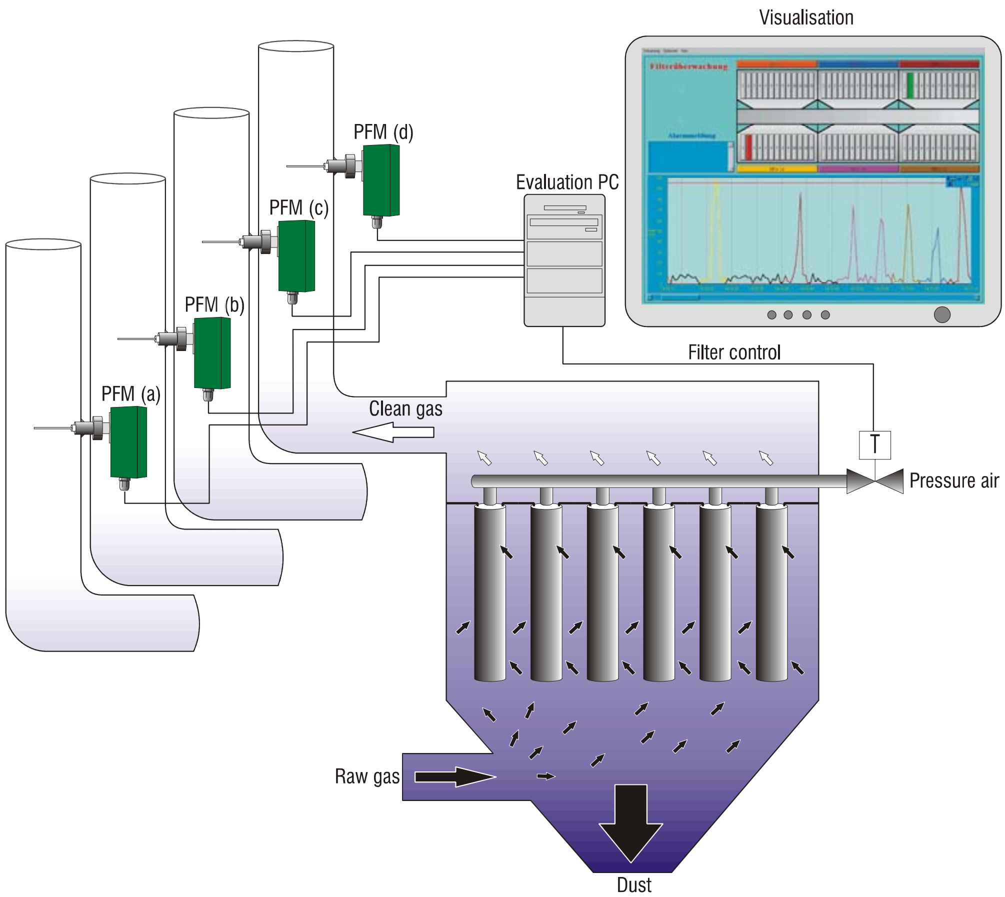

Figure 10: System for filter monitoring

After exceeding a pre-adjusted number of failures or violations of limit values respectively, an alarm message is generated which describes the type of the last failure. Further functions are a retrospective review in order to regard the signal trend of a single bag row, the display of all alarm messages as well as the individual configuration of the software for an optimum adjustment to the respective measuring task. Also included of course is the free adjustability of limit values.

The elaborate failure search for defects can be significantly shortened with regard to time as well as staff. Additional saving effects result from the systematic order of filter material as only defective elements have to be changed.

3.3 Costs and benefits of a filter monitoring system

The costs for this type of filter monitoring system are limited to the one-time investment and installation costs for the filter controllers and differential pressure transmitter, the evaluation system and software. No purging air etc. is required. The system's maintenance costs result from the annual zero point check of the triboelectric filter controllers and the differential pressure transmitters.

The above costs are counteracted by the following benefits of the filter monitoring system: Defects in the cleaning system are immediately identified (breakdown of compressed air, defective cleaning valves, defective filter control). Incipient filter wear is detected, localised and signalled. In this way it is possible to carry out systematic filter maintenance at the next regular shut down of the filter. Defective filter bags are changed selectively. So the usual prophylactic change of the whole filter material (e.g. every two years), which has been the custom up to now, can be omitted. The average lifetimes of the filter bags increase significantly. In the example described, the time-controlled filter cleaning was replaced by filter cleaning controlled by differential pressure. Thus the consumption of compressed air for cleaning as well as the ventilation capacity for conveying the gas stream can be optimised.

It should be emphasised that these cost savings are not made at the expense of higher emissions. The filter monitoring system is so sensitive that a rising amount of dust going through a bag row will already be detected a long time before an increase in the clean gas dust concentration is visible. This is why for modern bag filter facilities permanent clean gas concentrations of 1 to 3 mg/m³ (stp) can be achieved.

Moreover the system can be enlarged for the registration of additional relevant data.

Apart from monitoring with regard to the observance of emission limit values, application in the field of product filtration is also possible. The separation of valuable dusts such as for example cement additives, can be effectively controlled by a filter monitoring and control system. So product losses can be avoided.

4 Final remarks

Apart from the observance of limit values for dust stipulated by environmental law, by means of a filter monitoring system consisting of filter controllers, differential pressure measurement and evaluation system it is possible to reduce the dust emissions of a whole plant with many single and widely spread filter facilities down to a minimum. The system's relatively low investment costs are offset by:

- the plant's image - a substantial decrease of dust emissions of all - even so far neglected - sources
- preventive environmental protection (smaller defects will have already been detected long before dust emissions are visible to neighbours)
- possibility of the filter monitoring system's integration into an environmental management system
- reduction of operational costs by optimisation of consumption of compressed air and ventilation capacity
- a significant prolongation average lifetime of the filter material

It can be stated that the triboelectric dust measurement can be used for the monitoring of the observance of emission limit values as well as for process measurements (e.g. for operational filter monitoring). During recent years, these simple and robust measuring devices have superseded more and more the long-established optical measuring devices based on the principles of scattered light or extinction. Even dust deposits or crusts on the surface of an in-situ probe do not influence the triboelectric measuring result.

The application behind electrostatic precipitators - so far due to potentially disturbing influences only possible in a limited way - is subject of intensive research. First investigations in the laboratory of the Dr. Födisch Umweltmeßtechnik AG, however, showed that this measuring task can also be solved by means of an extractive sampling system.