Monitoring of Electrostatic Precipitators in Automatic Biomass Combustion Plants

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1 Introduction

Motivation: Since biomass combustion is related to PM in the ambient air, strict emission limits were introduced in the Swiss ordinance on air pollution control (OAPC) in 2007 with 20 mg/m^3 at 13 vol.-% O_2 for 500 kW to 1 MW nominal heat output. Since then, wood boilers larger than 500 kW are commonly equipped with electrostatic precipitators (ESP). Due to the varying heat demand, the boilers are often operated in on/off mode and with part load. Hence an optimum control is essential to avoid periods with high PM emissions due to inactive ESP.

Target: Monitor ESP availability with automatic boilers in practise:

1. To identify reasons for increased emissions, and to derive recommendations for control concepts.
2. To develop a monitoring concept enabling authorities to assess ESP operation and estimate PM emissions. As a pre-condition for acceptable cost, the concept shall be based on data from the programmable logic controller (PLC) without continuous particle measurement.

Approach: Seven heating plants with a nominal heat output between 450 kW and 3.5 MW were equipped with data acquisition to log PLC data from the boiler and the ESP. Data on load, temperatures, ventilators, lambda sensor, voltage and current of the ESP were collected during two heating periods with a frequency of 0.5 min^{-1} [1].

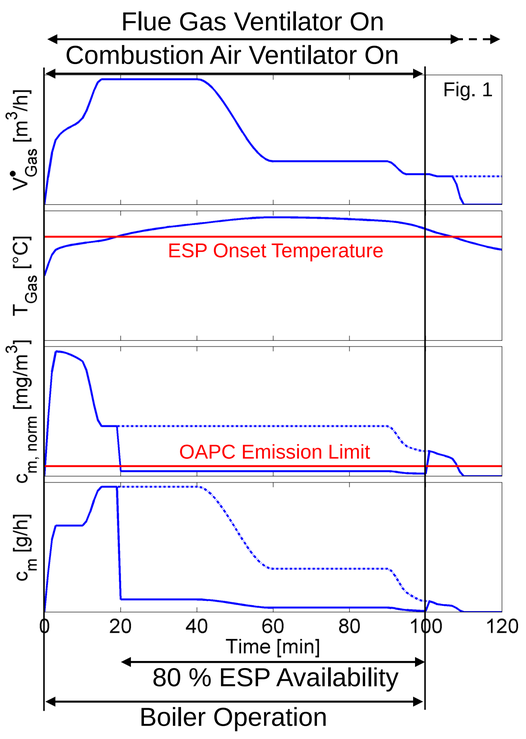
2 Monitoring Concept

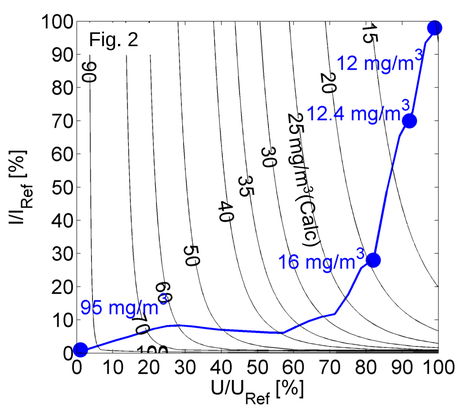
Definition of Boiler Operation: Fig. 1 shows an example for PM emissions at typical boiler and ESP operation in on/off mode.

In principle ESP have to be active as long as the boiler releases flue gas. Therefore a simple and universal definition for boiler operation is required to monitor ESP availability.

Today authorities request to use the combustion air ventilator to indicate active combustion. This definition covers at least 96% of the combustion time and the majority of PM emissions. Only emissions from boiler shutdown with inactive combustion air ventilator are not covered. But considering PM load, it can be seen that emissions from this phase without ESP operation are low, i.e. in the same order of magnitude as emissions during full load operation with active ESP.

However there is no universal alternative. In some control concepts the flue gas ventilator is permanently turned on and installed lambda-sensors are not always reliable.





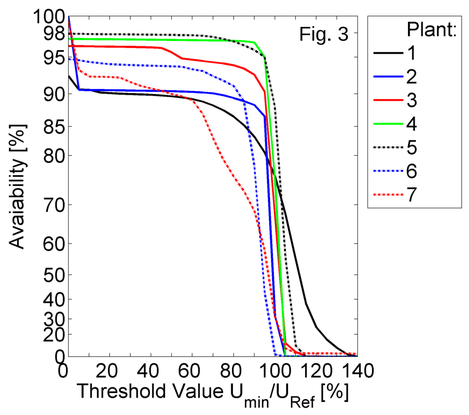
ESP Operating Points: Due to the lack of a reliable and affordable sensor to continuously measure PM emissions from biomass combustion, ESP operation has to be monitored depending on applied voltage and current.

Fig. 2 shows the current as a function of the voltage recorded in one ESP as blue line. Results of four gravimetric PM measurements are added as blue points from inactive ESP (U/U_{Ref} = 0%) to the operating point (U/U_{Ref} = 100%). Specific calculated isolines of PM emissions are added as black lines to show potential ESP behavior according to theory [2 & 3].

It can be seen that voltage and current have to be above a threshold value to effectively reduce PM and comply with OAPC emission limits.

ESP Threshold Values: Fig. 3 shows the ESP availability as a function of the voltage threshold value for the collected data of two heating periods. The voltage recorded during gravimetric measurement in full load operation is used as reference to normalise values.

Universal threshold values for voltage and current in the ESP to comply with OAPC emission limits can not be derived from calculations. Nevertheless the normal distribution of the operating voltage with a small deviation in normal operation allows to define threshold values which distinguish between active PM reduction and malfunction with a high certainty. For the presented results, threshold values of U/U_{Ref} = 60% and I/I_{Ref} = 30% are used.



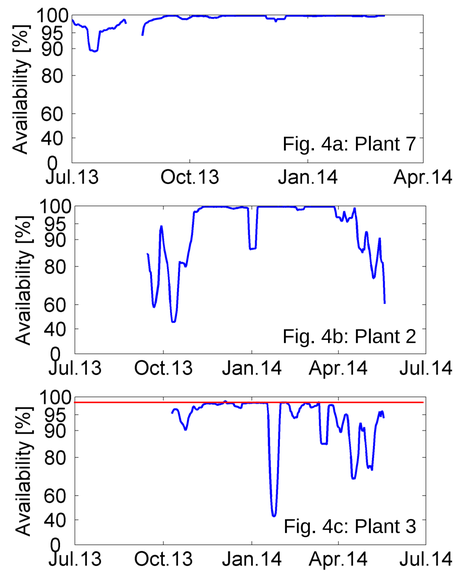
3 Seasonal Run of the Availability

The following figures show weekly averages of ESP availability during a heating period for three different plants. Three characteristic behaviours can be distinguished:

Fig. 4a shows that a high availability can be achieved, if the flue gas and ESP temperature are always above the ESP onset value.

Fig. 4b shows a seasonal dependency of the availability due to low flue gas temperature at reduced heat load. A boiler malfunction temporarily reduced the availability at the beginning of January.

Fig. 4c shows a general reduced availability of more than 1% due to time-delayed ESP operation plus a seasonal dependency of the availability. Additionally there was an ESP mal-function at the end of January with three days of unavailable ESP.



4 Resulting Availability

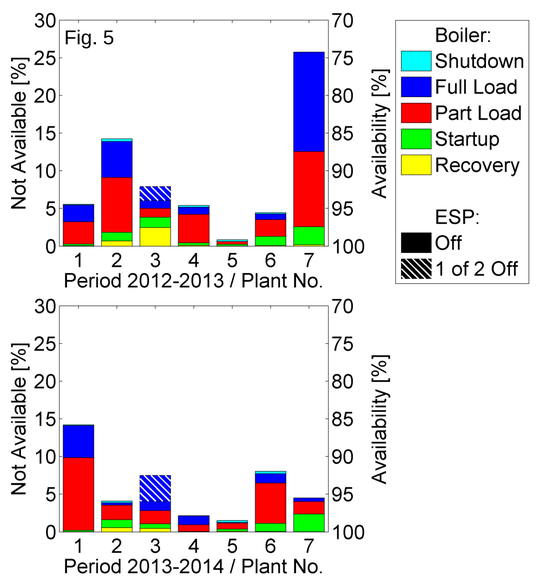


Fig. 5 allocates phases with unavailable ESP to boiler operating modes.

Only plant 5 experienced no malfunction during the two heating seasons. An availability of more than 98% is achieved.

On plant 1 and 7, no professional ESP maintenance was done for several years which first resulted in temporarily and finally in permanent interelectrode short circuit . On both plants the repair took several weeks.

On plant 2, an ESP false alarm occurred in almost every on/off phase which had to be reset manually. A software update at the end of the first season solved this.

On plant 3 and 6, ESP have long time delays to start which reduces availability depending on heat load especially on plant 3.

On plant 4, the temperature sensor in ESP produced a random error during the first period which restarted ESP with time delay.

5 Conclusions

ESP monitoring is crucial to ensure a high availability in practise. The investigation confirms that a monitoring concept based on availability derived from PLC data is a valuable tool to complement the periodical on-site inspection. Undesired operation and malfunctions of the ESP can be detected thus avoiding increased PM emissions of automatic biomass combustion plants in practise.

Monitoring Concept:

- A universal definition for boiler operation is necessary. Today's definition according to combustion air ventilator covers the majority of PM emissions.
- Improved definitions by use of flue gas ventilator are possible; however they need additional information (lambda or time delay) and are significantly more demanding.
- ESP operation must be defined according to universal threshold values for voltage and current as a percentage of reference values.
- Voltage and current recorded during acceptance control from authorities can be used as individual reference values.
- Improved availability should be initiated by manufacturers. The monitoring concept should require high availability but without disabling new control approaches.

Availability:

- Malfunction is found to be the major reason for reduced ESP availability.
- One day per year without ESP operation can reduce availability up to 1%.
- Regular ESP maintenance and prompt repair should be standard.
- High ESP availability can be achieved if the operating temperature of the ESP is safely maintained or rapidly achieved after startup. Thermal insulation between boiler and ESP is important.
- Time-delayed ESP operation can significantly reduce availability in on/off mode and should be avoided.

This is an ongoing project, final results and recommendations for implementation in coordination with the industry are presented September 2014.

Literature:
[1] Lauber, A.; Nussbaumer, T.; Good, J.; Jenni, A.: *Praxiseinsatz und Überwachung von automatischen Holzfeuerungen mit Elektroabscheider*, Bundesamt für Energie, Zürich und Bern 21.11.2013, 51 Seiten
[2] White, H.J.: Industrial Electrostatic Precipitation, Pergamon, Oxford 1963
[3] Hinds, W.C.: Aerosol Technology, Wiley, New York 1999

Acknowledgements
Swiss Federal Office of Energy (BFE)
Federal Office for the Environment (BAFU)
APF GmbH
BETH Filter GmbH
Meisterfilter AG
Scheuch GmbH
Mawera Holzfeuerungsanlagen GmbH
Müller Holzfeuerungen AG
Schmid energy solutions AG