Pulse Generators and High-Voltage Units with Automatic Controllers for Electrostatic Precipitators

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Abstract

The electrostatic precipitator is known to the cement industry as the preferred dedusting equipment for the main dust emission sources.

To understand the function better, a short description of the theory of precipitation is presented, with the factors influencing the performance.

The function of the precipitator is dependent on the high-voltage supply. The power input to the transformer is controlled by a microprocessor unit, which gives a very fast and accurate response to changing operating conditions. The controller unit is capable of automatic selection of intermittent energisation or DC-energisation, whichever gives the optimal performance, only on the information from the secondary voltage in the system. Furthermore, the total power input to the precipitator can be controlled by a continuous emission monitor.

Another approach to improving the efficiency of a precipitator is a pulse generator, where ultrashort (microsecond) pulses are applied to achieve a more efficient precipitation of especially high resistivity dust particles. By applying pulse generators, existing units can be improved without physical enlargement, or new units can be installed with smaller dimensions than units with traditional power supplies.

Basic Theory

The electrostatic precipitator consists of a casing, containing two electrode systems.

The collecting plates, forming ducts for the gases to pass, are connected to earth. The discharge electrodes, which are placed in the middle of the ducts, are connected to the negative pole of a high-voltage transformer/rectifier set.

The efficiency of a precipitator can be described by the Deutsch Formula as follows:

$$\eta = 1 - e - \frac{A}{Q} w,$$

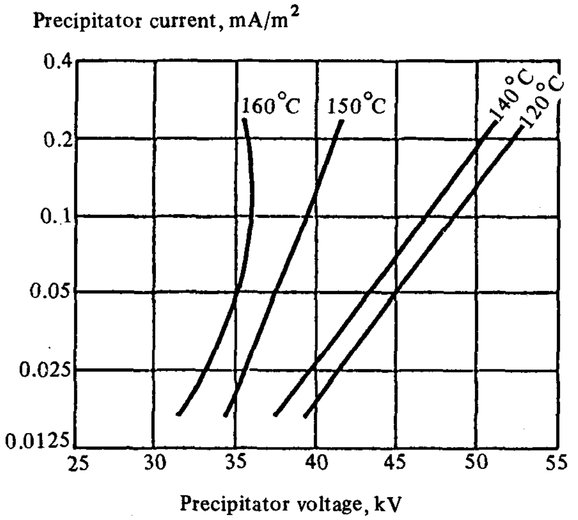
where η is the precipitation efficiency, A is the collecting plate area, Q is the gas flow, and w is a "velocity of precipitation" which depends on the application, and is known as the migration velocity.

It can be shown that this velocity is proportional to the particle diameter D, the peak value Ep, and the mean value Ea of the electrical field strength, as follows:

$$w = k \times Ep \times Ea \times D$$

From this it can be seen that for a given process, an increase in the voltage level will result in a better precipitator efficiency.

The voltage level which can be obtained in a precipitator is limited by the electrode geometry, and the physical conditions of the process gas and dust to be treated. The most important properties are gas temperature and moisture, and dust amount, grain size, and resistivity. For a given condition, the relation between precipitator voltage and precipitator current is shown in the curves.

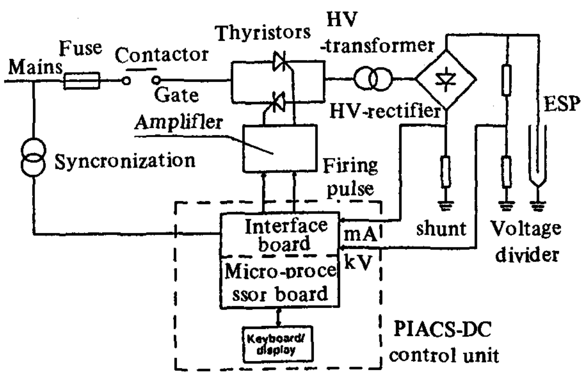


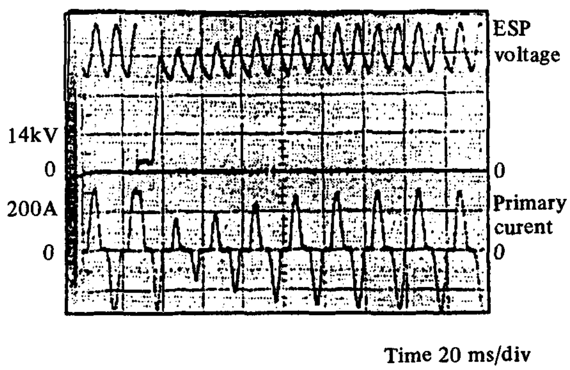
Control of DC-Power Supply

The voltage level in the precipitator is determined by regulating the incoming mains. Two thyristors are blocking a smaller or bigger part of the sine wave, thus regulating the current input to the high-voltage transformer/rectifier, which in turn gives the voltage level. The secondary voltage and current levels are measured and used as input for the microprocessor, which controls the power thyristors.

The task for the microprocessor is to keep the voltage level as high as possible, in order to achieve the biggest migration velocity. Since the voltage level in some cases increases with the current to the upper limit of the latter, or flash-overs can occur at many operating voltage levels, this is not a straightforward job.

The control of the voltage level by the FLS miljø PIACS (Precipitator Integrated Automatic Control System) is shown as oscilloscope pictures. The lower curve shows the primary current, where only part of the sine wave is utilized to the power supply. The upper curve shows the resulting secondary voltage level. When a flash-over occurs, this can be seen as a drop in voltage level, and as an increase in the current of an irregular shape. It can be seen that the microprocessor is capable of restoring the voltage in the precipitator already in the first half-period after the flash-over, that is within 10 milliseconds. This is by far superior to other microprocessor controllers, or analogue controllers of the former generation, where the restoration





time could be several hundred milliseconds. Since periods with voltage levels below the obtainable corresponds to reduced precipitator efficiency, the speed of regulation is important to the overall function.

The PIACS is capable of finding and maintaining the voltage level at its maximum for the actual operation. This is done by utilizing the measurement of the through voltage (minimum voltage), which will give a clearer indication than the average or peak value. An indication of a optimum voltage level, determined by the so-called back-corona phenomenon, is also used for adjustment of another important feature, the Intermittent Energisation.

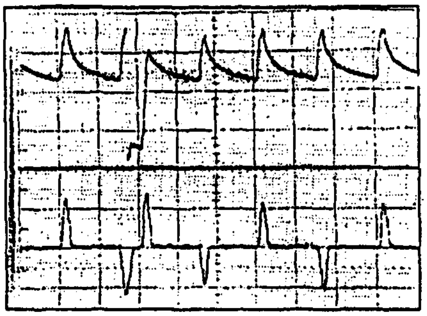
As explained before the migration velocity is dependent on both the peak voltage Ep, and the average voltage Ea. The peak voltage can physically be explained to take care of the charging of the particles, while the average voltage creates the field transporting the charged particles out of the gas stream. For dust with a so-called high resistivity, the current related to the charging peak voltage is the limiting factor, while precipitation of low resistivity dust is determined by the transporting field.

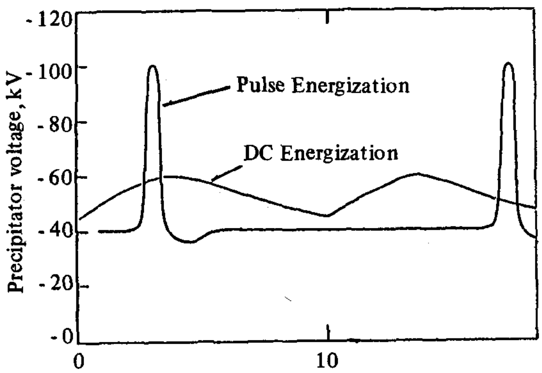
If the thyristors controlling the mains are blocked for say 2 half-periods out of three, the resulting secondary voltage will show a more irregular shape with a higher peak value, but a lower average value. For high resistivity dust this way of energisation will result in a better efficiency for the same or even lower power input, while no efficiency benefits can be found with low resistivity dust by intermittent energisation.

By following the through secondary voltage, the PIACS controller is capable of automatically selecting the number of half-periods to be left out of the power supply, that will give the highest precipitator efficiency.

Pulse Energisation

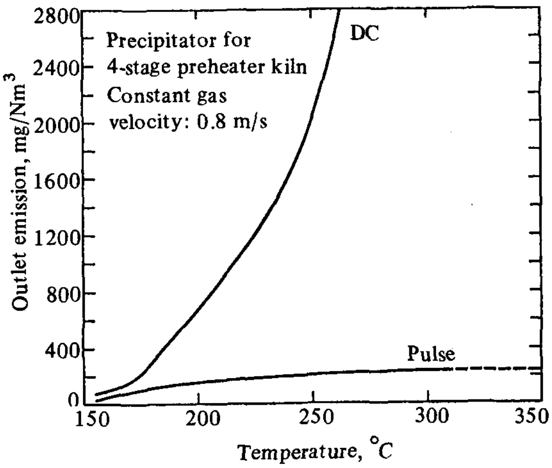
The description so far has been of the control of power supply with energisation based on the cycle of the incoming mains, 50 or 60 Hz, corresponding to a 10 - 8 millisecond cycle time. The travelling time for the charge from the discharge system to the collecting system is approx. 1 ~ 2 milliseconds, or a decade smaller than the power supply cycle time. With the FLS COROMAX pulse system, pulse of a duration of 0.1 millisecond are superimposed on a basis voltage, so that the total peak voltage level can reach approx. 115 kV, where the peak voltage level in normal DC operation is approx. 60 kV. The biggest part of the pulse charge is regained from the precipitator and stored externally, before it is reused in the next pulse.





As the pulse duration is a decade smaller than the charge travel time, it is possible to achieve the high voltage level without a flash-over.

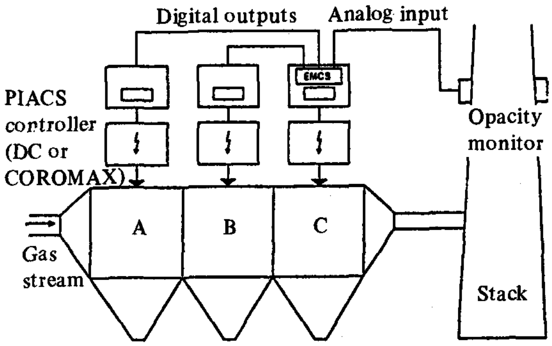
Since the peak voltage is increased significantly, the precipitator efficiency for high resistivity dust can be improved to a very big extent. This is shown for a 4-stage preheater kiln, which was equipped with conditioning tower followed by a 2-chamber precipitator, where the normal DC high-voltage units on one chamber were exchanged for pulse units. By turning down the water injection in the conditioning tower, emission levels were measured simultaneously for the two chambers.



As it can be seen from the operation at lower temperature, the difference in performance at the easier conditions is pretty small. The advantages of the pulse units are to be found at difficult operating conditions. Since the pulse generators have a substantially bigger cost than the DC high-voltage units, the most economic applications are in new installations for difficult precipitation conditions, or as improvement of existing installations, where the alternative would be an extension of the present precipitator. This would normally turn out very costly in installation and downtime.

Power Control From External Input

The FLS PIACS-DC and PIACS-COROMAX are both equipped with a possibility for overall power input control, by utilisation of a signal from an opacimeter. If the opacimeter measurement in the stack indicates an emission smaller than the target value, it is possible to reduce the power input to the high-tension units. In this way only the power needed to achieve the desired value is consumed in the precipitator.



Conclusion

With the development of advanced control strategies for the power input to precipitator high-voltage units, and application of the fast microprocessor technology to implement the strategy, it is now possible to obtain a better and less power consuming operation of a precipitator with conventional DC high-voltage units.

The pulse technology has further extended the application field for precipitators, and pulse generators are an interesting alternative to conventional energisation at retrofit or demanding new applications.