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The Study of Plate-Type Electrostatic Precipitators Electrical Supplies

Stricter environmental legislation in many countries is producing standards governing the emission of fine particles to the atmosphere from all sources. The industrial separating particles from process streams have numerous methods with different principles. In electrostatic precipitators is used electrical charge of dust particles.There are many aspects of pollution control in both solid and liquid phase using electrostatic precipitators.The operation of plate-type electrostatic precipitators is closely related to its electrical energization, to obtain high collection efficiency with low electrical energization consumption. The paper analyze the traditional direct current energization, the intermittent energization, the pulse energization and the switched mode at high frequency power supplies of plate-type electrostatic precipitators sections.

1. Introduction

To separating dust particles from process there are some methods with different principles: gravity separation, inertial separation with cyclones, impaction in mechanical filtration, electrostatic charge particles applied in electrostatic precipitators (tube type and plate type), contacting and impaction in the case of wet scrubbers.

Some methods can be very efficient in collecting the large dust particles, greater than 10μm, but the legislative emission levels for dust particles with 1 μm or less is now essential for a large number of processes. For large process gas streams (50 m^3/s upwards) is used plate-type electrostatic precipitators. This is the case of thermal power station. The plate-type electrostatic precipitators may be collect dust particles between 1000μm-0.01μm and with dust resistivity between 10^6 Ω·cm-10^{14} Ω·cm. Large plate-type electrostatic precipitators have from 2 to several sections, each of them are supply separately from a power supply [1,4].

2. Traditional DC energization

To control the Corona power, the line voltage is regulated by a thyristor controller (through phase control) before it is applied to the primary of the high voltage transformer. The high voltage transformer have some turns ratio n to desired high voltage, to obtaion Corona effect and than rectified by a high voltage silicon bridge rectifier. This voltage (ussualy up to 60kV) is applied to a precipitator section without additional filtering.

The high voltage is connected that the discharge electrodes have negative polarity and the plate electrodes are connected to the ground. The inductor L_1 is included to limit the current during sparking or short-circuit in section. The firing angle of the thyristors is determined by a control unit with microprocessor or microcontroller for every half-cycle of the voltage line. R_2-L_2 is a low-pass filter and it is used to filter the current with the frequency bigger then 50 Hz. R_{a1}, R_{a2} are damper resistances of high voltage cables [2].

The follwing quantities are normally indicated:

- precipitator mean current (I_{0nom});
- precipitator peak voltage without load (U_{0nom});
- primary r.m.s. current (I_{pnom});
- line voltage (U_{lnom});
- frequency (f);
- apparent input power (S).

An important quantity is the form factor k_f of the precipitator current:

$$k_f = \frac{I_{0\,rms}}{I_{0\,mean}} \quad (1)$$

$$I_{0\,rms} = \sqrt{\frac{1}{T}\int_0^T i_0^2(t)\,dt} \quad (2)$$

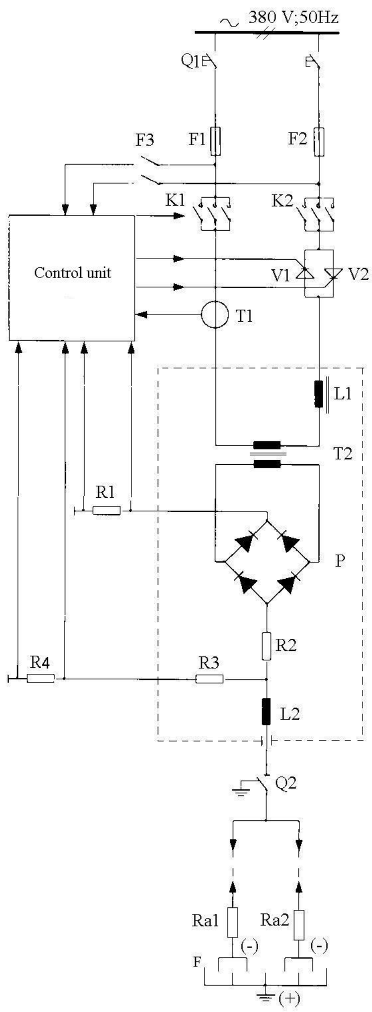
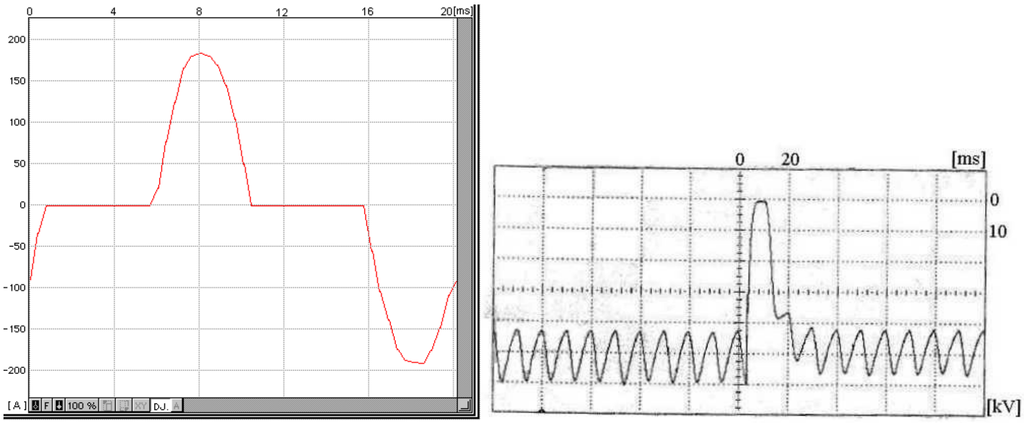


Figure1. Electrical power supply for a section.

$$I_{0\,mean} = \frac{1}{T}\int_{0}^{T}\left|i_{0}(t)\right|dt \tag{3}$$



a. b.

Figure 2. Primary current (a) and secondary voltage (b) for an electrostatic precipitator section.

The nominal current can be expressed by:

$$I_{pnom} = n \cdot k_f \cdot I_{0nom} \quad (4)$$

The apparent input power is given by:

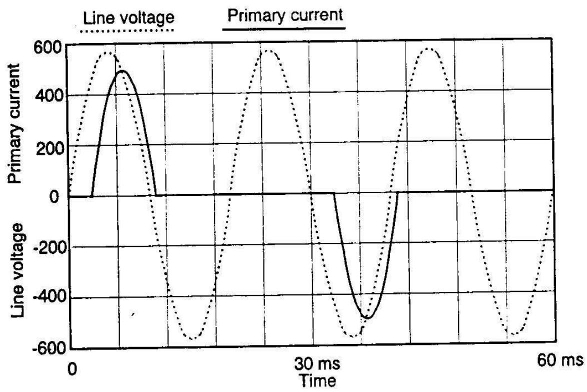
$$S = I_{pnom} \cdot U_{lnom} \quad (5)$$

The power factor is normaly better than 0.8, when k_f is approximayely 1.4.

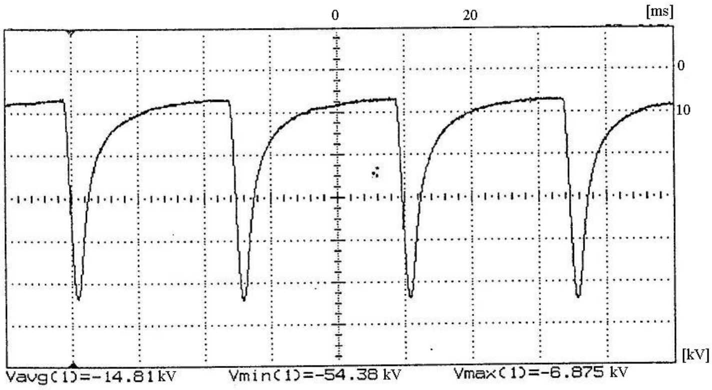
The section energization is used in the last three decades for normal dust resistivity between 10^6 Ω·cm-10^9 Ω·cm.

3. Intermitent energization

To obtain this energization is used the same electrical equipment used in traditional energization (fig.1). The difference is the automatic voltage equipment that suppresion a number of half-cycles of the primary current delivered to the high voltage transformer. Suppresion is obtained by not firing the thyristors in the respective half cycles. This suppresion of current pulses is called degree of intermitance D. In fig.3.a are presented the primary voltage and current waveforms and in fig.3.b the precipitation voltage in intermitent energization with D=3 [1,4].



a.



b.

Figure 3. Primary current (a) and secondary voltage (b) at intermitent energization

The firing angle corresponds to 3ms (54^0) after the zero crossing of the line voltage.

The mean current in intermitent energization I_{IE} is:

$$I_{IE} = K \frac{I_{DC}}{D} \qquad (6)$$

where k is a factor between 1-1.5 and I_{DC} is the current in traditional energization.

There are same difference between intermitent and traditional energization:
- the peak voltage value of the precipitator is higher;
- the minimum voltage value of the precipitator is lower;
- due the suppresion of current pulses, the mean and rms values of the precipitator current are reduced;
- the mean voltage value and Corona power delivered to precipitator are lower;

- the power consumption of the precipitator is reduced.

The collecting efficiency depends by migration velocities of dust particles. A practical way is to compare the migration velocity in traditional energization w_{DC} and the migration velocity in intermitent energization w_{IE}:

$$H = \frac{w_{IE}}{w_{DC}} \tag{7}$$

where H is enhancement factor. If H>1 than the collection efficiency is better in intermitent energization then in traditional DC energization, for the same dust.

The intermitent energization is used in the last 25 years for medium dust resistivity between 10^9 Ω·cm-10^{11} Ω·cm.

4. Pulse energization

Consists of short duration high voltage pulses superimposed on a continous voltage. The pulse of high voltage is between 1μs-100μs and the pulses frequency is between 1Hz-400Hz. It is obtain approximately 100kV.

In fig.4 is presented the voltage waveform obtained with pulse enegization and traditional DC energization for a precipitator [1,4].

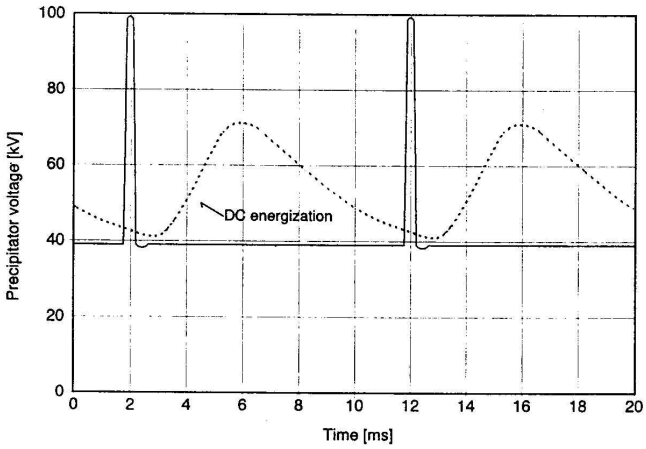


Figure 4. Voltage waveform obtained with pulse energization in comparision with DC energization

In principle there are two main circuits to supply the precipitator sections; one based on switching at low potential (fig.5) and one based on switching at high potential (fig.6).

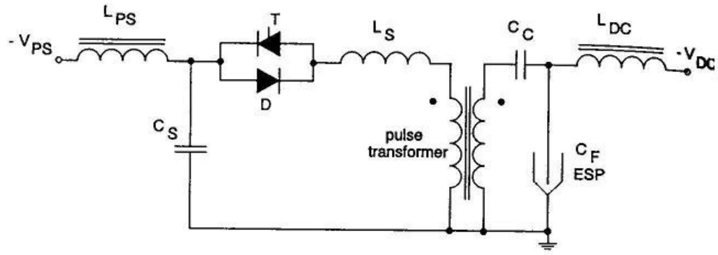


Figure 5. Circuit based on switching at low potential

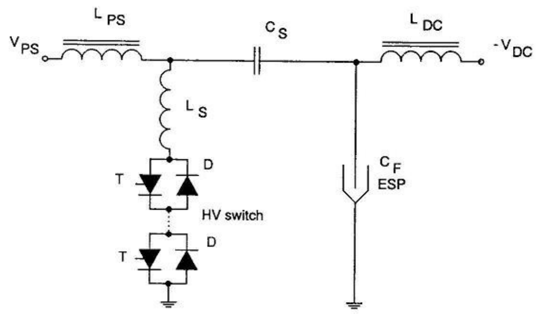


Figure 6. Circuit based on switching at high potential

In comparision with DC energization, the pulse energization are different:
- the high voltage pulses have a high amplitude;
- the continous voltage is kept close to obtain the Corona power.

The pulse current can be compute with:

$$i_p(t) = I_p \cdot sin(\omega_0 \cdot t) \tag{8}$$

where I_p is the peak current value and ω_0 is angular frequency of the oscillation.

The pulse precipitator voltage is:

$$u_p(t) = \frac{1}{C_F}\int i_p(t)dt \tag{9}$$

The enhancement factor H is:

$$H = \frac{w_{PE}}{w_{DC}} \tag{10}$$

where w_{PE} is the migration velocity in intermitent energization. If H>1 than the collection efficiency is better in pulse energization then in traditional DC energization, for the same dust.

The pulse energization is used in the last 15 years for high dust resistivity between 10^{11} Ω·cm-10^{13} Ω·cm.

5. High frequency power supplies

In the last two decades, the development of fast electronic switching devices (fast-thyristors, IGBT and so on) have cause the development of power supplies of precipitators. The main circuit of a.c.-d.c. convertor for a precipitator section is presented in fig.7 [1,3].

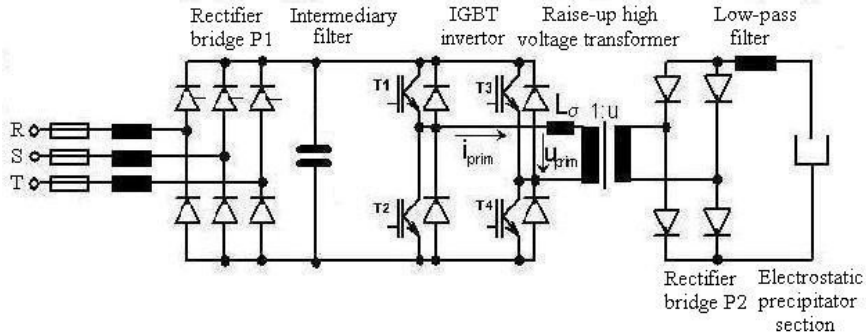


Figure.7. A.c.-d.c. convertor for a precipitator section

The circuit from fig.7 has the main components: the primary three-phase rectifier bridge P_1 without control; the c.c. intermediary filter to slow down the voltage ripples that is an electrolytic capacitor with small disipation; the primary invertor, with different configuration and components, with switching frequency in the range from kHz up to 50 kHz; the raise-up single phase transformer at high voltage and frequency (380V/65kV) for the precipitator section; is made from ferrite toroidal core for minimize disipation; the secondary high voltage and frequency rectifier bridge P_2 that is used to obtain the continuous voltage in precipitator section; the low-pass filter to reduce the current harmonics that appears from electrical and Corona discharges; is made from R-L components. The problems of interrupting power supply (arc and restablishing current of the precipitator) are reduced by operation at high frequency (approximatevly 10 kHz). The recovery time, to recharge the precipitator can be more controlled with the smaller time steps increments. In fig.8 are presented the precipitator voltage in traditional DC energization and with high frequency power supplies, for the same precipitator current. The enhancement factor H is:

$$H = \frac{w_{HF}}{w_{DC}} \qquad (11)$$

where w_{HF} is the migration velocity when is used high frequency power supplies.If H>1 than the collection efficiency is better when is use high frequency power supplies, then in traditional DC energization, for the same dust.

High frequency power supplies are used experimentally in the last years for normal and medium dust resistivity.

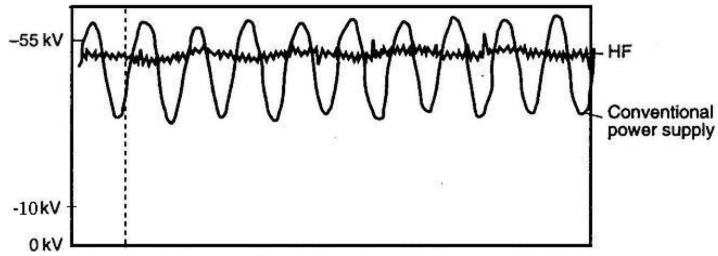


Figure 8. Precipitator voltage, conventional and HF power supply, at same current

6. Conclusions

The plate-type electrostatic precipitators are used to clean large gas streams of dust particles from different industries. An important application is in thermal power station. The power supplies of electrostatic precipitators sections is one of the most important factor that cause a high collection efficiency of dust particles. The paper presents four methods that may be use to supply the precipitator sections depending by dust resistivity. To compare this supplies methods, the best way is to compare the migration velocities in each case with DC energization.Acknowledgements: This work was suported by CNCSIS Grant AT no.27688/2005.

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