Emission reduction with three phase technology

J. von Stackelberg

Rico-Werk Eiserlo & Emmrich GmbH, Tempelsweg 12 - 14, 47918 Tönisvorst, Germany
Corresponding author: *j.vonstackelberg@rico-werk.com*

Abstract Worldwide the environmental laws and directives require lower and lower limit values for the emission of particles carried by waste gas, e.g. by power plants. The electrostatic precipitators of existing power plants have been constructed years ago to meet certain dust emission limits. Due to the reduction of the limit values that dedusting systems are no longer operating sufficient with reference to the new requirements.

The construction of the electrostatic precipitators was based on certain capabilities of the high voltage system which were standard in the time of the construction. With a new, improved high voltage power supply system it is possible to improve the precipitation rate of an electrostatic precipitator and meet the new, more strictly dust emission limit values. Compared with the investment costs for new fields in the electrostatic precipitator or even replacement of the ESP by baghouse filter or hybrid solutions, the investment for a new high voltage supply system is small. Hence the upgrade of an electrostatic precipitator with sufficient three phase technology to improve the dedusting behavior to a satisfying limit is a sensible measure to be processed.

Besides the improvement of the dedusting behavior of the electrostatic precipitator, even the EMC emission rate could be reduced by changing from single phase to three phase technology.

Keywords: Electrostatic Precipitator Upgrade, Gas Cleaning Improvement, EMC Reduction

1. Three Phase Technology

Three phase high voltage supply systems have some distinguishing attributes to other high voltage supplies which makes them an especially preferent high voltage source to be used for electrostatic precipitator upgrade projects:

– The output voltage has a very low ripple due to the overlapping sinus half waves of the three phases of the grid voltage. Thus the time voltage area with active precipitation is enhanced by at least 50%, depending on the thyristor ignition angle (Fig. 1).

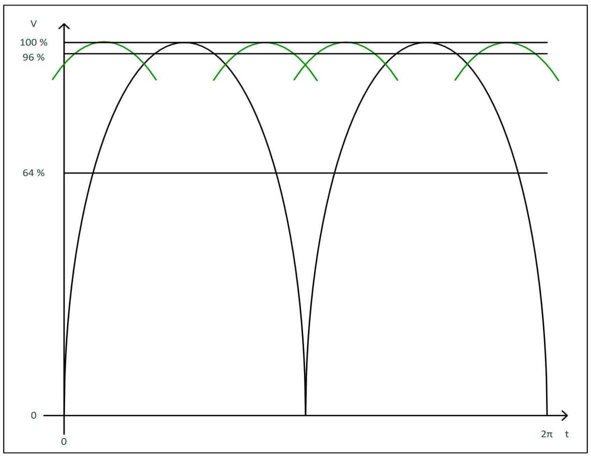

Figure 1. Rectified sine waves from a single phase system (black) and a three phase system (addition of green sine peaks) and their arithmetic mean values; as the single phase sine has an arithmetic mean value of 64% and the three phase system 96%, the difference is 50%; when the sine waves are cut by a thyristor, the difference becomes even higher

– The dynamic of the output voltage with remaining high quality, i.e. low ripple, spans from 22 to 100% of the nominal output voltage for the whole power band (Fig. 2, 3).

– The output power is not limited by switching semiconductor components, hence also electrostatic precipitator with large precipitation areas can be equipped sufficiently as the demand for the current can be met.

– Three phase high voltage power supplies can be used in the semi pulse mode to cope with high resistive dust conditions or reduce input power (Fig. 4).

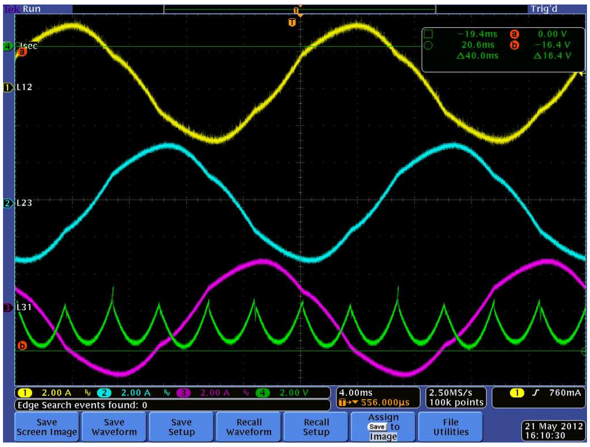

Figure 2. Input current and output voltage shapes of a three phase direct current high voltage supply; the yellow, blue and red lines are the input currents, the green line is the output voltage with 100% of nominal value

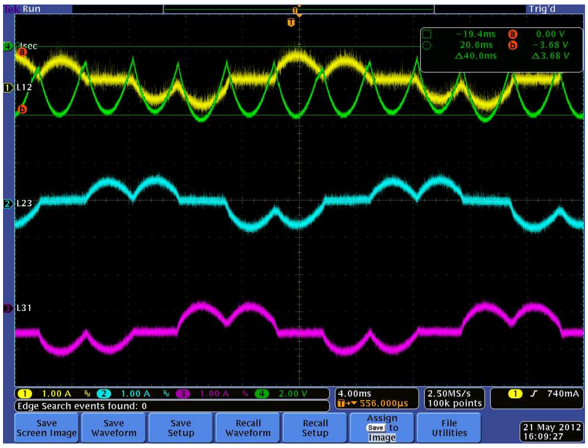

Figure 3. Input current and output voltage shapes of a three phase direct current high voltage supply; in this oscillograph the output voltage is 22% of the nominal output value; the voltage shape is similar to figure 2 with reference to the ripple

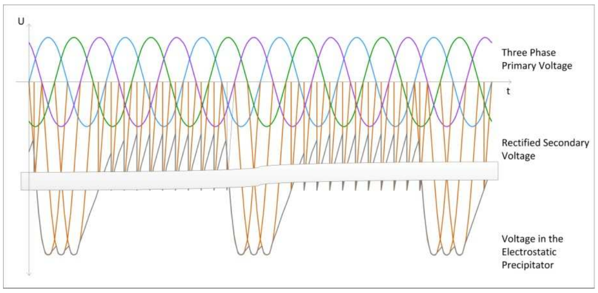

Figure 4. Three phase high voltage direct current supply in pulse mode operation; the input sine waves (red, green, blue) are intermittently cut by a thyristor to reduce the output voltage (rectified waves: brown; envelope: grey) between the pulses

2. Step by Step Upgrade of Power Plant Wedel

The cogeneration plant Wedel was formerly built in 1961 ... 1965 for the supply of electric power to Hamburg [1]. It consisted of four power generation blocks with 600 MW in total. In 1988/1989 two blocks were modified for the combined heat and power supply. At the same time a desulfuration system was added. In 1990 to 1993 a general overhaul was processed to make the power plant fit for the next 30 years of operation.

The power plant is mostly fed with hard coal and was equipped with electrostatic precipitators with two fields and single phase high voltage direct current supplies. The dust density in the output channel was about 10 mg/Nm^3.

Due to new requirements for the emission of dust in the environment it was necessary to put some reserves to the output dust density values. It was decided to make a previous test before the investment and install a three phase high voltage direct current supply system on the last field. This modification reduced the outlet dust density to 8 mg/Nm^3.

In another step the other field of the electrostatic precipitator was also upgraded. The single phase technology was removed and three phase high voltage direct current supply systems were installed. The result was an outlet dust density of 6 mg/Nm^3.

3. Partly Upgrade of Matou Power Plant (China)

Matou power plant is located close to Handan in the province Hebei. Actually there are four blocks in operation: block 7 ... block 10. The power plant uses hard coal.

The electrostatic precipitator which had to be upgraded is dedusting the waste gas of block 10. The generator power is 300 MW. The electrostatic precipitator consists of four chambers with 5 fields each. The last three fields of each chamber are equipped with micro pulse systems, the first two fields were equipped with single phase systems. The outlet dust density behind the electrostatic precipitator with this configuration was 20,4 mg/Nm^3.

The refurbishment activities included the dismounting of the transformer rectifier sets, the removing of the old cubicles, the adaptation of the oil troughs for the bigger tanks, the mounting, installation and wire connection of the three phase transformer rectifier sets, the mounting, installation and wire connection of the new cubicles. Most of the existing cabling could be used, hence the effort to pull new cables was low.

The high voltage controllers were connected to the master control system by Profibus communication. After the electrical start up of the three phase high voltage direct current supplies they were switched to the pulsing mode with a pulse rate of “4”.

The third party measurement, performed by NCEPRI Electric Power Research, proofed the improvement of the electrostatic precipitator efficiency, now with an outlet dust density behind the ESP of 14,2 mg/Nm^3.

4. Upgrade of Lignite Conditioning Plant Bergheim

The lignite conditioning plant in Bergheim in Germany improves the lignite from the nearby opencast lignite pits for further processes. Therefore the plant needs process heat and steam which is produced by a furnace. The electrostatic precipitator for the dedusting of the waste gas is a two field construction which was formerly equipped with two single phase high voltage direct current power supplies. The outlet dust density was in principle satisfying with about 10 mg/Nm^3, but the high voltage systems were operating at their limits, the spark over rates were quite low and there are discussions about purchasing different kinds of coal, hence it was decided to upgrade the electrostatic precipitator by replacing the high voltage supplies.

A special item for this upgrade project was the requirement, that the amount of harmonic waves caused by the high voltage supplies for the electrostatic precipitator must not exceed the condition with the single phase systems. Hence there had to be made one harmonic measurement before the replacement of the high voltage systems and one after the replacement.

The replacement in total consisted of replacing the cubicles with the power control units, partly replacing the cabling and replacing the transformer rectifier sets.

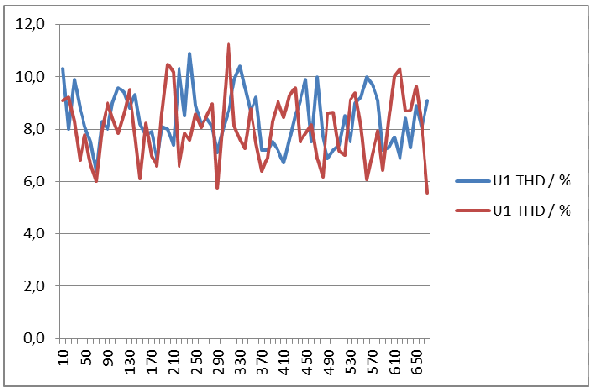

Figure 5. Diagraph of the voltage THD in% before (blue line) and after (red line) the replacement of single phase high voltage systems and three phase high voltage systems; the average value before the replacement is 8,4%, after the replacement it is 8,1%

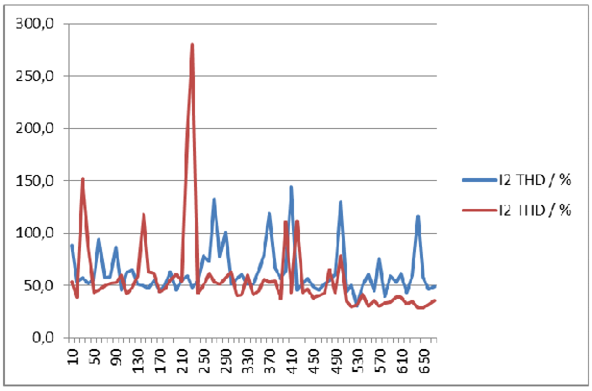

Figure 6. Diagraph of the current THD in% before (blue line) and after (red line) the replacement of single phase high voltage systems and three phase high voltage systems in the first ESP field; the average value before the replacement is 63,1%, after the replacement it is 57%

The measurement of the total harmonic distortion (THD) was performed for the voltages and for the currents.

The voltage THD is caused by the supply grid, i.e. all loads cause with their current THDs a certain dynamic in the voltage in the grid due to the voltage loss at the internal resistance of the grid, regarded as a voltage source.

The current THD is caused by the load which is regarded with the measurement. A high ratio value for the current THD does not always mean a major influence to the voltage THD of the grid when the current is small at the same time. This phenomenon of having a high current THD ratio with small influence occurs every time when the thyristor is operated with a small ignition angle as the harmonic waves are dominant but the current is still small.

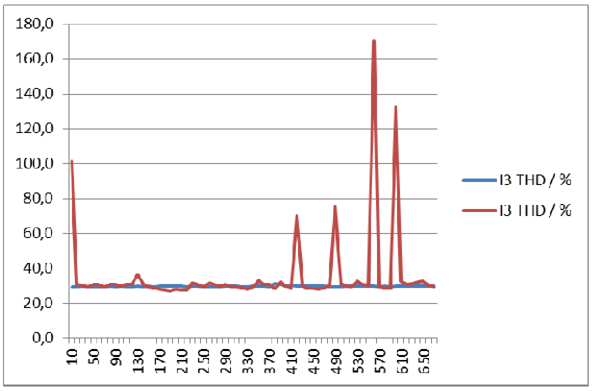

Figure 7. Diagraph of the current THD in% before (blue line) and after (red line) the replacement of single phase high voltage systems and three phase high voltage systems in the second ESP field; the average value before the replacement is 29,8%, after the replacement it is 36,1%

A comparison of the voltage THDs before and after the replacement shows that the voltage THD becomes slightly smaller (Fig. 5).

Looking at the current THD of the first field it can be seen that the current THD of the first field also becomes slightly smaller (Fig. 6).

At the second field the current THD becomes higher due to the amount of spark overs in the second field which occur now; with the single phase systems there do not occur spark overs which is an indication for too small high voltage systems (Fig. 7).

A comparison of the input power shows, that the input power into the ESP has increased significantly from 83 to 197 kVA. At the same time the outlet dust rate could be reduced from 10 to 7 mg/Nm^3.

5. Conclusion

Pulsing three phase high voltage direct current supply systems for electrostatic precipitators have in nearly all applications the potential to drive the ESP efficiency higher than single phase systems. Hence for the upgrade of an electrostatic precipitator for relatively small investment costs the pulsing three phase high voltage direct current supplies can be a reasonable choice.

A more surprising result of improvement at an electrostatic precipitator by using the pulsing three phase system however is the reduction of the THD ratio, despite an increasing of power input.

References

[1] www.wikipedia.org, “Heizkraftwerk Wedel”, date of latest update: Nov. 1st 2015