Upgrade of Chinese power plants with pulsing three phase systems

J. von Stackelberg

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

Keywords: Electrostatic Precipitator Upgrade, Pulsing Three Phase System

World wide emission requirements establish lower and lower limit values for the emission of dusts and other air polluting substances.

In China there are also set ambitious legal limits to reduce the dust emissions at the coal fired power plants. The legal limit for the dust density at the outlet of the electrostatic precipitator is 20 mg/Nm³. With this setting at the entrance of further waste gas treatment systems it should never be a problem to reach an outlet density at the chimney of 10 mg/Nm³, which is also a legal value. Certain power plants have different limit values for the outlet dust density at the electrostatic precipitator, due to their special conditions, e.g. further waste gas treatment equipment or especially difficult fuels.

One possibility to improve the situation at the electrostatic precipitators is, to equip them with a more efficient high voltage direct current power supply. This kind of upgrading an electrostatic precipitator has been performed successfully for different places already. Reports about the success stories have been published [1, 2, 3, 4].

There have also been several refurbishment projects in Chinese power plants with pulsing three phase current high voltage systems in the latest time which shall be introduced in this paper:
- Ma Tou Power Plant,
- Fa.er Power Plant,
- Jin Zhu Shan Power Plant,
- Lei Yang Power Plant.

The refurbishment projects were realized in that way, that the transformer rectifier sets were shipped from Germany. Also the controller technology was sent from Germany. The control cabinets were built in the workshop of our Chinese partner in Beijing, who did also all the dismounting, erection and cabling at the power plant sites.

The success stories described below were possible due to the trustful partnership to our partner and to the eagerness of the people to propel the projects forward to gain a positive result.

1 Pulsing Three Phase Systems

Three phase current power supplies, based on the grid frequency technology, combine the advantages from the robust, thyristor controlled grid technology, with the low ripple of the switched mode power supply technology [5, 6]. The construction time is moderate, therefore a three phase current power supply for an electrostatic precipitator can be adapted easily to the mechanical and electrical requirements for that special ESP the refurbishment is planned for.

Due to the construction of the transformer of the three phase current system, it is not a matter of course that they can be operated in the so called pulse mode. The pulse mode is a mode, in which not every sine (half) wave is switched through completely. There are always a certain numbers of half waves which are cut severely to reduce the output voltage significantly (figure 1).

Figure 1: Principle of the output signal of the three phase current system in pulse mode; between the fully switched through sine waves of the pulses (brown lines, long) there are a certain numbers of sine half waves which are cut to reduce the output voltage; the output voltage envelope (grey line) has the shape of a pulse voltage

If not taken care for every detail during the construction of the transformer, saturation effects can occur in the core of the transformer in the pulse mode which leads to damages in the power control parts or at least the fuses will trip.

Another constructional detail for the refurbishment of high voltage power supplies is the mechanical outline of the transformer rectifier sets. The location and the environment of the location are already fix, as there has already been placed a unit, the size of the oil trough is fix and defined by the footprint size of the unit having been installed, the position for the high voltage bushing also. To minimize the efforts for time and costs during the replacement activities, it is only sensible to take care for the footprint size and the high voltage bushing position and make it at the newly built units as they have been at the old ones. Therefore the new transformer rectifier set has to be constructed individually and tailor made. In certain cases it is
necessary to arrange the components inside the corrugated wall tank in a different way (figure 2, 3).

Figure 2: Outline of a three phase current high voltage supply in standard design; the tank is more long than high, the footprint of the unit does not comply with the footprint of a standard single phase high voltage system ...

Figure 3: ... while the upright standing version's footprint fits to the size and shape; the height of the high voltage bushing can also be adjusted to the high voltage connection at the electrostatic precipitator

The pulsing mode of the newly used high voltage power supplies can be necessary for two reasons:

- The resistance of the dust is particularly high and the high voltage power supply, operated in the standard mode, shows back corona effects; the low voltage level between the high voltage pulses gives the capacitance of the dust layer time to discharge [7].
- The connection power of the supply transformer for the electrostatic precipitator is too low for a full wave power connection of the high voltage systems, as the initial technology is too small in its dimension.

2 Ma Tou Power Plant

Ma Tou Power Plant is located in Ma Tou Town, close to Handan City in the Hebei Province of China. In total at the Ma Tou Power Plant there are ten units installed, from which units 1 ... 6 are out of order [8]. Unit 7 produces 220 MW (built in 1983), unit 8 200 MW (built in 1994), units 9 and 10 300 MW (built in 2010) each.

The dedusting system of boiler 10 consists of two electrostatic precipitators, which have 2 x 5 fields each. The precipitation area of each field is 2880 m², the wall distance is 400 mm. The fields in the rows 1 and 2 were equipped with single phase high voltage supplies from Zhejiang Feida, the specified values for the secondary no load voltage was 72 kV, the nominal current was 1200 mAar. As the load voltage of the high voltage systems is much lower than the specified no load voltage (about 60 % of the no load voltage), there is a maximum voltage of about 40 ... 45 kV to expect in full load operation.

With a wall distance of 400 mm there can be expected a load voltage of > 70 kV in the field, i.e. the new high voltage supplies have to provide more voltage. More voltage means also more current, therefore the specification for the replacement systems names 100 kV/1600 mA. The decision was made to replace the single phase current systems in the rows 1 and 2 (figure 4), as the micro pulse systems in the rows 3 to 5 were part of a former refurbishment project and could already improve the situation of the ESP.

Figure 4: Structure of one of two electrostatic precipitators; the single phase systems are replaced by pulsing three phase systems

The transformer rectifier sets for the new high voltage power supplies were constructed and produced in Germany and then shipped to China. The control cabinets were produced in Beijing. The high voltage regulation components were delivered from Germany, the standard equipment bought on the Chinese market.

The wiring between the cabinet room and the transformer rectifier sets was partly renewed according to the requirements for the new equipment; mostly the wires for the analogue measurement signals had to be renewed due to the necessary shielding.

Before the refurbishment project started, there was made a third party measurement of the outlet dust density behind the electrostatic precipitator with the result of 24 mg/Nm³.

The three phase high voltage power supplies are operated in pulse mode. The voltage in the
The electrostatic precipitator can be pushed up to > 70 kV. The third party measurement of the outlet dust density showed a result of 14.2 mg/Nm³.

3 Fa.er Power Plant

Located in a beautiful valley close to Faer town can be found Faer Power Plant, which is owned by the Datang Guizhou Power Co. Faer town is located in the Guizhou Province in China. The power plant operates 4 generators with 600 MW each [9]. The units went in service 2007 (unit 1), 2009 (units 2 and 3) and in 2010 (unit 4). The dedusting system for each boiler consists of two electrostatic precipitators with 2 x 5 fields each. The collecting area of one field is 4864 m².

As the fuel coal for Faer Power Plant is of multitude characteristics and therefore the load for the electrostatic precipitator might be too high for the legal limit of 20 mg/Nm³, there exists a permission to operate the ESP with 30 mg/Nm³ of dust density at the outlet.

The electrostatic precipitator of unit 1 is equipped with switched mode power supplies at the rows 1 and 2. The last three rows were equipped with single phase systems with nominal values of 72 kV and 1200 mA. Due to the large collecting area, the electric current flow was so high that the real voltage in the field was about 30 kV; this voltage is clearly too low for an efficient operation of the ESP. The manufacturer for the high voltage supplies was Zhejiang Jia Huan Electronics Co.

With a wall distance of 400 mm and a collecting area of 4864 m² the recommended size for the three phase current high voltage power supplies is 72 kV and 1200 mA. Despite the large current potential of the high voltage supplies, the main power supply for the electrostatic precipitator will be kept as it was, because the pulsing three phase systems shall be operated systematically in pulse mode.

In total there were replaced 10 units (figure 5). The selection of the fields for the replacement was due to economical regards.

Before the refurbishment, the outlet dust density at the electrostatic precipitator was 40 ... 80 mg/Nm³. After replacing the ten units and adjusting the pulsing three phase systems, the third party measurement showed a dust density of 21 mg/Nm³. As mentioned before, the limit value for Faer Power Plant is 30 mg/Nm³, hence the replacement project was successful.

4 Jin Zhu Shan Power Plant

Jin Zhu Shan power plant is located in Lengshuijiang City in Hunan Province in China [10]. It consists of 9 units in total, from which the units 1 ... 6 are retired. The units 7 ... 9 are in operation and provide an electrical power of 650 MW each. Units 7 and 8 have been switched on in 2006, unit 9 went in service in 2009.

The electrostatic precipitators for the boilers 7 and 8 have a sophisticated structure, as there have already been some attempts to reduce the outlet dust density (figure 6). As can be seen, the current capability of the SMPS systems was too low; therefore the fields of rows 2 and 3 were divided into three fields.

Figure 6: Layout of one of four electrostatic precipitators before the refurbishment project started; the layout of the other ESPs is equal; the different colours show the initial distribution of the rows; to gain more precipitation, the fields were divided in an earlier refurbishment project; the single phase systems had specific values of 72 kV and 1200 mA

The initial sizes of the fields were even different according table 2.

<table>
<thead>
<tr>
<th>m</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>3.8</td>
<td>3.8</td>
<td>5.7</td>
<td>5.7</td>
<td>3.8</td>
</tr>
<tr>
<td>Width</td>
<td>32.4</td>
<td>32.4</td>
<td>32.4</td>
<td>32.4</td>
<td>32.4</td>
</tr>
<tr>
<td>Height</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Wall distance</td>
<td>0.405</td>
<td>0.405</td>
<td>0.450</td>
<td>0.450</td>
<td>0.450</td>
</tr>
</tbody>
</table>

Table 2: Dimensions in meter of the fields of the electrostatic precipitator

After several discussions about how to get the most efficient result with the least necessary costs it was decided, to refurbish the electrostatic precipitators for the boilers 7 and 8. The new layout of the electrostatic precipitators is shown in figure 7. The weakest power supplies in any case were the single phase current systems, therefore they were replaced.

The tailor made pulsing three phase systems could be designed and constructed with the electrical
dimensions 110 kV/2100 mA, that it was no longer necessary to divide the fields in row 3.

Hence they were remounted to the initial layout condition. The rapping system on that electrostatic precipitator is realized with electromagnetic hammers which are mounted on the roof. Therefore the footprint of the single phase systems must not be overstepped; the three phase systems were built in the upright standing version.

On both dedusting systems for the boilers 7 and 8 the outlet dust density could be reduced from < 30 mg/Nm³ to < 20 mg/Nm³ which was the goal for the refurbishment project.

5 Lei Yang Power Plant

The last and the latest refurbishment project in the last two years was executed at Lei Yang Power Plant. Lei Yang power plant is located in Lei Yang City in Hunan Province in China [11]. The power plant consists of 4 units. The generators of 1 and 2 have a nominal power of 210 MW each and are in service since 1988, the units 3 and 4 have 300 MW each and are in service since 2004. The refurbishment was conducted at unit no. 3.

The high voltage power supplies of the rows 3 and 4 should be replaced, in total eight systems. The initial mounted systems were micro pulse systems with specified values of 100 kV and 1000 mA. As the collecting area of one field is 2185 m² and the wall distance is 450 mm, the recommended size for the high voltage power supplies is 110 kV and 1200 mA.

To reduce the mounting time for the refurbishment project, it was decided to construct the three phase current systems in a similar outline as the micro pulse systems which had to be replaced (figure 8). The main power supply for the electrostatic precipitator was kept, as the three phase current systems shall be operated in the pulse mode which reduces the power effort to a minimum. Before the refurbishment, the outlet dust density behind the electrostatic precipitator was about 50 mg/Nm³. Up till now the power plant is not yet in service again.

6 Conclusion

The high voltage power supply has become one of the key components for the electrostatic precipitator, due to the enhanced performance the semiconductor switches can provide. Therefore an electrostatic precipitator which was designed many years ago for a certain performance level, can be significantly upgraded by a relatively small investment, by replacing an existent high voltage supply by another type with better performance.

Figure 7: Layout of one of the 4 electrostatic precipitators with the newly mounted pulsing three phase systems

Figure 8: Outline of the transformer rectifier set, which is adjusted to the the micro pulse systems

The improvement of the performance of the high voltage power supplies is based on the one hand on the increasing of the voltage time area, i.e. the ripple is reduced. On the other hand the high voltage supply has to provide special functions, e.g. pulse mode, to optimize the functional level of the ESP. Further on the high voltage supply has to be able to provide enough voltage and current to the fields, and with regard to that requirement, it gets difficult to find a standard unit, may it be a three phase current system or an SMPS, in the market. Therefore in the refurbishment business it always pays, when a supplier is able by its standard processes, to construct a high voltage power supply according to the demands of the ESP, be it electrical or mechanical.

At all efforts to improve an electrostatic precipitator, it has to be clear, that an improvement on the electrical side has always to be accompanied by a proper condition of the mechanics.

References

[9] https://www.sourcewatch.org/index.php/Guizhou_Fa%27er_power_station