Challenges for Reduction in Emission in Old Electrostatic Precipitators at Lower Cost

Debasish Chakrabarti[1], Robert Pritchard[1], Martin Kirsten[2], Christer Mauritzson[2]
(1 Alstom Power Service, 16 Giffnock Avenue, North Ryde, NSW 1670, Australia
E-mail: debasish.chakrabarti@power.alstom.com
2 Alstom Power Service, Environmental Group. P.O. Box 1233, SE-351 Vaxjo, Sweden)

Abstract: Industrial plants are one of the major users of Electrostatic Precipitators (ESPs) for particulate emission control. These are primarily Cement, Metallurgy, Pulp & Paper and Aluminum industries. The paper generally speaks about the challenges that we face with the old Industrial Precipitators to cope with stringent emission norms in spite of Physical dimensional and plant layout Restrictions. The Precipitators in such Industrial applications are used not only for emission control but also to recover the dust either to recycle or to use as end product. In such conditions, ESPs really face challenges in front of Fabric Filters in spite of quite a few Operation and Maintenance advantages. Today's technology has advanced very fast, particularly in the area of High Frequency Power Supplies and really shows extremely promising results beginning usually at 30% emission reduction, but commonly much better than this - in spite of all the constraints. Present market scenario for such Industrial plants may sometimes not even allow a proper shut-down period to replace/rectify defective Mechanical components or to realign critical ESP internals or to carry out a reasonable Gas Distribution and sneakage Tests. For obvious reason, thrust is more and more towards Electronics and Controls to overcome problems in other areas as a substantial portion of the work can be carried out without a shutdown.

In this paper we discuss and compare the emission performance enhancement of two Industrial ESPs plants in Australia.

Keywords: ESP, electrostatic precipitator, emission, pollution, upgrade, control system, high voltage power supply, SIR, Transformer Rectifier, TR

1 INTRODUCTION

Industrial plants are one of the largest users of the Electrostatic Precipitators. Unlike Power Plants, the applications in Industrial plants vary widely depending on the Process conditions. Thus the Precipitator has to cope with parameter variations, such as extremes of temperature, moisture, particulate burden, Resistivity, the presence of volatiles etc.

An integrated cement plant may have e g:

- Cement Kiln ESP
- Lime Kiln ESP
- Alkali Bypass ESP
- Clinker Cooler ESP
- Raw Mill ESP (may be integrated with Kiln Circuit)
- Coal Mill ESP

There are different types of Kilns, as well as the raw material and fuel may vary widely from plant to plant - as well as over time. The fuel may be oil, coal or even RDF, and of course any variation influences the process conditions for the Precipitator.

Similar examples are valid for Pulp & Paper plants, Metallurgical plant and Aluminum industries.

In this part of the world (Australia), generally these industrial plants including the precipitator are quite old. With increasingly stringent statutory emission regulations, the Precipitators face increasing challenges and quite a few have been converted into Fabric Filters. On top of that, most of these plants are very compact and there is hardly any space to play around with the configuration of the ESPs or to add parallel gas passes. The thrust is more and more on ESP Controls to find a better way of optimization and to create a balance between Emission and Power Consumption. The Industrial plants are also very sensitive to emission level as they are located close to residential areas, and in most of the cases the collected dust in the Precipitator is recovered and is needed in the production plant.

The use of High Frequency Power Supplies–Alstoms trade name is SIR (Switched Integrated Rectifier)-is becoming a quite common method of improving the efficiency of ESPs in Industrial applications. SIRs operate at frequencies that are magnitudes higher than line frequency, 23 kHz–50 kHz, and thus reduce the ripple voltage down to negligible values.

A comparison between the ESP operational voltages from line-frequency and high-frequency power supplies is shown in Fig. 1.

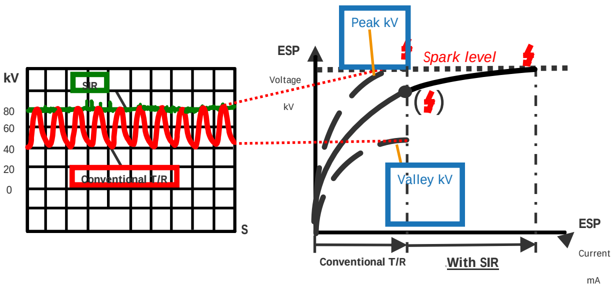

Fig. 1(a) Ripple difference between a SIR and a conventional TR in same bus section gives a much higher current with SIR – when the current is limited by sparking

The energy transferred from the converter input to the load during each cycle can be calculated as

$$W = \frac{P}{f}$$

where P is the power transferred to the load. The above equation establishes that a higher frequency reduces the energy transferred in each cycle. This also provides indication that the component involved in storing this energy can be smaller due to the increased operation frequency. The High-Voltage Transformer plays a major role. The system response time decreases with the increased frequency, and therefore high-frequency power supplies provide an improved power control for the ESP.

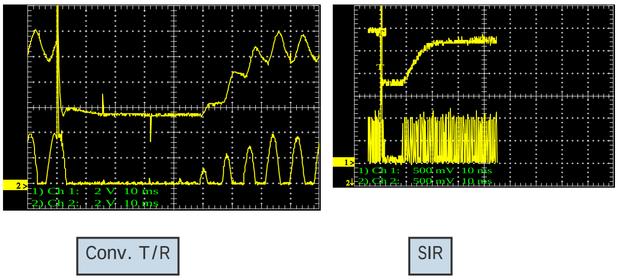

Fig. 1(b) Waveform Comparison, Conventional T/R vs. SIR

2 SOME SIR RESULTS FROM TWO INDUSTRIAL APPLICATIONS

Here we discuss the ESP collection efficiency improvement for two different Industrial Applications:

(1) An Integrated Cement Plant in the state of Victoria, Australia;

(2) A Pulp & Paper Plant in Kawreau, New Zealand.

3 CEMENT PLANT IN VICTORIA

This Cement Plant in Victoria has a Production Capacity of 325 000 Mtpa, and is equipped with a Rotary Kiln with two ESP casings. A portion of the gas is treated through an Alkali Bypass ESP. There is also a Clinker Cooler with a capacity 2100 TPD - also equipped with an ESP.

In this paper we shall discuss the Cement Kiln ESP. The Kiln is equipped with two ESP casings, each with three fields. Each field of the Precipitators is 2,5 m long × 7,25 m wide × 5,5 m high. The Collecting Electrode spacing is 250 mm and the total collecting area per casing is 1986 m^2 recalculated to 300 mm spacing.

One casing of the Kiln ESP is equipped with conventional Transformer Rectifier (TR) sets rated 55 kV, 600 mA. The other casing is equipped with SIRs rated 70 kV 800 mA.

A comparative analysis of the ESP Performance based on an in-depth study of a series of Electrical Readings has been made. Fig. 2 below shows the comparative Power consumption based on the VI readings:

(1) The Power Consumption of the ESP with conventional TRs is ca 80 kW;

(2) The Power Consumption of the ESP with SIRs is ca 150 kW.

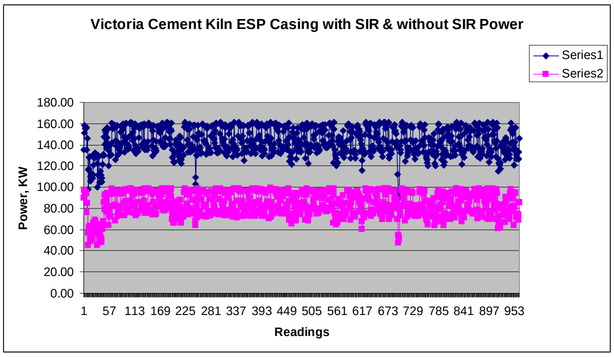

Fig. 2 Power consumption comparison based on VI readings for one ESP Casing where the lower curve (red) shows the conventional TR, and the upper curve (blue) shows the SIR readings

Thus it is clear that in this case the ESP equipped with SIRs accepts almost twice the power compared with conventional TRs.

Note, that the ESP casing equipped with conventional TRs were limited by sparking in first and second field.

The curves clearly establish the performance of the SIRs, and the emission measurement also shows the same trend:

(1) The emission level of the ESP with conventional TRs is around 50 mg/Nm^3 at the prevailing ESP process conditions.

(2) The emission level of the ESP with SIR is around 35 mg/Nm^3 at the prevailing ESP process conditions;

With this major improvement, the plant has ordered SIRs for the other ESP casing as well and these are now being commissioned.

4 PULP AND PAPER PLANT AT KAWREAU AT NEW ZEALAND

This Pulp and Paper Plant in New Zealand has a Pulp Production Capacity of 275 000 Mtpa, and is equipped with a Recovery Boiler with three ESP casings; North, Centre and South. The South- and Centre-casings are made of concrete, and the North casing is made of steel. The North casing is 57% larger than each of the South and Centre casings with and SCA of 65,7 $m^2/m^3/s$ in equivalent 300 mm spacing. All the ESP casings have two fields.

Originally the North Casing ESP had both field equipped with conventional TRs rated 70 kV, 1200 mA. During 2004 the front field TR sets were replaced with SIRs rated 70 kV 800 mA.

Fig. 3 compares the ESP Power Consumption for TRs and SIRs.

(1) The Power Consumption of the ESP with conventional TRs is 80 kW;

(2) The Power Consumption of the ESP with SIRs is 111 kW;

(3) This establishes that with a SIR installed in the first field only the total ESP power input increases by 40%.

The Outlet emission comparison also shows a similar trend:

(1) The emission level of the ESP with conventional TR was around 250 mg/Nm^3 at prevailing flue gas parameters;

(2) The emission level of the ESP with SIR was around 206 mg/Nm^3 at prevailing flue gas parameters.

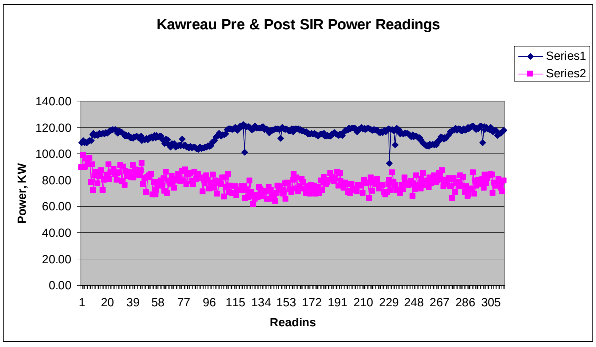

Fig. 3 Power consumption comparison based on VI readings for ESP first field with conventional TR and SIR

As a result of the major emission reduction seen in this plant this customer decided to install SIRs in the Recovery Boilers ESPs at another plant (located ca 100 km away, and has now installed a total of four SIRs in the first fields of four ESPs after two Recovery Boilers.

5 ANALYSIS OF ABOVE RESULT

An analysis of the above results clearly indicates that the increased Corona Power with SIRs is the primary reason for the reduced emission. The Power input is usually limited by:

Sparking inside ESP, or TR current limitation, or A combination of both

A conventional TR provides the ESP with a HVDC superimposed with a ripple component of about 30%-40% peak-to-peak. A SIR in the same ESP provides a HVDC with negligible ripple. With SIRs the kV arithmetic-, kV peak and kV valley values are for all practical purposes identical.

As the SIR output is controlled by transistors that operate at quite high frequency, the regulation becomes very fast, and the target to stay at highest possible kV is much better accommodated with SIRs than with conventional TRs.

The fact that a SIR very often is capable to deliver 2-3 times more corona power into the ESP can be very important for an old ESP, which may e.g. have loose discharge electrodes. With SIRs, sparking may sometimes be totally avoided by setting a kV or mA limit to a safe value below the sparking level–while the ESP can still operate at a much increased power level and reduced emission compared with conventional TRs.

The pulse time in SIRs can be substantially lower than in conventional TRs. Therefore, with SIR it is possible to stop and raise the HVDC flow at sparking and resume the HVDC much faster. This improves the ESP Collection efficiency, and is especially important for ESPs after Recovery Boilers.

SIR uses more kV to inject same current in a given ESP field compared with a conventional TR. The increased kV with SIR accelerates the particulates better, which in turn increases the ESP collection efficiency - primarily for low and medium resistive dusts, which are quite common in Industrial ESP Applications.

SIRs have two more advantages that do not affect the ESP collection efficiency, but are economically quite favorable:

(1) SIR has high power conversion efficiency, which means its heat loss is low.

(2) SIR has a high power factor (defined as kW divided by kVA) of ca 0.92.

A conventional TR typically has an overall conversion loss of ca 15 %, while a SIR - at full output of 60 kW HVDC-only has a power loss of ca 3 kW, or 5%. The difference–6 kW to SIRs advantage means a continuous economical gain for every SIR operator.

A conventional TR may have a power factor around 0.6-0.7, and this means that in comparison with SIRs Power Factor of 0.92 the mains supply kVA rating for same HVDC kW output to the ESP can be sized proportionally smaller with SIRs [ratio 0.6/0. 92 –0.7/0.92]. Of course, SIRs higher conversion efficiency also reduces the required mains supply rating by an additional ca 5%, compared with conventional TRs.

Very often the kVA mains power cables sized for the existing conventional TRs may suffice for more powerful SIRs, even though usually much more HVDC power is expected to enter the ESP when powered by SIRs. Of course, this is plant specific, but it is very easy to calculate.

6 CONCLUSIONS

The above results with SIRs indicate that for aging Industrial precipitators SIR certainly provides a unique solution, Not only can the overall ESP efficiency improve, the collection efficiency can increase to a point, that minor mechanical defects on the ESP internal parts may become permissible without exceeding emission limits. The above ESPs after a cement kiln and a recovery boiler are only examples from a long list of various process Industrial ESPs that Alstom has successfully upgraded with SIRs. The number of SIRs installed on industrial plants are now reaching c:a 900 units.

In comparison with other available means to reduce emission, SIRs certainly give great value for money and the relative payback period may be very short indeed.

As a SIRs installation is made only outside of the ESP, a big shutdown is never needed, which usually totally eliminates any plant production loss.

REFERENCES

1. Economical Aspects of Energizing Electrostatic Precipitators with High-Frequency Switched Power Supplies. Martin Kirsten & Anders Karlsson, ICESP X, Australia 2006.
2. ESP emission reductions with advanced electrode rapping together with novel energizing methods. Christer Mauritzson, Martin Kirsten, Anders Karlsson, ICESP IX,

South Africa 2004.
3. "On experiences of the application of high-frequency power converters for ESP energisation". Per Ranstad, Christer Mauritzson, Martin Kirsten & Russel Ridgeway, ICESP IX, South Africa 2004.
4. High Frequency power conversion: A technique for ESP energisation. Per Ranstad, Kjell Porle, EPRI/DOE International Conference on managing hazardous and particulate air pollutants, Toronto, August 1995.
5. Advanced Switched Integrated Rectifier for ESP Energisation Christer Mauritzson, Mats Thimansson & Anders Karlsson, ICESP VIII, USA 2001.