TRIALS AND TRIBULATIONS OF AN ESP SYSTEMS ENGINEER - BACK TO BASICS AT MATIMBA

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INTRODUCTION

Emission excursions are sometimes explained by weird and wonderful theories and speculations about changes in ash chemistry and a whole host of other often complex reasons. In many instances when this happens one finds that surprisingly often the "basics" have been overlooked. In extreme cases this could be something as obvious as a field being out of service. This Paper addresses the basics.

Matimba Power Station is situated in an environmentally pristine area in the northern part of South Africa, 13 km west of Lephalale in the Limpopo Province approximately 75 km from the Botswana border. This area is known for its "eco-tourism" and local environmentally conscious communities do not easily accept this Power Station and other industries associated with the abundant coal reserves found in the area. The long-suffering ESP Systems Engineer often has to bear the brunt of these conflicts of interests.

PLANT OVERVIEW

Matimba - the Tsonga word for "power" - is an appropriate name for a power station designed to generate 4000MW and that has the world's largest direct dry-cooled steam condensing system. Matimba comprises 6 X 660MW corner fired tower pulverised fuel boilers. Each boiler makes use of 2 x 8 field Electrostatic Precipitators (ESP's). Each casing has 2 gas passes with a narrow plate spacing of 275mm (10,8 inch) and a moderate (for the design inlet burden) specific collecting area (SCA) of 106,7 $Am^2/m^3/s$ (547 ft^2 / 1000 ACFM.) The design volume flow rate was underestimated at 1 040 Am^3/s (2,27x10^6 ACFM.) During normal operating conditions, Matimba burns over 1 million tons of coal every month. The average ash content can vary from 30% to 40%. The ESP is sized for a 33,9% ash content. This means that up to 400 000 tons of ash is produced monthly and has to be treated by the ESP's.

Table 1 provides some design comparisons with other Eskom plant.

DESIGN COMPARISONS
TABLE 1

	units	Duvha	Kendal	Lethabo	Matimba	Tutuka	Comment relative to Matimba
Specific collecting area (SCA)	s/m	141,6	89,4	191,6	106,7	91	
Adjusted specific collecting area (SCA)	s/m	141,6	119,2	191,6	97,8	121,3	smallest
difference	%	44,8	21,9	95,9	0,0	24,1	22% smaller than next smallest
# of fields in series	#	5	7	7	8	5	good feature
Plate spacing	mm	300	400	300	275	400	too narrow, trend was towards wider spacing
Aspect ratio (length / height)	Ratio	2	1,6	2,4	1,4	1,7	lowest - not good
Gas velocity	m/s	1,4	1,4	1,2	1,3	1,3	OK
Treatment time	s	20,1	17,9	28,7	14,7	18,2	too short
Design efficiency	%	99,60	99,78	99,88	99,77	99,80	

It can be seen from Table 1 that the basic design of the Matimba ESP's requires this plant to be in good mechanical and electrical condition at all times. Managing the impact of emissions on air quality needs a concerted effort by all personnel involved, from operating to maintenance personnel and most importantly by Management.

EMISSION MANAGEMENT

The cornerstone of emission management is to know what the emissions are at all times. Each boiler has its own dedicated flue in a 250m high stack. Each boiler flue is fitted with a Continuous Emission Monitor (CEM) that is correlated to VDI 2066 Standard at regular intervals, in accordance with an in-house Eskom Standard. (Ref. 1)

Eskom and CAPCO jointly developed the format of the Chief Air Pollution Control Officer (CAPCO) report. It comprises a tons emitted per month limit as a measure of net environmental impact coupled to a dust concentration (mg/Nm^3) limit as a measure of visibility or opacity. This limit is further sub-divided into a target, a limit and a CAP value, never to be exceeded. The station is permitted to emit above the limit value (but below the CAP) for up to 30 hours per month. This allows time to identify and rectify any deficiencies. A load loss is required in order to remain within the 30 hours and this loss of production has the effect of concentrating the minds of Management and all in their food chain.

THE ISSUES

To achieve efficiency and to prevent overloading of the ESP, a constant effort goes into optimisation of the operating parameters (electrical and mechanical) and up-stream conditions. An ESP can only do as it was designed to do or are allowed to do and therefore maintenance, operation and ongoing optimisation plays a critical part in the functioning of the ESP.

TEMPERATURE

ESP efficiency is very sensitive to inlet gas temperature and significant emission reductions have been achieved by reducing the boiler back-end temperatures (ESP inlet temperatures.) This causes decreased volume flow, reduced ash resistivity, reduced inlet burden and higher migration velocities resulting in lower emissions. Unfortunately, the malfunction of a primary plant is more likely to cause an increase in gas temperatures than a reduction.

The design inlet temperature is 129°C, but in hot and dry summer conditions, ambient temperatures rise to 38°C to 40°C and the ESP inlet temperatures rise to 145°C or more. The resulting increases in gas volume together with unstable boiler conditions requiring over-firing cause an excessively high inlet dust burden causing corona quenching with a consequent deterioration in ESP performance and higher emissions.

The direct dry-cooled steam condensing system is very sensitive to ambient temperature and wind direction. Wind direction can cause re-circulation in the air-cooled condensers (ACC's) such that their efficiency rapidly drops off and sudden load losses are required. The boiler attempts to increase steam production to compensate and the firing rate is increased, often drastically overloading the ESP's. This poses virtually insurmountable challenges to the ESP Systems Engineer.

To quantify the effect of increased inlet temperatures on the performance the ESP, a series of tests were carried out at Matimba Power Station. To summarize, factors causing high inlet temperatures include:

1. Ambient temperatures of 37°C - 40°C (this causes a higher firing rate).
2. Wind direction to the air-cooled condensers (this also causes a higher firing rate).
3. Blocked air heaters.
4. Unbalanced flow.
5. Damper positions.

ELECTRICAL CONDITIONS

The fundamental purpose of controllers is to provide the intense electric fields and corona currents needed for particle charging and collection. In addition, the stability and consistency of the controllers ensure a highly stable ESP with sustainable efficiency. Excessive spark rates cause instability, which will lead to consequent damage to the ESP internals, which in turn will reduce collection efficiency resulting in an increase in stack exit opacity. Too low a spark rate will cause the field voltages to be below that at which maximum ionisation occurs, leading to less ionisation with a resultant loss of ESP efficiency and an increase in stack exit opacity.

The best ESP efficiency is obtained by steadily increasing the voltage into the ESP fields, so that eventually an electrode potential is reached where an electrical spark is inevitable. This establishes the maximum electrode potential (maximum ionisation). It is therefore essential to adjust the controllers for maximum electrode potential in a way commensurate with an acceptable degree of sparking (about 30 sparks/minute in Matimba's case).

To successfully optimise these conditions both a good understanding of the fundamental processes involved and skill are required. The underlying concept is to keep the collection surface as dust-free as possible in order to achieve maximum ionisation.

The ESP performance can also be optimised further by mechanical and electrical evaluation and enhancement. If the performance is unacceptable then various forms of electrical and mechanical enhancements such as continuous mode, pulsing mode, reduced power rapping, off power rapping, full power rapping, incremental rapping, aggressive optimised rapping and electrical rapping can be tested and implemented.

Optimisation of electrical energisation is always a basic requirement for maximising ESP performance. Such optimisation is especially important when dealing with high resistivity particles, because of the disruption in electrical operation caused by such particles. Practical methods available to improve electrical energisation are fast acting spark quenching circuits and automatic control systems. Experience shows that ESP performance improves rapidly with higher operating voltages and currents. In practice, the highest ESP efficiency is obtained by raising the voltage to a safe and stable sparking level (too high a spark rate disturbs electrical operation and reduces collection efficiency). Low field power conditions are not satisfactory, it is imperative to maximise power transfer as close as possible to the full rated power of the electrical equipment. Initially high field voltages must be achieved and maintained followed by the highest field currents. It is important to remember that the field voltage has a direct impact on the collection and too high field current may cause excessive spark over. Increases in useful field input power produce improved ESP performance, resulting in decreased emissions.

At Matimba, ESP optimisation is very time consuming, for the following reasons:

1. Ash content in the coal that can change from 30 to 40% within a single eight-hour shift.
2. Load scheduling that can change from 350 to 665 MW within a three-hour period.
3. Ambient temperature that can change from 18 to 40°C within eight hours.
4. Oxygen levels that can change from 2.5 to 4.5 % within a single hour.

Matimba therefore purchased and helped to develop a locally designed fully automatic Plant Management System (PMS) that can change between ten previously optimised programs suited to the following conditions:

1. High load, Medium load and Low load modes.
2. Shutdown and Start-up modes.
3. Clean rapping mode.
4. Automatic rapper inspection mode.
5. Full hopper protection mode.
6. Power saving mode.
7. SO_3 injection mode.

RECTIFIER TRANSFORMER (T/R) PROBLEMS

After the installation of the PMS it is now possible to optimise (fine tune) the electrical parameters in a more professional manner so as to improve the performance of the ESP fields. It was then found that in the early mornings when the ambient temperature is low (<30°C), the ESP inlet temperature is <125°C and with moisture in the air, the electrical field performance is at it best. The field kV and mA readings would then be high, arc and spark rates would be low and therefore emissions would also be low.

However, by approximately 13h:00 with the ambient air temperature at 39°C or higher and the air very dry, the ESP inlet temperature increased to >135°C, the electrical field performances deteriorated rapidly, with low field kV and mA, and high spark and arc rates. By closely monitoring all 192 fields via the PMS, a serious problem was pinpointed. The T/R units had originally been designed to a specification that required operation in a maximum ambient temperature of 40°C but the ambient temperatures on the ESP roof can in fact exceed 65°C. Under these adverse conditions, the T/R units had been subjected to extended periods of over-temperature.

As a result, the T/R sets kept on tripping on high oil temperature alarm. In an attempt to keep the fields in service, the top oil temperature trip set point was adjusted from 90°C to well over 100°C. Over a long period of time the heat generated inside the rectifier transformers caused the deterioration and eventual breakdown of the mineral insulating oil and the formation of carbon. Due to the inherent DC fields within the T/R units, this carbon deposited on high voltage components and led to tracking and internal sparking and arcing within the T/R unit itself, forming yet more carbon. As a direct result of this deterioration, the controllers detected the internal sparking and power into the T/R units was reduced to the point that they frequently tripped on under-voltage. Under these conditions, the collection efficiency of the relevant fields was severely impaired.

To overcome this problem all 162 T/R sets are in the process of being completely rebuilt from the cores up and double rows of cooling fins are in the process of being fitted to the tanks.

ESP CONTAMINATION BY BOILER TUBE LEAKS

In December 2002 the emission from Unit 6 was 50 mg/Nm^3. In mid-January 2003 Unit 6 experienced an economiser tube leak that caused the emission to treble rapidly to 150 mg/Nm^3.

Two weeks later in February 2003 Unit 6 experienced another economiser tube leak that caused the emission to promptly increase further from 150 mg/Nm^3 to 230 mg/Nm^3. These high emissions forced Matimba to endure load losses. During a 34-hour tube leak repair outage we inspected the ESP and the found that the fields were contaminated with an ash layer of 30mm to 50mm on the collector plate and 20mm on the discharge electrodes. See Figures 1 and 2 below.

Figure 1
Fouled discharge electrode resulting from an economiser tube leak.

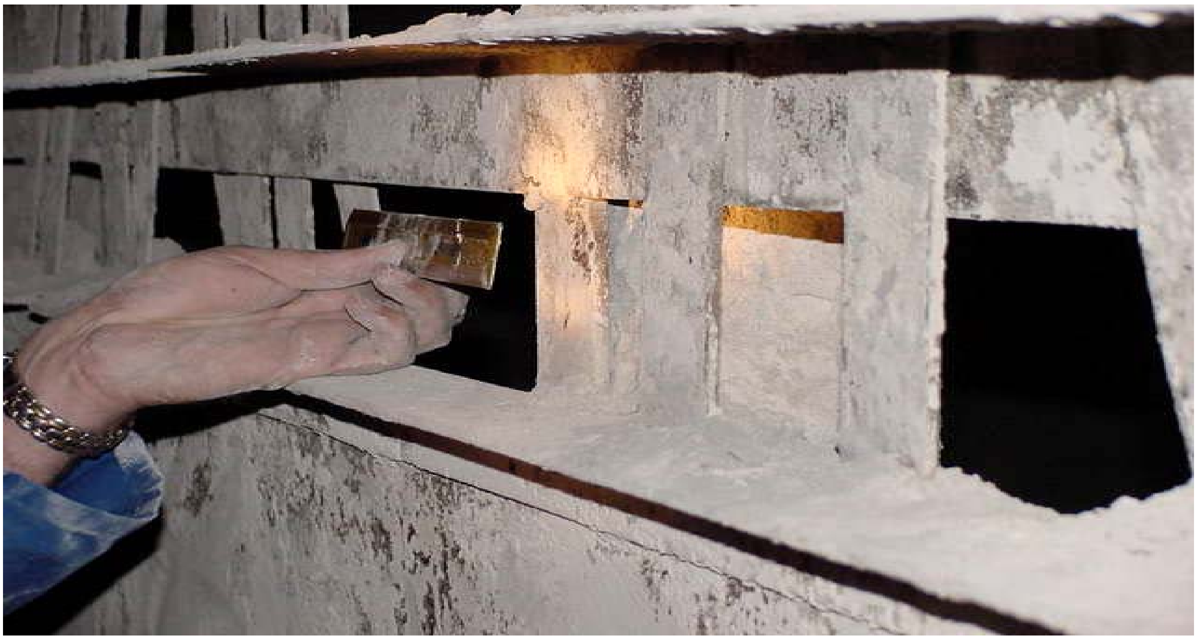

Figure 2
Previously blocked outlet distribution screen

In March 2004 the Unit was off for a 14-day outage and a decision was made to brush the plate and electrodes clean manually. After cleaning, Unit 6 was back to the normal 50 mg/Nm^3 after the outage.

INTEGRATED VIEW

It is absolutely essential that a holistic approach be taken when optimising ESP performance. The boiler operating parameters must be monitored as well as the electrical parameters on each ESP field. Only by constantly monitoring all these parameters together can stack emissions be reduced on a continuous and ongoing basis.

By means of continuous optimisation initiatives, Matimba Power Station will be able to carry on using ESP's whilst at the same time complying with the requirements of CAPCO.

COAL QUALITY / COAL MANAGEMENT

Matimba's ESP's are designed to operate with 33,9% ash in the coal. The ash content of the coal supplied from the mine varies from 28% to 36% during a normal 8-hour working day and can reach 40%. The average ash content over any given period is about 35%, the dust emissions are then about 55 mg/Nm^3 (the Matimba limit is 100 mg/Nm^3).

From January to March 2003 the emissions increased rapidly from 55 mg/Nm^3 to 150 mg/Nm^3. This was seen as an abnormal condition and Matimba was forced to accept load losses due to these high emissions.

The monthly average ash content was about 34,5% (normal to good), the weekly average ash content was about 34,8%, the daily average ash content was about 35,0%, but the hourly average ash content varied from 30% to 42% (unexpected). These high ash peaks of 36% and more cause unstable mill performance that in turn has a negative effect on ESP performance.

By close monitoring of the electrical parameters, especially the spark and arc rates, it was found that the ideal spark rate for Matimba is normally about 30 sparks per minute and about 10 arcs per minute when operating with an low ash coal.

With a high ash content in the coal the spark and arc rates increased rapidly to about 110 sparks per minute and about 50 arcs per minute and these high spark and arc rates affected the performance of the ESP fields negatively (see electrical conditions).

To avoid similar occurrences in the future, Matimba has negotiated with the mine to avoid such high ash peaks in future. The coal will be rejected by the Power Station if high ash peaks are found to occur in the future. The mine was also monitoring the coal on a monthly, weekly and daily average basis and they will now also focus on hourly average to ensure that the high ash peaks will be eliminated.

The above demonstrates the folly of having coal contracts based solely on long term averages and that instantaneous peaks do in fact have a lasting detrimental effect on ESP performance.

CONCLUSION

This Paper illustrates some of the daily difficulties and challenges the ESP System Engineer has to confront on a daily basis and also demonstrates the importance of a holistic approach when managing ESP performance in a sustainable manner.

REFERENCES

1. Standard for emission monitoring and reporting; GGS1086
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