ELECTROSTATIC PRECIPITATOR ENHANCEMENT BY ONLINE MONITORING OF COLLECTING ELECTRODE MASS

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ABSTRACT

South Africa’s Eskom is the African continent’s largest electricity Utility, generating 98% of South Africa’s electricity needs and 60% of Africa’s needs. It currently burns in excess of 100 million tons of coal annually and this is more than any other single Utility. Electrostatic precipitators (ESP’s) remain the primary device used for gas cleaning to clean 75% of this coal.

Eskom has now more widely applied the research lessons in the practical use of loadcells as a means of enhancing electrostatic performance by continuous real-time mass measurement of the collecting electrodes (CE’s). A previous paper presented at ICESP VIII detailed this work at Eskom’s Lethabo power station and its effectiveness in optimising plant operation. This paper will describe the continuation of this work at another Power Plant and focus on real-time, in-situ measurements.

The technology has been implemented on a single casing at Eskom’s 3 000 MW Kriel Power Plant as part of its upgrade and refurbishment program. This paper will detail this work and present measured results from both before and after the refurbishment. Other ESP operational CE patterns, will be also be presented with the aim to providing further insight into ESP operational behaviour.

1. INTRODUCTION

The use of collecting electrode (CE) mass monitoring to optimise an electrostatic precipitator (ESP) was presented at ICESP VIII, in Birmingham Alabama, 2001. The previous paper detailed the initial research conducted by Eskom into this technique at its Lethabo Power Station (LPS). This paper will discuss further work into the use of a loadcell system at Eskom’s Kriel Power Station (KPS), when implemented as part of a combined rebuild and optimisation strategy.

2. BACKGROUND

Eskom is Africa’s largest power utility, with a total generation capacity of some 38150 MW. Of this generation capacity, 25918 MW is currently serviced by ESP plant as a method of flue gas cleaning. KPS is located in the eastern South African province of Mpumulanga, in the heart of the coalfields. KPS was commissioned between 1975 and 1979 and was the first “step-up” in size of the “larger six pack” power stations for Eskom. At completion in 1979, KPS was the largest of its kind in the southern hemisphere. Prior to KPS, the largest boiler units were upto 350 MW in size. At KPS , six 500 MW units were constructed. After KPS, Eskom then built 7 “six pack” power stations with boiler units ranging in size between 600MW and 700 MW serviced by for total station power outputs between 3600 MW and 4020 MW.

KPS consists of 6 by 500 MW coal fired boiler units with a total capacity of 3000 MW. Each boiler unit’s flue gas cleaning is serviced by a dual pass, Rothemühle ESP. Each dual pass is further divided , internally, into a further two passes, though these are not discreetly isolated as in the case of LPS. ESP’s of KPS boiler units 1-3 have 3 fields in series, while boiler units 4-6 have 4 fields in series. Flue gas conditioning via sulphur tri-oxide was already implemented several years back.

The coal burnt at KPS is of approximately 19 MJ/kg, and 30 % ash content. The ESP’s at KPS are now approaching lifespans of between 25 and 30 years. These ages are often considered end of design lifespans for ESP’s, and is evident at KPS. ESP’s here are showing signs of severe wear and tear, and efficiencies are dropping as a result of operational problems due to plant out of service issues. The chief problem at KPS over the recent years has been broken discharge electrode (DE) wires. The removal of broken wires (an interim maintenance solution) has meant that the ESP’s are operating with up to 10% less wires in some cases. Broken wires, while the ESP is on load mean field malfunctions that can only be remedied with taking the boiler off load. Then, the only practical solution is to remove the offending wires, contributing further to the collecting efficiency problem. This in total, creates a generation load loss situation and is a serious problem to any power generation plant

With the above in perspective, resources and effort have thus been concentrated at KPS to remedy the situation. A total ESP rebuild has been investigated and this will cost in the region of R60 million (approx. $9 mil) per boiler. Eskom's intense ESP resources were thus mobilised to look into cost effective solutions. It is not within the scope of this paper to look at these other areas, but they include skew gas flow, dual flue gas conditioning (existing SO_3 conditioning in combination with newer research ammonia phase), electrical controller upgrades, better plant monitoring/management systems and finally rapping optimisation. This is the area of focus of this paper. However rapping optimisation, and all other ESP enhancement possibilities are only possible if basic ESP functionality is present. With this in mind, and with the broken wire problem, KPS decided to proceed with a "partial" rebuild in 2003. This partial rebuilds objective consists of addressing the chief problem, namely broken wires and consisted of replacing all DE rigid wire frames with a newer rigid frame "pipe and spike" one. This partial rebuild consists of spending substantially less than R60 mil per boiler, in an effort to see what emission improvements could be realised by firstly addressing the basic broken wire problem, and subsequently utilising in house developed ESP optimisation technologies.

KPS boiler unit 3 was chosen as the test unit to provide a gauge as to what could be achieved, in this "focused" approach. This would then provide insight into what could be done for the other 5 boiler units.

3. OBJECTIVES

The ESP loadcell system installation objectives at KPS are to provide insight into :

- Optimum, manual rapping settings for unit 3 as well as and other KPS ESP casings prior to any other rebuild or instrumentation being purchased. This is to provide an immediate benefit in operating the existing plant present.
- Effectiveness of the loadcell system for implementation on other casings for automatic control as part of the ESP rebuild phase, in conjunction with a suitable plant management system (PMS).
- Ability to monitor the effectiveness of other, parallel technologies currently being investigated (dual dosing and electrical controllers etc) and assist with fine tuning these other aspects.
- Help assess the way forward for critical future ESP rebuild scenarios at KPS.

4. METHODOLOGY

Since KPS has Rothemühle type ESP casings, the loadcell methodology used at LPS[1] was implemented here. The left hand outer casing was chosen for rapping optimisation experimentation. The loadcell system installed is a development borne out of the Eskom Research Development and Demonstration project entitled "ESP Rapping Studies". The technique consists of suspending two CE's from loadcells, in situ, and measuring the change in mass online and in real time.

Each of the three fields has two CE's instrumented. Each CE is supported from two loadcells, one at each end. These two loadcells are then connected in parallel to the necessary amplifiers and recording equipment. The loadcells are located in a specifically designed housing, found at each end of the relevant CE's, on the ESP cold roof. From here, cables are installed to the amplifiers and recording equipment, located in the ESP transformer control room, on the 15m level of the boilerhouse.

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The loadcell system was installed prior to ESP rebuild in order to assess the collection patterns for the "malfunctioning" ESP condition. Field collection trends were monitored for the "pre-rebuild" phase, and the loadcell system was then removed along with the rest of the ESP roof for the rebuild during late 2003. DE's were replaced and the loadcell system was re-installed. However turbine problems caused a delay in commissioning the boiler. The post optimisation phase is not complete at the time of writing this paper, but some post rebuild trends have been recorded.

5. PRE-REBUILD COLLECTION TRENDS

Some delays were experienced during the test and commissioning phase due mainly to plant availability issues. Fields out of service and inoperable rapper shafts, both due to internal faults were the main problems. Both these faults require outages to enable access to the ESP to rectify. This once again emphasised the ESP rebuild issue to cure current plant availability problems.

As part of the loadcell system's commissioning phase, the ESP's existing, current collection and operational trends were recorded. This was done simultaneously as the baseline iso-kinetic efficiency measurements. For this test phase, the boiler load was 500MW (full load). Stable ESP conditions were also achieved via no mill changes, sootblowing or automatic generator control during this time period. During this test period, the current rapping settings, used at KPS for units 1 to 3, was used. This is shown in Table 1, below.

Table 1 : Pre-Rebuild – "As found" Rapping Times

Field	**Run – On [Minutes]**	**Collect – Off [Minutes]**
1	3	3
2	3	9
3	3	45

Each field's CE's are serviced by one rapper shaft, located at the bottom of the CE's, above the dust hoppers. A run time of 3 minutes, above represents just over one turn [360°] of the rapper shaft, meaning cleaning of all CE's in that particular field.

For Field 1 (F1), the rapping times were 3 mins rap (clean), 3 mins off (collect). and from it a 1 hour trend (Figure 1 below) was plotted and some conclusions drawn.

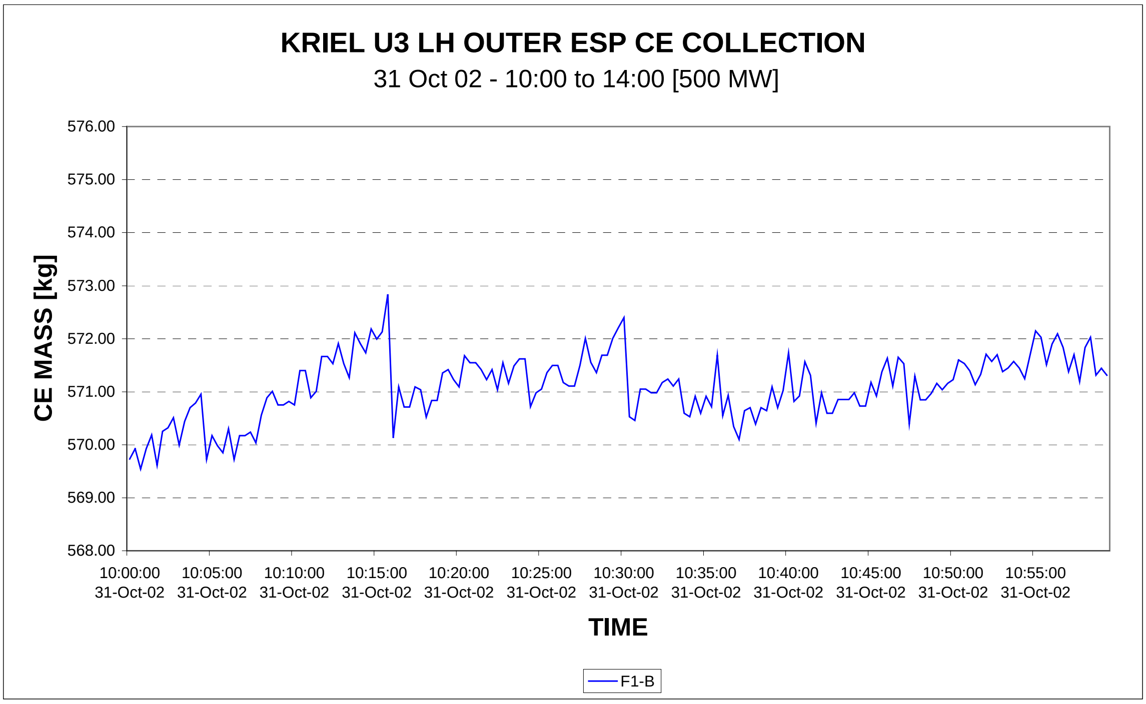

Figure 1

- Between raps (3 minutes), less than 1kg is being collected and dislodged per CE. This is considered too little, especially considering this is the first field. From previous research [[1]], it was advisable to collect larger amounts of ash and rap less frequently. This reduces rapping re-entrainment into the dust streams.

- It can be seen from the general pattern, that the preferred patterns of clearly defined ash collection and dislodgement is not present. This is due to too frequent rapping not allowing enough time for an ash layer to build on the CE's, and a "clean" shear off of ash when rapped is not seen for most 3 minute collection periods in between raps.

- What can be seen, from Figure 1, between the times of 10:00 and 10:15, is that something resembling the preferred collection trend is present. Now this is occuring despite the presence of 5 raps (at 3 min intervals). These 5 raps inbetween can be viewed as "wasted" raps, hampering the efficient collection ramp rate of the collection cycle. They also cause unnecessary re-entrainment losses and plant wear. Thus a more suitable rapping time for field 1 would be 3 minutes on and 15 minutes off. Currently from Figure 1, it can be seen that a larger ash layer (approximately 3kg) is being rapped off after 15 minutes. If the longer "off" times are installed, this value will rise considerably, due to electrical field stability, currently also being hampered by the too frequent rapping and the resulting field instabilites.

- The trend also indicates, notwithstanding the unnecessary rapping, a possible "scouring" effect. The "jagged" nature of the collection between the 3 minute rapping cycles suggests that field strength and relevant electrical controller capabilties can be improved, to minimise this. Of course, the "extra" rapping mentioned above often leads to residual vibration and motion of the already rapped CE's, thus further influencing the collection rates.

- The longer suggested collection times of 15 minutes will also be adequately serviced, and perhaps even enhanced by the existing CE hammer system, due to the shearing off a larger layer of ash. This should be noted, especially when considering the future ESP rebuild.

In general, the rapping times and subsequent collection patterns found at KPS are similar to those found at LPS during the research phase there. The deficiencies of the "excessive" rapping initially found there are also evident here at KPS. Thus gains in performance from both an emission viewpoint, as well as a plant life saving are possible. Rapper timing changes for the first two fields can be easily made via the existing system. The last field will be slightly more difficult due to hardware limitations.

At the end of the pre-rebuild tests the following was noted :

- The fields are not collecting to expectations. This is seen by the relatively low collection rates of F1 and also seen on subsequent fields. This makes the DE rebuild phase all the more significant.

- The rapping regime followed at KPS shows too frequent rapping, leading to both emission and wear and tear losses. Recommendations have been made to change this for the test unit, as well as all the other units at KPS. This will provide immediate, “manual” optimisation of the ESP’s, prior to any ESP rebuilds. After a rebuild, the system will be able to greatly assist with the re-optimisation of the ESP’s.

6. POST REBUILD COLLECTION TRENDS

The rebuild of the casing was completed as per final schedule, but due to turbine centreline problems, the boiler commissioning unit was delayed. However, test work could finally commence on the 9th March 2004. It should be remembered that this phase of the project is still in progress, at the time of writing due to the delays mentioned previously. However data will be presented for work in progress.

It is not within the scope of this paper to fully discuss the partial rebuild process, but to summarise :

- All DE’s frames were replaced, in all fields.
- SCA was not increased and existing CE’s were retained.
- Field electrical controllers were upgraded to the latest generation digital ones. (CASTLET MCS2 ‘s)

Figure 2, below shows a collection trend for this test session. F1 was the first field experimented upon.

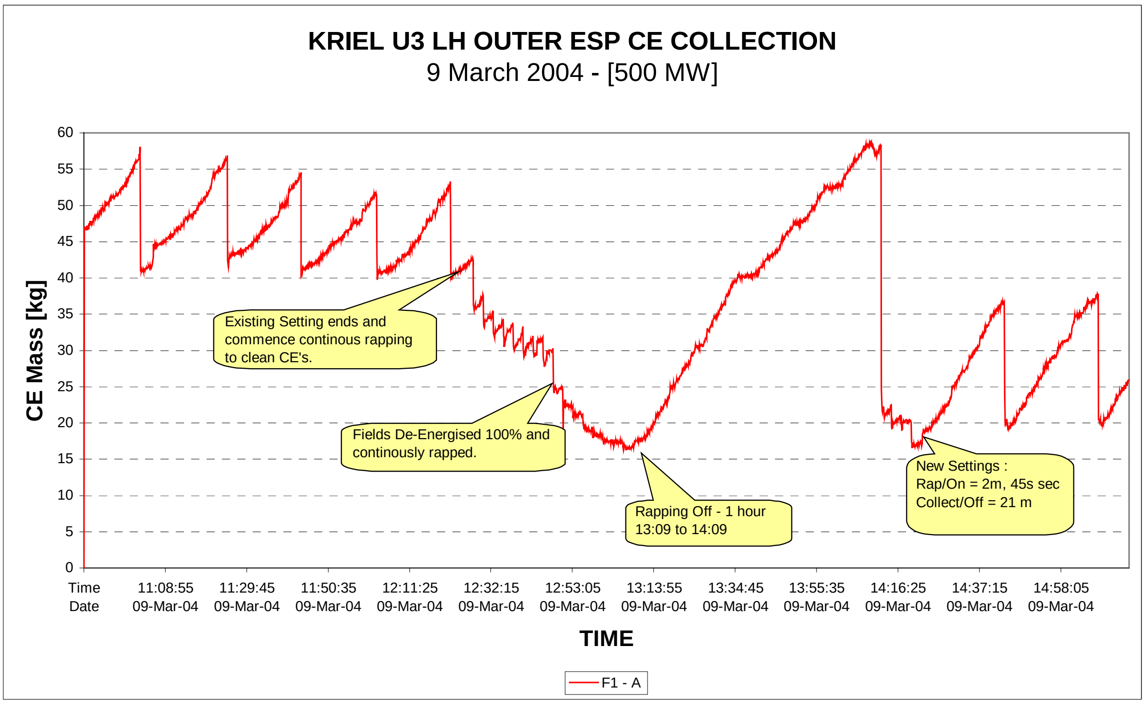

Figure 2

Data recording commenced around 10:48 with the rapping settings shown in the table below. These are shown in table 2 below. It should be noted that the rapper shaft motors take 2 minutes 43 seconds to complete 1 revolution. Data was then recorded until 12:25 with these settings. From Figure 2, above this is the period showing 5 raps.

Table 2,

Field	Run – On	Collect – Off
1	30 seconds	3 minutes
2	30 seconds	7 minutes
3	30 seconds	30 minutes

Comparing Figure 2 with Figure 1, it becomes fairly obvious that the new DE's combined with the field electrical controller have made a huge difference. More so, this difference will be felt when field out of service incidences due to broken wires are minimised or completely eliminated.

At 12:25, it was decided that before any field optimisation could commence, it was necessary to clean Field 1 (F1).

From 12:25, to 12:47, F1 rapping was switched into the continuous rapping mode, with the field fully energised (1 rap every 2m:43s). From Figure 2 it can be seen that the "base level" from which the previous rapping cycle was set slopes downwards. This indicates that the previous rapping setting was not fully cleaning the CE and allowing a layer of ash to, with time, build up on it.

At 13:08, the continuous rapping phase showed it had removed the "base/residual" layer of ash on the electrode to the best of its capabilities, while being energised. It was then decided to turn off the field electrical controller and further rap the CE's continuously. This was done to get the CE's to the best possible clean state, and to note what base layer of ash was not being dislodged from it. At 14:09 it became evident that the CE was in its "cleanest" possible state, using the boiler online options available. It was noted that between the start of the test (10:48) and now (14:09), the CE had 25 kg cleaned of it. The importance of this clean field state becomes evident later when new settings are put in.

At 13:09, it was then decided to conduct a "Field Off/Collect" test. This process was previously detailed in the work at Lethabo Power Station[1], and entails energising the field and turning the rapping completely off so as to trend its collection capability, for use in establishing optimised rapping times.

From 13:09 until14:09 (1 hour), F1 was fully energised and its rapping shaft turned completely off. This can be seen from Figure 2. It can also be seen that over the period of 1 hour, F1 never saturates, but a change in collection rate occurs after approximately 30 minutes.

F1 rapping times were then changed to 21 minutes collect/off and 1 revolution rap/on. This philosophy was introduced from the previous work at Lethabo Power Station[1] (section 5.2.1) and promotes the concept of rapping an entire field with one uninterrupted revolution of the rapper shaft as opposed to the incremental cycles as set up at the start of this test phase (Figure 2 10:48 to 12:25)

The new F1 rapping times were then monitored from 14:22 until the end of the chart trend.

Figure 3 , below shows 2 rap cycles. One from the un-optimised period (labelled "Before") of Figure 2 (10:48 to 12:25), while the second, labelled "After" is from the optimised period of Figure 2 (14:22 to chart end). It can be seen that the rate of collection after the "forced" cleaning, combined with the field mechanical stability (rapping shaft not turning) and hence electrical stability.

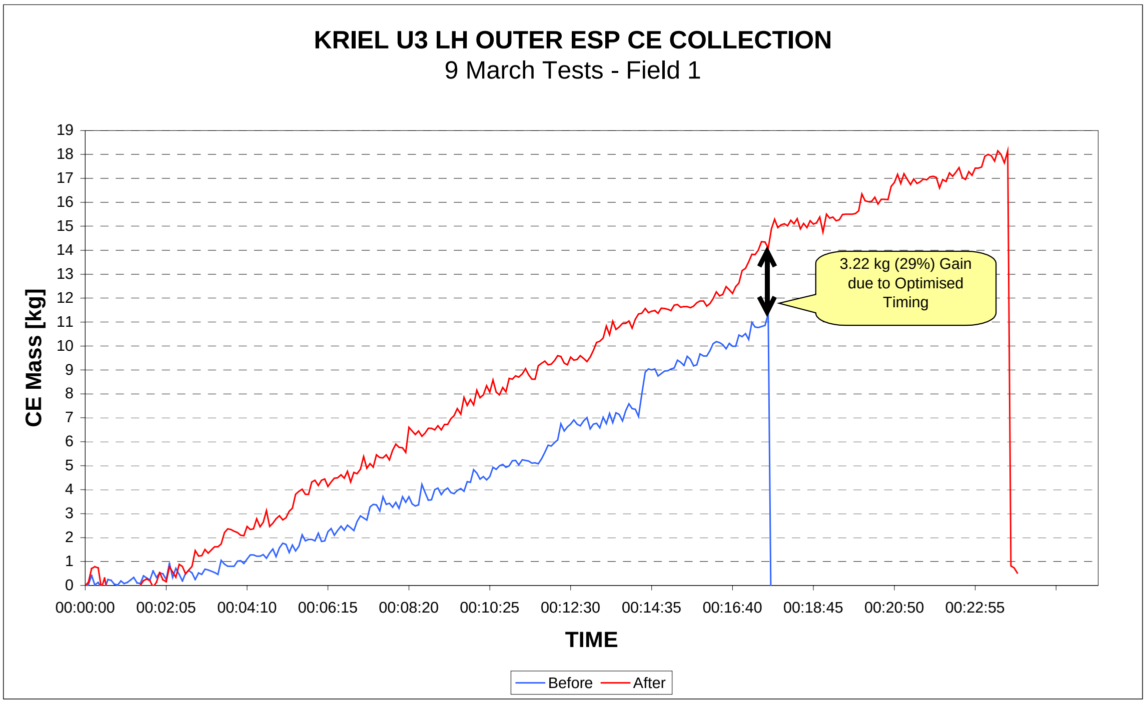

Figure 3

From Figure 3, it can be seen that F1 performs at a much better collection rate (29%) after being forced cleaned. This state of CE cleanliness must therefore be attempted to be maintained through longer term operation. Further tests at KPS will attempt to set up the electrical controller and corresponding rapping to perform power off rapping on a suitable interval, to ensure this cleanliness.

Further tests are planned for Fields 2 and 3, in conjunction with the SO_3 and Ammonia dosing systems and electrical controller, to optimise total ESP operation

7. RECOMMENDATIONS

- Previous optimisation efforts, not just those using the loadcell were hampered by frequent field out of service incidences due to broken DE wires. The rebuild will all but eliminate this and now intense efforts into optimisation of all ESP parameters must be undertaken.

- The project is still in progress and the remaining fields must be optimised using a similar approach as to that presented for field 1.

- The continued use of the loadcell system, for both manual as well as automatic control and optimisation of the ESP's at Kriel is recommended. Greater use and benefit will be seen when combined with a suitable plant management system.

8. CONCLUSION

The loadcell system continues to show its effectiveness in being able to monitor, measure, optimise and evaluate ESP operation by providing a direct in-situ, online, real time view to what is occurring inside the ESP.

9. ACKNOWLEDGEMENTS

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