

RETROFITTING FABRIC FILTER PLANTS INTO SMALL ELECTROSTATIC PRECIPITATOR CASINGS

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ABSTRACT

Electrostatic precipitators (ESP) built in the 20th century were suitable for the emission requirements of the time, but as environmental legislation and awareness increased, the performance of these precipitators were sometimes no longer compliant with increasingly stringent legislative requirements. Often these precipitators were two or three-field devices and it is difficult to improve the performance of such small-footprint plants to current requirements.

A viable option for improving the efficiency of these emission control devices is to retrofit pulse jet fabric filters into the old and small ESP casings. Such a project has recently been completed at Hendrina power station, South Africa.

The plant was originally equipped with ESP's for gas cleaning, but these were recently replaced with fabric filter plants (FFP), retrofitted into the two and three field ESP casings. The project was executed in three phases, starting in 1994. It was completed in 2004.

This paper will describe the original performance of the ESP's, the performance of the FFP's, the factors influencing the decision to improve the plant, and what criteria the new / refurbished plant had to meet.

1. INTRODUCTION

Hendrina power station is situated 45 km from Middelburg in Mpumalanga Province, South Africa. The power station is a 10x200MW coal fired plant and burns coal from the adjacent Optimum colliery.

The plant was originally equipped with three field electrostatic precipitators (ESP's) on units 1-5 and two field ESP's on units 6-10. The design efficiencies were 98% and 96% respectively.

The original ESP's were installed for approximately thirty-one years and were becoming highly maintenance intensive. The high maintenance cost and other factors such as the risk of emerging legislation with respect to air pollution, necessitated Eskom to either improve the ESP reliability and efficiency, or replace with new emission control equipment.

Due to environmental legislation becoming more stringent, the plant had to be able to achieve and maintain at least 100 mg/Nm³ of dust emission. After extensively evaluating various scenarios, a decision was made to retrofit FFP's into the existing ESP casings. The retrofit program was executed in three phases, starting in 1994 and continuing to 2004.

The retrofitted plants are of the rotating manifold design and utilize low temperature bags manufactured from Polyacrylonitrile (PAN) in all plants except for unit 1, which has high temperature Polyphenylenesulphide (PPS) bags.

2. ORIGINAL PLANT

The original ESP's were installed at Hendrina power station between 1973 and 1978. The plant details were as follows:

Unit 1

Weighted wire three field ESP.

Lane spacing - 250mm.

Analogue controllers.

Concrete casings and steel dust hoppers.

Emissions - approximately 400mg/Nm³.

Units 2-5

Electrode frame three field ESP.

Lane spacing - 250mm.

Analogue controllers.

Concrete casings and concrete dust hoppers.

Emissions - approximately 250mg/Nm³.

Units 6-10

Wire and frame two field ESP.

Lane spacing - 250mm.

Analogue controllers.

Concrete casings and steel dust hoppers.

Emissions - approximately 500mg/Nm³.

- All ESP's had two separate casings, each casing without a division wall. The ESP's were located at ground level outside the boiler house.

- The ESP's for boilers 1 to 5 were designed to extract 98% by mass of dust in the flue gasses fed into them with the Boilers operating at 97% MCR.
- The ESP's for boilers 6 to 10 were designed to extract 96% by mass of dust in the flue gasses fed into them with the Boilers operating at 97% MCR.
- The ESP's were fitted with sulphur burning flue gas conditioning plants in the mid 1980's to increase the fly ash collection efficiency.
- Dust extraction is done by means of Hydrovacs.

3. NEED FOR PERFORMANCE ENHANCEMENT

Emission limit

Hendrina could not meet the 100mg/Nm³ emission limit set by the Chief Air Pollution Control Officer (CAPCO) for particulate emissions. In fact, prior to 1994, Hendrina was one of the biggest emitters in the Eskom fleet. There was no means of limiting the emissions to the level required by CAPCO, other than rebuilding or upgrading the ESP's, or replacing them with FFP's.

Cost and performance sustainability

The ESP's would now be at least 31 years old. Maintenance cost was becoming a serious concern. Performance of the ESP's was not sustainable after maintenance, because of the mechanical condition of the internals. Wire breakages frequently caused short circuits and this resulted in high emissions.

Future coal characteristics and load factors

A comprehensive study was done of the coal fields that would supply Hendrina power station with coal into the future. The results indicated the future coal would increase the emission control problems. The ash content was expected to increase from the average 23% to approximately 32%, and calorific value (CV) would reduce, increasing the amount of coal burnt. At the same time load factors were expected to rise substantially as the country's economic growth rate increased.

4. CRITERIA FOR THE NEW PLANT.

Emission limit

Eskom Management Board made a decision that when major upgrading of an emission plant is required, the plant must meet the standard of 50mg/Nm³ or less. This represents a plume that is not visible. The extent of the work required on the ESP's at Hendrina made this Management Board directive applicable. This resulted in the plant being designed for an emission limit of 50mg/Nm³, better than the CAPCO requirement at that time of 100mg/Nm³.

Least Cost Option

Because an emission reduction plant is not a revenue generating plant and no financial returns could be expected, the cost had to be kept to a minimum. This meant that the least cost solution would be implemented.

Sustainable performance

Due to the increased pressure on the South African electricity network, we could not afford to de-load units because of high emissions. De-loading for compliance is required by legislation. The performance of the plant had to be sustainable and below the limit at all times.

Unit Capacity

One of the important criteria's for the project was that the new emission control plant should not limit normal operation or capacity of the unit.

Outage Duration

Execution had to be within the existing outage plan. The units are normally overhauled during an eighty day outage. This implies that the emission control plant upgrade had to be done in eighty day or less.

5. PHASING AND COST OF PROJECT

The project was executed in three phases and the total cost was R240.1 M (approximately USD38 M).

Phase 1

The worst performing ESP's were the two-field precipitators on Units 6-10. They were selected to receive attention first.

The contract started in 1995 and was completed in 1997. The specification called for a limit of 50mg/Nm³. The Enquiry Document invited bids for both an ESP upgrade or fabric filters.

The capital cost for an ESP that could meet the required emissions was high due to the need for costly casing extensions. Differential expansion involved with attaching and sealing a steel extension onto the existing concrete casings presented some serious challenges. The life cycle cost for FFP's were high relative to that of an ESP, but the total cost was lower for the best FFP offer followed by an ESP upgrade.

The contract was subsequently awarded for a pulse jet FFP.

The cost of the project was R78.3 M (USD12.43 M).

Phase 2

This project was for three units, units 1, 3 and 5. Unit 1 being of a different design, was the least efficient ESP of the remaining five ESP's. Units 3 and 5 were chosen because of their poor mechanical condition and non-sustainable performance. The project started in 2001 and was completed in 2003.

The specification again called for 50mg/Nm³. Both ESP and fabric filters would be considered.

The lowest price was for an ESP but calculations done during the tender evaluation indicated that the required emission level would not be met.

The contract was subsequently awarded for a Pulse jet FFP.

The cost for this phase of the project was R87.7 M (USD29.23 M).

Phase 3

The final phase was for two units, units 2 and 4. The project started in 2003 and was completed in 2004.

The contract for units 1, 3 and 5 had an extension clause that stipulated that the contract could be extended to units 2 and 4. This clause was used for the last two units to ensure similar plant.

The cost for this portion of the project was R74.1 M (USD 11.76M).



Figure 1: Hendrina Power Station after phase two. One chimney ESP's and one chimney FFP's

6. SPECIFICATION FOR TENDERING

The enquiry for tenders was a specification type enquiry. This project covered the applicable units on a unit by unit basis.

The project specification stipulated a total plant solution to control the particulate emissions to the stack from the boiler, to a guaranteed maximum of $50\text{mg}/\text{Nm}^3$ (with no corrections acceptable) under all normal conditions when burning coal within the specified range, and when operating the boilers in the specified load range from 40% to 100% MCR. Other parameters were also specified, for instance, the gas to cloth ratio and the maximum pressure drop.

The supplier had to provide all services, equipment, specialist personnel, material and all associated engineering services to fulfill and execute the requirements of the contract.

The enquiry was not prescriptive and either ESP's or FFP's could be offered.

Some additional requirements were specified, for instance, the use of vent fans during maintenance interventions, implosion dampers to protect the FFP inlet and outlet ductings and dust hopper heating.

7. ALTERNATIVES CONSIDERED

Continue to repair the precipitators and operate in the present mode with SO_3 injection

This option was investigated but was not viable due to the impending legislation on air pollution that was to be introduced in South Africa at the time. The ESP's were expensive to maintain and there were a large amount of broken wires and cracked plates.

Reduce the load on the units

Due to the higher than expected growth in electricity sales, the surplus generating capacity was being quickly eroded. The fact that every available generator is needed made this option not viable.

Enhanced maintenance / upgrading of current ESP's to reduce emission to approx. 70mg/Nm³

This option was investigated and evaluated in an investment model, but it was found that the cost of doing this as opposed to a full upgrade/retrofit was not economically feasible.

Rebuild the ESP's completely, install a fabric filter plant with high temperature bags or install a fabric filter plant with low temperature bags

After comparing this option with the other options and evaluating the economic benefits of each, it was found that this was both economically and strategically, the most feasible option.

8. NEW PLANT

Units 1-10, are all equipped with rotating manifold pulsejet FFP. There are fundamental differences between Units 1, 2-5 and 6-10 however.

Unit 1

Unit 1 is fitted with high temperature bags (PPS). This was required due to the boiler back end temperature being too high to effectively attemperate to 125 deg C. The performance of the plant is good with emission values consistently below the 50mg/Nm³ limit.

Table 1: Unit 1

Filter Plant Type	:	Pulse Jet (PJFFP)
Pressure Drop	:	2.4kPa
Number of Cells (n)	:	2 per Plant
Number of Bag Modules/Plant	:	12
Number of Bag Modules/Cell	:	6
Bag Length (M)	:	8 nominal
Filter Bag Material	:	High temp. (PPS)
Air Attemperation/Dilution		None
Outlet Dust Burden		
Expected	:	15 mg/Nm ³
Guaranteed	:	30 mg/Nm ³

Units 2-5

These units have similar FFP's to unit 1 but they utilise low temperature FFP's. The performance of the plant is good with emission values consistently below the 50mg/Nm³ limit.

Table 2: Units 2-5

Filter Plant Type	:	Pulse Jet (PJFFP)
Pressure Drop	:	2.4kPa
Number of Cells (n)	:	2 per Plant
Number of Bag Modules/Plant	:	12
Number of Bag Modules/Cell	:	6
Bag Length (M)	:	8 nominal
Filter Bag Material	:	Acrylic (PAN)
Air Attemperation/Dilution		Two per ducting
Outlet Dust Burden		
Expected	:	15 mg/Nm ³
Guaranteed	:	30 mg/Nm ³

Units 6-10

These units have low temperature bag filter plants with 8 nests per plant. The bag nests are bigger than those of units 1-5. The performance of the plant is good with emission values consistently below the 50mg/Nm³ limit.

Table 3: Units 6-10

Filter Plant Type	:	Pulse Jet (PJFFP)
Pressure Drop	:	2.4kPa
Plant Model	:	2 (4) 676 RF 8000
Number of Cells (n)	:	2 per Plant
Number of Bag Modules/Plant	:	8
Number of Bag Modules/Cell	:	4
Bag Length (M)	:	8 nominal
Filter Bag Material	:	Acrylic (PAN)
Air Attenuation/Dilution		Two per ducting
Outlet Dust Burden		
Expected	:	25 mg/Nm ³
Guaranteed	:	50 mg/Nm ³

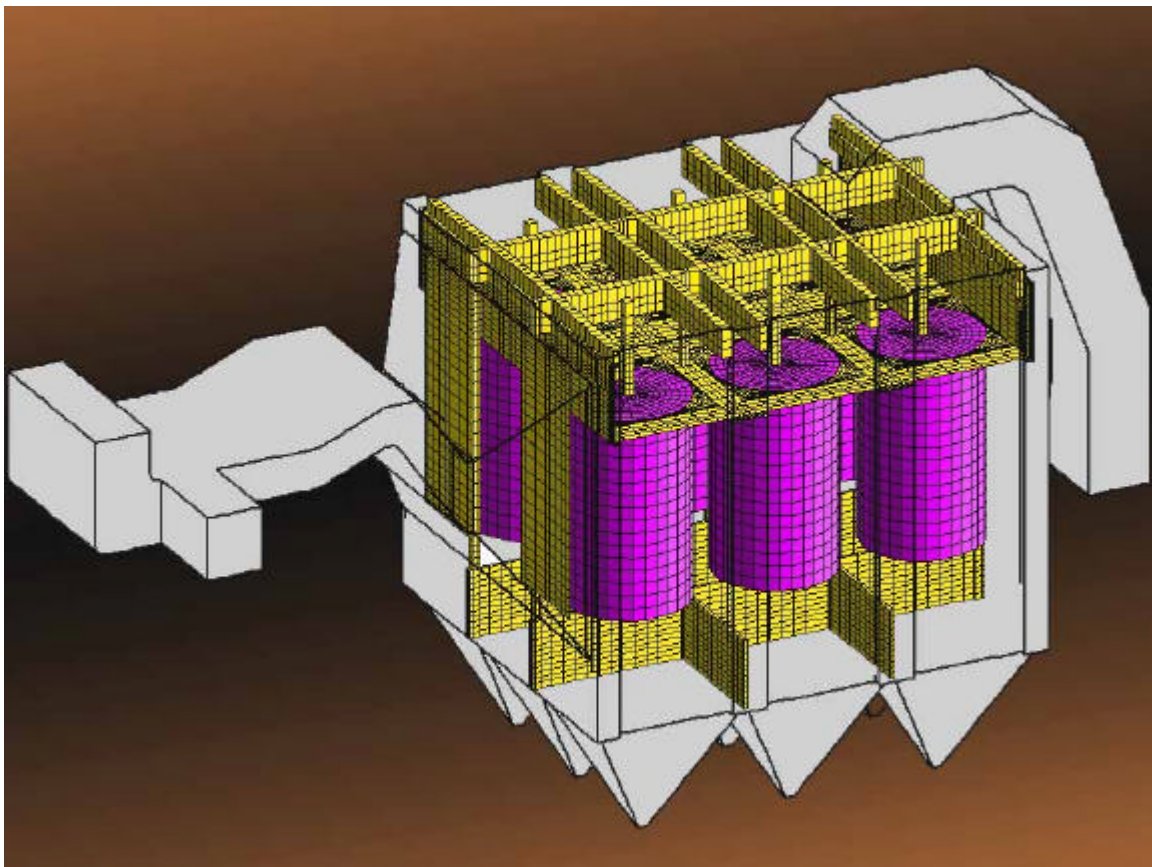


Figure 2: Units 1-5 FFP

9. INITIAL PROBLEMS WITH NEW PLANT

There were initial problems with the new FFP's. The most significant of these were:

Support Bearing failures.

The rotating manifolds have a support bearing at the bottom. These bearings were prone to failure initially. To rectify the problem, the maintenance philosophy was revised, the lubrication improved and a bearing with a different internal race design is being used.

Pulse tank diaphragm and spring failures.

The failure of diaphragms and springs was abnormally high. The problem was traced to incorrect material hardness of the springs. The hardness was corrected and the problem solved.

Compensator failures.

The fact that the ESP casings are concrete and the new FFP tube plate steel, poses a problem with expansion and sealing between these surfaces. The initial compensators were fabric and were prone to leaking. After modifications proved unsuccessful, the seal was totally redesigned. The new seal is manufactured from steel and fabric and is proving effective.

Tube plate hanger failure.

After a tube plate hanger failure on unit 10 FFP, the hanger design was revised and implemented on all FFP's.

10. CONCLUSION

Hendrina power station was the highest emitter in the Eskom fleet prior to 1994, but is now the best performing power station in terms of kg of particulates emitted per MWh sent out. This was achieved by utilizing the old ESP casings and retrofitting FFP's into them.

When the separate enquiries were issued we were not prescriptive as to what technology should be used. In both cases the tenders were evaluated in terms of capital cost, life cycle cost, technical suitability and predicted performance. In both cases FFP's proved to be the preferred option.

FFP's are normally more expensive in terms of life cycle cost, but the capital cost associated with adding additional fields to an ESP casing offsets the higher life cycle cost of a FFP in Hendrina's case. The retrofits were done in an average time of 74 days.

This proves that retrofitting FFP's into ESP casing can be a viable solution if a step change reduction in emissions is required.

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