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Particulate Emissions Control with a Fabric Filter Conversion at the Tutuka Power Station

Authors:
R.E. Snyder

Babcock & Wilcox
Barberton, Ohio, U.S.A.

L. Van Wyk
Eskom Holdings SOC Ltd.
Johannesburg, South Africa

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R.E. Snyder
The Babcock & Wilcox Company, Barberton, Ohio, U.S.A.

L. Van Wyk
Eskom Holdings SOC Ltd., Johannesburg, South Africa

ABSTRACT

As part of Eskom's strategy to comply with particulate emissions legislation requirements, pulse jet fabric filters (PJFF) were selected for all of the units. A fabric filter technology license was obtained from The Babcock & Wilcox Company (B&W). A case study of the Tutuka Power Station electrostatic precipitator (ESP) conversion to fabric filter technology is presented.

The primary challenge of the Tutuka Power Station project was working with an existing ESP which was installed 30 years prior. The engineering team, composed of members of both organizations, worked closely to evaluate reuse of material, configuration and implementation of features essential for future maintenance, safety issues and long-term operational reliability. The existing ESP configuration and the final fabric filter design will be presented.

Computational fluid dynamics (CFD) flow modeling was utilized as an aid in developing flow distribution devices within the fabric filter casing and compartments to enhance performance. The CFD results will also be presented.

INTRODUCTION

The Tutuka Power Station has six units with Unit 6 being selected first for upgrading. Upgrades of the remaining units are of the same design.

Unit 6 is a coal-fired boiler and generates approximately 609 MWe.

The conversion project goal is to reduce the particulate emissions to 10 mg/Nm^3, although legislation requires a limit of 50 mg/Nm^3.

The existing ESP is being retrofitted to accommodate a compartmented pulse jet fabric filter (PJFF).

The design team from Eskom and B&W worked jointly on the fabric filter, while the Eskom design team worked with Power Technology System Integrators on the balance of plant.

DATA AND RESULTS

Tutuka Overview

Unit 6 is a coal-fired boiler generating approximately 609MWe. The unit is arranged as shown in Figure 1. Each boiler has two air heaters with two ESP units being converted to two PJFFs. See Figure 2.

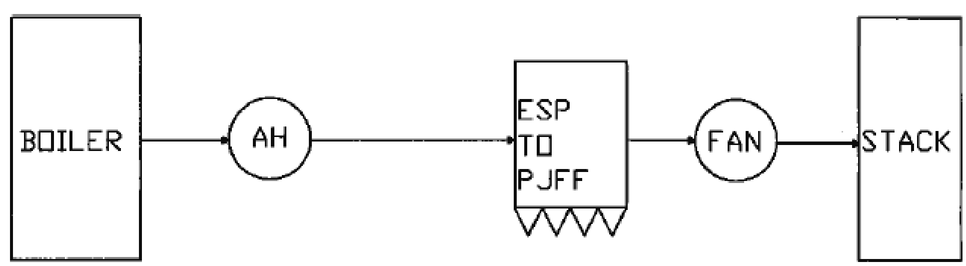

Figure 1 – Arrangement of emissions control devices.

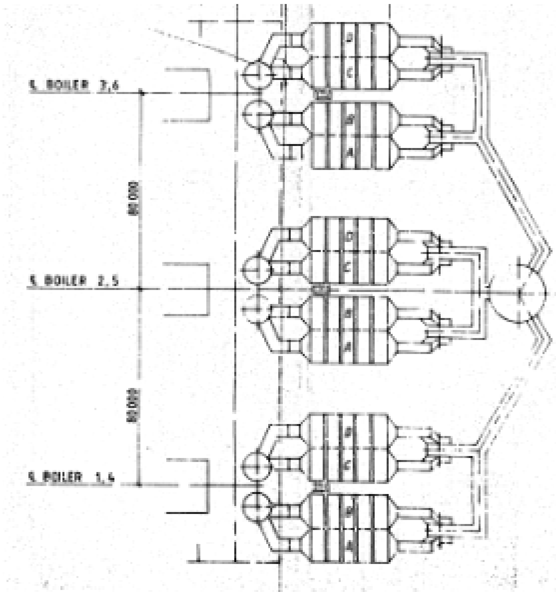

Figure 2 – Plant arrangement.

Figures 3 and 4 show the existing ESP side and plan views.

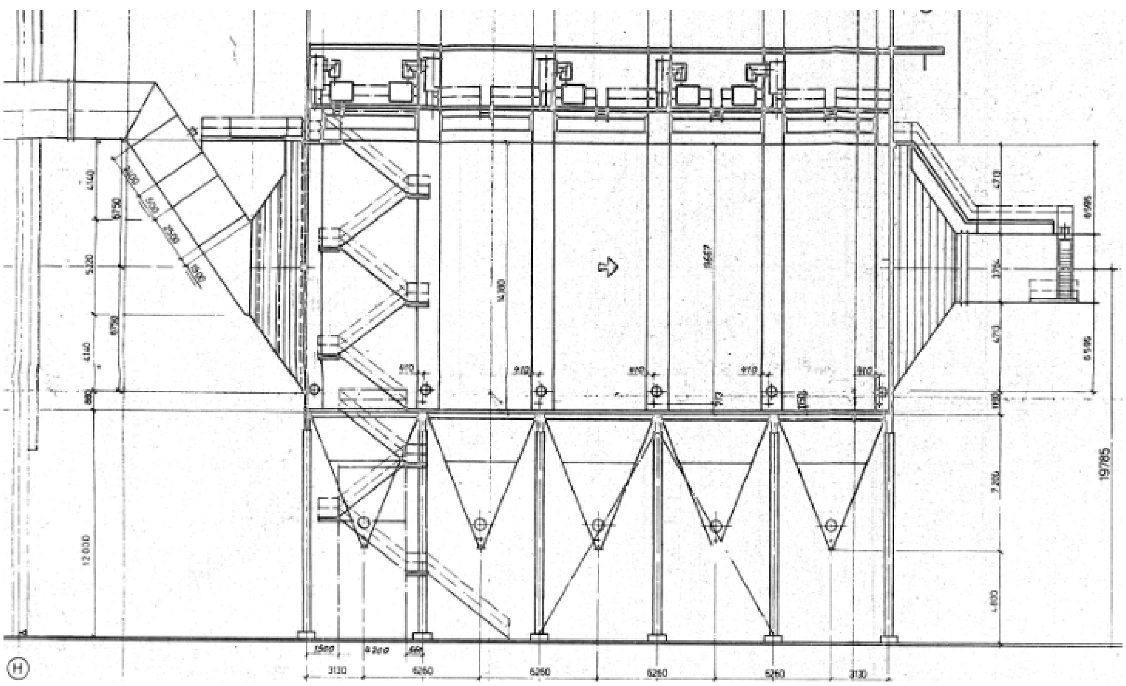

Figure 3 – Side view of existing ESP.

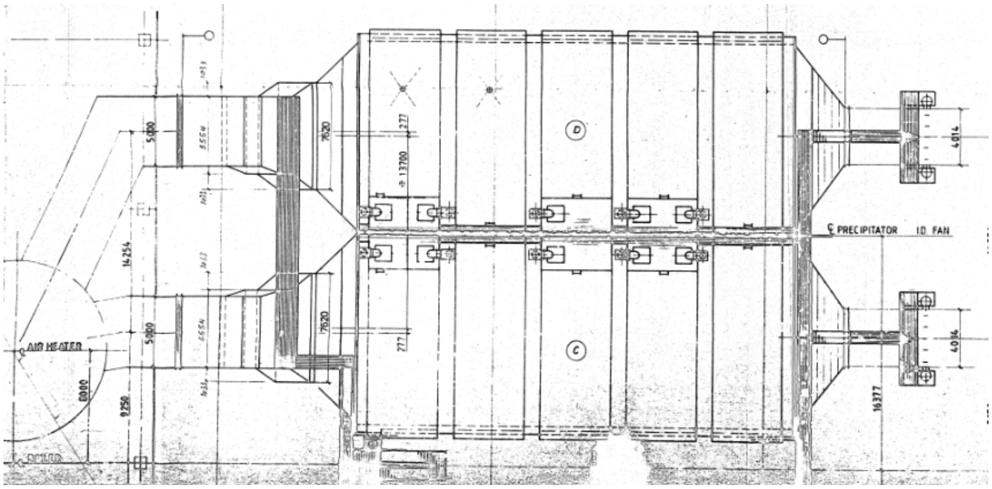

Figure 4 – Plan view of existing ESP.

Tutuka Process Requirements

Tables 1 and 2 show the particulate removal requirements and mass balance.

Table 1 – Particulate Removal Requirements

Customer	Eskom
Plant	Tutuka
Boiler Load	100% BMCR
Fuel	240-71273834 Revision 1 Rejection Coal (9% TM), Dimbo Calculation no. 44, Version 28
PJFF Particulate Loading	35 781 mg/Nm3 dry @ 6% O2
Particulate Outlet Emissions	10 mg/Nm3 dry @ 6% O2

Table 2 – Mass Balance

Description		Flue Gas to FFP	Air In-Leakage	Flue Gas to ID Fan
	Units	A	B	C
Volumetric Flow	Am3/s	679.3	---	700.2
Temperature	°C	157.2	---	157.2
Pressure	kPa (g)	-3.6	---	-5.1
Total Mass Flow	kg/hr	1 666 062	16 261	1 682 323
H_2O	kg/hr	71 989	211	72 200
N_2	kg/hr	1 131 187	12 326	1 143 513
O_2	kg/hr	108 626	3 724	112 350
CO_2	kg/hr	291 387	---	291 387
SO_2	kg/hr	4 017	---	4 017
Ash	kg/hr	39 929	---	11

Tutuka PJFF Design

The PJFF is a 10-compartment enhanced-plenum style unit complete with inlet and outlet isolation dampers. Each compartment has 1008 filter bags which are nominally 150 mm diameter and 10 m long. The filter bag cages are constructed in two pieces. The gross A/C (air-to-cloth ratio) is 0.88 m/min and the net A/C is 0.98 m/min. Each compartment has two pulse air headers with 24 pulse valves each. Each pulse valve provides cleaning air to 21 filter bags. Louver dampers are used for the inlet gas while poppet valves are used for the outlet gas.

The hoppers from the original ESP were reused and there are two hoppers per compartment. The ESP sidewalls were also reused.

Figure 5 shows an isometric view of the two pulse jet fabric filters for Unit 6, along with the flue routing.

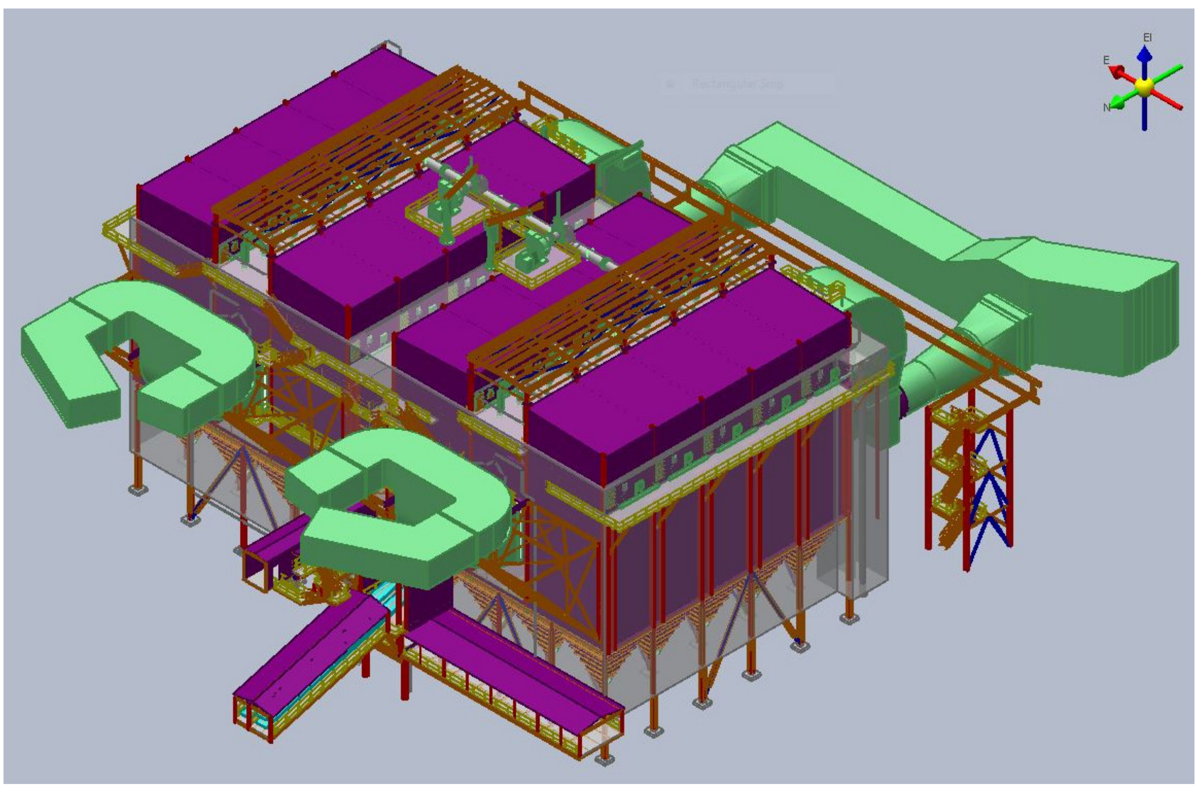

Figure 5 – Isometric view of Unit 6 PJFFs.

Figure 6 shows the PJFF upper area with the roofing removed for clarity. The ventilation blower, used to provide ventilation and cooling air during maintenance, is shown in green at the top of the unit.

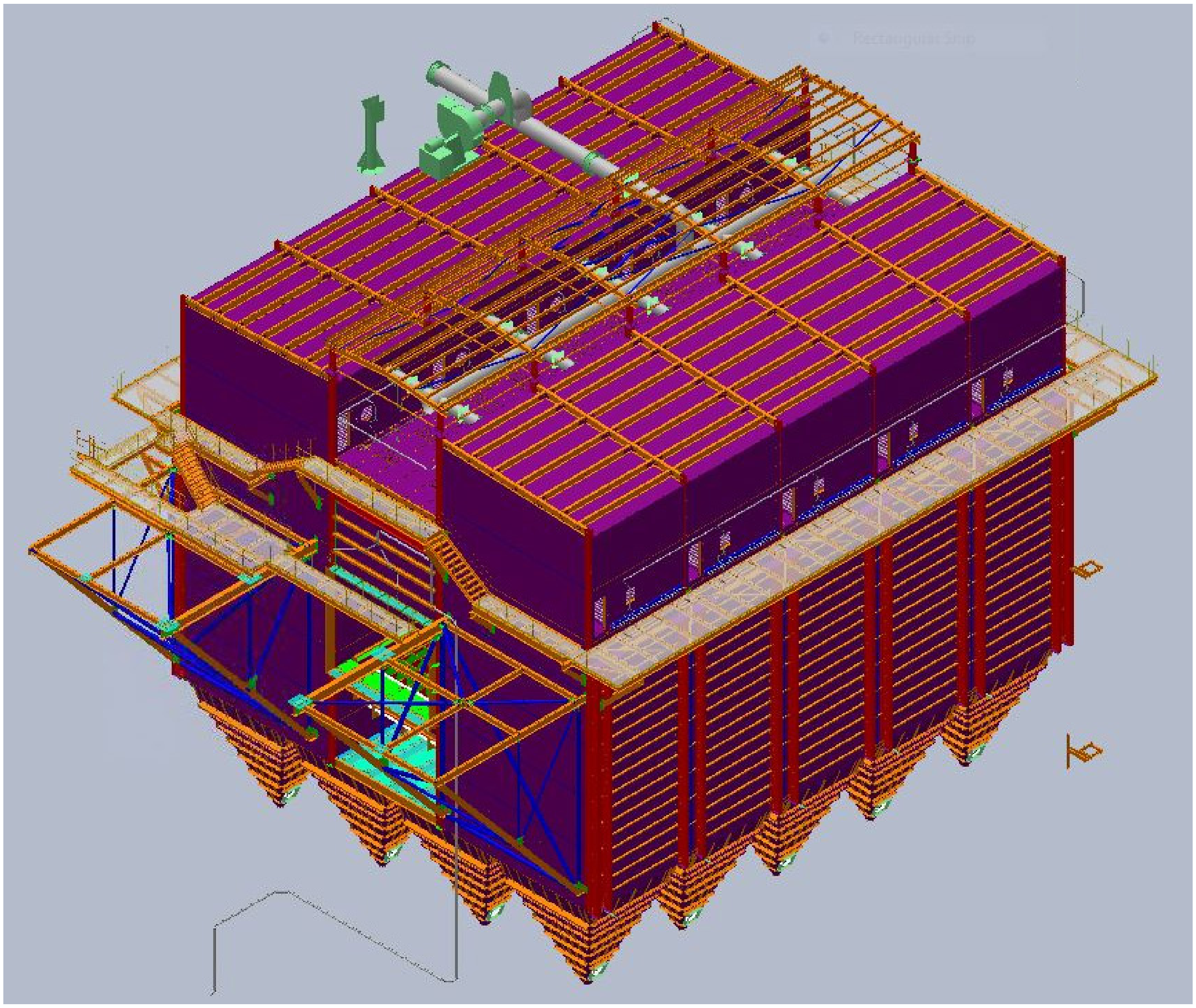

Figure 6 – Isometric view of a single PJFF.

Figure 7 shows the PJFF upper area sectioned to expose the area below the plenum roof elevation.

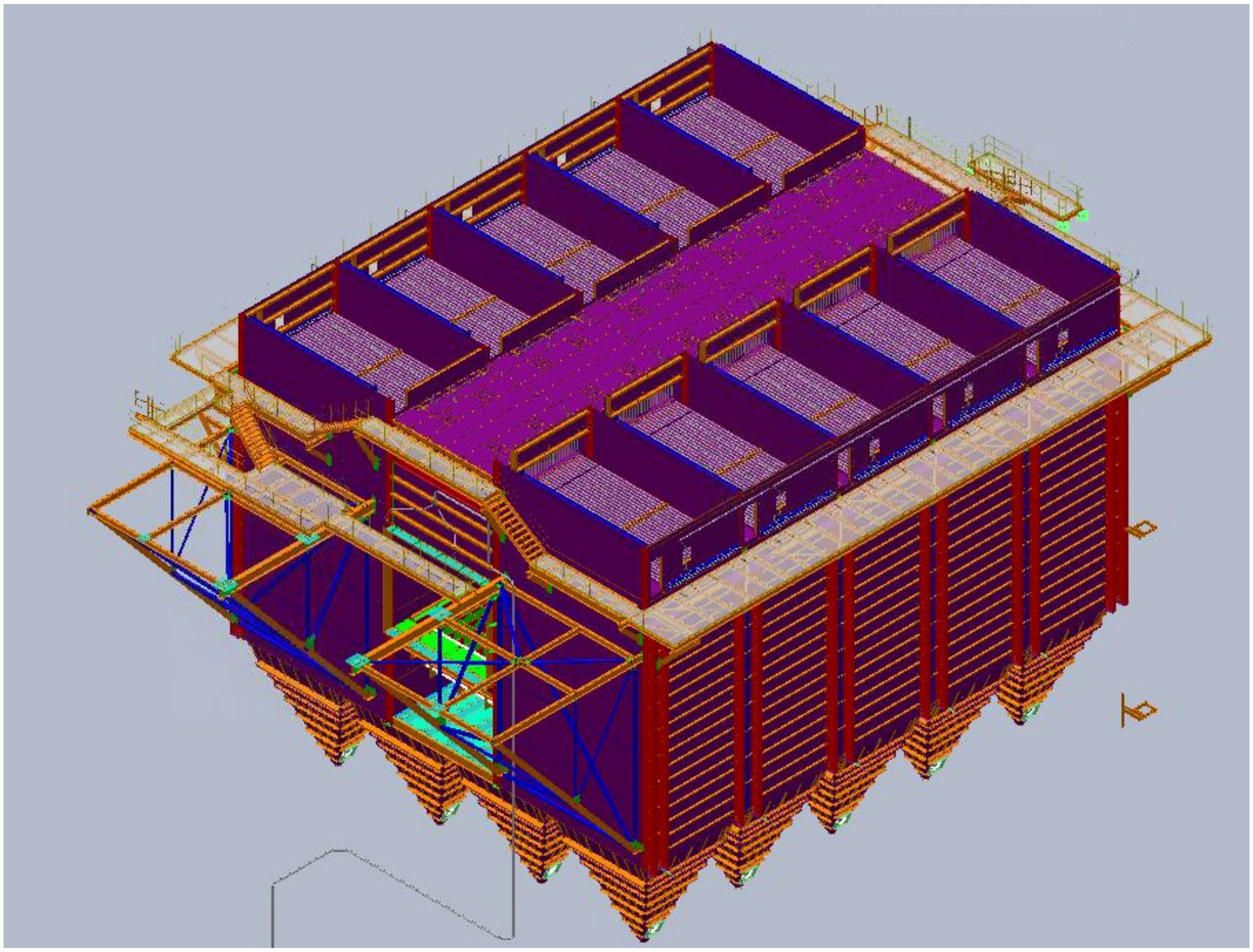

Figure 7 – Isometric view showing PJFF below roof elevation.

Tutuka PJFF Project Special Features

The Tutuka PJFF project included several unique features, including:

- A ventilation system was installed for cooling the compartments during maintenance.
- A dedicated system is used to precoat the filter bags and is installed at the inlet of the PJFF.
- A filter bag disposal chute was installed to allow removal of used bags from the upper external platform to a dumpster at grade level.

Tutuka CFD Optimization

The CFD model is a full-scale representation of the Tutuka PJFF system from the air heater outlet to the induced draft (ID) fan inlet. The wireframe model is shown in Figure 8. The CFD analysis was conducted using the fluid dynamics solver ANSYS® Fluent (v15). The 3D steady-state gas flow field was generated using the 2 equation K-epsilon realizable model with 2nd order discretization method.

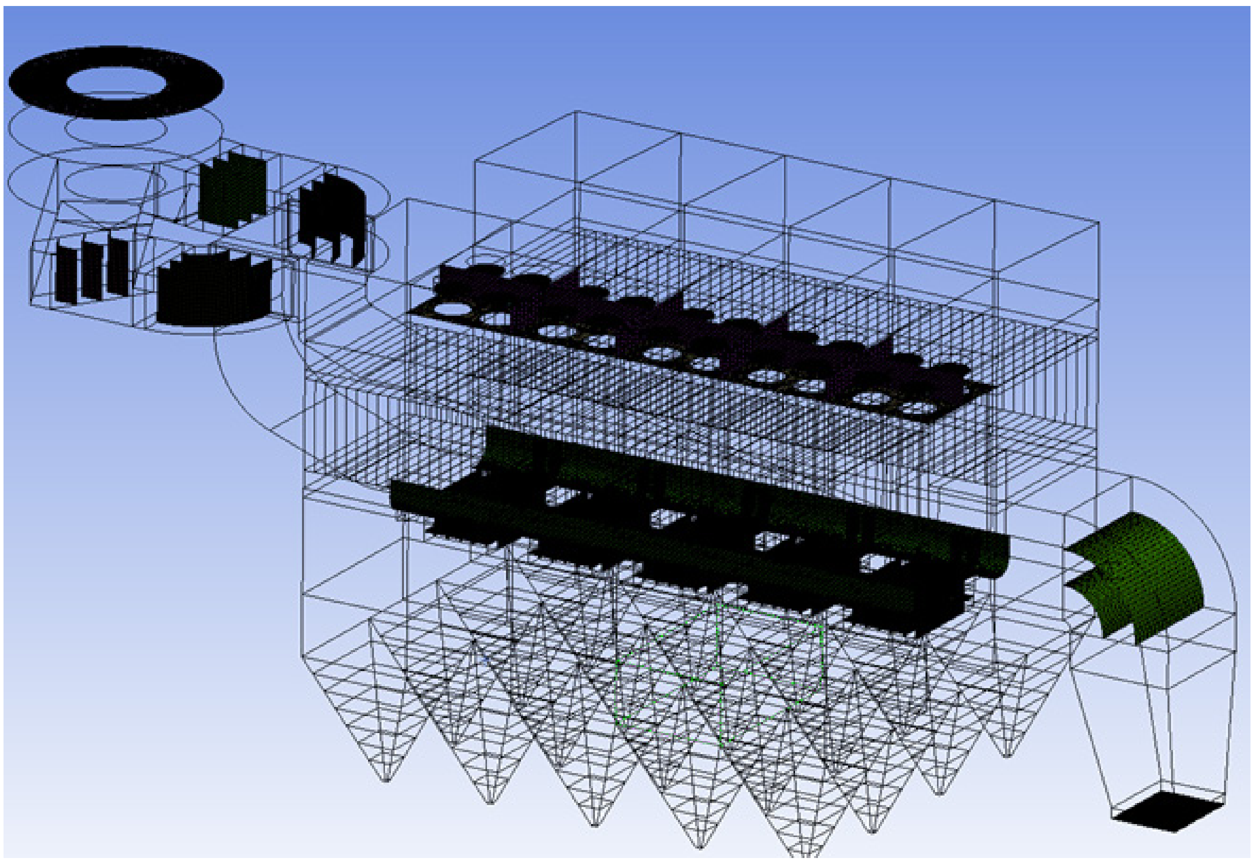

Figure 8 – CFD wireframe model of Tutuka PJFF.

The typical gas flow imbalance for a PJFF system with all compartments in service ranges from +/- 5%. The gas flow imbalance was optimized between +3.0 / -2.8%.

Controlling gas velocity within an individual compartment is critical for achieving ideal bag life. Figure 9 shows a mid-plane gas velocity profile as the gas velocity is reduced through the inlet nozzle. Figure 10 shows the gas velocity profile entering an individual compartment. Directional vanes are used vertically, spaced across the compartment width to aid in horizontal gas distribution, while turning vanes aid in vertical gas distribution.

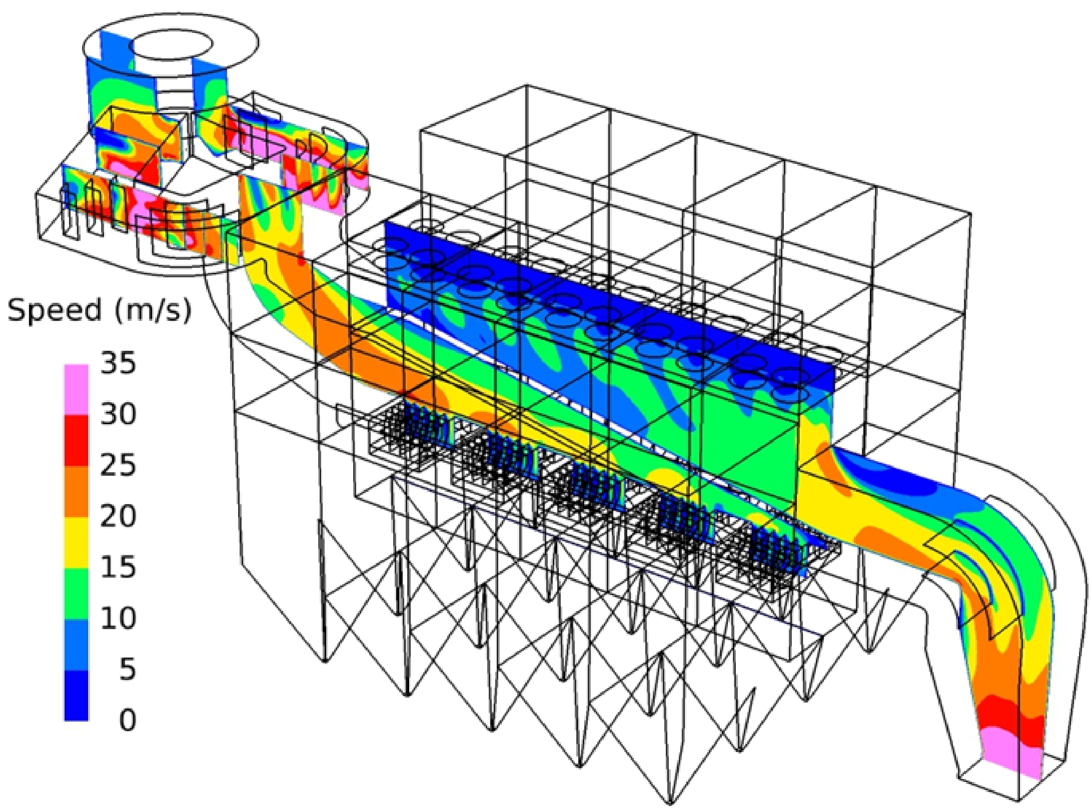

Figure 9 – Mid-plane velocity.

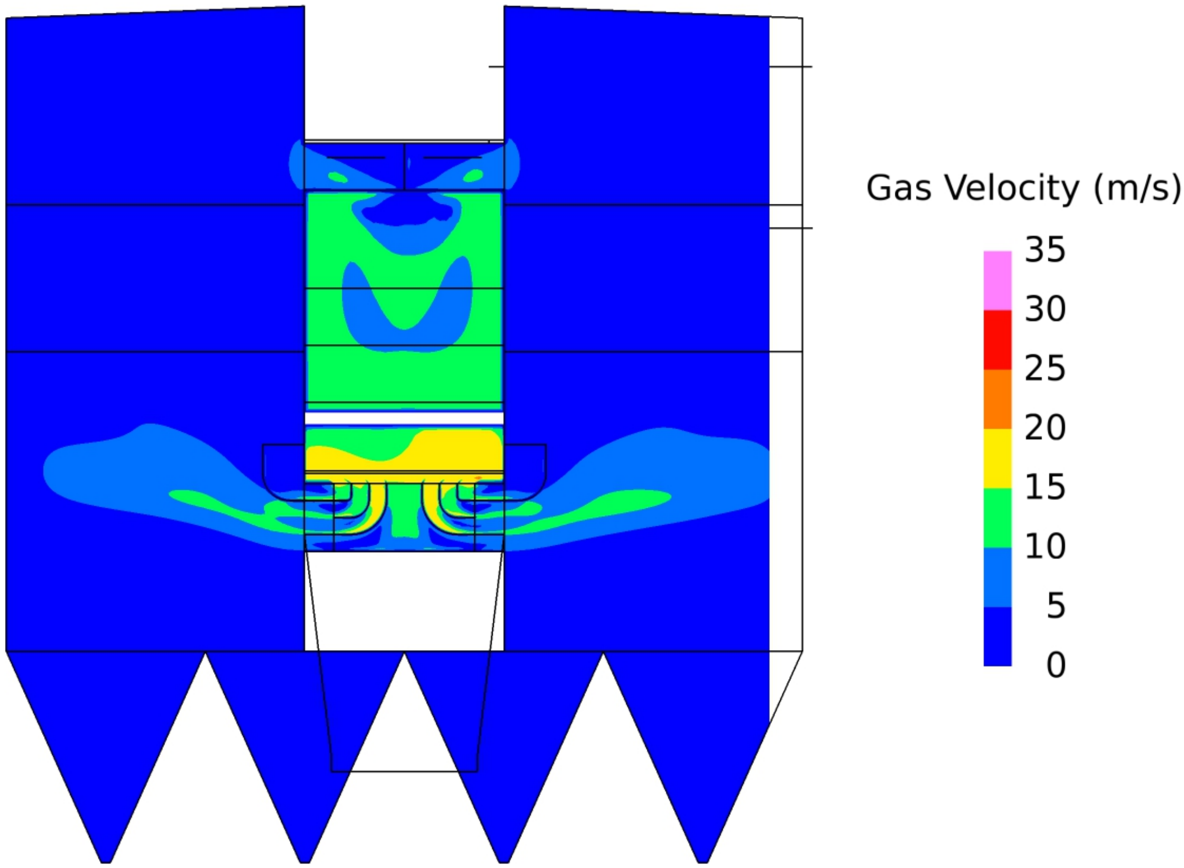

Figure 10 – Compartment CFD section velocity.

Existing Fan Capabilities

The existing ESPs are serviced by two centrifugal flow ID fans each having a flow capacity of 566 Am^3/s (actual cubic meter per second) at 3.8 kPa head. The PJFF will introduce additional system resistance which will need accounted for to maintain furnace pressure. Further, the units have deteriorated over time and coal quality has declined, requiring additional flow margin for the ID fans. The unit will therefore be upgraded to new axial flow fans with a flow capacity of slightly more than 700 Am^3/s at a pressure of 7.3 kPa.

The change from a centrifugal fan to an axial flow fan poses a construction challenge as the foundation requirements for the two types of fans differ quite considerably. Construction sequencing and erection methodologies had to be carefully evaluated so that the outage duration of 120 days is not compromised. Figure 11 shows the new ID fan arrangement superimposed on the existing foundation.

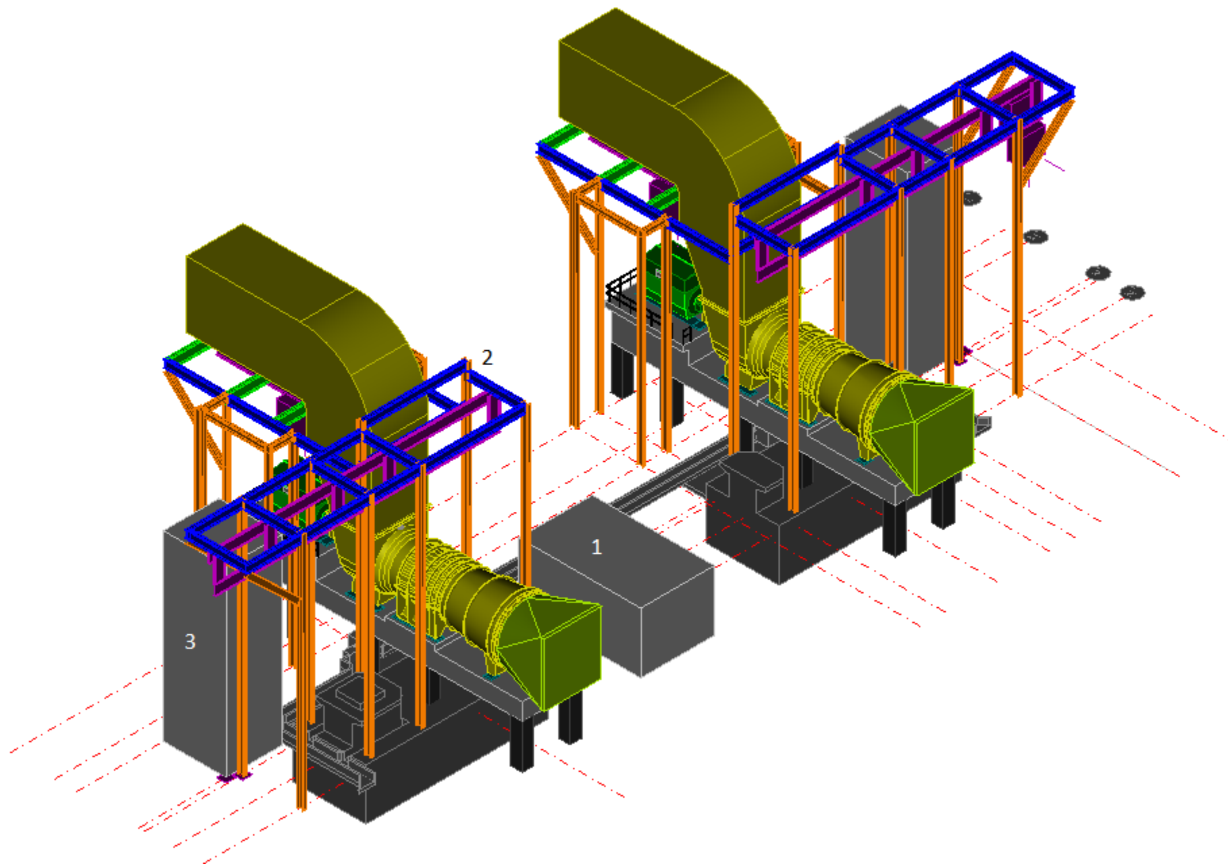

Figure 11 – New ID axial fan arrangement.

Economic Examination

Retrofitting an existing ESP with a modern state-of-the-art PJFF requires significant capital investment. For this reason, an evaluation was conducted prior to the design of the PJFF to verify the economic differences between building a greenfield PJFF compared to retrofitting the existing ESP. A new standalone PJFF was found to be 45% more expensive than a retrofit due primarily to the amount of excavation, civil work requirements, additional work and relocation of existing infrastructure. The economic evaluation did not include a benefit due to loss of production as other significant outage work needs to be carried out which would not result in a shorter duration of the outage to do the retrofit.

It was further evaluated to reuse as much of the existing infrastructure as possible to further minimize costs. The design was therefore adapted to reuse the current vertical walls of the ESP (additional stiffeners were installed) as well as the current support structure, foundation and stairways.

Conclusion

The project is currently in the final preparations to proceed to construction. The technology partnership between B&W and Eskom worked well and the two design teams delivered a quality design despite being challenged with geographical and time-zone constraints.

The foundation evaluation posed a significant risk to the reuse of the existing ESP structure and the teams successfully developed a solution to suit the current foundation.

The inlet duct to support the new central plenum to each of the PJFFs required an innovative design as the current inlet duct is cantilevered off the ESP casing. With its smaller cross-sectional area, the central plenum design also posed a challenge to properly distribute the loads to the foundation.

A thorough design approach was used to maximize the reuse of existing plant infrastructure to reduce overall project costs.