Fabric filter retrofits - an electrostatic precipitator upgrade technology

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Increasingly more stringent emission limits have required many electricity-generating utilities to upgrade existing electrostatic precipitators (ESP’s). Retrofitting pulse jet fabric filters into these small casings has provided a cost effective solution to Eskom. These fabric filters require a small “footprint” and emissions of less than 50 mg/m³ are sustainable and not as dependant on coal quality and up-stream conditions as is the case with ESP’s. This is an important consideration for Eskom because legislation requires load reduction or unit shutdown prior to contravening emission limits. A total of 7700 MW of Eskom’s plant has been or is presently being converted to fabric filters.

This paper provides an overview of one of these projects presently in progress at Camden power station on 6 x 200 MW boilers. These fabric filters have a unique 4 cell design allowing for on-load maintenance, bag changes and operating flexibility. Lessons learnt from previous projects and improvement in fabric material and construction through research will ensure that these advanced fabric filters are successful.

Traditionally, in the power industry throughout the world, ESPs have been used for the removal of particulate matter from coal-fired boiler flues. These ESPs have always been sized and designed according to the emission requirements at the time of power station construction. It follows, therefore, that as law has reduced emission limits over time, older power stations have found it increasingly difficult to meet these requirements.

In addition, limits governing the emission of harmful gasses have been introduced, and in many countries the emission of sulfur dioxide has been severely restricted. This has forced power stations burning high sulfur coal to switch to lower sulfur coals, and in so doing decreased the efficiency of the ESP. It should be understood that the design and sizing of an ESP is performed largely around the ash and sulfur content of a coal, and if these parameters change, so will ESP performance.

Affected power stations need to consider cost effective options for reducing the now increased particulate emissions. The first option initially is to simply increase the physical size of the ESP and enhance the electrical performance. However, this is costly, and does not guarantee that future requirements will be met in terms of particulate emission reduction.

Flue gas conditioning (FGC) has become another option, whereby the sulfur trioxide (SO₃) content in low sulfur coal flue gases is increased, thus enhancing the performance of the ESP. This has a significant effect in reducing the particulate emissions, provided the ESPs are of sufficient size, and the fly-ash particles respond well to the conditioning process. Smaller, older ESPs however, do not respond sufficiently well to FGC, and limited, if any, reduction in emissions is obtained.

In recent years, retrofitting the existing ESP casing with pulse jet fabric filters (PJFFs) has produced the most significant results in terms of particulate emission control. In all retrofit applications, a fly-ash removal in excess of 99.9% is obtained. This generally constitutes particulate emissions of less than 50 mg/m³ (0°C and 101,325 kPa), and visibly clear smoke stacks.

Initial problems were experienced in earlier PJFF retrofits in that the filtration material or fabric failed prematurely, which led to high operating costs and a reluctance to further utilise this technology.

However, in more recent times, and following extensive research, methods of fabric construction and fibre manufacture have improved. The life of filter bags has now been extended to the degree that operating costs of a PJFF compare more favourably with other technologies, and the benefits of a visibly clear smoke stack are guaranteed. Ongoing research and development into improved fabric for PJFFs worldwide suggest that further benefits will be seen in the future.

Design considerations

Needless to say, when retrofitting an ESP, various factors have to be taken into account. The...
condition and structure of the existing casing has to be ascertained and defects need to be rectified. Other design considerations include the following:

Flow modification

It is essential that gas flow be evenly distributed around the bags, and in such a manner that no high velocity streams of gas impinge directly on the bag surfaces. In addition, it must be decided on whether to implement a side or bottom gas entry or a combination of both.

Twenty years of experience with bag filters has yielded optimised gas flow distribution in the fabric filter. The benefits of proper gas flow distribution are increased fall-out of particulates before reaching the bags as well as minimal re-deposition of fine particles on the bags after pulsing.

Attemperation of flue gas

Should low temperature fabric be used for the filter bags, the flue gas may have to be cooled, using either dilution air, or evaporative cooling, to keep the temperature below the maximum allowed for the fabric in question.

Upgrading of induced draught (ID) fans

The differential pressure across a PJFF is considerably higher than across an ESP, and therefore it is usually necessary to increase the suction capacity of the ID fans in order to accommodate the additional load.

Implosion protection

The increased ID fan power required to compensate the higher differential pressure caused by the filter bags makes it necessary to protect the casing against implosion. Implosion dampers therefore need to be installed upstream of the ID fans, which will automatically open thereby relieving the casing of excess suction pressure in the event of an emergency.

Cross-over ducting and dampers

Should a section (say one cell) of the PJFF need to be isolated for any reason, the flue gas is then diverted to the other cells by way of the cross over ducting which links the left hand and right hand casings of the filter plant. The cross over damper may also be used to balance flows between left hand and right hand casings.

The retrofit of 6 X 200 MW coal fired boilers at Camden Power Station (South Africa) - a case study

Camden Power Station was built in the 1960s and the units were fitted with three-field ESP’s at the time except for units 3 and 4, which had two-field ESP’s with mechanical collectors (cyclones) upstream. The Station was placed in a state of preservation (mothballed) in the late 80s to early 90s.

Eskom decided to return these units to service in order to meet the increasing demand for Power in South Africa. In October 2004, Howden Projects was awarded a contract by Eskom to retrofit six ESP’s at their Camden power station with PJFF’s. Each of the six units has an output of 200 MW.

Apart from a “clear stack” emission requirement the Eskom specification called for a design to allow on-load re-bagging i.e. downtime is reduced and plant operational flexibility is improved.

Design

Filtration area

Although the six casings were different, based on gas flow, the correct sizing of the plant called for just less than 10 000 filter bags per unit, each eight metres long.

Flow distribution

A computational fluid dynamic (CFD) diagram was used to determine optimal flow into and around the bags. It is critical to eliminate areas of high flow velocity and to ensure that each bag is utilised for filtration. In addition to flow distribution the model considers the temperature profile in the inlet duct in order to reduce any temperature stratification caused by the operation of the rotating air heaters installed upstream of the filter plant. A typical result of the flow model is shown in Fig. 2.

Construction

The casings (Fig. 3) are all constructed of concrete, with approximate dimensions of 12 m wide x 16 m high x 21 m long. The existing structures are approximately 45 years old, and still in relatively good condition. Each ESP has two casings, and three electric fields per casing, except for units 3 and 4 which have two fields per casing.

Removal of ESP internals

The internal collecting plates and wires of the ESP were removed through the roofs, which were opened completely.

All internals were removed except for portions of the inlet screens.
Cutting of holes in the casing

In order to gain access to the casing, holes were cut in the sides of the casing (Fig. 5). Doors and viewing windows were fitted in the walk in plenum chambers. Viewing windows are used to inspect the clean side of the fabric filter during operation and to confirm that the rotating manifolds are working and the tube plates are free of dust.

Installation of tube plates and flow distribution baffles

Once access was gained through the roof, the tube plates from which the filter bags are suspended were installed, providing the barrier between the dirty and clean gas chambers. A set of flow distribution baffles (Fig. 6), were installed in positions determined by CFD flow modelling. In addition to the tube plates and distribution baffles, a dividing wall, spanning the dirty and clean sides, was installed effectively dividing the casing in two halves. A novel feature of the design is that the clean gas chamber (above the tube plates) was constructed of a steel plate shell thus eliminating the need for a problematic metal to concrete seal.

Ductwork modification

It was necessary to modify the outlet ducting in order to accommodate the clean gas chamber, and allow for space to install cages in the filter bags (Fig. 7). The original outlet ducting was then blanked off.

Installation of pulse jet cleaning system

The low pressure pulse jet cleaning system is the heart of the plant (Fig. 8). It comprises the blower plant, pulse tanks, diaphragm valve, rotating manifolds and associated pipe work. The blower plant is comprised of a number of Roots type blowers housed in a building at ground level. The old HV buildings, used to house the ESP controllers and switchgear, are typically modified to accommodate the blowers. These buildings are pressurised with filtered air mainly to keep the blower plant and switchgear clean.

Replacement of dust hoppers and dust removal system

The sections of the dust hoppers which were dis-assembled, and the “hydrovac” dust removal systems were both replaced. All hoppers were fitted with hopper heaters in order to keep the ash hot and fluid.
Installation of ID fans and cross-over dampers

As discussed earlier, upgraded ID fans were needed to cope with the increased differential pressure across the PJFF. Cross-over dampers were installed to allow on-line maintenance as well as flow balancing (Fig. 9).

Bag installation and pre-coating

Finally the bags were installed and pre-coated with lime (Fig. 10). The layer of lime on the bags protects the bags from the oil used for start-up and prevents the acid present in the flue gas from depositing on the bags.

Fig. 10: Installation of bags.

Conclusion

The first unit at Camden (Unit 7) was completed on schedule during September 2005 and worked flawlessly during hot commissioning. There were no visible emissions from the flue stack. Similar units at Hendrina are into the third set of bags since new and are also still running flawlessly.

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