THE CLEAN USE OF HIGH SULPHUR COAL: AN ADVANCED CFB SOLUTION

C.Harghel; S.Gabiccini (Enel Produzione, Italy)

O.Dinale (Enelpower, Italy)

M. Duprey; R. Hickey (Alstom Power Inc.)

1 INTRODUCTION

The energy market liberalisation, acting this period in Italy, is demanding reduced energy production costs while meeting environmental stringent requirements.

This paper describes the refurbishment of an old 240 MWe pulverised coal unit near Porto Scuso with a CFB boiler technology producing 340 MWe; it is being designed to fit within limited space requirements and to meet the strict emissions limits of local Sardinian environmental policies.

Enel Produzione, owner of the Sulcis Power Plant granted the construction of the new unit to Enelpower a company of Enel Group as Main Contractor and the international tender for the boiler supply was awarded to Alstom Power. The boiler will be based on the CFB technology. The boiler will be constructed and put into operation within 41.5 months and the commercial operation is expected for 46.5 months.

As the plant is located near the Sulcis coal mines, a large amount of mines' production will be burned in the new boiler. The Sulcis coal has particularly high sulphur content and the CFB technology was chosen as being the most adaptable, without the need for external flue gas desulphuration and denitrification. A fabric filter with a very high efficiency will be used for dust control.

The Sulcis project considers the environmental and occupational policies and melts them together with a high efficiency and availability of the plant and with optimised plant response to the electric grid requirements.

2 GENERAL PROJECT INFORMATION

In the new Italian power generation market, Enel Produzione is the main player with a total capacity of 38.900 MW with more than 65% of total production from fossil fuels (oil, coal and gas).

The Sulcis Power Plant was initially composed of three units equipped with pulverised coal boilers, The Sulcis Unit. no.1 and Unit no.2 have been dismantled in 1999 and the Unit no.3 is now producing 240 MWe. The unit no.3 is equipped with ESP dust control system, SCR for NOx emission reduction and FGD for SO2 control. As part of plant updating and emission control policies Enel Produzione decides to refurbish the Sulcis Unit no.2 with a new plant based on CFB technology. Figure 1 reports plant general arrangement.

Local occupational policies require that the Sulcis mines production be increased resulting in the increased consumption of the Sulcis coal. The Sulcis coal is typically a high sulphur content coal (up to 8%, average 6%), high volatile (average 38%) and high ash content (average of 17%). Because of the coal characteristics and the stringent emissions limits imposed by the authorities in the Sulcis area, it was determined that the best technology for the new plant would be circulating fluidised bed technology.

Alstom Power was the winner of the international tender for the boiler delivery. Alstom has studied the available space in order to place the new CFB boiler in the same area occupied by the demolished boiler, which requires great accuracy in the lay-out of the boiler. The same accuracy was required of the Main Contractor (Enelpower) for boiler auxiliaries positioning (for example: fabric filter, air and flue gas fans, coal crushers, hot and cold ash conveyer system).

The boiler will be the largest of this type in the world with a production of 1026 t/h (2,261,940 lb/hr) of superheat steam at 565°C (1050°F) and 169 bar (2450 psi) and 836 t/h (1,843,062 lb/hr) of reheat steam at 580°C (1075°F). These high outlet temperatures result in a high efficiency plant cycle. Guaranteed efficiency value for the new power plant will be about 40%. All components in the balance of plant will be involved in a complete refurbishment.

Figure 1 Sulcis Power Plant Arrangement. (New unit - red)

The main cycle balance of plant is composed of four low pressure heat exchangers (single line), and four high pressure heat exchangers (double line). New steam turbine and generator will be provided.

The new boiler will have the ability to burn various types of coal. The basic boiler design was predicated on burning Sulcis and South African coal mixtures. The coal will be mixed at the coal disposal area and delivered to the 5 coal silos within the existing coal conveyor system. Some modifications will be made to the coal transporting system in order to assure the required availability for the two units. Under the existing silos will be positioned the new crushers and new coal and limestone supply systems. The limestone will be supplied at the fineness required for the optimum sulphur capture in the boiler and stored in dedicated silos with 6000 cubic meter (64,550 cubic feet) capacity, in an existing dedicated area. A pneumatic line and a drying system, with line and fan redundancy, will be available for boiler continuous limestone supply.

The hot ash from the boiler bottom collecting will be extracted by means of 7 screws, cooled by a dedicated water-cooled closed loop. Heat extracted from the closed loop is recovered in the main condensate with 2x50% heat exchangers placed before the low pressure heat exchangers. Heat dissipated by the generator is recovered by a hydrogen heat exchanger. After the bottom ash is cooled, it is transported by the ash conveying system, milled to reach the fineness of the fly ash and conveyed with the fly ash to the ash extractors and to the ash collecting silos. The fly ashes will be collecting within a high efficiency fabric filter. The dust concentration in the flue gas at the filter outlet will be lower than 30 mg/Nm^3.

Particular attention has been given to the water balance of plant. The plant is provided with a water production system that produces demineralised water from sea water. In order to optimise the water usage in balance of plant the blowdown system will be connected to the industrial water tank and all the released water will be conveyed to the existing water treatment plant.

The general CFB and auxiliaries diagram is reported in Figure 2. The main parameters nominal values can be found in Figure 3, referred to a coal mixing of 80% (thermal input percentage) of South African coal and 20% of Sulcis Coal.

1. Combustion Chamber
2. Cyclons
3. Convection pass
4. FBHE
5. Coal silos
6. Limestone Silos
7. Air Heater-Ljungström
8. Fabric Filter
9. Chimney

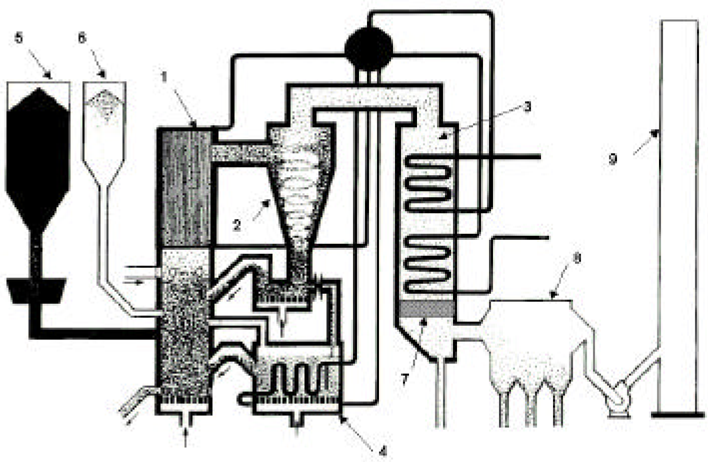

Figure 2 General CFB and auxiliaries diagram

Power Plant	
Mix coal consumption, Nominal outlet	119 t/h
Boiler efficiency	93%
Plant net efficiency	40 %
Boiler e thermal cycle	
Boiler inlet temperature	295 °C
Maximum superheated steam	1026 t/h
Inlet pressure HP turbine	168.6 bar
Maximum reheated steam	835 t/h
Inlet pressure MP turbine	39.4 bar
Superheated steam outlet temperature	565 °C
Reheated steam outlet temperature	580 °C
Generator	
Nominal power output	340 MW
Voltage	20 kV
Flue gas cleaning	
Desulphuration degree (in boiler)	95%
Maximum limestone consumption	14.1 t/h
Dust removal efficiency	99.9%

Figure 3 Main technical parameters for nominal boiler condition, burning 20% of Sulcis coal

2.1 Boiler design

Fluidised bed combustion has inherent environmental benefits. Sulphur dioxide is captured in-bed by adding limestone which allows flexibility to burn coals with a wide range of sulphur content while achieving sulphur reduction exceeding 95%. As the combustion temperature is lower than typical temperatures reached in pulverised boiler technology, about 865°C (1590°F), low emission values for thermal NOx can be obtained. The combustion air system is designed in such a way that NOx emissions are reduced to under 200 mg/Nm3 (dry, 6%O2), or 0.16 lb/Mbtu.

The boiler was designed to burn up to 100% of Sulcis Coal with 8% sulphur content, having also the capacity to burn a multitude of other coals. The design performance of the boiler has been studied for four coal mixtures between Sulcis and South African coal (100% Sulcis, 20%Sulcis and 80%South African, 50%Sulcis and 50% South African, and 100% South African) in order to allow wide operational limits of the boiler. The Sulcis and South African design coal analyses are reported in Figure 4.

The Unit will be equipped with five fuel trains, one for each coal silo, with each one connected to a coal crusher. The fuel trains discharge through a double dump valve and fuel feed isolation valve into the furnace. In order to have the required redundancy only four fuel trains are required for operation at maximum boiler load. Start-up burners, using secondary air as combustion air, preheat the CFB furnace up to the solid fuel firing temperatures, approximately 650°C (1200°F).

The limestone will be fed into the boiler by a pneumatic system made up of rotary feeders, blowers and conveying pipes.

The main combustion air is made up of primary air introduced through a plenum assembly located at the bottom of the refractory covered furnace section. The remaining combustion air enters the combustor through secondary air ports located 915 mm and 4783 mm (36 inches and 188.3 inches) above the plenum. A small portion of combustion air is introduced into the seal pots and used for fluidising at that location.

As different pressures are required for primary and secondary air, two different fans are necessary. The air distribution in the boiler is designed to maintain the NOx and CO emission values below the guarantees, 200 mg/Nm3 (dry, 6%O2) and 150 mg/Nm3 (dry, 6%O2) respectively (0.16 lb/Mbtu NOx and 0.12 lb/Mbtu CO). The lower furnace temperatures of this CFB technology (865°C or 1589°F), compared to conventional pulverised coal technology (typically about 1700°C or 3100°F), allows for the greater reduction in NOx emission values.

A regenerative type air/flue gas heat exchanger, trisector type, is provided in order to perform the primary and secondary air heating. Gas outlet temperatures will be reduced to 130°C (266°F), resulting in high boiler efficiency and allowing for normal operation of a fabric filter positioned downstream of the regenerative airheater.

The solids entrained by the combustion gases leaving the furnace enter high efficiency cyclones where over 99% of solids are captured. These cyclones divert the solids downward into a stand pipe, through an air fluidised refractory line seal pot back to the furnace. The heat is extracted from the solids recirculating loop by two external FBHEs (Fluidised Bed Heat Exchangers). FBHEs provide a means of maintaining optimum performance while burning different fuels and different fuel combinations. Solids flow through each FBHE and are controlled independently by the use of ash control valves located at the seal pot under the cyclones. The flow control capacity is critical not only in the burning of multiple fuels, but also during partial load operation. As final reheater is placed in one of the FBHE, the solids flow control allows for the minimisation of the reheater spray water flow. The second FBHE contains economizer heat transfer surface. The primary and final superheater, primary reheater and final economizer are positioned in the convection back pass.

Bottom ash is discharged from the furnace bottom and enters water cooled ash screw coolers (ASCs). The ASCs reduce the furnace bottom ash temperature to approximately 100°C (212°F). A dedicated water cooling close loop will be provided in order to recover the ash heat into the main cycle.

As a large part of the boiler is refractory lined, particular attention will be made to the supply and installation of the refractory material.

Proximate analysis (%in weight)	Sulcis coal	South African Coal
Humidity (%)	11.52	8.00
Ash content (%)	17.33	15.00
Volatile matter (%)	38.87	23.00
Fixed carbon (%)	33.09	54.00
Ultimate analysis (% in weight)		
Carbon	53.22	65.88
Hydrogen	3.89	3.71
Sulphur	5.99	0.55
Nitrogen	1.29	1.50
Oxygen	6.76	5.36
Ash (%)	17.33	15.0
H2O –total(%)	11.52	8.00
LHV (MJ/Kg)	20.83	24.79

Figure 4 Sulcis and South African coal proximate and ultimate analysis

2.2 New Turbine and Generator

The new steam turbine and generator will be designed to meet the required feedwater temperature and the superheater and reheater steam temperatures. The existing turbine design, characterised by the separation of the high pressure inlet and the medium pressure inlet will be maintained in order to avoid stress temperatures to the turbines inlet.

The steam extraction tubes to the high pressure heat exchangers, to the deaerator and to the low pressure heat exchanger LP1 will have no control valve. Control valve for flow regulation purposes will be provided on the steam extraction to the low pressure heat exchangers LP2 and LP3. The use of this valves will be combined with the use of the condensate control valve for primary frequency control purposes.

2.3 Boiler balance of plant

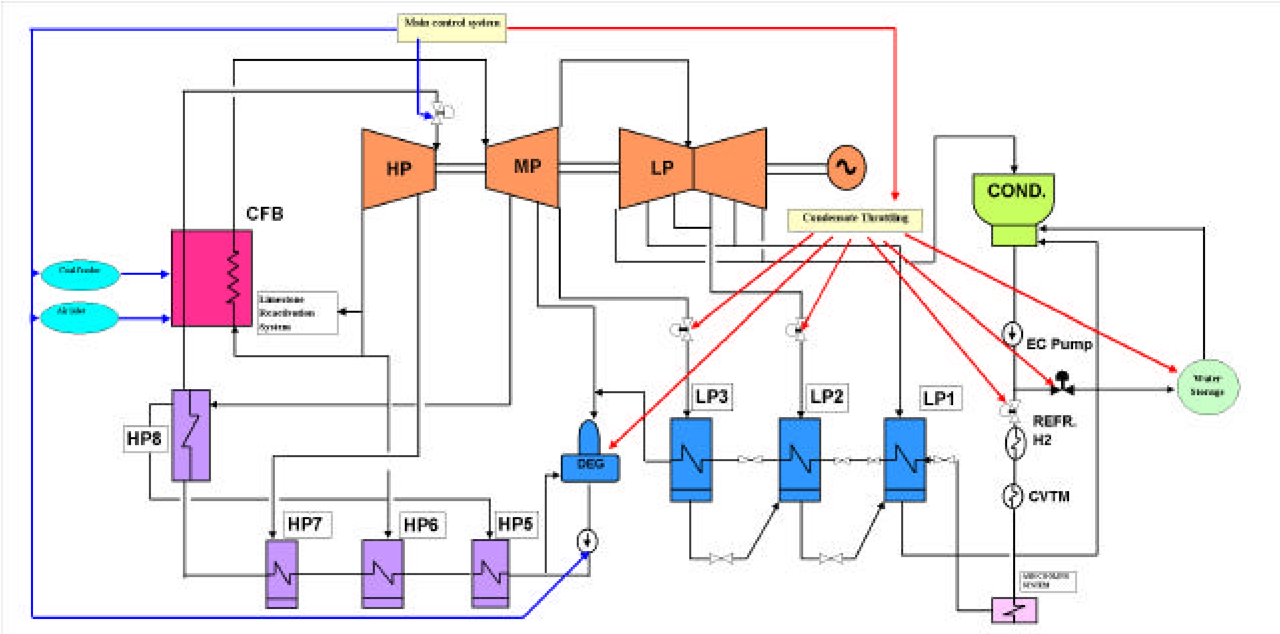

Figure 5 Sulcis general balance of plant with frequency primary control diagram ("Condensate Throttling" method combined with turbine valve control)

All low pressure and high pressure heat exchangers will be new and they will be designed in order to meet the feedwater characteristics required by the boiler. In Figure 5 is reported the new plant balance diagram. Some auxiliary devices, such as feedwater pumps and sea water to condenser pumps will be reused after brief maintenance activities.

2.4 Plant response to frequency grid dynamics

In order to avoid the persistent turbine control valve movement in case of load increasing request by the electrical grid the "condensate throttling" solution was chosen together with turbine valve load control.

When higher load is required to the plant, no movement of the turbine valve will occur if the frequency variation is turning back to nominal condition in a short time. In this case the control valves placed on the low pressure heat exchangers LP2 and LP3 turbine steam extraction lines close and the condensate flow rate will be reduced. The condensate flow will be deviated from the extraction pumps outlets to the external water storage and the steam not directed to the heat exchangers goes through the lower turbine stages producing more load.

Closing the steam extraction valve and reducing the condensate flow rate it is possible to increase up to 5% the nominal power load and to maintain it for about four minutes. This method avoids the control system requires more coal by means of coal crusher velocity control system. That means a more stable and smoother operation and lower fuel overshot.

Figure 5 shows the primary frequency control diagram.

2.5 Erection scheduling

To reduce on-site construction time a number of major boiler components will be preassembled and the erection schedule was studied in order to reduce the site activities.

The foundation erection was begun at the beginning of 2002. The completion of the erection activities is expected for mid 2004. Figure 6 and Figure 7 report the erection on-site activities at the beginning of 2002.

The project milestones include:

- Start commissioning August 2004
- First fire of the boiler September 2004
- Initial operation /turbine synchronisation October 2004
- Commercial operation February 2005

Figure 6 Working to Boiler Foundation in progress at the beginning of 2002

Figure 7 Working to Boiler Foundation in progress at the beginning of 2002

3 CONCLUSIONS

As some important quantities of coal are available in the South West Sardinian coast and the environmental requirements are more and more stringent, the Sulcis project, described above, has as its main purpose the reduction of the total emissions in the Porto Scuso industrial area.

The project foresees for the 240 MWe Unit n° 2 of the Sulcis Power Plant, originally equipped with a conventional pulverised coal boiler, a complete rehabilitation by installing a CFB boiler equipped plant, new steam turbine and generator and substitution of main BOP components (auxiliaries, heat exchangers, etc).

The nominal electrical power output will be of 340 MW. The Sulcis Unit n° 2 will be the biggest plant in the world equipped with fluidised bed with an estimated plant life higher than 25 years, from commercial operation start up. The capacity of the plant to burn up to 50% of local Sulcis coal will allow mining activities growth with expected increase of employment in the Porto Scuso area.

As the Sulcis coal is a typical high sulphur (6-8% sulphur content) and high ash coal, a circulating fluid bed boiler has been selected to be the best solution. SO_2 and NO_x emissions limits of 400 mg/Nm^3 (0.32 lb/Mbtu) and 200 mg/Nm^3 (0.16 lb/Mbtu) will be met without any back-end emission control technologies. CFB boilers achieve these low emission levels by burning coal or other solid fuels at relatively low combustion temperatures, which allows SO_2 capture via limestone while minimising NO_x formation. For the particulate collection a fabric filter will be employed to meet a 30 mg/Nm^3 (0.24 lb/Mbtu) emissions limit. Particular attention will be paid to water plant consumption.

The high plant efficiency, about 40%, will be obtained using the FBHE technology for having high steam temperatures, recovering the heat from the bottom ash and from the generator release.

The plant design foresees redundancies for the main components in order to achieve high plant availability. “Condensate Throttling “system will be used to obtain more stable operation condition