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executive summary

Retrofitting lignite plants to improve efficiency and performance

The worldwide lignite power industry faces an unprecedented challenge to generate electricity efficiently and cleanly against a background of ever tightening emission legislation. Modern high efficiency low emission (HELE) lignite power plants can approach the performance of hard coal electricity stations. However, typical low-cost power generation utilises raw lignite feed and subcritical steam boiler technology. The lignite fleet has stations up to 60 years old with an average efficiency of about 28% (40% for HELE plants). Nevertheless, lignite power is an essential supplier in many countries and outdated plants must be upgraded to meet current and future standards. The industry exhibits two distinct trends: construction of new stations in developing countries, which require an increase in generating capacity where alternate sources are of high cost; while in mature economies lignite power competes against renewable energy sources resulting in underperforming stations being re-assigned to reserve supply.

The latest acid gas emission limits present a significant challenge to existing plants; typical current limits of 200 mg/m^3 are under review. For example, China has set limits of 100 mg/m^3 NOx for stations up to twelve years old. Mercury is now on the list of regulated flue gas components; furthermore, new stringent limits have been set for fine particulates. To comply with the USA Clean Power Plan, in addition to lowering emissions, a network of generators must show higher efficiency, achieved either by plant upgrades or by closure of coal generation.

New lignite plants are designed with the recognised 'best available technologies' that include: selective catalytic reduction (SCR), particulate bag houses, carbon injection and flue gas desulphurisation (FGD). These adaptations may not be appropriate to retrofit long running plants due to lack of space, high cost and plant outage duration. A potential efficiency upgrade from sub to super or ultra-supercritical (USC) steam systems is unlikely to be implemented for these reasons; for example, in China small subcritical plants have been replaced entirely by larger capacity USC boilers combined with the latest emission treatment.

Suitable retrofit technologies seek to extend the operating lifespan by 10 to 15 years through improved performance and reduced emissions. Typical plant modification involves either: the replacement of aged equipment; selection of technologies that straightforwardly add to existing plant; fitting treatment methods of lower cost than mainstream technologies and require a short outage time for installation.

A US power plant review concluded that plant alterations with the most impact on overall efficiency are lignite beneficiation and steam turbine replacement. Other options to improve plant operation include: modern control systems and improved wireless instrumentation; smart antifouling methods; and replacement of aged pumps and ID fans. The optimum upgrade package will be dependent on national regulations and vary for individual plants.

Lignite benefication has been extensively investigated; fluidised bed pre-drying utilising low-grade heat streams is currently the most promising technique. Established plants in Germany (RWE/WTA) and the USA (GRE/DryFining™) show efficiency gains of several percent dependent on the degree of dryer integration. The two technologies differ in that WTA is designed for wet lignite (>60% H_2O) while DryFining™ (~35% H_2O) also

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possesses a segregation step that partially removes dense minerals containing sulphur and mercury, alleviating downstream treatment.

Steam turbines demonstrate energy losses of 3% to 4% over a period of 20 years, while new designs incorporating contoured and extended blades offer improved durability and higher efficiency. Steam turbine replacement can now utilise existing casings reducing the installation time and has become the most common retrofit efficiency improvement.

Alternatives to mainstream effluent treatment combine a set of technologies to match SCR/FGD performance and include hybrid and multicomponent systems to reduce the emission of acid gases and other pollutants. Suitable retrofit technologies may be of relatively low initial investment cost but consume higher levels of reagents.

To match the efficiency of a new SCR NOx unit, hybrid systems incorporate low NOx burners (LNBs) and selective non-catalytic reduction (SNCR) technologies. Originally conceived as an ammonia slip trap 'compact SCR', at one quarter scale, can match the full SCR performance but fit into existing piping. An ozoniser forming part of a hybrid system that oxidises rather than reduces NO can achieve lower levels of NOx than SCR, and can also oxidise mercury to soluble HgO.

Muti-component technologies remove several contaminants in a single device. Airborne™ utilises sodium bicarbonate (SBC) which reacts with both acid gases to outperform SCR+FGD. Novel regeneration of the SBC to produce fertiliser overcomes previous economic barriers. The 'Clean Combustion System' is a gasifier 'add-on' hybrid reactor, which adapts an existing boiler to create reducing conditions, thus preventing the formation of NOx. Furthermore, sulphur forms molten sulphides which are removed prior to the boiler section, especially attractive for processing high ash fuels. This technology has the potential to essentially replace an effluent treatment plant.

The introduction of more efficient technologies beneficially impacts upon the carbon footprint of a lignite station. Alternative measures to lower CO_2 emission include the use of co-feeds with a lower carbon profile such as natural gas and biomass. Due to the advantaged feed cost, lignite plants have been selected as the test ground for carbon capture, utilisation and storage technology (CCUS), currently applied at the Boundary Dam project in Canada. An aged 115 MW subcritical plant has been adapted to incorporate an amine CO_2 capture plant; the carbon dioxide used for enhanced oil recovery.

For countries implementing renewable energy, lignite plants will need to respond to a variable load range. The primary aim of flexibility measures is to maintain the reactor in a 'hot' state to minimise the time needed to bring the plant fully on-stream. Flexible plant options include: energy storage; indirect lignite firing; and integrated gas cogeneration.

In regions of low natural gas cost, the combination of a gas turbine and lignite plant can maintain the lignite boiler at readiness (using waste heat), enhance overall capacity and allow early synchronisation to the grid. Alternatively, a hot water reservoir can be introduced to even out the effects of capacity load variation on the steam system.

The technologies outlined offer a range of options to improve plant efficiency, flexibility and emission. The significance of these technologies, specifically for plant retrofits has become increasingly relevant due to recent exacting legislative standards.