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POWER PLANT DESIGN AND MANAGEMENT FOR UNIT CYCLING

The integration of variable and intermittent renewable energy (VRE) such as wind and solar into electricity grids means that coal-fired power plants must adopt new operating regimes to balance fluctuations in power output from these sources. The growing role of VRE has become central to the energy policies of advanced economies, especially in the EU, but it is also relevant to the United Nations Sustainable Development Goals (SDGs) which support energy development in emerging economies. Goal 7 promotes affordable and clean energy and encourages the development of more sustainable energy sources in the form of VRE. It includes advanced fossil fuel technologies such as HELE (high efficiency, low emissions) coal plants which can be operated in flexible mode to provide adequate back-up baseload and dispatchable power which is vital to support deployment of VRE. Flexible coal-fired power plants, in addition to other options such as grid and demand-side management, can ensure the stability of the electricity grid.

There is no 'one-size-fits-all' solution to make a coal-fired power plant flexible. This is because the flexibility requirements vary between different power plants, depending on grid characteristics, electricity market design and cost factors. For some, achieving low minimum load is important while, for others, it is all about fast start-up and rapid load ramp rates. A range of operations in which a power plant's output changes, including starting up and shutting down, and load following is known as plant cycling.

Flexible plant operation can have a significant impact on all areas of a coal-fired power plant due to the increase in thermal and mechanical fatigue stresses in various parts which, together with other effects, often occurring in synergy, reduce the lifetime of many components. Unit heat rate reduction is another detrimental effect, along with higher auxiliary power consumption and corresponding specific CO_2 emissions . Additionally, when there is a high penetration of VRE to the electricity grid, the operating costs for fossil fuel-fired plants can increase by 2–5% on average.

The flexibility of existing power plants can be improved in various ways, including: retrofitting new technologies, modifying existing, or adopting new, operating procedures and staff training. Usually, improvements start with upgrading of the instrumentation and control systems as they behave differently during full load and part load operation. These upgrades improve accuracy, reliability and speed of control, and, as the most cost-effective way to increase plant flexibility, should be a precondition for other measures. However, for older power plants with a limited remaining service life, it may not be viable to retrofit new systems, so their flexibility can be improved by plant management strategies. These include maintenance strategies and adoption of new, or modification of existing, operational practices.

One flexibility requirement is the ability of a plant to operate at low minimum load, as this can minimise the number of shut-downs required, which in turn reduces the impact on plant component life and lowers operating costs. A minimum load of only 10% is possible if various measures are implemented, as demonstrated by some plants in Germany. Although low minimum load can be achieved in many ways, ensuring stable combustion is key. This requires the deployment of measures including optimisation of coal fineness and air/fuel flow; indirect firing; changing the size and number of mills; and reliable flame monitoring.

Start-up procedures are complex and expensive as they usually require auxiliary fuel during ignition of the burners. Shortening start-up time and the ability to ramp up rapidly ensure a quick response to changes in market conditions. This can be achieved by several measures including: reliable ignition, integration of a gas turbine, reducing the diameter of thick wall boiler components such as headers, or including more headers, cleaning deposits from the boiler and turbine: advanced sealings, turbine bypass and internal cooling. Many of these improvements aid high ramp up rates. Other measures include exploring mill storage capacity, condensate throttling, and the use of an additional turbine valve.

The performance of emission controls can also be affected by flexible operation, mainly due to the temperature of the flue gas which changes with the cycling regime. Hence it must be maintained at the required level, particularly for NOx controls. This can be achieved in several ways. For example, by using an additional heater for the flue gas prior to the selective catalytic reduction (SCR) inlet. In selective non-catalytic reduction (SNCR), the use of multiple zones of injection and the ability to take injectors in and out of service as needed, ensures the required performance. For flue gas desulphurisation (FGD), the number of shut-downs and start-ups needs to be minimised to avoid slurry solidification and accumulation of start-up fuel oil residues on linings, as well as averting long warm-up periods. Particulate matter (PM) controls usually cope well with flexible operation conditions providing that the flue gas temperature does not fall below 90°C.

A high proportion of on-load failures originate from preventable damage caused during off-load periods. The risks are higher for cycling units as frequent start-ups/shut-downs and standby periods disrupt the physical and chemical conditions within the water/steam circuit, leading to corrosion and other damage during standby. Thus, proper preservation of the all water-steam circuits is essential and can be achieved by various methods, which should be selected based on the plant's individual characteristics.

Designers of new plants have an opportunity to include flexibility requirements in their design. For example, the use of new advanced materials for thick-wall high-pressure components such as headers, or designing them based on a shorter baseload operational life have been shown to reduce life consumption during rapid cycling. The designers of new power plants, however, may face a conflict between flexibility and efficiency, both with added expense.

The technologies described in this report enable coal plants to extend their dynamic capabilities as flexible back-up to VRE and their deployment results in the maximisation of the environmental benefits of VRE integration, and the minimisation of any offset which may result from reduced plant efficiency and increased cycling cost.

Each executive summary is based on a detailed study which is available separately from www.iea-coal.org. This is a summary of the report: Power plant design and management for unit cycling by Dr Malgorzata Wiatros-Motyka CCC/295, ISBN 978–92–9029–618-8, 94 pp, August 2019.