Gas-Fired Power

HIGHLIGHTS

- **PROCESS AND TECHNOLOGY STATUS –** Approximately 21% of the world's electricity production is based on natural gas. The global gas-fired generation capacity amounts to 1168 GW_e (2007). In Europe, the total electricity generation capacity is about 804 GW_e, of which 22% is based on natural gas. In the United States, the total capacity is about 1039 GW_e, with 400 GW_e based on natural gas. There are two types of gas-fired power plants, viz. open-cycle gas turbine (OCGT) plants and combined-cycle gas turbine (CCGT) plants. **OCGT** plants consist of a single compressor/gas-turbine that is connected to an electricity generator via a shaft. They are used to meet peak-load demand and offer moderate electrical efficiency of between 35% and 42% (lower heating value, LHV) at full load. Their efficiency is expected to reach 45% by 2020. **CCGT** is the dominant gas-based technology for intermediate and base-load power generation. CCGT plants have basic components the same as the OCGT plants but the heat associated to the gas-turbine exhaust is used in a heat recovery steam generator (HRSG) to produce steam that drives a steam turbine and generates additional electric power. Large CCGT plants may have more than one gas turbine. Over the last few decades, impressive advancement in technology has meant a significant increase of the CCGT efficiency by raising the gas-turbine inlet temperature, with simultaneous reduction of investment costs and emissions. The CCGT electrical efficiency is expected to increase from the current 52–60% (LHV) to some 64% by 2020. CCGT plants offer flexible operation. They are designed to respond relatively quickly to changes in electricity demand and may be operated at 50% of the nominal capacity with a moderate reduction of electrical efficiency (50–52% at 50% load compared to 58–59% at full load). In general, because of the lower investment costs and the higher fuel (natural gas) cost vs. coal-fired power, CCGT plants are lower in the merit order for base-load operation, although the competition also depends on local conditions, variable fuel prices and environmental implications.
- **COSTS –** Due to the high price of materials and equipment and the increasing demand for new CCGT plants, the investment cost of CCGT power plants has been increasing almost continuously from some \$800/kW_e in 2002 to \$1100/kW_e in 2009 (costs quoted in 2008 US dollars). At present, if compared with the 2008 peak cost, the CCGT investment costs might be slightly declining because of the reduction of material costs and the low demand for new capacity due to the ongoing economic crisis. While technology learning is not expected to significantly reduce the investment cost of mature technologies, technical developments in CCGT plants may still drive cost reductions from today's \$1100/kW_e to \$1000/kW_e in 2020, and to \$900/kW_e in 2030. The investment cost of OCGT plants is approximately \$900/kW_e. Modest cost reductions are also expected for OCGT plants, namely \$850/kW_e in 2020, and \$800/kW_e in 2030. The annual operation and maintenance costs of CCGT and OCGT plants are estimated at 4% of the investment costs per year. The generation costs of CCGT range between \$65 and \$80/MWh (typically, \$73/MWh), of which \$30–45/MWh is for the fuel. Generation costs of OCGT are much higher, e.g. \$200–225/MWh (typically, \$210/MWh), of which \$45–70/MWh is for the fuel. In the OCGT plants, the fuel cost may be up to 50% higher than in CCGT as the efficiency is about two-thirds that of a combined cycle. However, the main reason for the OCGT high generation cost is the low load-factor of the peak-load services, typically 10% vs. 50-60% for the CCGT plants.
- **POTENTIAL & BARRIERS –** CCGT technology is a strong competitor for all power generation technology. Its share in electricity generation has been growing fast over the past decades. In comparison with coal-fired power, CCGT plants offer shorter construction time, lower investment costs, half as much CO_2 per kWh and high service flexibility, but higher fuel costs. Non-greenhouse gas (GHG) emissions such as SO_2, NO_x, and particulate matter are also relatively low. The current CO_2 price is low (see European emission trading) and moderately affects the electricity cost. In the future, however, it may rise and have a strong impact on the competition between coal- and gas-fired power, renewable and nuclear energy. In addition, current uncertainties on natural gas prices make it difficult to adopt robust strategies for CCGT deployment and may result in a changing economic balance between gas- and coal-fired power.

PROCESS AND TECHNOLOGY STATUS – Open-cycle gas turbines (**OCGT**) for electricity generation were introduced decades ago for peak-load service. Simple OCGT plants consist basically of an air compressor and a gas turbine aligned on a single shaft connected to an electricity generator. Filtered air is compressed by the compressor and used to fire natural gas in the combustion chamber of the gas-turbine that drives both the compressor and the electricity generator. Almost two-thirds of the gross power output of the gas-turbine is needed to compress air, and the remaining one-third drives the electricity generator. OCGT plants have relatively low electrical efficiency ranging between 35% and 42% (lower heating value, LHV). Aero-derivative gas-turbines provide efficiency of 41–42%, but their size is limited to 40–50 MW_e. Since the early 1990s, combined-cycle gas turbines (**CCGT,** Fig. 1) have become the technology of choice for new gas-fired power plants (IEA, 2008). CCGT plants consist of compressor/gas-turbine groups – the same as the OCGT plants – but the hot gas-turbine exhaust is not discharged into the atmosphere. Instead it is re-used in a

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