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STEAM-, GAS-TURBINE, AND COMBINED-CYCLE POWER INSTALLATIONS, AND THEIR AUXILIARY EQUIPMENT

Prospective Gas Turbine and Combined-Cycle Units for Power Engineering (a Review)

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Abstract—The modern state of technology for making gas turbines around the world and heat-recovery combined-cycle units constructed on their basis are considered. The progress achieved in this field by Siemens, Mitsubishi, General Electric, and Alstom is analyzed, and the objectives these companies set forth for themselves for the near and more distant future are discussed. The 375-MW gas turbine unit with an efficiency of 40% produced by Siemens, which is presently the largest one, is subjected to a detailed analysis. The main specific features of this turbine are that the gas turbine unit's hot-path components have purely air cooling, due to which the installation has enhanced maneuverability. The single-shaft combined-cycle plant constructed on the basis of this turbine has a capacity of 570 MW and efficiency higher than 60%. Programs adopted by different companies for development of new-generation gas turbine units firing synthesis gas and fitted with low-emission combustion chambers and new cooling systems are considered. Concepts of rotor blades for new gas turbine units with improved thermal barrier coatings and composite blades different parts of which are made of materials selected in accordance with the conditions of their operation are discussed.

Keywords: gas turbine unit, combined-cycle power plant, power capacity, temperature, efficiency, turbine, compressor, combustion chamber, materials, coatings

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The growing need for energy carriers and international competition in the field of supplying them to consumers are factors that lead to an essential growth of their cost. In such circumstances, achieving better efficiency of power stations is becoming extremely important. It should also be pointed out that use of more efficient power installations firing natural gas as fuel results in smaller emissions of CO_2 into the atmosphere, which is important for improving the environmental situation around the world.

Electric load is characterized by nonuniform daily and yearly schedules. The use of simple gas turbine units (GTUs) and combined-cycle power plants (CCPs) seems to be an attractive choice for covering peak loads and for operation in a load following mode. It is already at present that such installations are operating with essential daily variations of load, which are expected to grow still further in the future.

The economic efficiency of gas turbine units depends essentially on the following factors:

(i) power cycle parameters (temperature and pressure of gases upstream of the turbine);

(ii) perfectness of GTU components (the better the components, the higher the compressor and turbine efficiencies); and

(iii) flowrate of air taken for cooling the turbine hot parts.

With the presently achieved levels of initial temperatures (1500°C) and compression ratio (CR) in the compressor equal to around 20, the dependences of GTU efficiency on the CR have a fairly flat pattern, and the temperature of spent gases downstream of the turbine is around 600°C. At such parameters, the compressor's isentropic efficiency is at a level of 89–91%, and only limited possibilities for its further improvement are available.

In modern GTUs, 18–20% of the air taken by the compressor is used for cooling the turbine and supplied for seals. Measures taken for decreasing air consumption result in essential improvement of the GTU and CCP performance characteristics. In CCPs this is obtained owing to better efficiency of the GTU and also due to higher parameters and flowrates of steam in the loops of the heat-recovery boiler owing to higher temperature of gases downstream of the turbine at the same value of their initial temperature. Accordingly, better economic efficiency of the CCP is achieved.

Unlike the CCPs produced previously for operation in base-load modes of operation, the prospective CCPs will operate in the variable part of the load curve. The possibility of quickly starting from different thermal states, the ability to promptly change the load, the possibility of deep unloading, and keeping the emissions of polluting substances during operation at low power within the permissible limits must become