Combustion Turbines

Natural gas-fired combustion turbines are the most widely adopted and very mature technology for grid-connected power generation worldwide. Gas turbines consist of a compressor, combustor, and turbine-generator assembly as shown in Figure 5.1.

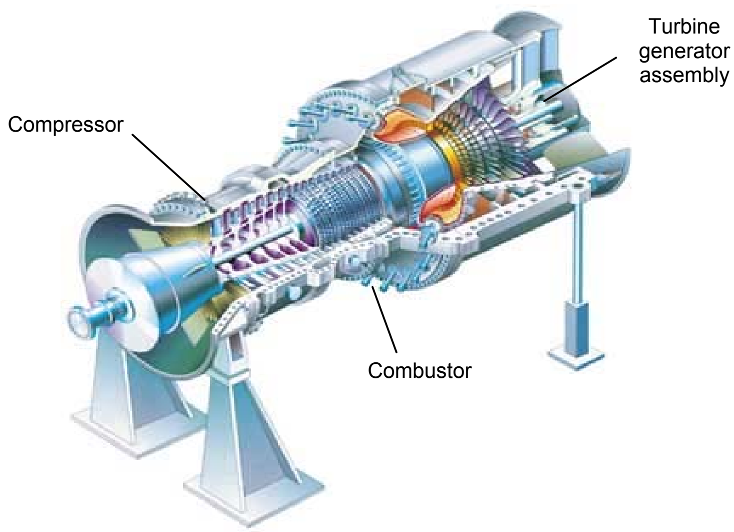

Figure 5.1: Gas Turbine Cross-Section
Ansaldo Energia - V94.3A 260MW Class

The simple-cycle gas turbines are based on the thermodynamics of the Brayton cycle, which works as follow: Air is drawn into the compressor and is compressed to very high pressure. The compressed air is then passed to the combustor, where the compressed air is heated via fuel combustion under constant pressure conditions. The heated air-fuel mixture is allowed to expand through a turbine to perform work, rotating the turbine blades, thus producing electrical power. The exhaust gases subsequently are discharged to the atmosphere. Lower heating value (LHV) efficiencies for this design (compressor, combustor, turbine) range from 18-35% [1]. Like the microturbine, the turbine efficiency can be enhanced with recuperation. The thermal energy from the

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exhaust gas flow is used to heat the compressed air, thus gaining more work out of the fuel. Table 5.1 summarizes general characteristics of combustion turbines.

Table 5.1: Gas Turbine Characteristics

Feature	Present	Future Development
Capacity	500kW – 25MW	-
Initial costs ($/kW)	$300-$1000/kW add $100-$200/kW with heat recovery	10% reduction in costs
Non-fuel O&M costs (c$/kWh)	$0.005-0.007/kWh	
Efficiency	20 – 45%	Up to 60%
Life	20-25 years	-
Emission	For medium GT: NO_X: 0.61 lb/MWh; SO_2: 0.007 lb/MWh; CO_2: 1,327 lb/MWh; PM-10: 0.07 lb/MWh; it is expected to further reduced NO_X and SO_X emissions.	
Applications	Utility-scale applications, industry, mechanical drives, base load grid-connected power generation, and remote off-grid applications	

Commercially available Gas Turbines:

Combustion Turbines typically range in size from about 500 kW up to 25 MW for distributed generation applications, and up to approximately 250 MW for central power generation.

Costs:

The capital cost of combustion turbines varies from $300 per kW output to $1000 per kW output. It is ultimately to be determined by manufacturers' quotes; however past projects can serve as a guide. Like other technologies, capital cost of combustion turbines reflects economy of scale. Note that Balance of Plant (BOP) equipment costs and other miscellaneous costs can be expected to increase first costs by 30-50%. These costs include control package, fuel supply system, electrical system and attendant power-switching and safety protection features such as grounding, circuit breakers and transfer switches. Adding heat recovery capabilities increases the capital cost by $100-$200/kW. Including other balance-of-plant components, the typical installed cost of a mid-sized gas turbine with a heat recovery unit will be in the $1,000-$1,200/kW range. The DOE Advanced Turbine System (ATS) research and development program is aimed to achieve operating costs of 10-20% lower than conventional power systems in the future.

Efficiency

Simple cycle turbines have efficiencies generally in the range of 20 - 45%. The heavy frame turbines have slightly lower efficiencies (20 - 34%) than the aero derivative turbines (26 - 45%). The range in efficiency values is generally a result of size; the larger the turbine the better the efficiency. Combined cycle turbines can reach efficiencies of up to 55% (LHV). However, these are generally utilized in central power plant arrangements, rather that distributed generation [2]. In 5 to 10 years, one of the objectives of the ATS program is to bring the high efficiencies of the larger turbines into the smaller industrial sizes and break the 60% barrier in net thermal efficiency.

Emissions:

Emission rates (NO_X, SO_2, PM-10, CO_2, and CO) for combustion turbines depend on a particular type and size ranges of turbines, and they also vary from manufacturer to manufacturer. The emission levels for reciprocating engines are listed below:

Table 5.2: Emissions from Gas Turbines

Emission Rates	Small Gas Turbine	Medium Gas Turbine	Large Gas Turbine	Large Gas Combined Cycle
Typical Capacity (MW)	4.6	12.9	70.1	500
NO_X (lb/MWh)	1.15	0.61	0.59	0.06
SO_2 (lb/MWh)	0.008	0.007	0.007	0.004
PM-10 (lb/MWh)	0.08	0.07	0.07	0.04
CO_2 (lb/MWh)	1,494	1,327	1,281	776
CO (lb/MWh)	0.7	0.6	0.6	0.1

Source: [3]

Applications

Combustion turbines are used primarily for power industry. Nearly all new power plants are combined cycle combustion turbines. Smaller versions can be used for DER. Most independent power producers and cogeneration plants use combustion turbines. Small combustion turbines are found in a broad array of applications including mechanical drives, base load grid-connected power generation, and remote off-grid applications. Some cogeneration units are available, but the cogeneration package must be added to the basic turbine.

References:

[1] Anne-Marie Borbely and Jan F. Kreider, Distributed Generation: The Power Paradigm for the New Millennium, 2001.

[2] California Energy Commission, www.energy.ca.gov/distgen, as of Dec 2002.

[3] Regulatory Assistance Project (RAP), website: http://www.rapmaine.org/ DGEmissionsMay2001.PDF, as of Dec 2002.