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Gas Turbines

B Parvathamma
B.Tech Scholar,
Department of Electrical and Electronics Engineering,
Siddhartha Institute of Engineering and Technology,
Vinobha Nagar, Ibrahimpatnam, Hyderabad,
Telangana-501506.

M Shankar
Assistant Professor,
Department of Electrical and Electronics Engineering,
Siddhartha Institute of Engineering and Technology,
Vinobha Nagar, Ibrahimpatnam, Hyderabad,
Telangana-501506.

ABSTRACT

The purpose of turbine technology is to extract the maximum quantity of energy from the working fluid, to convert it into useful work with maximum efficiency, by means of a plant having maximum reliability, minimum cost, minimum supervision and minimum starting time. It has been found that a considerable amount of heat energy goes as a waste with the exhaust of the gas turbine. This energy must be utilized. The complete use of the energy available to a system is called Total Energy Approach. The objective of this approach is to use all of the heat energy in a power system at the different temperature levels at which it becomes available to produce work, or steam, or the heating of air or water, thereby rejecting a minimum of energy waste. Development of mixed cycle is the efficient and effective effort in this direction.

I.INTRODUCTION

Engineering advancements pioneered the development of gas turbines in the early 1900s, and turbines began to be used for stationary electric power generation in the late 1930s. Turbines revolutionized airplane propulsion in the 1940s, and in the 1990s through today have been a popular choice for new power generation plants in the United States [1-4]. Gas turbines are available in sizes ranging from 500 kilowatts (kW) to 250 megawatts (MW). Gas turbines can be used in power-only generation or in combined heat and power (CHP) systems. The most efficient commercial technology for central station power-only generation is the gas turbine-steam turbine combined-cycle plant, with efficiencies approaching 60 percent lower heating value (LHV).1 Simple-cycle gas turbines [5-7] for power-only generation are available with efficiencies approaching 40 percent (LHV). Gas turbines have long been used by utilities for peaking capacity. However, with changes in the power industry and advancements in the technology, the gas turbine is now being increasingly used for base-load power. Gas turbines produce high-quality exhaust heat that can be used in CHP configurations to reach overall system efficiencies (electricity and useful thermal energy) of 70 to 80 percent [8-10]. By the early 1980s, the efficiency and reliability of smaller gas turbines (1 to 40 MW) had progressed sufficiently to be an attractive choice for industrial and large institutional users for CHP applications. Gas turbines are one of the cleanest means of generating electricity, with emissions of oxides of nitrogen (NOx) from some large turbines in the single-digit parts per million (ppm) range, either with catalytic exhaust cleanup or lean pre-mixed combustion [11-12]. Because of their relatively high efficiency and reliance on natural gas as the primary fuel, gas turbines emit substantially less carbon dioxide (CO_2) per kilowatt-hour (kWh) generated than any other fossil technology in general commercial use.

1.1 Application

The gas turbine is used where high power and speed are main consideration. Gas turbine is used in jet population unit in air craft, in ships as population unit, in supercharging system in automobile and also in electric generating station and in locomotives.

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The open cycle turbine is mainly used in airplanes. Today we have discussed about gas turbine types, advantages and disadvantages, working and application. If you have doubt regarding gas turbine, ask by commenting.

1.2 Types

1.2.1 Jet engines

Typical axial-flow gas turbine turbojet, the J85, sectioned for display. Flow is left to right, multistage compressor on left, combustion chambers center, two-stage turbine on right Airbreathing jet engines are gas turbines optimized to produce thrust from the exhaust gases, or from ducted fans connected to the gas turbines. Jet engines that produce thrust from the direct impulse of exhaust gases are often called turbojets, whereas those that generate thrust with the addition of a ducted fan are often called turbofans or (rarely) fan-jets. Gas turbines are also used in many liquid propellant rockets, the gas turbines are used to power a turbopump to permit the use of lightweight, low-pressure tanks, which reduce the empty weight of the rocket.

1.2.2 Turboprop engines

A turboprop engine is a turbine engine which drives an aircraft propeller using a reduction gear. Turboprop engines are used on small aircraft such as the general-aviation Cessna 208 Caravan and Embraer EMB 312 Tucano military trainer, medium-sized commuter aircraft such as the Bombardier Dash 8 and large aircraft such as the Airbus A400M transport and the 60 year-old Tupolev Tu-95 strategic bomber.

1.2.3 Aeroderivative gas turbines

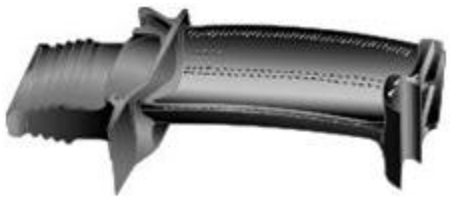

Fig1: Diagram of a high-pressure film cooled turbine blade

Aeroderivative are also used in electrical power generation due to their ability to be shut down, and handle load changes more quickly than industrial machines. They are also used in the marine industry to reduce weight. The General Electric LM2500, General Electric LM6000, Rolls-Royce RB211 and Rolls-Royce Avon are common models of this type of machine.

1.2.4 Amateur gas turbines

Increasing numbers of gas turbines are being used or even constructed by amateurs. In its most straightforward form, these are commercial turbines acquired through military surplus or scrapyard sales, then operated for display as part of the hobby of engine collecting. In its most extreme form, amateurs have even rebuilt engines beyond professional repair and then used them to compete for the Land Speed Record. The simplest form of self-constructed gas turbine employs an automotive turbocharger as the core component. A combustion chamber is fabricated and plumbed between the compressor and turbine sections.

More sophisticated turbojets are also built, where their thrust and light weight are sufficient to power large model aircraft. The Schreckling design constructs the entire engine from raw materials, including the fabrication of a centrifugal compressor wheel from plywood, epoxy and wrapped carbon fibre strands.
Several small companies now manufacture small turbines and parts for the amateur. Most turbojet-powered model aircraft are now using these commercial and semi-commercial micro turbines, rather than a Schreckling-like home-build.

1.3 Some of the principles of the gas turbine are

1. It is capable of producing large amounts of useful power for a relatively small size and weight.
2. Since motion of all its major components involve pure rotation (i.e. no reciprocating motion as in a piston engine), its mechanical life is long and the corresponding maintenance cost is relatively low.

3. Although the gas turbine must be started by some external means (a small external motor or other source, such as another gas turbine), it can be brought up to full-load (peak output) conditions in minutes as contrasted to a steam turbine plant whose start up time is measured in hours.
4. A wide variety of fuels can be utilized. Natural gas is commonly used in land-based gas turbines while light distillate (kerosene-like) oils power aircraft gas turbines. Diesel oil or specially treated residual oils can also be used, as well as combustible gases derived from blast furnaces, refineries and the gasification of solid fuels such as coal, wood chips and bagasse.

The usual working fluid is atmospheric air. As a basic power supply, the gas turbine requires no coolant (e.g. water).In the past, one of the major disadvantages of the gas turbine was its lower efficiency (hence higher fuel usage) when compared to other IC engines and to steam turbine power plants. However, during the last fifty years, continuous engineering development work has pushed.

1.4 Gas Turbine Components

A greater understanding of the gas turbine and its operation can be gained by considering its three major components the compressor, the combustor and the turbine. The features and characteristics will be touched on here only briefly. Compressors and Turbines: The compressor components are connected to the turbine by a shaft in order to allow the turbine to turn the compressor. A single shaft gas turbine (Fig. la and 1b) has only one shaft connecting the compressor and turbine components. A twin spool gas turbine, which is found in land- and marine-based applications, has two concentric shafts, a longer one connecting a low pressure compressor to a low pressure turbine (the low spool) which rotates inside a shorter larger diameter shaft. The shorter, larger diameter shaft connects the high pressure turbine with the higher pressure compressor (the high spool) which rotates at higher speeds than the low spool.

A triple spool engine would have a third, intermediate pressure compressor-turbine spool. Gas turbine compressors are either centrifugal or axial, or can be a combination of both. Centrifugal compressors (with compressed air output around the outer perimeter of the machine) are robust, generally cost less and are limited to pressure ratios of 6 or 7 to 1. They are found in early gas turbines or in modern, smaller gas turbines. The more efficient, higher capacity axial flow compressors (with compressed air output directed along the center line of the machine) are used in most gas turbines. An axial compressor is made up of a relatively large number of stages, each stage, consisting of a row of rotating blades (airfoils) and a row of stationary blades (stators), arranged so that the air is compressed as it passes through each stage.

Turbines are generally easier to design and operate than compressors, since the hot air flow is expanding rather than being compressed. Axial flow turbines will require fewer stages than an axial compressor. There are some smaller gas turbines that utilize centrifugal turbines (radial inflow), but most utilize axial turbines. Turbine design and manufacture is complicated by the need to extend turbine component life in the hot air flow. The problem of ensuring durability is especially critical in the first turbine stage where temperatures are highest. Special materials and elaborate cooling schemes must be used to allow turbine airfoils that melt at 1800-1900°F to survive in air flows with temperatures as high as 3000°F.

Combustors: A successful combustor design must satisfy many requirements and has been a challenge from the earliest gas turbines of Whittle and von Ohain. The relative importance of each requirement varies with the application of the gas turbine, and of course, some requirements are conflicting, requiring design compromises to be made. Most design requirements reflect concerns over engine costs, efficiency, and the environment. The basic design requirements can be classified as follows:

1. High combustion efficiency at all operating conditions.
2. Low levels of unburned hydrocarbons and carbon monoxide, low oxides of nitrogen at high power and no visible smoke for land-based systems. (Minimized pollutants and emissions.)
3. Low pressure drop. Three to four percent is common.
4. Combustion must be stable under all operating conditions.
5. Consistently reliable ignition must be attained at very low temperatures, and at high altitudes (for aircraft).
6. Smooth combustion, with no pulsations or rough burning.
7. A low temperature variation for good turbine life requirements.
8. Useful life (thousands of hours), particularly for industrial use.
9. Multi-fuel use. Characteristically natural gas and diesel fuel are used for industrial applications and kerosene for aircraft.
10. Length and diameter compatible with engine envelope (outside dimensions).
11. Designed for minimum cost, repair and maintenance.
12. Minimum weight (for aircraft applications).

A combustor consists of at least three basic parts: a casing, a flame tube and a fuel injection system. The casing must withstand the cycle pressures and may be a part of the structure of the gas turbine. It encloses a relatively thin-walled flame tube within which combustion takes place, and a fuel injection system.

1.5 Open Cycle Gas Turbine

A simple **open cycle gas turbine** consists of a compressor, combustion chamber and a turbine as shown in the below figure. The compressor takes in ambient fresh air and raises its pressure. Heat is added to the air in the combustion chamber by burning the fuel and raises its temperature.

1.6 Simple open cycle gas turbine plant

The heated gases coming out of the combustion chamber are then passed to the turbine where it expands doing mechanical work. Some part of the power developed by the turbine is utilized in driving the compressor and other accessories and remaining is used for power generation. Fresh air enters into the compressor and gases coming out of the turbine are exhausted into the atmosphere, the working medium need to be replaced continuously. This type of cycle is known as open cycle gas turbine plant and is mainly used in majority of gas turbine power plants as it has many inherent advantages.

II. Advantages

1. **Warm-up time:** Once the turbine is brought up to the rated speed by the starting motor and the fuel is ignited, the gas turbine will be accelerated from cold start to full load without warm-up time.
2. **Low weight and size:** The weight in kg per kW developed is less.
3. **Fuels:** Almost any hydrocarbon fuel from high-octane gasoline to heavy diesel oils can be used in the combustion chamber.
4. Open cycle plants occupies less space compared to close cycle plants.
5. The stipulation of a quick start and take-up of load frequently are the points in favour of open cycle plant when the plant is used as peak load plant.
6. Component or auxiliary refinements can usually be varied in open cycle gas turbine plant to improve the thermal efficiency and can give the most economical overall cost for the plant load factors and other operating conditions envisaged.
7. Open cycle gas turbine power plant, except those having an intercooler, does not need cooling water. Therefore, the plant is independent of cooling medium and becomes self-contained.

III. Development of gas turbines

The earliest device for extracting rotary mechanical energy from a flowing gas stream was the windmill (see above). It was followed by the smoke jack, first sketched by Leonardo da Vinci and subsequently described in detail by John Wilkins, an English clergyman, in 1648. This device consisted of a number of horizontal sails that were mounted on a vertical shaft and driven by the hot air rising from a chimney. With the aid of a simple gearing system, the smoke jack was used to turn a roasting spit. Various impulse and reaction air-turbine drives were developed during the 19th century. These made use of air, compressed externally by a reciprocating compressor, to drive rotary drills, saws, and other devices. Many such units are still being used, but they have little in common with the modern gas-turbine engine, which includes a compressor, combustion chamber, and turbine to make up a self-contained prime mover.

The first patent to approximate such a system was issued to John Barber of England in 1791. Barber's design called for separate reciprocating compressors whose output air was directed through a fuel-fired combustion chamber. The hot jet was then played through nozzles onto an impulse wheel. The power produced was to be sufficient to drive both the compressor and an external load. No working model was ever built, but Barber's sketches and the low efficiency of the components available at the time make it clear that the device could not have worked even though it incorporated the essential components of today's gas-turbine engine.

Although many devices were subsequently proposed, the first significant advance was covered in an 1872 patent granted to F. Stolze of Germany. Dubbed the fire turbine, his machine consisted of a multistage, axial-flow air compressor that was mounted on the same shaft as a multistage, reaction turbine. Air from the compressor passed through a heat exchanger, where it was heated by the turbine exhaust gases before passing through a separately fired combustion chamber. The hot compressed air was then ducted to the turbine. Although Stolze's device anticipated almost every feature of a modern gas-turbine engine, both compressor and turbine lacked the necessary efficiencies to sustain operation at the limited turbine-inlet temperature possible at the time.

IV. CONCLUSION

In this study, combined cycle power plants were investigated by energy, energy and thermo economic analysis. General methodologies of these methods were discussed and also applied to case studies. The operating parameters of combined cycle power plants were chosen to study their effect on overall thermal efficiency and energy destruction in different components. An empirical correlation was determined for different set of operating variables and assessment parameters. Cost analysis was applied to a four stage intercooling, four stage reheating and three stage regenerating combined cycle by using software, cycle pad. Five different configurations were made and analyzed on cost basis. Cost of electricity production per MWh was calculated for each configuration.

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