Microturbine Generators

An Online Continuing Education Course for Engineers

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Microturbine Generators

Lee Layton, P.E.

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Introduction

Microturbines are small combustion turbines that burn gaseous or liquid fuels to drive an electrical generator. Microturbines are 25 to 500-kilowatt gas turbines, which evolved from piston engine turbochargers, aircraft auxiliary power units (APU), and small jet engines.

They are used for stationary energy generation applications at sites with space limitations for power production. Microturbines have few moving parts, high efficiency, low emissions, low electricity costs, waste heat utilization opportunities, and are lightweight and compact in size. Waste heat recovery can be used in *combined heat and power* (CHP) systems to achieve energy efficiency levels greater than 80%. Microturbines are ideally suited for micro-grids.

C65 Microturbine
Photo Credit: Capstone

Microturbines can be used for cogeneration, distributed generation, and even to power hybrid electric vehicles. Most of the waste heat is contained in the relatively high-temperature exhaust, making it simple to capture. Microturbines are ideal for combined heat and power (CHP) applications because exhaust heat can be used for water heating, space heating, drying processes, or absorption chillers, which create cold for air conditioning from heat energy instead of electric energy.

Microturbines include a compressor, combustor, turbine, and electric generator generally on a single shaft. They can have a recuperator capturing waste heat to improve the compressor efficiency, an intercooler, and reheat. They rotate at over 40,000 RPM, and a common single shaft microturbine usually rotates at 90,000 to 120,000 RPM. They often have a single-stage radial compressor and a single-stage radial turbine.

Advances in electronics allow unattended operation, and electronic power switching technology eliminates the need for the generator to be synchronized with the power grid, allowing it to be integrated with the turbine shaft and to double as the starter motor. Microturbines accept most fuels, including natural gas, sour gas (high sulfur, low Btu content), gasoline, kerosene, diesel fuel, and heating oil.

The electrical generation efficiency of microturbines declines significantly as load decreases. Therefore, microturbines generally provide the best economic performance in base load applications where the system operates at, or near, full load. An exception is modular packages where one or more individual microturbines can be shut down while the remaining microturbines operate at or near full load.

Table 1 lists some of the attributes of microturbines.

Table 1 **Microturbine Attributes**	
Capacity	Available from 30 to 500kW.
Thermal Output	Exhaust temperatures in the range of 500 to 600F, suitable for supplying a variety of site thermal needs, including hot water, steam, and chilled water (using an absorption chiller).
Fuel Flexibility	Microturbines can be operated with a wide range of gas and liquid fuels. For CHP, natural gas is the most common fuel.
Reliability and life	Design life is estimated to be 40,000 to 80,000 hours with overhaul.
Emissions	Low NO_x combustion when operating on natural gas.
Modularity	Units may be connected in parallel to serve larger loads and to provide power reliability.
Part-load Operation	Units can be operated to follow load with some efficiency penalties.
Dimensions	Compact and lightweight. 2.3-2.7 cubic feet (cf) and 40-50 pounds per kW.

Because of their compact size, relatively low capital costs, low operations and maintenance costs, and automatic electronic control, microturbines are expected to capture a significant share of the distributed electric generation market.

This course is divided into five brief chapters. Chapter One provides an overview of microturbine technology and a description of each of its major components. Chapter Two describes the operating characteristics of microturbines. Chapter Three explains the estimated costs associated with microturbines. Chapter Four addresses associated operations and maintenance costs and Chapter Five describes several potential applications for microturbines.

Chapter 1 - Technology Description

Microturbines are Brayton Cycle machines, just like large gas turbines, and share many of the same basic components. In a *Brayton Cycle* engine, atmospheric air is compressed, heated (by introducing and burning fuel), and then forces the resultant hot gases through an expansion turbine that drives both the inlet compressor and a drive shaft capable of providing mechanical or electrical power. Other than the size difference, microturbines differ from larger gas turbines in that they typically have lower compression ratios and operate at lower combustion temperatures.

In order to increase efficiency, microturbines recover a portion of the exhaust heat in a heat exchanger called a recuperator, to increase the energy of the gases entering the expansion turbine, thereby boosting efficiency.

Microturbines are classified by the physical arrangement of the component parts: single shaft or two-shaft, simple cycle, or recuperated, inter-cooled, and reheat. The machines generally rotate at over 40,000 revolutions per minute.

There are two types of microturbine designs available, based on the position of compressor turbine and generator: a single-shaft design and a two-shaft design. A high-speed *single shaft* design with the compressor and turbine is mounted on the same shaft along with the permanent magnet synchronous generator. The generator generates power at a very high frequency ranging from 1500 to 4000 Hz. The high-frequency voltage is first rectified and then inverted to a normal AC power at 50 or 60 Hz.

Another design is the *two-shaft* (or split-shaft) system in which a turbine on the first shaft directly drives the compressor while a power turbine on the second shaft drives the gearbox and conventional induction generator producing 60 Hz of power. The two-shaft design features more moving parts but does not require complicated power electronics to convert high-frequency AC power output to 60 Hz.

A single shaft microturbine with high rotating speeds of 90,000 to 120,000 revolutions per minute is the more common design, as it is simpler and less expensive to build. Conversely, the split shaft is necessary for machine-driven applications, which do not require an inverter to change the frequency of the AC power. Efficiency gains can be achieved with greater use of materials like ceramics, which perform well at higher engine-operating temperatures.

Simple cycle vs. Recuperated Microturbines

Microturbines may be either simple cycle units or recuperated units. In *simple cycle* (un-recuperated) microturbines, compressed air is mixed with fuel and burned under constant-pressure conditions. The resulting hot gas is allowed to expand through a turbine to perform work. Simple cycle microturbines have lower efficiencies at around 15%, but also lower capital costs, higher reliability, and more heat available for cogeneration applications than recuperated units.

Recuperated microturbines use a sheet-metal heat exchanger that recovers some of the heat from an exhaust stream and transfers it to the incoming air stream, boosting the temperature of the air stream supplied to the combustor. Further exhaust heat recovery can be used in a cogeneration configuration. The fuel-energy-to-electrical-conversion efficiencies are in the range of 20 to 30%. In addition, recuperated units can produce 30 to 40% fuel savings from preheating.

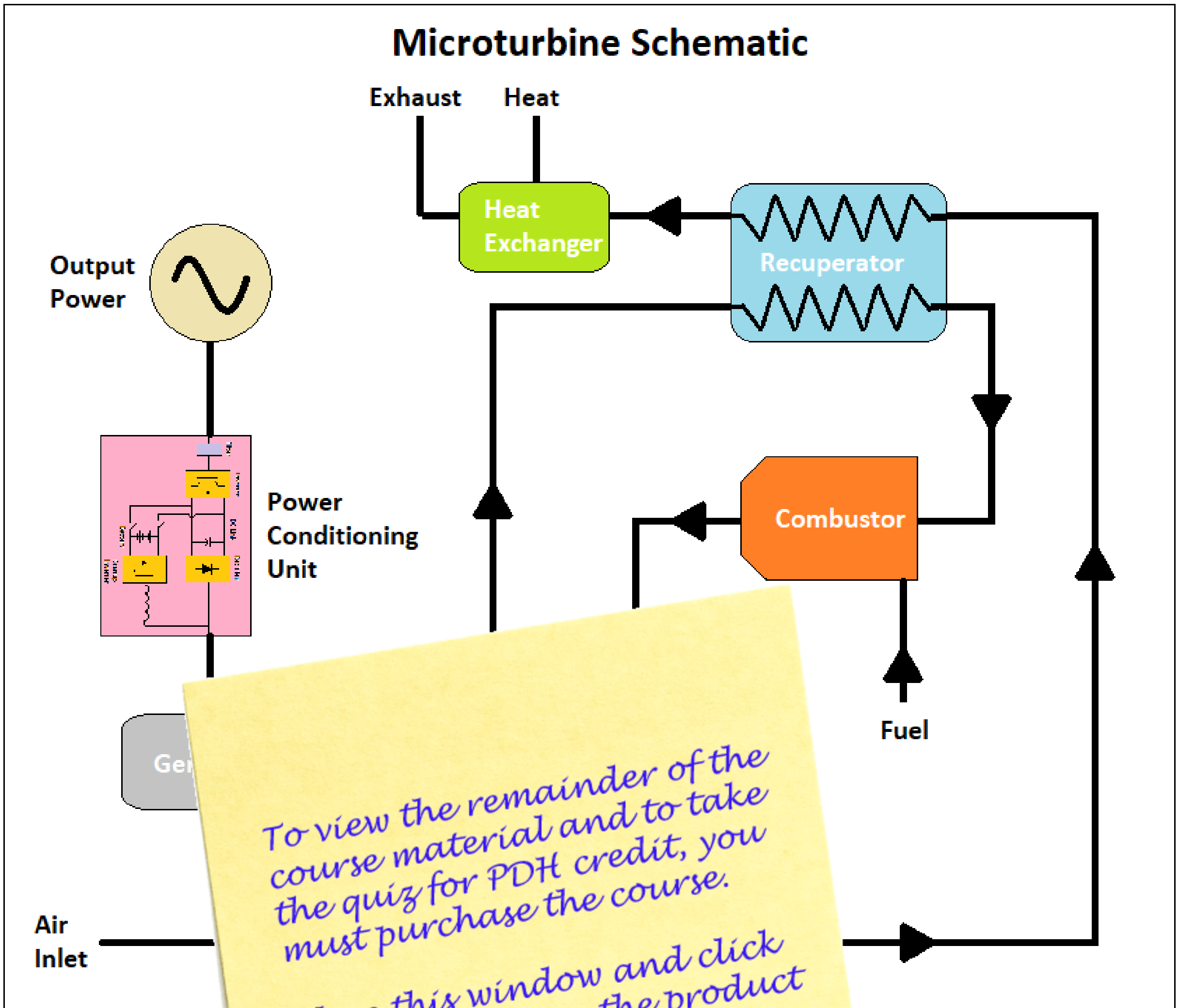
Components

The following is a discussion of the components in a microturbine. The basic components of a microturbine include

- Combined compressor/turbine unit
- Generator
- Recuperator
- Power Conditioning Unit
- Combustor
- CHP heat exchanger

Figure 1 illustrates the operation of a single shaft microturbine. Essentially, air enters the compressor and is preheated for combustion in the recuperator. The air mixes with the fuel in the combustor, and the combusted air/fuel mixture expands through the turbine. The turbine shaft drives both the compressor and the generator. The exhaust from the turbine is fed back through the recuperator to preheat the incoming combustion air.

The waste heat from a microturbine is primarily in the form of hot exhaust gases. This heat is suitable for powering a steam generator, building heat, thermal storage devices, or for use in an absorption cooling system. The recuperator will limit some of the waste heat available for other applications. In non-recuperator systems, the exhaust gas temperature is around 1,200F. However, with a recuperator, the exhaust gas temperature may be less than 600F.



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For comparison, Fig [...] design. This system is similar to the single- [...] er turbine and does not need the electronic c[...]