Principles and Working of Microturbine

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Abstract:-

A new small gas turbine technology is being developed which promises to bring the economic, environmental and convenience benefits, advancements in the automotive sector, generation of electricity and mechanical power needs of the commercial sector. The technology is of the microturbines.The micro turbine is an example of Micro Electro Mechanical Systems, which is efficiently used to develop power at a small scale. Microturbines are small combustion turbines approximately the size of a refrigerator with outputs of 25 kW to 500 kW. Microturbines are part of the future of onsite, or distributed energy and power generation. They are actually single shaft machines, in which turbine, compressor and generator are mounted on the single shaft. This unit can be used for distributed power, stand-alone power, stand-by power and vehicle application like turbocharger. The commercial customer requirement for small prime movers are that they be very cleans (low NOx, CO and unburned hydrocarbons), of better efficiency than the reciprocating engines, require infrequent maintenance, have a very low forced outage rate and of course be of low installed cost so as to provide rapid payback for the owner. These conditions are better fulfilled by the microturbines compared to the conventional Reciprocating Engines, Gas turbines, Coal fired steam engines etc.

Introduction

Micro-Electro-Mechanical Systems [MEMS]:
Micro-Electro-Mechanical Systems (MEMS) is an integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through the utilization of microfabrication technology. MEMS are truly an enabling technology allowing the development of smart products by augmenting the computational ability of microelectronics with the perception and control capabilities of microsensors and microactuators. MEMS technology makes possible the integration of microelectronics with active perception and control functions, thereby, greatly expanding the design and application space. Although MEMS devices are extremely small (e.g. MEMS has enabled electrically-driven motors smaller than the diameter of a human hair to be realized), MEMS technology is not about size. Furthermore, MEMS is not about making things out of silicon, even though silicon possesses excellent materials properties making it a attractive choice for many high-performance mechanical applications. Instead, MEMS is a manufacturing technology; a new way of making complex electromechanical systems (like power generation) using batch fabrication techniques. Already, MEMS is used for everything ranging from in-dwelling blood pressure monitoring to active suspension systems for automobiles. Recent examples of the advantages of MEMS technology consider the MEMS accelerometers, which are quickly replacing conventional accelerometers for crash air-bag deployment systems in automobiles. Micro turbine is one of the best examples of the recently used MEMS. The technology is to generate power for at a small level for a few houses or as a stand-by power source. It is given hype now days and further research work is also in progress. Now let us know what exactly the microturbine is.

Gas Turbine:
Gas turbines are Brayton cycle engines, which extract energy from hydrocarbon fuels through compression, combustion, and hot gas expansion. Air is drawn in to a compressor, which increases the air pressure. The compressed air is mixed with fuel and ignited in a combustor. Then, the hot gas is expanded

through a turbine, which drives the compressor and gives useful work through rotation of the compressor-turbine shaft. The shaft power can be used to drive a electrical generator, thereby providing electricity.

Micro turbine:
Micro turbines are small gas turbines used to generate electricity. Occupying a space no larger than a telephone box, they typically have power outputs in the range of 25 to 300kW. In comparison, large powerstations are entire buildings and have much higher power outputs of around 600MW to 1000MW. The small size of microturbines is a major advantage that allows them to be situated right at the source of electricity demand. This eliminates energy losses that usually occur when transmitting electricity from power stations. Such transmission losses are quite significant and can easily amount to 7% of the power generated. Micro turbines are a new class of small gas turbines used for distributed generation of electricity. Microturbines are small version of gas turbines emerged from four different technologies viz. small gas turbines, auxiliary power units, automotive development gas turbine and turbochargers. Microturbines are new class of gas turbines used for distributed generation of electricity. Microturbine development is based on turbines used for aircraft auxiliary power units, which have been used in commercial airlines for decades. One way in which Microturbine can be distinguished from larger turbines is that Microturbines use a single shaft to drive the compressor, turbine and generator. Whereas in large power plants, the turbines and generator are on separate shafts and are connected by gears that slow down the high-speed rotation of the gas turbines, simultaneously increasing the torque sufficient to turn much large electric generators. Some microturbines even include the ability to generate electricity from heat of exhaust gases.

History
In 1900 when a 2 MW steam turbine was installed at Hartford, its size was 4 times bigger than any of the existing steam turbines. From then on economy of scale meant bigger and bigger. By the end of the 1970s and largely driven by nuclear power plants, steam turbines exceeded 1000 MW. The electric efficiency of steam turbine power plants eventually reached 34%. That trend was broken in the 1980s. More efficient gas turbines combined with steam turbines could produce electric power with efficiencies up to 55%. This new technology, combined cycle power plants, was the technology of choice for independent power producers. It was now possible to build competitive power plants down to the range of 100-200 MW. Micro turbines have been experimented with since 1945, when Rover tried to develop one for a vehicle application. Since that time, automobile, aerospace, aircraft and military contractors have tried to develop an economical and functional Microturbine for different industrial and commercial applications.

Need of micro turbine:
In today's energy economy, most electricity is produced using fossil fuel-burning generators. These machines consist of a motor and a dense coil of copper wires that surround a shaft containing powerful magnets. To get that power to a home or factory typically requires a local utility to run a heavy copper cable to the residence or business site. But what if the site requiring energy is in a remote mountain location, or it's an offshore oil rig where electricity is scarce and hookups don't exist? Here the microturbines come into the picture. It is one of the best options to set up a local power-generation plant, perhaps using a Microturbine -- a small, sometimes portable, fossil fuel-burning system that can provide enough electricity to power anywhere from 10 to 5,000 homes. Also it has an important application as a turbocharger in vehicles when more energy is required from the engine in less amount of fuel

Construction of micro turbine: Micro turbines are typically single shaft machines with the compressor and turbine mounted on the same shaft as the electrical generator. It therefore consists of only one rotating part, eliminating the need for a gearbox and associated numerous moving parts. Microturbines are miniature versions of the huge machines used to generate power from natural gas, and evolved from aircraft engines and automotive turbochargers. A cutaway view of a Microturbine is shown in Figure1. The single stage Turbine and Compressor wheels are inertia welded to the shaft, which supports the generator alternator rotor and provides for a cold end drive. A block diagram showing a complete cycle of the Microturbine is shown in Figure2. The inner bearing is a hydrodynamic bearing and the outer bearing utilizes a ceramic ball race. A device called recuperator plays an important role in completing the cycle of Microturbine.

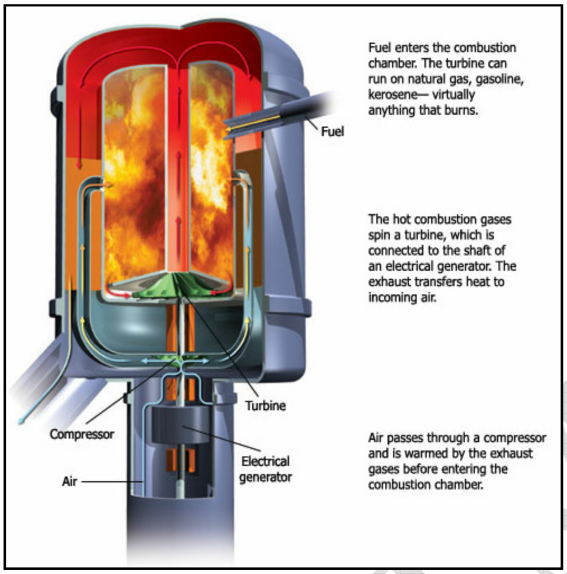

Figure 1: Sectional view of a typical micro turbine [1]

Principle and working of micro turbines:

The high velocity exhaust gases coming from the combustor rotate the turbine used in the micro turbine. The basic principle of working of the micro turbine is that the compressor as well as the electric generator is mounted on the same power shaft as that of the turbine. Because of this the compressor and the generator also rotate with the turbine. The generator rotates with the same speed as that of the turbine and generates the electricity. The electricity is first given to the power conditioning devices and then it is supplied to the required areas. The combustor is supplied with the fuel in the gaseous form by the gas compressor. Also fresh and compressed air is supplied to the combustor by the compressor through the recuprator.

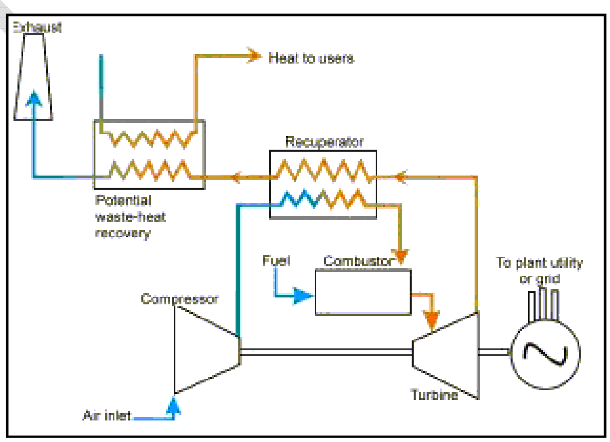

Figure 2: Working cycle of a micro turbine [2].

Here the recuprator plays an important role of heat exchanger. It absorbs the heat from the hot gases coming from the turbine. Then it gives this heat to the compressed air coming from the compressor. Thus the air supplied to the combustor is hot and compressed. This helps to increase the overall efficiency of the cycle.

Performance

The performance of the microturbines is given in the tabular form as below,

Configuration	Efficiency
Unrecuperated	15%
Recuperated	20-30%
With Heat Recovery	Up to 85%

Table No.1 Microturbine Efficiency for 25 to 500kw [1]

Commercial micro turbines used for power generation range in size from about 25KW to 500KW. They produce both heat and electricity on a relatively small scale. The energy to electricity conversion efficiencies are in the range of 20 to 30%. These efficiencies are attained when using a recuperator. Cogeneration is an option in many cases as a Microturbine is located at the point of power utilization. The combined thermal electrical efficiency is 85%. Unrecuperated microturbines have lower efficiencies at around 15%.

Features

Micro turbines offer many potential advantages for distributed power generation. Selected strengths and weaknesses of Microturbine of the Microturbine technology are listed below:

Advantages:-

- Small number of moving parts.
- Compact size.
- Light weight.
- Good efficiency in cogeneration.
- Low emission.
- Can utilize waste fuel.
- Long maintenance intervals

Limitations:-

- Low feul to electricity efficiency.
- Loss of power output and efficiency with hieghr ambient temperature and elevation

8. FUTURE SCOPE:

Extensive field test data collected from units currently in use at commercial and industrial facilities will provide the manufacturers with the ability to improve the Microturbine design, lowering the cost and increasing performance, in order to produce a competitive distributed generation product. Utilities, government agencies, and other

Organizations are involved in collaborative research and field-testing.

Development is ongoing in a variety of areas:

1. Heat recovery/coregeneration
2. Fuel flexibility
3. Vehicles
4. Hybrid systems (e.g. fuel cell/Microturbine, flywheel/Microturbine)

Applications

While the simplest application for a micro turbine prime mover is of power generation other application exists. Microturbine prime movers can be used for cooling, refrigeration; air compression and pump drive application whereby the inherent high speed of the power shaft can be used to drive high efficiency and low cost centrifugal compressors. Microturbines can be used for stand by power, power quality and reliability, peak shaving, and cogeneration applications. In addition, because microturbines are being developed to utilize a variety of fuels, they are being used for resource recovery and landfill gas applications. Microturbines produce between 25kw to 500kw of power and are well suited for small commercial building establishments such as restaurants, hotels/motels, small offices, retail stores and many others. The development of the micro turbine technology for the transportation application is also in progress. One of the major applications used is the turbocharger in the small vehicles. Automotive companies are interested in microturbines to provide a light weight and efficient fossil fuel- based energy source for hybrid electric vehicles, especially buses.

Case Study on Distributed Generation:

Introduction:

Distribution generation is a concept of installing and operating small electric generators, typically less than 20MW, at or near electrical load. The premise of distributed generation is to provide electricity to a customer at a reduced cost and more efficiently with reduced losses than the traditional utility central generating plant with transmission and distribution wires.

Micro turbine in distributed Generation:

Micro turbine is small scale combustion turbines ranging inside from 28 kW to 500kW, which include a compressor, combustor, turbine, alternator, recuperator and generator. Microturbines are smaller, lighter and operate with no vibration and less noise. All of these features help to make on - site installation possible without compromising the environmental aspects. They have potential to be located on site having space limitations to produce power.

Working principle:

The technology used for distributed generation is that of micro turbine. The three basic equipments, viz. the turbine, the generator and compressor are mounted on a single shaft. The core of the Microturbine is a high-speed compressor -turbine section, which rotates very fast - 96000rpm in Capston model 330. On the same shaft is a high-speed generator using permanent magnets. A key element for designs of Microturbine is air bearings (or more correctly gas bearings). Air bearings enable the high speed only air cooling a long life almost maintenance free. The high speed generator delivers a high frequency power. To "gear it down" to useful 50/60 Hz power, electronics is brought into application.

The following table shows the speed of Microturbine for different power generation capacities.

POWER	SPEED
45 KW	90,000 TO 1,16,000 (RPM)
80 KW	70,000 (RPM)
200 KW	50,000 (RPM)

Table No.2 Speed of Turbine for Different Power Ratings [2].

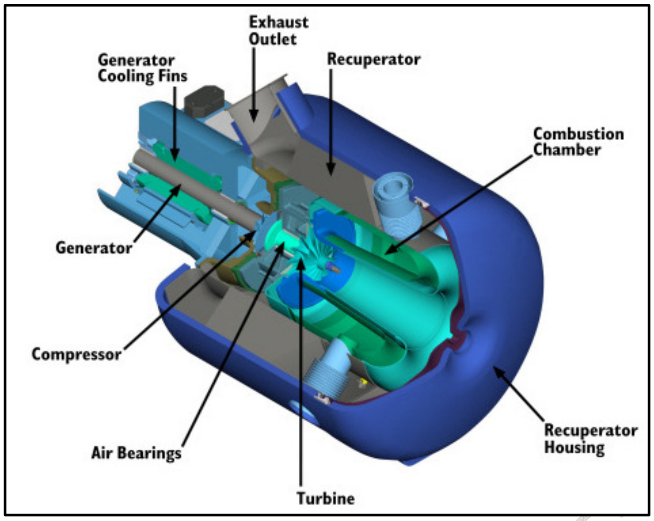

Figure 3: Cutaway of the Capston 330 turbine [3].

Advantages:

The general advantages of Microturbine are that there are small number of moving parts are compact in size, light weight and have opportunities for greater efficiencies, lower emissions, lower electricity costs and use renewable fuels such as land fill or sewage treatment gases. Microturbine in general offer to be advantages

1 lower emission and
2 low maintenance.

As illustrated below (Table no.3), the Capston Microturbine has one of the best emission performances of any fossil fuel combustion.

Item	NO (ppm)	CO (ppm)	HC (ppm)
Reciprocating Engines (500kW)	100	340	150
Gas Turbines (4.5MW)	25	50	10
Coal Fired Steam (500MW)	200	N/A	N/A
Microturbine	9	25	9

Table No.3 Comparison of Emissions [3]
Source: Cambridge Energy Research Associates.

With very low emissions and maintenance, microturbines hold promise to enable small-scale cogeneration. To exhaust heat can be use water heating, absorption cooling, dehumidification, etc. It is possible to reach efficiencies of 70-80%. Because of the three exhausts with no risk of any oil fuel (due to the air bearing) it should be possible to use the exhaust gas directly in some industrial processes.

Benefits of Distributed Generation:

Thus the benefits that distributed generation could potentially provide, depending on the technology, include reduced emissions, utilization of waste heat, improved power quality and reliability and deferral of transmission or distribution upgrades.

Hydropower Generation:

A typical use of Microturbine is the hydropower generation. Microturbine technology equipment's harness the best possible energy source that is the discharge flow of even minor streams, in that sense; they constitute cleaner, superior environmental alternatives to the less acceptable fossil fuel powered generators. The technology is very simple as shown in figure .A turbine with a generator on its shaft is fitted in the way of water flowing in a river or a stream.

In most cases, Micro turbine views only a small portion of a stream's flow that is channeled through a penstock. As it is clear from the figure, we can say that reliable and renewable hydro-energy generation (with the help of microturbines of course) does not require a reservoir or the flooding of low-lying areas. Microturbine technology turbines may be installed low discharge flow streams and rivers. They are efficient even in cases of low drop river fall, as Microturbine technology turbines generate electricity from as little as one meter of hydraulic head.

Turbocharger:

Turbocharger is one of the applications of micro turbine. It uses the principle of mounting the compressor on same shaft as that of turbine. Here also the exhaust gases drive the turbine. Today with precise control offered by the computers, turbochargers are making small engines more efficient and capable of producing more power. Microturbines are evolved from automotive and truck turbochargers, auxiliary power units for airplanes, and small jet engines and are comprised of a compressor, combustor, turbine, alternator, recuperator, and generator.

Turbo charging Principle:

A turbocharger is a device that uses exhaust gases, rather than the engine power to run an air pump or compressor. The air pump then forces an increased amount of air into the cylinders. Both the diesel and gasoline engines in the market use turbochargers. Figure 3 shows a typical schematic of air and exhausting a turbocharged engine. High velocity exhaust gases pass out of the exhaust ports. From there they pass through a turbine driven pump. Here the exhaust gases cause the exhaust turbine to turn very rapidly.

The exhaust turbine causes the intake compressor to run very rapidly. As the compressor turbine runs it draws in a large amount of fresh air. The intake air is pressurized and forced into the intake port. The increase in the pressure in the intake manifold is called as boost. Boost may produce pressure in the intake manifold of about 6 to 10 psi or more depending on the manufacturer.

Conclusion:

As a breakthrough technology, allowing unparalleled synergy between hitherto unrelated fields of endeavor such as biology and microelectronics, many new MEMS applications will emerge, expanding beyond that which is currently identified or known. In the industrial sector, MEMS devices are emerging as product performance differentiators in numerous markets with a projected market growth of over 50% per year. Microturbine (MEMS) also promises a lot of further development. The introduction of competition into the electric marketplace has driven the development of new electrical generation technologies. Most technologies being developed for distributed generation application are currently too costly, and can only be utilized in some applications. For this the Microturbine is one of the best applications. Micro turbines are capable of generating power even with the availability of low grade fuel or low head of water. It is rightly said that the Microturbine will start eating the market share that diesel engine has so far enjoyed.

References

[1] www.microturbine.com
[2] www.distributed generation.com
[3] www.memsnet.org
[4] E.Schwaller, Turbocharger, Automotive Technology, Delmar publications.
[5] Electrical Review, Microturbine, Vol.235, 22nd January 2002