THE BEST MICROTURBINE APPLICATIONS

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Microturbine technology has been identified by the Department of Energy as one of the promising technologies in the United States. The simplicity of this technology, ease of its deployment, and low emissions appear offer great promise for local power generation. Since 1995 the combination of several maturing technologies has helped the microturbines continue to develop. Although this technology is still emerging and maturing, it is being deployed in commercial, industrial, and residential applications. Some of the best microturbines applications are where there is an economical value, such as the combined heat and power, resource recovery, or combinations thereof.

Microturbines are small high-speed power plants that usually consist of compressor, combustor, turbine, generator, and power electronics. These small power plants typically operate with natural gas; however, microturbines are also able to operate with other kind of fuels such as, propane, waste gases, such as landfill, and digester. Most microturbines are single stage radial flow devices with high rotating speeds generally in the range of 50,000 – 120,000 rpm. Electric power is produced in the 10,000 HZ, converted to high voltage DC, and then inverted back to 60 HZ, 480 VAC by an inverter.

These engines operate on one of the same thermodynamic cycle, known as the Brayton Cycle, as larger gas turbines. During the engine operation, air is drawn into the unit and passes through the recuperator where the temperature is increased by hot exhaust gas. The air then flows into the combustor where it is mixed with the fuel, ignited and burned. The combusted gas passes through the turbine nozzle and turbine wheel, converting the thermal energy of the hot expanding gases to the rotating mechanical energy of the turbine. The turbine drives the compressor and generator. The gas exhausting from the turbine is directed back to the recuperator and then out the stack. The temperature in the exhaust ranges between 400- 650^{o}F, which makes available about 4000-15000 Btu/KWh for further applications.[1]

One of the exciting aspects of microturbines is that they are still evolving in their development and deployment plan. Several ancillary technologies are growing and maturing; for example, control systems power electronics, and new metallurgy. At the same time, the improvement of several components, such as better recuperators and ceramics, are helping the microturbines to overcome some of the obstacles that are limiting this technology from being recognized as being economically available for a wider variety of applications. Although microturbines will experience additional improvements, microturbines offer desirable characteristics right now.

There are several characteristics that make the microturbines beneficial for different applications depending on the use and the needs of the customer. Cogeneration, fuel flexibility, low No_X emissions levels (at full load operations), expected low maintenance cost at maturity, compact size, and quiet operation are some of the characteristics that make microturbines a somewhat unique technology relative to other distributed generation technologies.

As microturbine technology evolves, applications are emerging and growing. The microturbines can be implemented in several applications according to the customer needs. However, not all applications make the most of microturbine technology. Projects with multiple applications have the greatest potential to gain from microturbine technology. The use of a large number of the microturbine's capabilities makes the applications more efficient, cost effective, and productive. CHP, energy resource recovery, and direct uses of exhaust heat are some of the applications where the use of microturbines makes more sense to consider applying. The key for the best application of microturbines is where there is a demand for heat and power. Power is usually a secondary consideration, ideally resulting in economic operation.

Distributed generation technology is more likely to be implemented and utilized for more than a stand-by power, peaking power, or even for premium power, if it provides the customer with multiple sources of benefit. The major point in on-site power generation is to reduce the energy cost and increase the efficiency through cogeneration, or combined heat and power. Cogeneration or (CHP) is the use of heat and production of power from the same fuel source. CHP applications convert about 80^{+}% of the input fuel into usable energy[2]. Furthermore, CHP has the potential to reduce carbon dioxide and air pollutant emissions and increase energy efficiency.

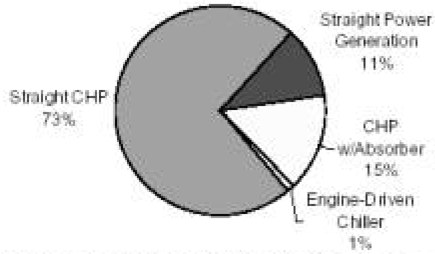

Figure 1. 2002 U.S. Industrial Cooling, Heating and Power Market Potential (33 GW)

Traditional CHP has been used in industries with large heat loads; for example, textiles, electroplating, food and paper processing, agricultural, and other industries with high use of thermal energy. The application of CHP systems has been used in the industrial sector for several years. Typically CHP systems generate hot water and steam. However, this application can also be implemented to provide cooling using an absorption chiller. Figure 1 shows the potential implementation of CHP in the US Industrial Sector.

Combined heat and power is not limited to high intensive heat recovery. It can also benefit a wide variety of industries, such as commercial office buildings and institutions such as restaurants, colleges, universities, hospitals, office building, data center, apartments, hotels, and theaters. Since on-site generation generally improves power reliability, CHP systems become even more valuable when improved reliability is needed. CHP particularity helps during hot summers and during peak demand periods.

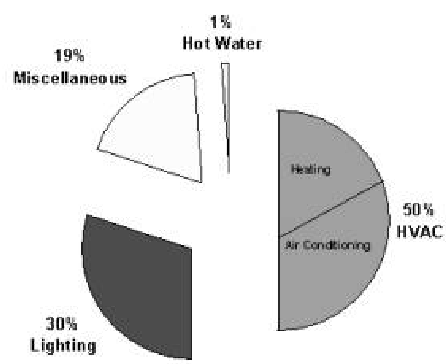

Figure 2

Microturbines are able to produce thermal output temperature in the 400 to 600^{o}F range, and thereby capable of supplying or supporting a variety of building thermal needs. Thermal output of a microturbine is suitable for applications such as domestic hot water heating, seasonal cooling using absorptions chillers, desiccant dehumidifiers, heat for light production process, and condensate. For example, a microturbine can be implemented in a laundry, which needs hot water, or direct heat or electricity. Microturbines can help to provide water up to 200^{o}F using a recovery boiler. Schools or universities, which use boilers, can implement microturbines to heat the pools and at the same time use the electricity generated to supplement power to other applications in the campus. Figure 2 shows other applications where the power and the heat can be utilized around a campus.

Figure 3

The University of New York campus at Buffalo has installed a CHP system that will use emerging microturbine technology to produce heat and electric power. Two 60 kilowatt Capstone microturbines provide electric power to pumps that continually circulate water in the university's competition swimming and diving pools. Meanwhile, approximately 75 % of the waste heat from the microturbines is recovered and utilized for heating the circulated water, virtually eliminating the need to use the existing electric heaters. The system is designed to pre-heat one million gallons of continuously circulating water in the pools. The installation cost of the system was $620,000; however, it will help to save about 2,000MWh/yr in electricity and it will bring savings of $70,000 per year, according to the university.

Microturbines exhaust heat is a practical source of direct heat. Microturbines have very low exhaust emissions, ranging between 3 to 25 ppm, which can be compared with a residential kitchen stoves, at around 50 ppm.[4] Exhaust emissions from natural gas combustion are often low enough not to cause adverse health affects. A large number of industrial and commercial industries require heat in the range of 100^{O}F to 500^{O}F (38^{o} to 260^{O}C), which microturbines can be utilized to supply such need for heat. In addition, microturbines' exhaust gas is rich in CO_2 while can make them valuable for further applications, such as in greenhouses. Many industrials processes require hot air at relatively low temperatures, in the range of a few hundred degrees Fahrenheit in order to dry products. Microturbines providing valuable electricity at the same time can exploit the need for hot air at relatively low temperature. A brick manufacturer uses a 80 kW Bowman microturbine to provide hot air to dry bricks before firing is an example of this application. The microturbine is a not recuperated unit and its exhaust is directly ducted to the brick-drying kiln. (See figure 4). Thermal energy produced by the microturbines offsets a portion of the energy that would otherwise have been obtained from burning natural gas and thereby potential reduces the operating costs. The microturbine runs 24 hours per day and all exhaust heat is used in the drying process. Generated electricity helps to reduce on site power consumption from the grid[5]. According to Bowman Overall system efficiency is greater than 90 percent resulting and it is a cost effective application.

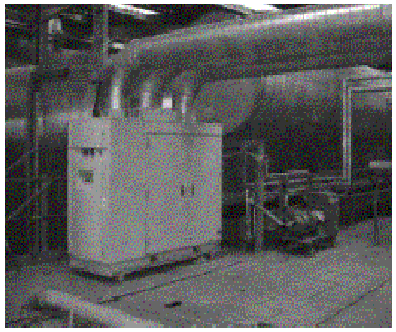

Figure 4

A complete analysis should be conducted before CHP implementation. The U.S. Department of Energy (DOE) has developed a walk- though analysis that takes up to two days to complete[3]. This analysis quickly weeds out any applications that are not economically viable (See figure 5). DOE explained its steps at different levels with details at its website. The steps are as follow:

- *Walk-through analysis (figure 5)*

•*Feasibility analysis- more details such as electric tariffs, standby/backup rates, transmission and distribution tariffs, fuel access and price, capital budget, operation and maintenance costs/modes, interconnection, environmental issues and other costs associated with carrying out a project.*

•*Preliminary design- a more comprehensive evaluation for analysis of hourly energy requirement and cost plus system part load performance*

•*Detailed design – the basis for performance modeling and budget*

Figure 5

DOE's walk-though analysis can be used for considering any sort of CHP application, whether or not a microturbine is involved.

Microturbines have multiple applications; however, one the great advantage of microturbines is that can operate using a number of different fuels, such as, natural gas, sour gases (high sulfur, low Btu contents), and liquid fuels, for example, gasoline, kerosene, and diesel fuel/heating oil. With this advantage microturbines can be successfully implemented in the use of waste or by-product methane. Diesels generators emitted nearly 300,000 tons of nitrogen oxides. Overall NO_X emissions from fossils fuel fired power plants in 1999, according the EPA, were 5.715 millions tons.[6] On the other hand, studies had revealed that when microturbines are operated on natural gas, NOx levels are reported at less than 10 ppm and CO is below 25 ppm without any post combustions controls.[7]

The flexibility of fuels is desirable feature of microturbines. Along with natural gas; microturbines can run with back-up fuel, such as propane and fuel oils. Nevertheless, in some cases the primary fuel for microturbines has been landfill gas (LFG) and digester gas found in wastewater treatment facilities. Natural gas will have a heating value of about 1,000 Btu's per cubic foot; in contrast, digester gas will have a lower Btu value, between 350 and 600 Btu per cubic foot. A great advantage of digester gas is that it is free and renewable, which makes economical sense for its application.

One of the first applications for microturbines was in resource recovery for oil patch applications. The purpose of resource recovery is the utilization of flammable gas instead of discharge into the atmosphere. This application recovers valuable usable energy while often reducing emissions. Most of the oil fields burned the natural gas by flaring pipes; however, large amounts of wasted gases are produced. Flare acts as a pilot light, so large volumes of gas can be diverted into it, immediately ignited, and safely burned off. The U.K Offshore Operators Associations (UKOOA) states that 1,886,572 tons of natural gas were flared in 1998 by those offshore rigs run by U.K firms.[3] This represents about 2193 GWh of power depending on the energy content of the natural gas and the heat rate of the generation technology. In fact, U.S. industry flares waste gas equivalent to 2.0 Tcf of natural gas/year.[8]

Figure 6

Prior to using the microturbines for flaring, gas engines were used to burn the gas. Operators expected the microturbines to require less maintenance than reciprocating engines. The production of gas in oil fields is essentially free since it is going to be burned; the utilization of a microturbine may be cost effective. Even with the lower efficiency of a microturbine relative to the new combine cycle central plants, the free fuel production makes this application potentially economically and environmentally friendly -- such as the example of Bentley-Simonson Inc. (BSI) project (Figure 6). The system consists in a 70kw microturbine form Ingersoll-Rand. According to BSI, the microturbine is able to supply about 80% of the power needed at the facility using the natural gas, which is supplied, by BSI's own wells. This application makes up one growing markets for microturbines due to its economical value. The utilization of microturbines in this application brings valuable benefits both economic and environmental benefits.

The application of microturbines in the energy resource recovery is expanding and growing. Likewise, the application of microturbine in the landfill is emerging and especially in the smaller landfills where larger electric generation plants are not generally feasible due to economic factors and lower amount of LFG (landfill gas). Landfills offer free fuel in that they produce methane. The energy contents of the methane produced has lower energy content lower than the pipeline quality natural gas. The recovery and the use of methane produced in municipal solid waste landfills have environmental and economical benefits.

About four trillions cubic feet of gas is flared worldwide. As of November 2002, more that 340-landfill gas projects were operational in the United States[3]. The EPA estimates more than 500 other landfill sites present attractive opportunities for project development. There are presently 10 projects involving microturbines in the EPA data base for landfill projects.

For example, Mobile, AZ; Burbank, CA.; Agoura Hill, CA.; Jamacha, CA; Lakeview Terrace, CA; Monterey Park, CA; Martinez, CA; Antioch, IL, Indianapolis, IN; and Baraboo, WI are some of the projects involving microturbines. The recovery and utilization of methane has created environmental and economic benefits in local and global entities.

Figure 7

Energy resource recovery technology and its application is well established and it offers little technical risk. Several obstacles affect the development of landfill gas projects. The major obstacle of landfill gas projects is the potential risk of a gas shortfall occurring prior to recovery investment and profit, which brings economical obstacles for its investment. The use of microturbines in landfill gas projects has helped to reduce environmental impact and reduce cost. Such as is the example for the OII microturbine project from New Cure, Inc. in California. The project employs six 70kW Ingersoll-Rand microturbines, which use the landfill gas with methane content as low as 35%. The facility uses about 80% of the power generated from the microturbines. Some of the loads of the facility include the leach ate treatment plant and a landfill gas flare station. According with to New Cure Inc. the project has exceeded its expectation and New Cure believes that its microturbines have helped to achieve savings. According to New Cure, it expects the pay back of this project to be in two years.

Microturbines have the flexibility and advantages to be implemented in ways not previously considered for generation units. Stand alone, peak shaving, standby and emergency power are some others applications for microturbines; nevertheless, the some of the most promising implementations of any microturbine are where there are environmental and economic benefits. The utilization of microturbines in a project with multiple applications seems to make the most economic sense, such as heat recovery for space, hot water heating and the availability "free" or "cheap" fuel such as oil well flares or landfills. Additional applications may results as microturbines mature.

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