11 - Micro Gas Turbines and Heat-Driven Cooling

Australia's availability to inexpensive natural gas and the expansion of the gas network will lead to growth in the use of new micro gas-turbines. These turbines have the ability to increase overall efficiencies of power generation and lower greenhouse emission to highly attractive levels.

Australia has proven and probable reserves of national gas that amount to around 110 trillion cubic feet. This figure would be able to provide for around 100 years of natural gas at current usage levels.[1] Australia is able to provide some of the least expensive gas in the world both to industry and to residential customers. This structure is based upon the two factors of domestic supply and export markets.

The provision of gas to the Australian domestic market is dependent upon the gas pipeline infrastructure. The existing pipeline covers over 90,000 km linking around 3.5 million customers with 13,000 km of pipeline having been laid between 1995 and 2000.[2] Developments such as these are providing for a more competitive, dynamic and efficient gas network within this still emerging network.

However, if gas is to be used more intensively as an electricity generation fuel, further expansion of the existing pipeline and construction of new pipelines to service new areas is important.[3] For the eastern states, gas supply is expected to be available from local sources until 2020. After this time, a pipeline from north-west Australia would be able to meet eastern states demand.[4]

The Electric Power Research Institute predicted that over the next 20 years, the developed world will largely meet the need for additional electricity generation capacity using gas-fired turbines. The conversion of gas to energy using the lower heating value (See Box 11.1 – Heating Values) for gas turbines is expected to be at around 60 per cent efficiency if the waste heat is used.[5] This compares with around 38 per cent and 26 per cent for black and brown coal electricity without use of the waste heat. The use of gas is expected to meet the need for peak supply loads with coal providing for base loads.[6] In a distributed generation model for electricity generation, described in Chapter 10, gas will be the main fuel for this emerging infrastructure.

BOX 11.1 – HEATING VALUES

The method used to describe the amount of heat generated from natural gas is known as the heating value. The term "Higher Heating Value" (HHV) is equivalent to Gross Heating Value (GHV). The Higher Heating Value is used more frequently and is defined as the total heat obtained from combustion of a specified amount of fuel with the necessary amount of air to burn all the carbon, hydrogen and sulphur. Gas is usually sold on the Higher Heating Value.

Lower Heating Value (LHV) is the higher heating value less the latent heat of vaporisation of water formed during the combustion of the hydrogen in the natural gas. This Lower Heating Value is usually considered to be 90 per cent of the higher value. The Lower Heating Value is generally used when calculating the efficiency of a gas turbine.

Micro Gas Turbines

A number of manufacturers have developed large gas turbines that are very efficient and have low maintenance costs. However some of these manufacturers have recognised the utility of smaller turbines in the 30 to 2000 KW range. While these smaller units are not as efficient as the larger units, they offer a simple means of generating reliable power from gas and simple energy recovery. These generators challenge petrol or diesel reciprocating generator efficiencies when the waste heat from the turbine is used.

In a distributed generation infrastructure, the generating equipment would need to be located close to the end user. In some situations this will mean siting the equipment within high-population areas. The issue of air quality will be very important in this instance. Interestingly, the exhaust from these turbines is acceptable for use within these areas as emissions are primarily carbon dioxide and water vapour mixed with air.

In a populated area, nitrous oxide is a particularly dangerous gas. When burning air in a high temperature combustion, oxides of nitrogen (NOx) produce nitric oxide (NO) that oxidises to produce nitrogen dioxide which has a significant detrimental effect on human wellbeing. The presence of oxides of nitrogen lead to the development of ozone (O_3) which can cause smog and respiratory problems. The micro gas turbines being used by the CSIRO produce nitrous oxides at around 0.223 gm/kWh.[7] This is low when compared to the 4 gm/kWh produced by a standard diesel engine.

While some of the large base-load Australian producers have been using gas turbines, the micro gas turbine has not reached the market adoption that is evident in North America and Europe. The CSIRO has installed three 60 kW micro turbines at its new facility in Newcastle for research and development purposes and electricity generation. A 60 kW plant will be installed at the Hornsby Library mid 2003 and will use waste heat to operate a cooling system (see below for section on Heat-driven Cooling).[8]

As discussed above and in Chapter 10, gas turbines are primarily expected to meet the needs of peak load requirements. These sites are likely to be within industry and commercial areas. For industry, the cost of peak-load power may be able to be offset through a distributed generator thus reducing the cost of electricity. In commercial situations, the increased power use for heating and air-conditioning would be met through the distributed generator.

There are a few drawbacks with the micro gas turbine. One of the more important is the temperature of the air at intake. A gas turbine compresses air and the greater the compression, the greater the efficiency. As a cold gas is more dense than a hot gas, the micro turbine is able to produce a greater output with cold air at the intake. This presents a difficulty for gas turbines as the air at peak-times is usually warm to hot and the efficiency of the turbine is reduced and therefore inlet air cooling is used to improve efficiencies in hot climates.

There is the projection that the use of gas use will grow at a rate of around 3.4 per cent per annum for the next two decades. This will lift the total primary consumption from 18 per cent to 24 per cent putting it after oil and coal.[9] Therefore it is expected that there will be an increase in the number of installations of gas turbines. The installation of the micro turbines is reasonably uncomplicated provided that initial training has been completed. However as the number of installations increases, so will the number of individuals who will become involved.

Co-generation

The waste heat produced by a gas turbine is primarily in the form of hot exhaust gas as mentioned above. This heat is able to be used to power a steam generator, indirect heating of a building, allocation to thermal storage facilities or in heat-driven cooling systems.

Depending upon the configuration of the gas turbine, the temperature of the exhaust gas is able to satisfy one of two requirements. Where the exhaust gas is to be used for steam generation, the gas exits at a temperature of between 550 to 600 degrees Celsius in a non-recuperated turbine. If the gas is to be used for indirect heating and operating a cooling system, lower temperatures are generally required and this is available from a recuperated turbine at around 270 degrees Celsius. There is greater efficiency in a recuperated turbine for electricity production.

Co-generation systems will see further development over the coming years as the popularity of gas turbines increases, the electricity market becomes less regulated and the application of co-generation becomes more acceptable.

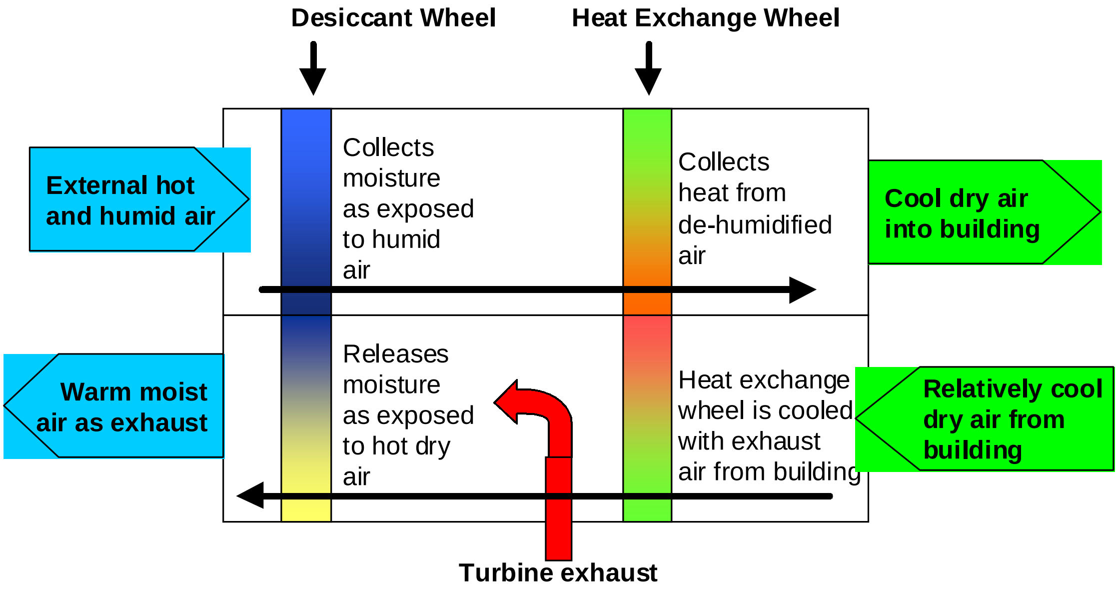
Heat-Driven Cooling Systems

The heated exhaust produced by the gas turbine is able to be captured and used rather than letting the gas escape into the atmosphere. As outlined in the comments above, recent growth in the use of peak-load electricity is seen to be a result of the increased use in air conditioning equipment. A co-generation process is able to use the hot gas to operate two types of cooling systems. These are two-wheel desiccant and absorption cooling systems.

Desiccant Cooling Systems

The primary advantage of this technology is that it is able to use “waste” heat to provide for cooling and dehumidification. This technology is an alternative to conventional vapour compression systems (refrigerated air conditioning) and has been commercially available for 20 years.[10] This system is able to efficiently co-exist with a gas turbine configured as a primary power generator - that is, low exhaust heat. See Figure 11.1 – Two-wheel desiccant cooling.

Figure 11.1 – Two-wheel desiccant cooling



This system does require a careful examination of the site and the collection of data to prove that economic benefits will be available once the equipment is installed. The CSIRO at the Hornsby Library collected data over a season before the installation was recommended. The system being installed is known as a two-wheel desiccant system but other systems are known as liquid spray-tower, solid packed tower, rotating horizontal bed or multiple vertical bed.

The term “two-wheel” comes from the design of the system which has one wheel containing the desiccant and the other is a heat exchanger (also known as sensible heat wheel). The system is also divided into two sections with an external-to-internal and internal-to-external air flow. The operation of the system is continuous and requires small amounts of electricity to drive the motors for the wheels and requires an air stream at a temperature greater than 80 degrees Celsius to regenerate the desiccant.

The process works on external humid air entering the system and passing through the desiccant on the first wheel. The desiccant absorbs the water allowing warm, dehumidified air to pass through to the heat exchanger. As the desiccant wheel rotates into the internal-to-external air stream, the hot exhaust gas from the micro turbine evaporates the moisture from the desiccant. The dry desiccant is then rotated into position to collect moisture from the incoming external air.

The heat exchanger collects heat from the air after the desiccant wheel has removed the moisture. This allows for cooler, drier air to enter the building. The heat exchanger rotates into the out-going air stream from the cooled building and releases the collected heat to the out-going air stream. Although the air is heated by this process, the outgoing air is not hot enough to remove the moisture from the desiccant wheel and the hot exhaust gas from the micro turbine provides this additional heat. The hot air moves through the desiccant wheel and exits as hot, moist air.

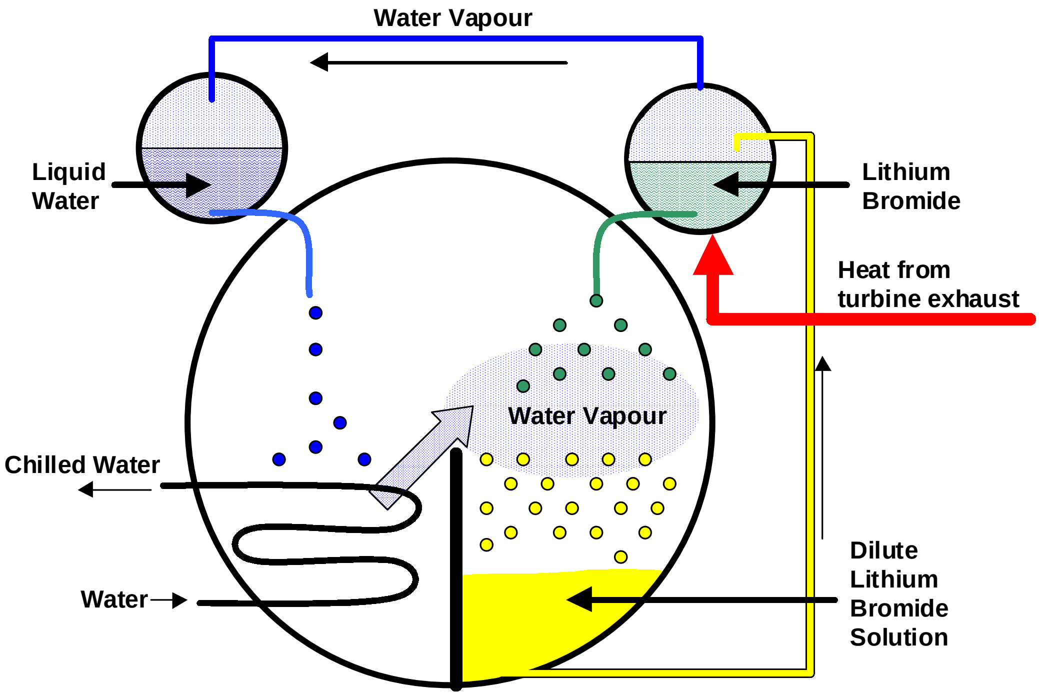
Depending upon the temperature and humidity differences between the cooling system and the building, an evaporative or vapour compression system may provide the final process. Obviously these end-systems will be utilising cooler, drier air and will be smaller in size than if the two-wheel system had not been used.

Absorption cooling

This cooling system is a closed system that uses a number of processes to transfer heat from one fluid to another. The system works on the basis that water boils at different temperatures based upon atmospheric pressure. At a single atmosphere, water boils at 100 degrees Celsius. If the atmospheric pressure is lowered, the water will boil at a lower temperature. The interest in this cooling system is that heat is required to operate the process rather than the electrically driven compressor and condenser in a refrigerant system. This heat can be gathered from the exhaust from a micro turbine.

One absorption cooling system uses a combination of water and lithium bromide in a vacuum tank. The process is somewhat complex and a full examination of the technology will not be made here. Essentially, liquid water is injected into a tank with a vacuum so that it boils at around 3.7 degrees Celsius. The evaporation of the water cools a set of pipes containing a transfer liquid for cooling (See Figure 11.2 – Absorption Chilling system).

Figure 11.2 – Absorption Chilling system.



In operation, the vacuum tank fills with water vapour. Lithium bromide is added which absorbs the water vapour at a low temperature and forms a dilute solution of lithium bromide in water. This solution is removed from the bottom of the tank and transferred to a heat source. At this heat source, the water is released from the lithium bromide as a vapour state and is transferred to a condenser tank linked to the inlet of the vacuum tank. The lithium bromide, is returned to a 63 per cent solution as it is heated and the water evaporates. This concentrated solution of lithium bromide is then able to be returned to the vacuum tank to complete the cycle.

Benefits from combined gas turbine and heat-driven cooling systems

The exhaust from conventional reciprocating engines is hot enough to drive these cooling systems but the exhaust gas contains high levels of noxious gasses. The exhaust from a micro turbine using natural gas provides for a clean exhaust with all of the waste heat contained in the exhaust. The microturbine has lower maintenance costs than the reciprocating engines and provides for a more efficient use of fuel when combined to produce electricity and temperature control.

The combined use of these two technologies lifts the efficiency of the entire process from around 26 per cent for the higher heating value to around 60 per cent for cooling systems. Greater efficiencies are able to be gained where indirect heating of water, air, swimming pools and horticultural greenhouses which may be as high as 90 per cent efficiency. This is certainly a more efficient use of fossil fuel than would be the case in a coal-fired station.

Summary

Australia has substantial reserves of natural gas and a developing pipeline infrastructure. The use of natural gas as a primary energy source will increase to around 24 per cent of the total behind oil and coal. The installation of distributed generation systems is expected to increase with micro gas turbines providing for some of the expanded system.

There will be an increasing need for individuals who can install, commission and maintain these distributed systems. Additionally co-generation applications are expected to be combined with these micro gas turbines to provide steam for industrial use or electricity generation, heating and cooling.

IMPLICATIONS FOR THE SHARED TECHNOLOGY INDUSTRIES

Automotive

As this technology applies to stationary power generation there are no applications expected.

Building and Construction

The technologies mentioned here will have a significant impact on the design and construction of integrated HVAC systems. Additionally, retro-fit activities can be expected as the energy market becomes more deregulated and peak-load pricing begins to impact upon profitability for industry. The single-dwelling residential market is unlikely to utilise this technology but is applicable for apartment housing.

Electrical

This industry will install, commission and maintain these systems on an increasing basis. The adoption of this technology will see electricians become involved with connections from the distributed generator to the building and to the grid. Maintenance and remote monitoring will also involve members of this industry.

Electronics

This industry will not be greatly affected by the adoption of this technology as existing electronic systems have already been developed.

Engineering

The HVAC industry will become more involved in the establishment of these co-generation systems with heat-driven cooling systems. Local climate conditions will determine which systems are utilised.

Information Technology

Distributed generation will require the management of an integrated and interruptible power supply to ensure that web-based services are able to maintain operations in the event of power outages.

Telecommunications

Many of the installations for distributed generation will be monitored remotely and secure and robust connections will be required.

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