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Gas Utilisation

W Hammonds[1]

APPIN AND TOWER METHANE ENERGY PROJECT

A world first in energy innovation

BHP has teamed with Energy Developments Limited and Lend Lease Infrastructure, to establish an electrical power generation facility that utilizes methane produced as a by-product of mining at BHP's Appin and Tower coal mines in southern New South Wales.

In what is believed to be a world first, Energy Developments Limited has developed technology which will capture not only the drained methane, but also a portion of that which is present in the ventilation air, reducing BHP Collieries Division's greenhouse emissions by approximately 50 percent. The methane gas is converted to electricity using state-of-the-art lean burn gas engine technology.

Construction and installation of two plants, comprising a series of one megawatt gas engines, commenced in July 1995. Full capacity was achieved on 5 September 1996. The combined output is 94 megawatts of electrical power.

Gas supply tends to vary with geological conditions and mining performance. An advantage of the multi-engine concept is that engines are brought on-line as required to match the available gas supply, thus optimising the total efficiency of the plants.

The gas engines are capable of consuming a total of 161,262 tonnes of methane per annum (93,712 tonnes from Appin and 67,550 tonnes from Tower).

The electricity generated at the plants will be supplied to the local distributor, Integral Energy, and be sufficient for up to 60,000 homes.

Environmentally – Positive power generation

The Methane Energy Project is a powerful illustration of how an imaginative approach to greenhouse reduction can achieve a number of beneficial effects simultaneously, namely the prevention of methane being vented into the atmosphere; high safety standards prior to mining activity in the mines; and the advantages of electricity production from an otherwise unused resource.

BHP's Appin and Tower mines are considered gaseous, meaning for reasons of safety they require gas drainage (drilling bore holes into the coal seam and strata ahead of the mining operations and piping the methane to the surface). Large volumes of ventilation air must also be passed through the mine to dilute the undrained methane.

In the past, methane at the Appin and Tower mines was captured by the methane drainage plants and exhausted along with mine vent air directly into the atmosphere. Some of the methane from Appin Colliery was used to power a gas turbine to generate up to 14 megawatts for supply to the State grid.

The Methane Energy Project is unique in that it is not only reducing greenhouse gas emissions, but utilizing available energy sources in capturing the methane and burning it in high efficiency engines to produce electricity.

The project will reduce Australia's output of greenhouse gases by 0.5 percent, helping to meet the national emission reduction target. In fact, this project is the single largest contributor to reduction targets in Australia.

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An award-winning development

The success of the project in reducing greenhouse emissions by 160,000 tones (4.3 million tonnes CO_2 equivalent per annum) contributed to winning the project a National Energy Award 1995 in the Production / Conversion of Energy Category.

One of the main elements of the award judging focussed on those projects that have taken energy issues beyond good management into new areas of innovation.

The Appin Project was also awarded the prestigious Premier's Award for Environmental Excellence in the New South Wales Minerals Industry.

More importantly, this power is generated by disposing of a waste product – hence it is referred to as "Clean Power'

A cleaner atmosphere leads to more benefits

In addition to the environmental gains, other benefits resulting from the Methane Energy Project include:

- The ability of the mines to operate from an independent electricity source. This has safety benefits in the event of an emergency evacuation of the mines,
- The effective use of an otherwise wasted energy resource,
- The provision of cheaper and more reliable electricity to consumers,
- The creation of up to 30 new jobs now that the plants are in operation (more than 60 jobs during construction), and
- The technical, commercial and contractual proving of a process that will have further applications in the mining industry and the general community.

Considerable interest has been shown in the project throughout the coal industry and the community in general. Experience gained from the Methane Energy Project will encourage further use of waste methane for power generation in mining and other industries. The use of such gas for small and large scale electricity generation may apply at other coal mines – particularly where deep, gassy seams are confronted.

The power partners

BHP Collieries Division initiated the project and also supplies gas to the operation

BHP Collieries Division is based in Wollongong, New South Wales, employing a workforce of approximately 1,700 and operating five underground coal mines. Using modern long wall mining techniques, the Division mines in some of Australia's best reserves of coal, producing more than six million tonnes of clean coking coal and one million tonnes of energy coal each year.

The Appin power partnership energy developments limited

Energy Developments Limited is an integrated energy company which develops, owns and operates power generation and power transmission projects. Energy Developments Limited operates Power Stations with a total installed capacity of over 200 megawatts in South Australia, Victoria, New South Wales, Queensland and the Northern Territory, including power plants fuelled by natural gas, landfill gas and coal seam methane. The Company undertakes the initial design and construction and commissioning as well as the final operation of these plants.

Lend lease infrastructure

A subsidiary of the Lend Lease Corporation, Lend Lease Infrastructure is both a developer and operator of power and water infrastructure projects in Australia. Lend Lease Infrastructure has approximately 165 megawatts of generating capacity under development or completed. Some of these are directly managed and operated by Lend Lease Infrastructure, including hydro-electric power stations supplied from existing irrigation dams in New South Wales and Western Australia. These projects provide significant environmental benefits and regional economic development to our communities. The Lend Lease Corporation is able to utilize its considerable resources to provide specialist risk assessment, financial structuring and project management expertise.

GAS UTILISATION

Introduction

This section considers some of the technical issues in utilising Coal Bed Methane. It attempts to cover all of the important issues to consider and then to explain the logic and the reason for the success of the EDL solution.

Understanding the fuel source - methane drainage plant

This plant provides the primary source of coal bed methane. This fuel source is characterised by large variations in volume and quality. The variations tend to occur over a reasonably long time frame associated with the mining activity. Below is a typical specification of the mines gas from Appin and Tower.

	Minimum	Maximum	Average	
Total Flow M^3/sec	3.5	6.5	4.4	
Methane Concentration %	40	80	45	
Carbon Dioxide %	0	12	3	Note 1
Higher Hydrocarbons	0	1	1	Note 2
Air	20	60	51	

Note 1 Appin has experienced some CO_2 but these numbers are relatively low compared to Westcliff.

Note 2 Higher hydrocarbons are not significant in the CBM drained from underground. The surface boreholes that collect gas from the Bulgo Sandstone overlying the coal measures can contain significant levels of higher hydro-carbons (4-8%).

Mine ventilation air

The mine ventilation air differs from ambient air in the following ways that are relevant to utilisation.

- Vent Air tempature approximately 10°C lower than ambient
- Vent Air Methane Content 0 to 1% CH_4
- Vent Air Dust loading is significant
- Vent Air moisture content is very corrosive

Natural gas

Natural Gas is used as a supplementary fuel source and can be considered a very clean source of methane. It is worth noting that the ethane content varies to maintain the specified heating value.

Safety considerations

As the methane drainage process and the mine ventilation system are all driven by improving mine safety it is critical not to compromise the safety of the mine whilst utilising the gas. There are five main safety issues to be are aware of.

Flammability limits

The upper flammability limit (UFL) of methane air mixture increases with pressure and temperature as defined below:

Pressure Variation of UFL

$$UFL = 14. \ + 20.4 \log P(atm)$$

Temperature correction defined as

$$\frac{UFL\ t°C}{UFL\ 25°C} = 1 + 0.000721\ (t - 25)$$

The above formula provides a UFL of 37.8% for a pressure of 9 atmospheres and temperature of 200°C.

This factor is very significant in considering utilisation technology. In gas turbine applications it is necessary to compress the fuel for injection into a combustion chamber. The increasing UEL means it is unsafe to compress beyond a reasonable pressure for a known methane concentration. This fact eliminates the aero derivative style gas turbines and some of the very highly efficient industrial gas turbines.

Interface with the methane drainage plant

Methane Drainage plants are a very important part of the safety equipment at the mines and are designed to "fail safe" and always provide a path for gas from the mine. This occurs in a plant shutdown or blackout by by-passing gas from the suction side of the plant to atmosphere via a non-return valve. In an operational mode this is achieved by having multiple stacks and "fail open" control valves to ensure a path for the gas.

The interface to the utilisation plant must preserve the by-pass facility for shutdowns and blackouts. It must also collect the gas in such a way that should the utilisation plant stop a path is always available for the methane drainage outlet. This can be achieved with tiered pressure control loops and appropriate valves.

Interface with the mine ventilation air

This interface must also be accomplished without compromising the mines safety. The major requirements of this interface are.

- Never to impact on the ventilation fan performance by adding back pressure.
- Never to utilise the ventilation air if the CH_4% is too high or following a ventilation failure.
- To let the colliery management establish when ventilation is normal and when it is acceptable to utilise ventilation air.

Safety devices

All fuel sources must continuously be monitored to ensure they are safely above the UEL or safely below the LEL. These systems are duplicated by the Colliery and the utilisation plant.

As a back-up, flame arresters are installed at appropriate place to prevent propagation of flames. It is essential to have a thorough understanding of flame arresters so that their installation guarantees their performance rather than ensures their inadequacy.

Explosion protection

Clearly the processing of coal bed methane establishes many hazardous zone of various levels and the equipment needs to be explosion protected for the relevant zones. In Appin and Towers case the plants have been designed to comply with the Coal Mine Regulations and the Australian Standards as well as the AGL gas codes.

Gas turbine versus gas engines

In considering which type of equipment to use there are several factors which need to be considered:

Ventilation air

Physically it is possible to direct ventilation air into either a gas engine or a gas turbine. In a gas engine the air stream's sole purpose is to mix with the fuel to provide the correct air fuel ratio for the combustion process. In a gas turbine not all of the air from the compressor is used as combustion air. Part of the air is used for cooling and it mixes with the exhaust having by-passed the combustor.

Utilising the ventilation air concerns gas turbine manufacturers for two reasons.

- The environmental emission problems resulting from the cooling air circuit mixing with the exhaust.

- The particulate and chemical contaminant that could easily attack the exotic metals in the blades.

Currently no manufacturers have operated gas turbines on ventilation air. Energy Developments is planning to trial such technology in 1998.

Plant efficiency

Efficiency is normally improved by either increasing temperature or pressure or both.

Thus gas turbines with high efficiencies have higher pressure ratios and as discussed earlier cannot be safely applied to an air-methane mixtures.

The turbines that can be safely used on air-methane mixture have a pressure ratio of 20:1 or less and a typical efficiency of 30-35%. A gas engine can match these efficiencies.

The most important aspect to consider with the efficiency is the part-load efficiency. As the mine gas quantity varies it is not possible to continually provide maximum fuel requirements (unless an undersized plant is installed and surplus gas is vented to atmosphere). The part load efficiency of a gas turbine is quite poor compared to a gas engine and this is significant in the selection process.

Compression

To inject the fuel into a gas turbine significant expense is required for compression equipment. This adds both to the capital cost ($\approx$ 40%) and the parasitic load of the Power Station. Gas engines if they are low pressure engines require no compression equipment. High pressure gas engines require relatively low cost and low pressure compression equipment.

Tolerance to fuel variations

This gas engine has greater tolerance to low methane concentration and high carbon dioxide concentrations than does a gas turbine. Typically a gas engine can operate down to a composition of 35% CH_4 and 35% CO_2 and a gas turbine would be limited to 50% CH_4 and 20% CO_2. This can be a very significant consideration as the Westcliff Gas Turbine has not operated for approximately two years due to their high CO_2 levels.

Maintenance

There is no doubt there is more maintenance on reciprocating engines than on gas turbines. The maintenance costs are also higher but the maintenance tasks can be scheduled so as not to interfere with revenue production. The maintenance of a gas turbine also involves more skilled trades persons and when it occurs it will involve a significant down time.

Flexibility and redundancy

This consideration is more relevant to the number of units and the unit capacity rather than the technology. There is no doubt that the Appin Tower project has significant advantages in design redundancy.

ECONOMICS & STATISTICS

The utilisation of C.B.M is a very essential environmental initiative and should also be economically viable.

The viability of such projects is influenced by the following:

- Mines Gas Availability
- Electricity Tariff
- Natural Gas Tariff
- Power Plant Efficiency
- Power Plant Availability
- Power Plant Capital Cost
- Power Plant Operating Cost

Mines gas availability

Mines Gas Availability is certainly a very critical factor. Ideally the mine should continuously supply the full fuel requirements of any utilisation plant. As the CBM production varies with mining conditions it is necessary to manage the gas availability by selectively collecting gas form boreholes that are not essential to mine safety. Such management produces a fairly uniform supply of gas and importantly gas is not vented to atmosphere. If a mine is not prepared to manage the gas resources then either shortfalls of mines gas will reduce revenue or surplus production will be vented to atmosphere reduce the environmental benefits.

Electricity tariff

The recent changes in the electricity industry have provided competition in the industry and resulted in lower electricity prices. The implementation of a competitive bidding process for generators has resulted in very low generation or pool prices. This relatively low price is expected to remain whilst supply comfortably exceeds demand. The current pool price would cover operating and fuel costs but would not service the capital investment. This low price is therefore not sustainable in the long term.

As far as utilisation of C.B.M is concerned it is a particularly difficult time to enter the market unless it is a small project which does no export power. In such cases the avoided cost of not purchasing electricity would improve the economics.

Natural gas tariff

The Natural gas tariff is obviously only relevant if Natural Gas is used as a supplementary fuel. The deregulation of the natural gas industry should result in a reduction of natural gas prices.

Power plant

Appin and Tower Power Station have an annual availability of greater than 98% and maintain an efficiency of approximately 35%. This excellent performance maximises the revenue to the project. The performance of the engines on mines gas has been good and the operating costs are below budget.

Viability From the miners perspective

The economic viability for the mine owners is dependent on a reliable supply of CBM. The quality needs to be within specification and sufficient quantity to fully fuel the power station. The returns to the mine are also influenced by the length of contract and the type of guarantee linked to gas supply.

It is possible to structure a project so that the mine owner can recover all or a substantial part of the underground methane drainage costs.

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