INTRODUCTION TO THE BI-FUEL TECHNOLOGY AND IT'S APPLICATIONS FOR DISTRIBUTED GENERATION

ABDUL BASIT, HERCULES ENERGY CONSULTING

1. INTRODUCTION

A challenge exists today in the competitive energy markets for the need to provide an efficient and low cost method of producing power at an end-users location. Onsite power production has always been given different titles for different applications. This includes co-generation (combined heat and power), peak shaving, distributed generation and prime power generation. To serve this market, various technologies have been used to provide the physical means of onsite power production, such as micro-turbines, fuel cells, natural gas reciprocating engines and natural gas turbines. While some of these technologies are relatively new and others have been in existence since the dawn of electric power. Thus the question arises, is how to obtain the greatest market infiltration and success rate with which available technology. This is the question that a natural gas utility or a similar constituent must answer, in order to promote the applications that are available for onsite power generation.

This paper will specifically look at a technology known as the dual-fuel or bi-fuel technology. This is a conversion technology that has the capacity to convert diesel reciprocating engines to utilize a mixture of natural gas and diesel. The importance of this technology will be shown, by its ability to provide the natural gas utility another method to promote onsite power generation at an inexpensive first cost installation.

The advantages of such a technology will focus on three main benefits. These include financial, environmental and fuel supply issues. In addition, this paper will also provide specific applications and their challenges at a hospital, college and hotel. Also a specific example will be provided, by giving information on a real life application of the dual fuel technology.

2. DESCRIPTION OF THE TECHNOLOGY

2.1. The Basics

To understand the technology that is to be discussed, a quick overview is needed on the basic technology of natural gas and diesel engines. While the obvious difference between the two engine types is the fuel input, the basic technology of a diesel and natural gas reciprocating engine is also different. Natural gas engines are similar to gasoline driven engines utilized in vehicles, by the requirement of a spark-ignited method. This means that a spark is required to start combustion. The spark plugs are necessary because natural gas like gasoline has a heat content that cannot create combustion by itself.

However diesel engines utilize a fuel that does not require spark plugs because the heat content of the fuel is enough to combust with a compression cycle. This method allows for a piston to compress the fuel/air mixture, whereby combustion occurs due to the compression.

To allow diesel engines to use natural gas would require a change to the technology. This would mean installing spark ignition systems and various other changes. Such conversions are not cost efficient and also do not maintain the original power output that the engine was designed to provide.

2.2. Overview of Market

In the United States, diesel generators hold the majority of power generation sales towards electric power end-users. This is because of building codes, onsite emergency power requirements and first cost considerations. First, diesel generators have onsite fuel capacity while natural gas generators do not. Second, the cost of a diesel generator is about $300 to $500 (USD) to install while the cost of a natural gas generator is about $750 to $1,000 (USD) to install. Third, natural gas is not available everywhere.

Thus Diesel generators are a significantly larger market to the actual users of electric power. While natural gas is the desired fuel for large turbines (greater than 10 MW), which are used by electric utilities and very large co-generators, diesel generators hold the share of end-use electric power users. In addition, the number of service and maintenance providers for diesel generators is significantly more than that of those companies that are certified and expert in the service of natural gas generators.

Both natural gas and diesel power generation are provided by a large variety of manufacturers. These range from such widely known firms as Caterpillar, Cummins, Mitsubishi and many others.

Thus there are many medium to large sized power users that already have onsite power generation. The only problem is, it is diesel. The challenge that exists is how to ask a customer who has existing power generation onsite to look at a purchase of a new natural gas generator. Based on experience, the challenge is immense since the end-user must now consider spending $100,000's or $1,00,0000's to create an onsite power system that uses natural gas. This is where the bi-fuel technology comes into the picture.

2.3. The bi-fuel technology

The dual fuel technology allows diesel reciprocating engines to use natural gas. This allows the diesel engine to use a mixture of natural gas and diesel. The dual fuel system can replace up to 80% of the diesel fuel requirements of the engine.

The bi-fuel system is comprised of four main components. An air-fuel mixer, gas power valve, gas train and an engine control system. The gas flow initially enters the gas train, which will reduce the inlet gas pressure to atmospheric pressure. The negative outlet pressure allows

the system to pull natural gas depending on the intake airflow of the engine. Thus, as engine load will change, the intake air volume will draw additional fuel into the mixer.

Once the natural gas leaves the gas train, the gas power valve is used to provide the engine the required gas flow rate for a given engine load. After leaving the gas power valve, the natural gas is mixed with air in the air-fuel mixer. This device allows for the correct mixture of air and natural gas.

The air-natural gas mixture is then compressed in the turbo-charger and distributed to each cylinder, where it is compressed and ignited when diesel is injected into the cycle. The whole process is monitored by the electronic control system and pressures temperature, exhaust gas temperature, gas pressure, engine vibration, and manifold air pressure. The electronic control uses this information to ensure that the engine will not operate in bi-fuel mode if any of these measurements go beyond their expected parameters.

It is important to note that the dual fuel technology does not replace the diesel fuel 100%. This is self explanatory because the diesel generator operates on a compression cycle it is necessary to maintain a level of diesel fuel to operate the system. The diesel fuel is also needed for providing lubrication of the diesel engine system.

The performance of the engine does not change with the bi-fuel system. There is no de-rating of the engine and the total BTU input is the same for the natural gas/diesel mixture as it would be for 100% diesel. In addition, if natural gas is lost during the bi-fuel operation mode, then the diesel generator will revert back to using 100% diesel fuel with no interruption.

Finally, the bi-fuel system does not require a substantial natural gas pressure. The range of pressure required for the bi-fuel system ranges from 1 to 5 psi. Thus it is not necessary to install any sort of compressor to provide high pressure natural gas. The pressure requirements provides an added logistical for application of this technology, especially in areas of natural gas service where natural gas pressure is low due to age of the system or code requirements.

With this explanation of how the bi-fuel system works, an overview will be given to show the various benefits of utilizing the dual fuel technology.

3. BENEFITS OF THE DUAL FUEL TECHNOLOGY

3.1. Overview

The dual fuel technology has the capability to convert a diesel engine to use natural gas. For the vast majority of customers, the primary reason to convert their existing diesel engine to natural gas must create some sort of economic incentive. In addition the dual fuel technology provides environmental benefits and fuel supply benefits.

3.2. Economic Benefits - Combined Heat and Power

The first method is to see if the customer can create a combined heat and power (CHP) application at the facility. This is also known as co-generation. Combined heat and power allows a customer to use the waste heat that is created by the exhaust and water jacket for a heating application. For this to be successful, there has to be an existing use of heat or steam. Usually the facility will be using the heat for sterilization, heating, or some industrial process that requires steam. Once it has been determined that the facility is a good candidate for combined heat and power, then the consideration must be given for the technology.

The next question that arises is whether the existing generator is capable of being used for anything other than emergency power. Sometimes the generator is old and is only considered capable by the customer that it can be used as an emergency power system. It should be noted that all diesel generators maybe used for providing power on a constant basis. A manufacturer will provide a standby KW rating, and also a continuous KW rating. Therefore, when an end-user states that their generator is only capable of providing standby/emergency power, it is the responsibility of a knowledgeable individual to explain to the customer what the generator is actually capable of.

Once it has been determined that the generator is properly functioning and the facility has the ability to use the waste heat of the generator, the logistics of the project must exist. The generator should be located near the source of where the heat will be required. For example, if boilers are used by the facility, it is beneficial to have the generator as close to the boiler plant as possible. Also, the generator should be able to feed into the electrical system of the facility, so that if power is lost, backup is available from the local electric utility.

If the physical and logistical aspects of the project are favorable to the project, then an economic analysis should be done to determine the monetary savings. The following assumptions will be used for this example:

Cost of natural gas:	$0.18/cubic meter Cost includes all charges and commodity
Cost of diesel fuel:	$0.20/liter for #2 diesel fuel
Size of existing diesel genset:	500 KW prime power rating
Conversion rate:	80% natural gas and 20% diesel
Natural gas consumption:	107 cubic meters/hour
Diesel consumption:	26 liters/hour
Cost of conversion:	$20,000 (including conversion costs and other costs)
Maintenance costs:	$0.01/kw-hour
Cost of electricity from utility:	$0.10/kw-hour
Hours of Operation per year:	8,000 hours
Current natural gas usage: (Used by Boilers)	275,000 cubic meters

Based on these assumptions, let us first determine the cost of purchasing electricity from the local electric utility:

8,000 hours (500 KW) ($0.10/kw-hour) = $400,000 per year

In addition the cost of the boilers is:

275,000 cubic meters ($0.18/cubic meter) = $49,500

Thus the current total annual energy cost is $449,500

The cost of operating the bi-fuel system is as follows:

Cost of Diesel:	$0.20/liter (26 liters/hour) (8,000 hours) = $41,600
Cost of natural gas:	$0.18/cubic meter (107 cubic meters/hour)(8,000 hours) = $154,080
Cost of maintenance:	$0.01/kw-hour (8,000 hours)(500 KW) = $40,000

Based on the performance of the engine, the bi-fuel system will produce enough waste heat, that the boiler will not be required. Thus the total cost will be $235,680

Based on this simple calculation, the annual savings are $213,820. As one can see, the pay-back will vary drastically if one is converting a diesel generator to use the bi-fuel system or having to purchase a brand new system.

3.3. Economic Benefits - Peak Shaving/Load Control application

In the scenario where the customer does not have any heat usage at the facility, the dual fuel technology can be used to provide economic benefits through another means. The onsite diesel power generation system can be utilized to load shed or peak shave the electric power consumption from the local electric utility. Load shedding is when a customer's onsite generation is turned on during the request of the electric utility. The electric utility will request the customer's onsite power generation in times of insufficient power or some sort of force majuere. A customer will in return receive a reduce rate or rebate for utilizing the onsite power generation. Peak shaving is the application of a generator during times of peak electric demand. A customer may use a more electricity for just a couple of hours a day, and by running a generator can substantially reduce monthly electric costs.

It should be noted that with both this application and the CHP application, the regulatory and governmental regulations are very important in whether the application will happen. For example, a state operated and owned electric utility may forbid end-users to generate any electric power onsite. However, electric utilities may use this technology to promote load control/load shedding applications, which can benefit them.

3.4. Environmental Benefits

By replacing the diesel fuel with natural gas, it is expected that there will be some benefits as they pertain to the emissions data of a diesel engine.

A diesel engine will produce some basic emissions. These include Sox, SO2, NOx, CO, CO2. Dependent on the country and what regulations exist, some or all of these emissions are limited to a specific amount per year. For example, US Federal facilities are required to reduce CO2 in addition to NOx and CO.

Because the bi-fuel system eliminates up to 80% of the diesel consumption of the diesel engine, there are going to be related reductions in emissions. However it should also be noted that because natural gas is now the main fuel that is being consumed, certain emissions will increase.

The bi-fuel system clearly can provide advantages in reducing certain emissions. If for example, local environmental regulations require a certain SO2 emissions requirement and the diesel generator will be in violation of that SO2 limit, then the bi-fuel system could certainly create a situation that allows for the operation of the generator.

Because a bi-fuel system also reduces the amount of hourly diesel consumption, the onsite fuel capacity will also be reduced. This could be advantageous in a situation where regulations may not allow for an underground diesel tank. With a bi-fuel system it is possible to install an above ground tank. This above ground (also known as a belly tank) tank is usually located right below the footprint of the generator.

3.5. Fuel Supply Benefits

When utilizing the bi-fuel technology, there can be a replacement of up to 80% of diesel consumption with that of natural gas. While the benefits can be seen from an environmental and economic standpoint there are also benefits to supply concerns.

With a 100% dedicated natural gas generator, if natural gas is lost (usually for emergency reasons) then the generator cannot operate. With a 100% diesel generator, the onsite fuel is only available for a set amount of time, and additional fuel may not be available if there is an emergency situation.

The bi-fuel system can provide an additional benefit for those with diesel generators. For example, a bi-fuel system is used to convert a diesel generator allowing for a mixture of 80% natural gas and 20% diesel. Because of this fuel mix, the capacity of the diesel tank has now increased by a factor of four. This is due to the fact that the diesel generator is now only consuming 20% of the fuel that it would have been required.

In the event that natural gas is lost, then the diesel generator will revert back to 100% diesel consumption. Therefore, the bi-fuel system provides an additional level of supply during an event that requires emergency power.

Because the diesel generator can revert back to 100% diesel, this allows a commercial customer to use an interruptible natural gas rate for service. This is beneficial to the natural gas utility too, considering that they have a reliable customer who can be interrupted.

4. APPLICATIONS OF THE DUAL FUEL TECHNOLOGY

4.1. Overview

By providing the benefits of using the bi-fuel technology, here are some specific examples are given on the specific challenges and benefits for some specific customer types. It should be noted that there may be some issues that are not addressed.

4.2. Hospital

Because of the nature of the business that hospitals are involved in, the vast majority of healthcare institutions around the world maintain onsite emergency power operations. Depending on what the regulations are, the size of the onsite power generation can operate a partial or the full electricity requirements of the facility.

For example, in the United States, diesel generators are available at all hospital facilities. This is because of regulations that require onsite fuel, which is more of a challenge with natural gas generation than with diesel generators.

To pursue a bi-fuel application at a hospital, it is best to focus on a system that avoids providing any power to services directly used for patient care. The electric requirements that are used for patient care, operating rooms, and the hospital should be supplied by the local electric utility. However, systems such as chillers, cooling towers, lighting that can be isolated from the rest of the hospital electric requirements should be investigated.

Since hospitals have large requirements for natural gas (if available), a co-generation application utilizing the bi-fuel system on an existing diesel generator is very high. Also the diesel generator can be converted to bi-fuel operation and be utilized to peak shave electric power requirements.

4.3. University

A college or university will have emergency diesel power generation onsite, for various campus buildings as well as the physical plant. For the diesel generators that are used to provide emergency power, these generators should be used specifically for peak shaving or load shedding applications. This is because most of the generators are not sized for the total building load but rather for providing power to elevators/lifts and emergency lighting.

If the campus has a central physical plant with a central boiler system then the bi-fuel system can be used to convert existing diesel generation to create a co-generation system.

Some of the issues that relate to using any kind of generator at a campus are usually associated with the sound. Most emergency generators are only expected to operate during an emergency and not during times when classes or other activities are taking place. Therefore, an added cost would be looking to provide some kind of sound attenuation.

4.4. Hotel

Hotels will usually have a small to mid-sized generator onsite for providing emergency power for the facility. One of the biggest issues in operating a generator is the sound. If the generator is located nearby hotel rooms, it is unlikely the generator will be used for anything other than what was originally intended. If a hotel can use the generator, then it can be used for a variety of different scenarios. One scenario is to peak shave non-critical electric systems. Some hotels have redundant chiller or pumping systems that can be connected to the generator allowing for a peak shaving mode.

Co-generation is also a very good scenario. A hotel will have a heat load, usually for heating, laundry, or hot water. The bi-fuel generator is a great way to implement a cogeneration system, if the hotel already has the sunken cost of a diesel generator. As long as the logistical costs of using the waste heat and any costs associated with sound attenuation, emissions or other factors are kept to a minimum.

4.5. Electric Utility

An electric utility's basic function is to generate, transport and meter electricity. A non-deregulated electric utility will provide all three functions. The transportation and the metering is usually maintained, owned and operated by the utility. However with power generation, the electric utility will obtain the power from several resources. First the electric utility will have their own power plants. If this power is not enough to provide 100% electric service, then the electric utility may purchase power from some sort of wholesale market that supplements their power generation facilities.

Finally, the electric utility may implement some kind of commercial load interruption/control program. The is where the utility will give a discounted rate to a commercial/industrial customer and in exchange will allow the utility to interrupt them when necessary. It is expected (hopefully) that the commercial customer will have an onsite generator to provide power during the times of interruption.

The bi-fuel system provides an enhancement to a load control program. It allows the utility to focus on marketing a load control program to a wider range of customers, since the natural gas supply provides a greater comfort zone for the electric utility customer.

Another scenario that exists is for municipal or government owned utilities. A government owned utility can enhance it's electric service by enacting a load control program with governmental buildings and facilities. For example a city owned electric utility can convert diesel generation to use bi-fuel. Again, it could be that the diesel generators cannot be operated because of emission issues and environmental concerns. With the conversion of the diesel generation with the bi-fuel

system, the utility can use these generators during times of excess demand verses existing power supply.

5. REAL LIFE APPLICATION: THE UNIVERSITY OF MIAMI – ANIMAL RESEARCH CENTER

5.1. Background

The University of Miami is the largest private higher education institution in the state of Florida within the USA. The University of Miami has four campuses within the metropolitan Miami area. This includes a marine research facility, an animal research center, a medical research campus, and the central university campus.

This project was initiated at the animal research center in South Miami. This center is used by various governmental and corporations to conduct medical research on animal subjects such as monkeys.

5.2. Application

At one of the buildings located at the campus, a diesel generator was converted to use the bi-fuel technology. The diesel generator is sized at 450 KW and is a Cummins engine operated generator.

The current electric power requirements of the building are approximately 250 KW, thus there are no issues or problems with power requirements. In addition, there are no sound issues because the generator is located to ensure no problems to humans or to animals being kept at the research facility.

The converted bi-fuel generator is being used peak shave the electric load of the building. The generator is set by automatic controls to operate during the time of the day when electricity is the most expensive. During the evening and early morning hours the generator does not operate since it is cheaper to purchase power from the local electric utility.

5.3. Preliminary results

The generator began operation in May 2002. The generator operation was suspended until September 2002, due to other reasons not pertaining to the generator itself. Since September 2002, the generator has been operating on bi-fuel mode. The generator is utilized for peak shaving and is operated daily from 12pm to 8pm, Monday to Friday.

The logistics were favorable to the installation of the project. A natural gas line was very close by to the location of the diesel generator. In addition, the natural gas line pressure was more than sufficient to allow operation of the bi-fuel generator. It should be noted that the natural gas line is used to also serve a natural gas boiler for the same facility.

There have been no mechanical or electrical challenges that have presented themselves in this project. The biggest challenge in this project is to maintain the cost of natural gas to a competitive price and to provide the facility with the best electrical rates during off-peak hours.

6. CONCLUSION

By utilizing the bi-fuel technology, a customer is able to utilize their diesel generator in a brand new way. Allowing the diesel generator to use natural gas, allows the consumer to enhance their energy consumption and costs. In addition, the bi-fuel technology allows for various benefits that have been outlined in this paper.

These include the following:

- No Engine modifications
- Lower emissions
- Low cost and ease of installation
- No requirement for high pressure gas supply
- No efficiency losses or de-rating of the engine
- Increased fuel capacity of existing diesel fuel capacity
- Providing the potential for economic/financial savings

The bi-fuel technology provides natural gas utilities and consumers of natural gas the ability to control their energy costs and use a technology that is available on the market. While natural gas utilities should put as much effort into promoting 100% natural gas technologies, the benefits of the bi-fuel technology can be seen to be self-evident.

One of the functions of a natural gas utility is to promote new gas technologies and enhance revenue for the utility at the same time. It is common knowledge that some of the new generation technologies such as micro-turbines and fuel cells have captured the imagination of the energy industry worldwide. With an efficient and affordable power generation system that can be used by a large number of commercial energy users, the energy supply and transportation system would be revolutionized. If the distributed generation (DG) concept were to become a reality, it would change the way the world consumes and uses energy.

However, these technologies do not provide the best method of producing and consuming energy. Why? First, micro-turbines are still too expensive for a large number of small commercial energy users to purchase. Fuel cells are even more cost prohibitive. It is interesting to note that a 20 KW micro-turbine costs $20,000 (USD) to install. For someone who only uses 10 to 30 KW maximum demand per month, $20,000 (USD) is a considerable amount of money in comparison to what is spent yearly on electrical power costs. It should also note that a 100 KW diesel generator only costs $30,000 (USD) to install. Until micro-turbines come down in cost, in the range of $150 to $200 per KW, it is unlikely that there will be a mass market for the product.

Until these concept technologies become more affordable, a natural gas utility will have to find a technology that can provide a larger market share. It is in this author's opinion, that the bi-fuel technology has the potential to create that market share that is not possible with the other technologies.

In conclusion, the bi-fuel technology provides the natural gas utility the capability to target a large percentage of customers within their

territory. The natural gas utility does not have to invest in upgrading existing natural gas pipelines, because the pressure requirements are minimal. In addition, it does not ask a potential customer to invest in a significant amount of money to implement a co-generation or peak shaving scenario. The bi-fuel technology can be installed in a variety of different applications, because of the widespread use of diesel power generation around the world. Until other technologies become more cost effective, the bi-fuel system has the potential to implement the distributed generation concept and allow natural gas utilities to enhance their services and products that they provide to their customers.

REFERENCES

1. GTI Brochure Information on the dual fuel conversion system
2. Basit, A. (2000). The bi-fuel technology. An Introduction. *Energy Engineering,* April 2000