COMMERCIAL APPLICATIONS OF FUEL CELLS AT BILLINGS

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Abstract

This fuel cell project at Billings involves four components of programs: (1) Residential Housing, (2) Remote Rural Energy, (3) Commercial Facilities, and (4) Major Power Generation. As an umbella to all of these programs the Center For Applied Economic Research – Montana State University, Billings provides current marketing and business economic background support as well as project economic payback analysis.

This paper will focus on the last two programs that are of special interest to DOE's Hydrogen Programs. Regarding Commercial Facilities, the program involves the implementation of a demonstration commercialization project in a local Billings hospital that involves steam-reforming of medical red-bag and other wastes to produce hydrogen-rich syngas that will drive a molten carbonate fuel cell that will provide production of electrical power, steam, and space heating. Regarding Major Power Generation: A Feasibility Study was recently completed that has shown that the repowering of the 163 MWe J. E. Corette coal power plant is economically attractive with a simple payback of 5 years when it takes advantage of high temperature fuel cells, particularly the Siemens/Westinghouse solid oxide fuel cells, to increase electrical generation efficiency. A Texaco gasifier can accept Conoco Refinery wastes and produce syngas (a mixture of hydrogen

and carbon monoxide) which is then converted into heavy paraffins that are returned to Conoco where they are converted to middle distillates and used as blending stock to improve the refinery output and produce low sulfur fuels. Hydrogen is produced from the syngas as an important product that is also sent to Conoco. The gasifier will also produce high quality steam to be augmented by steam from the fuel cell waste heat boilers to drive the Corette steam turbine-generator system.

Introduction

It has been said, *"the area that develops fuel cell technology will be the Silicon Valley of the 21st Century"* – certainly, the Billings, Montana region could fit the bill. Since this project has started, the amount of fuel cell business activity has increased tremendously at Billings. CTA Architects Engineers has directed their efforts toward the Commercial Facilities markets and has started design/planning work at Deaconness Medical Center, St. Vincent Hospital, Montana State University, and several businesses as well as an exciting project that plans an entirely new town in remote Montana that plans to be a model for energy efficienty and sustainability. These projects involve very large numbers of fuel cells, which will help reduce unit costs from the increased manufacturing level to approach the needed economy-of-scale commercial activity.

Power Generation needs in the area are supplied by a 1967 vintage, 33% efficient, 163 MWe, J. E. Corette coal power plant. The use of this plant has been less than desirable in the community because of its air emissions and use of out-of-state coal as feedstock. Our concept is to upgrade this coal plant to a first-of-its-kind coal plant of the future, where local coal can be fully utilized as an important energy and chemical resource without emissions of carbon dioxide (CO_2) and without the typical problems of NOx, SOx, VOCs, and other particulate emissions.

The plant upgrade conceptual design includes the use of several advanced technologies, most of which have been proven individually, but which have never been integrated into a single system. The Texaco gasifier would be located at the Corette site or an adjacent site where the coal feedstock, co-mixed with Conoco's petroleum coke, API separator bottoms, DAF float, and possibly other minor industrial/municipal waste, would be gasified to produce syngas and steam. Some of this syngas would be fed into a solid oxide fuel cell/turbo-electric generator system to produce electricity.

Royal Dutch Shell and Texaco are two well-known examples of organizations in the petroleum industry that have built, installed and operated full-scale gasification units as front ends to refineries and power plants. In addition, Intellergy has direct experience with steam-reforming waste products at Westinghouse's Oak Ridge, Tennessee commercial facility.

Two examples of fuel cells that can accept syngas are the Solid Oxide Fuel Cell and the Molten Carbonate Fuel Cell. Siemens/Westinghouse and others have made great progress with recent developments in Solid Oxide Fuel Cells (SOFCs) that can use syngas for this project.

The efficiency of the proposed plant would be around 68%, which would double the current plant's efficiency of 33%. This will allow the plant to produce the same electrical output of 163 MWe, while producing additional hydrogen for Conoco and syngas for fuel cells to produce more electrical power and fully utilize the turbo-generator system capacity. Additional syngas is reacted over a Fischer-Tropsch catalyst to form higher hydrocarbons, such as heavy paraffins or waxes or other useful hydrocarbon products. These waxes, for example, form a feedstock to the Conoco gas-oil hydrotreater plant functioning as a moderate pressure hydrocracker where they are reacted to form low sulfur, high cetane diesel fuel , kerosene, and naphtha. Additional “Premium Power” would be supplied across the fence to Conoco that has higher quality specifications and high reliability (almost uninterruptible).

The production of some hydrocarbon products, like middle distillates, is necessary in order to utilize the feed carbon source so as to eliminate any carbon dioxide emission. With a mass feed rate to the plant of 2160 tons/day, the middle distillate production would be around 8,250-barrels/day while Corette’s electrical power output would still be at 163 MWe.

Another parallel effort is to implement a demonstration commercialization project in a local Billings hospital that involves steam-reforming of medical red-bag and other wastes to produce hydrogen-rich syngas that will drive a molten carbonate fuel cell that will provide production of electrical power, steam, and space heating.

Discussion

The Center For Applied Economic Research – Montana State University has set the stage of the business environment with a resource inventory of electrical generation and distribution in Montana and Wyoming. It is important to understand how electricity is supplied to consumers in order to apply fuel cell technology efficiently and effectively in the future. A detailed market analysis and survey of the rural electric cooperatives in Montana and Northern Wyoming was prepared in the belief that they represent a large potential market for fuel cell technology in the Yellowstone Region.

The second part involves an economic analysis that first focuses on PEM fuel cell manufacturers. Although response to our mail survey by these manufacturers was nil, the information we obtained from follow-up telephone conversations was enlightening. While it is likely that the average cost of the initial PEM residential fuel cell systems will be around $10,000 installed, this cost must decrease significantly in order to be cost effective for the consumer, to under $4,000. Full commercialization is projected for 2003 to 2004, but this date could be pushed back as it has in the past. One of the major challenges that these PEM developers face is that there are not many companies that manufacturer parts and materials for PEM fuel cell systems. The developers often use in-house engineers to design parts for their test systems, and then go to the marketplace to find a vendor to manufacture the parts for production. This definitely presents an opportunity for the Billings region to manufacture parts for or to assemble PEM fuel cell systems. The obstacle we face is getting information from the PEM developers, as competition is fierce and they are hesitant to disclose too much information.

We studied related fuel cell organizations, and had the opportunity to visit two fuel cell research centers: The National Fuel Cell Research Center in Irvine, California and The Desert Research Institute in Reno, Nevada. These visits were very helpful and afforded us the opportunity to visit with the each center’s director, who will be a good resource as this project continues.

We have provided some information on the net metering laws in Montana. The Montana legislature believes that it is in the best interest of the public to promote net metering because it encourages private investment in renewable energy resources, stimulates Montana's economy, and enhances the diversification of the energy resources in the State. However, the current PSC code would have to be modified slightly to allow an individual to actually sell their excess electricity rather than just receive a credit for it. Given the legislature's beliefs, one would think that this is possible, particularly with the many economic benefits that fuel cells could provide to the Yellowstone Region.

The Feasibility Study centers on Intellergy's concept for the re-powering of the Corette Power Plant in Billings. We are finalizing a detailed net present value and payback period analysis of the revenues and costs for this project. Both the NPV and payback period are encouraging.

We have compiled statistics on the 1,177 coal fired electrical generating units throughout the United States. Coal plants represent the largest generating capacity in the U.S., and have a median and average age of 25, and 24 years, respectively. Coal is an important national resource. With coal consumption by the electric power industry at 90% of the U.S. total coal production, coupled with the increasing energy demands of the nation, coal-fired utility plants will not disappear anytime soon.

In 1997, coal-fired units at electric utilities accounted for 72% of the country's carbon dioxide emissions, 80% of the country's nitrogen oxide emissions, and 86% of the country's sulfur dioxide emissions. Intellergy's concept for the Corette re-powering project in Montana provides a unique opportunity to upgrade a typical old coal plant to a new state-of-the-art coal plant where coal is utilized as an important energy resource without emissions of CO_2, and without the typical problems of NOx and SO_2 emissions. The opportunity to package this concept and apply it to other coal-fired electric plants across the country is immense. We have quantified an estimated dollar value for each state if they reduce CO_2, NOx and SO_2 emissions by just 50%, and the potential dollar benefits alone appear to be enough to pay for the technology/equipment in many instances. In the next phase of the project, we will begin to look at some individual coal-fired electrical generating plants around the country and prepare a cost-benefit analysis for re-powering these plants.

Currently, we are conducting two market studies – one of residential consumers and one of institutional consumers. The residential market study is a telephone survey of Yellowstone Valley Electric Cooperative customers, and we expect to have approximately 500 responses to analyze. The institutional survey is directed at hospitals of varying size throughout Montana, and we will contact as many of the 60+ hospitals as time allows. We can continue this study of hospital power requirements, as the Montana Society of Healthcare Engineering's quarterly meeting will be in Billings this September. This society's membership is made up of the facility service directors at Montana hospitals.

For Power Generation, we focus on the 1967 vintage, 33% efficient, 163 MWe Corette coal power plant. This petroleum coke/coal-steam-reforming/gasification project will require that the fuel cell type accept carbon monoxide and other light hydrocarbons in addition to the normal hydrogen. This requirement almost guarantees that the only two types to be considered are Solid Oxide Fuel Cells (SOFCs produced by Siemens Westinghouse Power Corp. (SWPC) [1-3] or Technology

Management , Inc.) or Molten Carbonate Fuel Cells (MCFC) [4]. We estimate that about 56 0.5 MWe AC fuel cells units can be powered at maximum by the 1379 tpd or 1900 lbs/min syngas generated from the coal feed stream, assuming around 85% coal to chemicals utilization and an electrochemical 68% fuel cell/turbo-generator efficiency [5-7]. This is 6.93 kW/scfm of H_2, which is much higher than the strictly electrochemical phosphoric acid fuel cell at 4 kW/scfm of H_2 (which cannot use CO in the syngas).

We envisage a four-phase program that begins with a single natural gas-fed 250 kWe fuel cell at atmospheric pressure that provides dc electrical power to an inverter and also a hot exhaust gas stream that can drive a waste heat boiler to raise up to 130 kWt (0.44 x10^6 Btu/hr), 1005°F, 1950 psig steam for the Westinghouse steam turbine-generator system rated at 192MWe. The second phase would add additional natural gas-fed, commercially-priced SOFC fuel cells (maybe in 250 kW or 1 MW module increments or a combination) to total say 14 MWe and 7.2MWt of steam for the Corette turbine. The third phase would add say a single 1000 tpd Texaco gasifier to begin using more local coal plus petroleum coke from Conoco refinery next-door and supply syngas for the fuel cells and hydrogen for Conoco as well as high grade steam for Corette's steam turbine and possibly for Conoco. The fourth phase would add an additional gasifier around 1000 tpd to be co-fed with local coal and coke together with some community waste streams and supply syngas to a small plant supplying low-sulfur and high cetane middle distillates in addition to additional hydrogen and high grade steam to Conoco. This last fourth phase will expand the gasifier/fuel cell scale such that a full quantity of steam is supplied to the Corette steam turbine-generator system to produce full rated electrical output of 192 MWe of electrical power plus some additional 28 MWe from the fuel cells to increase the Corette plants output to around 220 MWe. Upon this full repowering of Corette, the old furnace/boiler can be retired. This newly configured plant would have substantial load-following capability. This four phase program, if fully implemented, could cover roughly ten years.

Delivery for the SOFC fuel cells to meet the project schedule involves a plan to reserve an early adopter position in the waiting list for fuel cell demonstrations in time frame from 2003 to 2004.

Process Configuration

The details of the integration of the fuel cells with the gasifier and the turbo-generator electric power producing system in shown in FIGURE 1. It is the combined cycle integration of the SOFC fuel cell with the Corette steam turbine train that raises the efficiency as a power plant to high values approaching 68%. The SOFC air feed is pressurized by one of the turbine-driven compressor (could be a separate blower) and then heated in the "Heat Recuperator" that recovers waste heat from the SOFC. This heated air is then expanded to generate power in the second turbine stage. And finally, a portion of the steam generated from gasifier together from steam generated in the SOFC are used to power the third stage. The purpose of the water condenser is to accept the SOFC gas outlet containing steam and CO_2, and separate the water to make steam for the steam turbine and to recycle the CO_2 for reuse in the gasifier. Although this water condenser is symbolically shown as a single simplified unit, there are heat exchangers as part of this unit to efficiently condense the water and reboil the separated water before it is passed to the gas-phase "Heat Recuperator" to elevate to the high temperature that feeds the steam turbine.

The low pressure steam discharge from the steam turbines that are an integral part of the fuel cell package can be provided to offsite users that are adjacent to the Corette Plant, such as the sugar plant and the Greenhouse business operations. This scheme will eliminate the need for large cooling towers with steam plume discharges. This is a significant cost savings and an environmental credit. We will need to insure that the heat demand of the sugar plant and greenhouses matches closely the low pressure steam discharge from the upgraded Corette Plant.

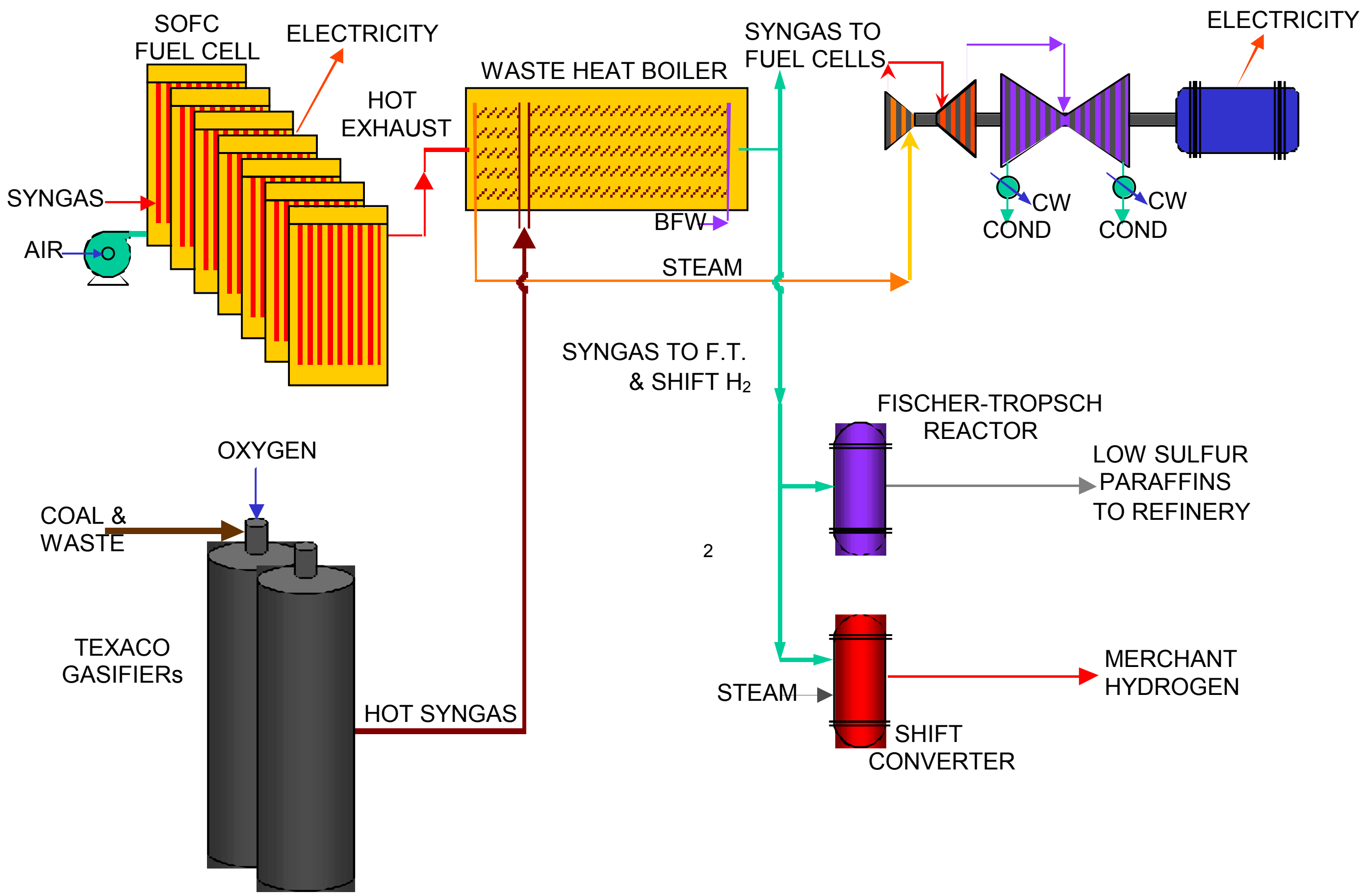

Figure 1: Integrated Gasification Fuel Cell Combined Cycle

The syngas can also be used for the production of speciality agricultural chemicals and solvents or other commodity chemicals at a significant profit. With a mass feed rate to the plant of 2160 tons/day of coke and coal, the hydrocarbon product production would be 346,000 gallons/day or 8,250 barrels per stream day (bpsd), which would be sold for additional income. And this approach of manufacturing carbon-based products which are never burned in their use lifecycle fully sequesters the carbon source so as to eliminate any carbon dioxide emission.

Current Year Progress:

A layout plan for Deaconess Hospital has been completed showing the locations and equipment sizes as well as the internal utility interconnections. The economic analysis is underway at this time.

The most labor-intense task for this year involved the completion of the Corette Power Plant Feasibility Report consisting of 22 chapters. The interfaces with the Corette Power Plant and Conoco Refinery have been identified and scoped for the exchange of critical process streams such as refinery delayed coke supply to the gasifier, hydrogen and paraffin co-product streams to the refinery, steam to Corette existing steam turbine and the utilization of waste heat. Also the recycle of any CO_2 streams back to the gasifier for conversion into useful chemical co-products.

Status of Economic and Systems Analysis:

The initial results of on-going economic analyses of the Corette Power Plant repowering with gasification and fuel cells shows that the simple payback period for around $540 million in capital investments in plant and equipment is around 5 years. The critical aspects of this design leading to such encouraging economics is the fact that the plant not only produces 34% more electric power at a higher electrical generation efficiency, but it produces valuable chemical co-products such as hydrogen and low sulfur paraffins as well. Also being explored is the possibility of co-producing some valuable sulfur-containing agricultural products that can be sold for an attractive price. As mentioned earlier, greenhouse gas emissions are nearly eliminated through the chemical utilization of CO_2 and other gases to make the chemical co-products. If commercial CO_2 emissions trading becomes more active within the U.S., these reduced emissions can also represent an important income stream for this plant.

Conclusions

The Center For Applied Economic Research has set the stage of the business environment with a resource inventory of electrical generation and distribution in Montana and Wyoming. We are beginning to understand how electricity is supplied to consumers in the region and how they apply fuel cell technology efficiently and effectively in the future.

CTA Architects Engineers has identified and are pursuing Commercial Facilities markets and has started design/planning work at Deaconness Medical Center, St. Vincent Hospital, Montana State University, and several businesses as well as an exciting project that plans an entirely new town in remote Montana that plans to be a model for energy efficienty and sustainability.

The feasibility analysis has determined that the Corette plant repowering would be a cutting-edge, future-looking project that could gain the support and pride of both local communities and environmental groups alike that could be owned and operated by PPL Montana or a partnership with the gasifier supplier. It would be a model for future coal plants and would help coal to be considered one of the environmentally safe fuels for the future. The project makes full use of DOE’s Vision 21 concepts and will demonstrate their commercialization. The project also has already started to stimulate the local economy by bringing in fuel cell activity and supporting technologies into the Billings area. There is planned the formation of the Center for Advanced Fuel Cell Technologies that would provide the process system studies, operating data, construction costs, emissions performance, maintenance records, etc. to promote other similar projects around the world. These projects involve very large numbers of fuel cells, which will help reduce unit costs from the increased manufacturing level to approach the needed economy-of-scale commercial activity. This could mean additional jobs as well as additional business opportunities and improved tax base. It will also be a source of local pride as Montana becomes recognized as a leader in sustainable energy production without pollution.

Future Work

The Technical Advisory Team will critique the findings in the Feasibility Report and select the best combination of plant configurations, and then a design team will be assembled that will scope out the design effort to proceed to install the equipment and make plant changes as needed for the commercial demonstrations.

Objectives For Next Year: The following objectives are established as goals for next year:
•Continue economic analysis of the fuel cell business environment in the region
•Cost out the design effort for both the Deaconess &/or St. Vincent hospital design.
•Obtain Technical Advisory Team consensus on the optimal scope for process installations at Corette, at Conoco, at the Sulfur Plant, and possibly on an adjacent parcel of land.
•Assemble the design team to examine the plat locations for process units and piping runs.
•Cost out the design effort for four phases of Corette Plant conversion: (1) single SOFC low pressure fuel cell demonstration powered by natural gas, (2) a field of some significant number of natural gas-fed fuel cells, (3) a field of 56 fuel cells supplied by syngas from a 1000 tpd gasifier producing steam for the existing steam turbine, and (4) installation of a second 1000 tpd gasifier, plus Fischer-Tropsch reactor to produce paraffins, plus Shift Converter to produce high grade hydrogen for the refinery, and a sulfur process to market the sulfur.
•5 Obtain funding to begin the design efforts for the two projects above.

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