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Fuel Cell as an Alternative Distributed Generation Source under Deregulated Power System

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Abstract - This paper proposes the fuel cell power plants as alternative energy sources for distributed generation in Jeju Island, Korea. This will help to increase the fuel efficiency, at least double the current thermal power plants, decrease environmental pollution, virtually to none, increase the reliability of power supply, reducing the dependency of the HVDC link, and provide quality power to the growing infrastructure in meeting the requirements for the free-trade international island.

1. Introduction

Small scale power generating technologies, such as gas turbines, small hydro turbines, photovoltaics, wind turbines and fuel cells, are gradually replacing conventional generating technologies in various applications in the electric power systems. These distributed technologies have many benefits, such as high fuel efficiency, short construction lead time, modular installation, and low capital expense, which all contribute to their growing popularity. In addition, the industry restructuring process is moving the power sector in general away from the traditional vertical integration and cost-based regulation and toward increased exposure to market forces. Competitive structures for generation and alternative regulatory structures for transmission and distribution are emerging from this restructuring process [1].

Electricity competition has led to significant changes in the operation of the bulk power grid, which are the power plants and high-voltage transmission facilities that make up the wholesale power market. More electricity is being shipped longer distances over a transmission system that was initially designed only to provide limited power and reserve sharing among neighboring utilities. Electric utilities that were once solely responsible for ensuring that adequate generation was available to meet demand now purchase a substantial amount of the power they need from the wholesale market, relying on independent power producers to build and operate plants.

2. Distributed Generation

The concept of DG has a variety of meanings, often resulting in some confusion. DG will refer to any modular generation located at or near the load center. These small, self-contained, decentralized power systems are categorized as photovoltaic, mini-hydro, and wind systems or in the form of fuel-based systems, such as fuel cells and microturbines [2].

The introduction of DG to the distribution system will have a significant impact on the flow of power and voltage conditions at the customers and utility equipment. These impacts might be positive or negative depending on the distribution system operating characteristics and the DG characteristics. Positive impacts include: i) voltage support and improved power quality, ii) diversification of power sources, iii) reduction in transmission and distribution losses, iv) transmission and distribution capacity release, v) improved reliability.

However, some operating conflicts related to over-current protection, voltage regulation, power quality problems, ferroresonance and others might result when the distributed generators are to operate in parallel with the utility distribution system.

2.1 DG Technologies

There are various types of distributed generation technologies ranging from the well established reciprocating engines and gas turbines to more recent types of renewable sources such as wind farms and photovoltaic. Emerging technologies such as fuel cells and micro-turbines are recently commercialized.

One especially promising feature of distribution generation is its ability to supply the power-hungry electronics installations that account for a substantial share of demand growth. The idea that their proponents claim will be able to generate electricity more cheaply and efficiently than gas-fired plant, is for all usable fuels to be converted and for carbon emissions to be fully sequestered, so that the technology essentially emits no carbon.

2.2 Limited Impact on Fuel Conservation

Just about any smaller-scale energy source has the potential to help reduce reliance on natural gas: by providing peaking power where needed, cutting losses and costs associated with distribution and transmission, and providing a backup to centrally generated electricity. Distributed generation and storage also can yield greater trustworthiness than the "three nines"(99.9 percent reliability) that has been the power industry standard.

A major limitation of the distributed-generation concept, however, is that the most promising technologies - both fuel cells and microturbines - almost always rely on natural gas as the preferred feedstock. Thus they can do little to cut back on the use of gas beyond improving distribution efficiencies - by reducing line losses, for example, and allowing for energy to be used more flexibly [3].

In Europe the High Integrated Hybrid System (HIHS) instead permits to design a power supply system able to guarantee the continuity of the supply mixing the different renewable energy sources - like PV, WG (even micro-hydro if possible) - limiting the DGS use for back-up purpose only. A way to increase sustainability of the system consists in substituting the DGS backup set with a fuel cell (FC). In this way, it is possible to use the energy surplus to produce, by a hydrolysis process, the hydrogen needed from the FC. In the case of FC, the costs are higher because of the absence of a real market for FC maintenance. FC cost will be reduced in the next years because ofthe increase of the FC production. In particular, the possibility of substituting the Diesel Generator backup group with a fuel cell for supplying isolated telecommunication devices is investigated both through the energy balance and an economic investment. Using the fuel cell technology as backup device the need of periodic maintenance and refueling operation is limited or removed. Accounting environmental cost, the photovoltaic-wind-fuel cell configuration, having this latter near-zero emission, permits an increasing of environmental sustainability and then a decreasing of the increment due to external costs in the electric power generation [4].

3. Fuel Cells

Fuel cells generate electricity through an electrochemical process in which the energy stored in a fuel is converted into DC (direct current) electricity. The process is similar to that of a battery. Because fuel cells generate electric energy without combusting fuel, they have many advantages. Some are as follows: high energy conversion efficiency, modular design, very low emissions, low noise, fuel flexibility, cogeneration capability, and rapid load response

There are four main types of fuel cells currently being developed and/or distributed. They include Phosphoric Acid Fuel Cells (PAFC), Molten Carbonate Fuel Cells (MCFC), Solid Oxide Fuel Cells (SOFC), and Proton Exchange Membrane Fuel Cells (PEMFC). Technological comparisons between these four fuel cells are outlined in [5]. Zinc Air, Alkaline Fuel Cells, and Regenerative Fuel Cells are other technologies that are similar in design or output to fuel cells.

3.1 Specific Applications

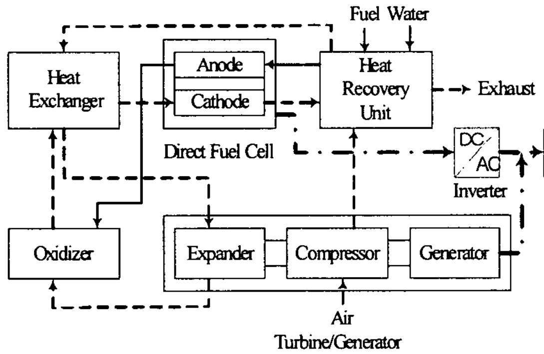
Fuel cells allow for a number of different types of applications, including stationary power sources, portable power sources, micro power sources, and those found in vehicles. Among the fuel cells, the high temperature fuel cells, MCFC and SOFC, are primary candidates for large power production for stationary sources.

Stationary power sources are connected to the utility grid. However, these types of fuel cells have the capability of providing premium power quality that the utility grid cannot, especially in the cases of voltage sags. Premium power can be cleaner, less polluting, more secure, and more reliable. For these reasons, hospitals, plastic extruders, data centers, telecommunication switching centers, and cell phone towers will find fuel cell technology valuable.

Fuel cells may be used in residential homes, small commercial businesses, and larger commercial or industrial companies for emergency backup electricity, baseload/lifeline electricity, high-power quality requirements (i.e., in-home office connections), energy self-sufficiency, and remote off-grid locations. Utilities and other energy providers may also use fuel cells to ensure high customer power quality, meet transmission upgrade deferrals, and fit in with the "Green Power" market. Such distributed generation is modular, provides ease of sitting, and ensures lower capital cost.

3.2 Molten Carbonate Fuel Cell (MCFC)

The Direct Carbonate Fuel Cell (DFC) is a type of molten carbonate fuel cell (MCFC) that internally reforms methane-containing fuels within the anode compartment of the fuel cell. This technology, as a mature product, has a projected net fuel-to-electricity efficiency of 55-60% and a total thermal efficiency approaching 85%.The cells and stacks were based on "direct fuel-cell technology" developed by Fuel Cell Energy (FCE). Natural gas is internally reformed into hydrogen, partially in an internal reforming unit and partially at the cells. The approach is a combination of indirect internal reforming (IIR) and direct internal reforming (DIR), which provides for better thermal management. A simplified process flow diagram of the fuel cell/turbine hybrid system is shown in Fig. 1. This consists of a lumped representation of direct fuel cell stacks together with the balance-of-plant (B.O.P.), turbine/generator, and invertor to connect to the utility grid. A dynamic model for the fuel cell including B.O.P. has been described in [6].



<Fig 1> **Fuel cell/turbine hybrid system.**

4. Implementation of Fuel Cell Plants in Jeju Island

Although small, Jeju Island power system has all power system components, including generation, transmission, distribution and retail services. It shows annual load increase of 8-9%, which is faster than that for the main land Korea. As the island thrives to become a free-trade international city, the need for reliable supply of electric energy sources is becoming urgent. Not only the supply of energy, but also the quality of power is becoming an important issue to meet the expectation of international standard in building the infrastructures. Therefore, expansion of generation facilities is an essential requirement for securing power system stability and reliabilityin Jeju Island. Furthermore, since the island is located in a hurricane path and is known to have frequent lightening, there has been frequent contingencies because of the system heavily depending on overhead transmission and HVDC tie lines.

The total installed capacity of Jeju Island is 587 MW, which includes 150 MW transfer through the HVDC from the mainland. The power transfer through the HVDC is about 50% of the total demand in the island, and more than 40% in the average annually.Recently, relatively larger units are being planned and thus, the impact of failure of a unit is expected to be greater than before.Most of the units use expensive oil as the fuel. Wind turbine and LFG are new energy sources being introduced in recent years, 10 MW and 1 MW, respectively.

4.1 Large Fuel Cell Plants

To reduce the dependency on the HVDC cable, large fuel cell plants are proposed in various locations. Fuel Cell plants require the basic fuel in the form of LNG or Buncker-C oil. In principle, all current oil-based thermal plants can be replaced or augmented by Fuel Cell Plants in order to increase the fuel efficiency. Assuming the scenario that an LNG port will be available in South Jeju, the following plants are possible sites in the southern Jeju Island: i) two 40 MW Fuel Cell Plants in South Jeju near the LNG port, ii) one 40 MW Fuel Cell Plants in Joongmoon/Seoquipo, iii) one 40 MW Fuel Cell Plants in Hanra S/S, iv) one 40 MW Fuel Cell Plants in Hanrim S/S

In addition to the sites in the southern Jeju Island, Fuel Cell Plants can be located in the following sites in the northern Jeju Island: i) two 40 MW Fuel Cell Plants in Jeju T/S, ii) one 40 MW Fuel Cell Plants in Shinjeju S/S, iii) one 40 MW Fuel Cell Plants in Dongjeju S/S.

Some units can be in the hybrid with gas turbine in order to increase the fuel efficiency to over 80%.

4.2 Small Fuel Cell Plants

In addition to the large Fuel Cell Plants for maintaining capacity for the Jeju Power System, there are number of applications for localized use of fuel cell plants: i) industrial, ii) government facilities, iii) universities, iv)hospitals, v) apartment complex. Some units can be in the hybrid with combined heat and power production (CHP), such as ones used for industrial and apartment complex. As long as there are fuel lines available, either for LNG or Buncker-C oil, a unit of 250 kW can be installed on site next to the buildings.

5. Conclusion

The paper has proposed the fuel cell power plants as alternative energy sources for distributed generation in Jeju Island, Korea. Substantial number of new plants can be planned with fuel cell technology and it's hybrid with gas turbine and/or combined heat and power production. Although the initial investment cost is high, it's long term operation will reduce the total operation cost, in addition to the benefit of maintaining clean air for the Jeju island. As a means of reducing the capital cost, it is essential to develop the fuel cell technology as a national priority as in the United States and Japan. This will also reduce the maintenance cost for sustaining the fuel cell power plants as a viable alternative for long-term operation.

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