13TH WORLD CLEAN AIR AND ENVIRONMENTAL PROTECTION CONGRESS AND EXHIBITION

LONDON, UNITED KINGDOM
AUGUST 22-27, 2004

DISTRIBUTED GENERATION IN DEVELOPING COUNTRIES

Submitted by

Stanley M. Greenwald, P.E.
Professor and Chairperson
Department of Environmental Technology
New York Institute of Technology
Old Westbury, NY 11568
sgreenwa@nyit.edu

ABSTRACT

Electricity demand is increasing by 10% per year or more in many of the developing countries. The corresponding increase in infrastructure systems to provide the generating capacity is often beyond the means of most countries especially those with large, often isolated rural populations. Thus, decentralized or distributed generation (DG) using a variety of locally available fuels is often the only attractive solution to insure sustained economic growth and reduction in air pollution. The future technical leadership in developing the DG capacity can be provided by graduate students currently enrolled in the M.S. in Environmental Technology or M.S. in Energy Management programs at the New York Institute of Technology. A graduate level course, Power Plant Systems, taught by the author, requires that each student submit a feasibility study for DG in their home country. Fortunately, a number of students come from developing nations that are experiencing large demands in electric power generation, i.e., Nepal, Jamaica, Philippines, Turkey, Poland and Ecuador. Using the results of the feasibility studies, this paper will focus on the variety of DG techniques that can meet the growing demand for electric power in the developing world and the training necessary to assure the availability of competent technological leadership.

Introduction

Electric power is becoming the required source of energy for economic growth in the modern world. Rapid economic growth in the lower wage developing countries requires electric power to produce the goods in demand by the more developed part of the world. The industrialized countries require more reliable sources of electric power to maintain their growth while increasing the reliability of the information and energy infrastructure. It is generally recognized that the developing countries of the world contain 80% of the world's population but consume only 30% of the global energy resources. In addition, it is estimated that approximately 40% of the developing countries' population do not have access to electricity. The per capita consumption of electricity in the developing countries, 900 kWh per year, is roughly 10% of that of their more developed neighbors.

The world's population is expected to increase to approximately 7 billion by 2020 with poorest 2 billion lacking modern energy in the form of electric power. If we assume that each of the poorest 2 billion individuals are allocated a single 100 watt light bulb to sustain his/her health, learning or just survival, each person will consume approximately 500 kwh per year. From the perspective of new capacity at 60% availability, it will require 120 gigawatts of newly-installed generation in the next 15 years. This can translate into 240 new power plants with each producing 500 MW of power.

Technical Leadership and Training

The ability to meet the growing demand for power generation is directly dependent on the technical leadership and training received by students from the countries in need of new generating capacity. In this regard, both the Master of Science in Environmental Technology and Master of Science in Energy Management programs at New York Institute of Technology offer a course, "Power Plant Systems," that requires each student to submit a feasibility study for the development of Distributed Generation Systems in their homeland.

Each study includes demographic analysis of a local area in question and estimation of electric load requirements for residential, commercial and industrial customers. A site plan, type of power plant, quantities of fuel, generating capacity, construction and generating costs are also required in the feasibility study. In addition, the student must discuss the environmental concerns and impacts on the area in question.

Results

Most of the students from developing nations that are experiencing increased demands for electric power, chose to present a feasibility study of their home countries. However, it should also be noted that several students, because of the lack of information concerning power needs in their home countries, were forced to chose their temporary residential areas in the USA for the study. This paper will present the results of feasibility students in three countries; Nepal, the Philippines and Poland.

FEASIBILITY STUDIES

Micro Hydro Power Generation in Nepal[1]

A majority of population is dependent on traditional sources of energy like fuel wood and animal dung. The energy consumption statistic of Nepal shows that about 80% of total energy need is supplied from fuel wood in 1995 which means over 13 million tones of fuel wood are consumed annually (WECS, 1998). Various conservation efforts are made from government and private sectors to cope with the problem of over dependency on traditional sources of energy but the progress could not be made to the desired level. As a result, forest degradation continued and deforestation has picked up at the rate of 1.3% annually (Forest Survey, 1999). This is mainly due to unsystematic settlement, infrastructure development and industrialization. As a result soil erosion, flooding, ecological imbalance, depletion of natural resources resulting adverse impact on agricultural production and economic development of nation.

Greenhouse Gas Emission Reduction

It is likely that any additional energy generation will eventually contribute to reducing the use of fuel wood and Kerosene. However, in the short run, since the equipment and distribution system will not be existent immediately, we must consider that the thermal generation will reduce the green house gas emissions. In Nepal, much of the estimated hydropower potential of over 43,000 MW consists of small and medium projects in the range below 50 MW. Many sites have so far been identified through preliminary studies.

Proposed Power Plant

The Khudi Hydropower Project will generate on average over 25,000 MWh annually for the next 50 years and is expected to cost CA$ 7.5 Million. This energy will be used by the National Electricity utility to reduce its thermal generation initially and extend the distribution of electricity to the remaining 85% of the population who have no access to electricity and who depend on fuel wood and residues for energy source. In the short run, the energy produced by the Khudi project will be used to reduce the thermal production, thus providing an estimated reduction of 19,949 tones/yr. of CO_2 emissions. Thus, in the long term, the energy produced by the Khudi project will provide a significant reduction of emissions and will avoid the cutting of thousands of acres of forest annually, and thus contributing to carbon sequestration.

Conclusion
Sustainable distributed electricity development in Nepal would have to be achieved by relying on the indigenous hydropower, because in the case of Nepal the viability of electricity generation from other sources has not been established yet. Due to Nepal's mountainous terrain it is very difficult and expensive to construct power transmission lines in many urban hilly areas of Nepal. Such stand alone small distributed generation hydropower projects are the only way electricity can be provided to the majority of the mountainous regions in Nepal.

Municipal Solid Waste Power Plant in Payatas, Quezon City, Philippines[(2)]
Quezon City is at the northeastern portion of Metro Manila. It has a land area almost one-fourth of the National Capital Region (NCR) and is the biggest among NCR's 12 cities and 5 municipalities. Situated on the Guadalupe Plateau, the city's topography is largely rolling with alternating ridges and lowlands. The southern region of the city has low-grade terrain while the northern half is undulating, culminating at the Novaliches Reservoir. Served by a network of rivers and creeks, the city is efficiently drained except for some portions which experience flash floods due to the deterioration of waterways. The City also shares an aquifer system with Metro Manila which, due to overdrawing, has been subjected to saltwater intrusion.

Power Supply
The power supply of the city is mainly sourced from the Luzon Power Grid. The Luzon grid services the largest island in the country. As of August 2003, the Luzon Power Grid had an Installed Capacity of 11810 MW. It is projected that with the function of economic development, the peak demand of the grid will reach about 17512 MW by 2013 and will exceed its Dependable Capacity by 2007. Due to this, there will be a need for more power plants to supply the grid. Electric supply comes from a number of power plants operated by the National Power Corporation and Private Independent Power Producers in the island.

Proposed Power Plant
Presently, the Luzon Power Grid has enough power supply to energize its customers, one of which is Quezon City. The proposal to create a Municipal Solid Waste power plant within the area of the city is not intended to make the city independent in its power needs. Rather, the construction of the plant hopes to put more power on the grid as older power plants are retired with the demand continuing to increase. Furthermore, the project will hopefully help manage the solid waste problem of the city and the surrounding municipalities and hopefully reduce the need for dumpsites and landfills.

The proposal is to make a 500 MW mass burn municipal solid waste power plant with an overall efficiency of 40%. The plant will follow the typical Waste-to-Energy Facility similar to the one designed by American Ref-Fuel. Steam turbines will be used in producing the electricity from the steam produced by the boilers fueled by the MSW. Three 200 MW capacity Mitsubishi Single-Cylinder reheat turbines are to be used.

The proposed location of the Municipal Solid Waste power plant is in Baranggay Payatas, which contains one of the country's largest municipal dumpsite/landfills at 23.3 hectares. In June 1998, the newly elected President Estrada, who considers the Payatas dumpsite an "eyesore," ordered the closure of the dumpsite in September 1998 and formed the Task Force for the Development of Payatas. Today, more than 80,000 people live in the shanty-town that surrounds the dump. Ironically, the community is called "Lupang Pangako" which means the Promised Land. On October 29, 1998, four shanties were buried by garbage but no one was killed. However, a later trash avalanche claimed hundreds of lives.

With Metro Manila's 8000-ton daily garbage production, and with ongoing proposals to close other existing dumpsites in the metro and surrounding municipalities and suburbs, the volume of garbage to be thrown in Payatas will significantly increase. With this, it is possible to create a municipal solid waste power plant in the area to "use-up" the garbage. There have been initial moves in harnessing methane gas from the landfill for power but these usually are small scale due to the high costs in doing research and obtaining technical expertise.

Power Plant Impacts

Waste-to-energy facilities, such as a municipal solid waste power plant, pose a number of concerns for the different sectors in society. There are questions of whether the advantages obtained from the operation of a plant outweigh the discomforts and problems that it might cause.

Advantages

According to wte.org, a promoter of waste-to-energy (WTE) technologies, these technologies are clean, renewable, and reliable in terms of operation. According to the EPA, due to the post-combustion technologies that WTE plants employ, it will have less environmental impact than almost any other source of electricity. Furthermore, EPA estimates that WTE technology annually avoids eleven million metric tons of greenhouse gases that would otherwise be released into the atmosphere. WTE technology is also renewable because the source of its fuel is waste, which is easily and readily replenishable due to the consistent generation of wastes. In addition, since WTE plants supply power 365-days-a-year, 24-hours a day, facilities average greater than 90% availability of installed capacity. WTE plants generally operate in or near an urban area, easing transmission to the customer.

Disadvantages

In contrast, some groups say that even with modern post-combustion pollution control equipment, some toxic gases may still be emitted into the air. Also, due to the high cost of constructing WTE facilities, the price of electricity produced may not be competitive. Furthermore, the ashes that are produced in the facility, may eventually cause groundwater contamination, even when disposed of in modern landfills with good linings.

Environmental Impacts

The top concern in any combustion operation is air pollution. According to a study made by World Bank Philippines, the air quality in the country does not meet some of the standards set by the World Health Organization. The data was sourced from the Philippine Clean Air Act of 1999 and the World Health Organization/SDE/OEH/00.02, Geneva 2000. To address these problems of air pollution, the power plant must either carefully select the waste being burned in the plant, or improve post-combustion technologies to reduce emissions, in order to prevent high sulfur wastes such as tires to reduce the amount of SO_2 emitted in the atmosphere.

The power plant will also produce some wastewater for their sewer systems from the removal of liquid waste that usually comes with MSW and from the cleaning operations in the power plant. This wastewater must be treated in the plant before being released into the municipal sewer system because the wastewater may contain a number of hazardous wastes from the MSW. The other problem will be the ash that will be collected from the incineration of wastes. The ash must be landfilled properly since it may contain amounts of heavy metals that may leach into the groundwater through faulty soil linings in the landfill. Magnetic separators may be used to remove metals from the ash and bring these metals to recycling facilities.

Natural Gas Fired Combined Cycle Power Plant for Suwalki, Poland(3)

Poland has the 63rd largest area in the world, the 9th in Europe and is inhabited by over 38 million people. Suwalki with its 69 thousand inhabitants is one of the largest towns in northeast Poland and until quite recently it was the capital of the Suwalki Province. The town was founded by the Wigry Cameldolite Order within their vast properties. It was built near the Czarna Hancza meanders, where historical routes from Grodno to Krolewiec and from the Mazovia to Lithuania met.

Power Plant

A natural gas combined cycle 70 MW power plant will generate electricity using two methods, the steam cycle and the gas cycle. A combined cycle power plant will operate by combining the gas cycle and the steam cycle for higher efficiency of approximately 60%.

Air Pollution in Poland

Air pollution in Poland has been at the top of the environmental policy agenda of the Polish government since the transition to democracy. Acid rain had taken its toll on the foliation rate of Polish forests and health standards for the population were threatened because of the excessive amounts of sulfur dioxide (SO_2), nitrogen oxides (NO), carbon dioxide (CO_2), particulates, heavy metals (lead, cadmium, arsenic, mercury) and carcinogenic hydrocarbons being placed into the atmosphere by the Polish energy sector which relied on coal as its primary fuel source.

During the 1980s, Poland's Katowice district, which is part of the Silesia region and makes up 2.1% of the country, accounted for as much at 20%-25% of the country's total emissions of sulfur dioxide (SO_2), nitrous oxides (NO_x), and dust. In the region now known as "the Black Triangle," home to the largest deposits of brown coal in Europe, approximately 200 million tons of coal were produced each year, leading to 3 million tons of SO_2 and approximately1 million tons of NO_x emitted each year.

Environmental pollution in Silesia resulted from years of maximum industrial activity concentrated within a relatively small area. Emission of excessive amounts of pollutants resulted in severe acid rain, practically destroying the mountain forests and acidifying the soils in the Karkonosze and the Izerskie Mountains. As a result, the death rate for men in Katowice between the ages of 30 and 59 exceeds the national average by 40%, children are usually born underweight, and the occurrence of birth defects in the region is up to 60% more common than average.

Working with the U.S. Environmental Protection Agency (EPA), the Krakow Air Monitoring Project has bought and installed a network of meteorological instruments to provide real-time air quality assessments. The effects of these efforts to improve air quality have been dramatic: air pollution by industry has decreased by 30-50% and is on the decline. The focus of Polish environmental efforts now has shifted to developing effective pollution control strategies for the more challenging "non-point" and mobile sources, where pollution has been on the rise.

The principal environmental concerns associated with gas-fired combined-cycle power plants are emissions of nitrogen oxides (NO_x) and carbon monoxide (CO). Carbon dioxide, a greenhouse gas, is an unavoidable product of combustion of any power generation technology using fossil fuels. The carbon dioxide production of a gas-fired combined-cycle plant on a unit output basis is much lower than that of other fossil fuel technologies.

Conclusions
The gas cycle has another advantage in that it can provide power within minutes after startup whereas the steam cycle takes several hours to create enough steam to drive the steam turbine. The gas turbine is useful during times of peak electricity demand when extra power must be added for a short period during the day. It can be turned on during peak demand periods to quickly add electricity to the grid and turned off when the demand drops to normal levels. The combined cycle plant takes advantage of the efficiencies of running both cycles simultaneously to produce power very cost effectively during those peak periods, thereby saving the utility from having to purchase power to meet spikes in demand.

Completed Feasibility Studies

Country	**DG Power Plant**
Nepal	Micro Hydro
Philippines	MSW Steam Turbine
Poland	Natural Gas Combined Cycle
Jamaica	Fuel Cells
India, Vadodam	Hydropower
Denmark	Wind Turbines
India, Bharuch	Wind Turbines
India, Polavaram	Hydropower

Conclusion
The three summaries of the feasibility studies presented in this paper and all presented in the class show the diversity of solutions to the single problem of the need for additional generating capacity. Although the students are from different countries with distinct economic, political and cultural backgrounds, they were able to focus on the problem of energy generation with familiar and almost predictable results. Thus, the future leadership for expanding power generation in the developing world must come from the education and training of graduate engineering students.

References

1) "Micro Hydro Power Generation in Nepal: Its Potential for Village Electrification and Distributed Generation," by Malika Pande, NYIT, Power Plant Systems, Spring 2004.
2) "Building Dreams in Payatas: A Proposal for a Municipal Solid Waste Power Plant in Payatas, Quezon City, Philippines," by John Paolo Dalupung, NYIT, Power Plant Systems, Spring 2004.
3) "Feasibility Study fro a Natural Gas-Fired Combined-Cycle Power Plant for the City of Suwalki, Northeast Poland," by Konrad Kislowski, NYIT, Power Plant Systems, Spring 2004.