Importance of Nuclear Power Generation in the Developing Economy of Pakistan

By

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Pakistan has a population of nearly 100 million people and is one of the countries of Asia where in a short span of eighteen years, since independence, economic development has been remarkable. Starting from a purely agricultural economy in 1947, Pakistan is emerging with a more balanced economy as a result of emphasis on the development of industries. Manufacturing now accounts for about 20 per cent of the gross national product and production in large-scale industries increased ten-fold from 1950 to 1963. The country is now in the period of rapid economic growth, typical of nations in the formative years of industrialization.

There is no area of human endeavour more vital to the economy of a developing country than electric power. In Pakistan, the annual per capita power consumption has risen from two kwhr in 1947 to forty kwhr in 1963. For years to come this trend will continue if the tempo of economic growth is to be maintained and targets of the national Five-Year Plans are to be achieved. Unfortunately the conventional sources of generation of power within the country, hydro and fossil fuels, are limited and will not meet the power demands of a growing economy on a long-term basis extending over the next 35 years. Pakistan has, therefore, to look to other sources of power generation and nuclear energy offers the most attractive alternative as a major source to fill the gap between demand and supply . Pakistan, in general, presents a favourable climate for the development of nuclear power because of its limited supplies of indigenous fuels, the prevailing high costs of imported fuels, and the confinement of unexploited hydro-electric potential to the inaccessible hilly regions of West Pakistan.

This paper presents a study of the economic feasibility of nuclear power in the three largest power demand areas of Pakistan : the Karachi area, the West Pakistan Grid Area, and East Pakistan, because of the distinctive characteristics of these independent areas with regard to fuel and water resources, power demand, and composition of existing and planned generating capacity. To determine the immediate feasibility of nuclear power, the predicted power

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demand and the scheduled and proposed plant additions are reviewed for each power demand area, and the most suitable capacities are determined for new thermal plants added at the time that nuclear plants could first be in operation. Energy costs are computed for nuclear power plants of these capacities and compared with costs for equivalent gas or oil-fired plants, based on available plant factors estimated from the study of each power demand area and present gas and oil prices. As coal is more expensive and is not being used generally for power generation, except to a very limited extent in some places generally outside the areas selected for study in this paper, cost comparisons have not been made with coal-fired plants.

This paper has been based on the following assumptions :

(1) The energy cost comparison assumes an economic plant lifetime of twenty-five years for both nuclear and conventional plants, and is based on three reference conditions of interest rate which are typical of probable project loans. The results are presented in such manner that they can also be evaluated on the basis of loan life rather than plant life, using annual fixed charge rates appropriate to several loan conditions.

(2) It is presumed that the plants generated under this program will be operated by a Government-owned Agency and the operation will not require the accumulation of a sinking fund to replace the plant at the end of its life. Replacement, if desired, would result in a higher capital charge. The incremental effect on power cost is shown for the reference condition.

(3) It will take approximately $3\frac{1}{2}$ to $4\frac{1}{2}$ years from date of orders to construct and start operation of a nuclear power plant, depending upon location and power rating.

General conclusions on the economic feasibility of nuclear power in each of the three power demand areas studied in this report, with certain salient features of these areas, are summarized below :

East Pakistan

The terrain of the Province is such that the hydro potential is extremely limited. The only major hydro potential is confined to the hilly regions of the southeast in the catchment area of Karnafuli river, where Kaptai dam is under construction with a peak capacity of 120 mw. There are no proven deposits of coal. Exploitation of peat deposits for fuel has been investigated but found to be uneconomical. No oil deposits have been discovered so far and the limited quantities of natural gas found in Sylhet are reserved for production of fertilizers and at best can generate power only to a limited extent. Further

development of power generation will, therefore, depend on high cost imported oil or on nuclear power.

The whole of the Province is one of the most densely populated areas of the world, accounting for nearly fifty five per cent of the total population of Pakistan. The present annual per capita consumption of power in the Province is less than twenty-five Kwhr.

The rivers Brahamputra and Padma virtually divide this Province into two distinct zones : the Eastern zone and the Western Zone. There are no less than three hundred electric generating plants in these two zones with the maximum generating capacity ranging from one kw to thirty mw—the latter being the capacity of the station at Siddhiraganj near Dacca. Transmission and distribution grids for each of the two zones have been planned, but due to the pace of industrialization in the Eastern zone priority is being given to the development of the grid in that zone.

The latest power survey shows that in 1966, there will be a deficiency of fifty-nine mw between firm capacity and total demand in the Eastern zone grid area which will increase to approximately one hundred mw by 1970.

A fifty mw unit would fill the power deficiency in the Eastern zone in 1966. Comparative cost economics of fifty mw conventional and nuclear power plants show that the cost of generation of power at 80 per cent plant factor would be 9.53 mills*/kwhr from a nuclear plant and 11.94 mills/kwhr from an oil-fired plant. The plant factor in either case would be 70 per cent in 1967, increasing to over 80 per cent by 1970. Over the lifetime of a fifty mw thermal plant at 80 per cent plant factor, the total monetary savings would amount to about twenty-one million dollars and the foreign exchange savings on the fuel portion only would amount to about ten million dollars.

In the Western zone, the power survey shows that by 1967 a grid will have been established, whose total usable generating capacity would be of the order of fifty mw of which only forty-five mw are likely to be firm. At the same time the system demand will have grown to about eighty mw, so that the establishment of a fifty mw thermal or nuclear power plant, operating at about 80 per cent plant factor could be justified in this zone. Because of higher prices of oil delivered to the Western zone, the cost of generation of power from a nuclear plant will be more competitive than in the Eastern zone—9.53 mills/kwhr from a nuclear plant and 12.32 mills*/kwhr from an oil-fired plant. The total monetary savings over the plant lifetime would amount to 25 million dollars and the foreign exchange savings on fuel only would be about 10 million dollars.

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*One mill equals one-thousandth of U. S. dollar.

If the grid systems of the two zones could be interconnected, a hundred mw nuclear power plant could be installed of two fifty mw plants. The larger unit would be more efficient and economical, realizing an additional cost savings of about 2.2 mills/kwhr at 80 per cent plant factor. This alternative, however, can be considered only after the plans for interconnecting the two grids are finalized.

West Pakistan

West Pakistan is nearly six times the area of East Pakistan. Half of the land area of the Province is contained in the Quetta and Kalat divisions which are covered by barren hills. The other half constitutes the Indus Basin, skirted by a range of high hills, in the north and the northwest. The Province has one of the most extensive artificial irrigation systems in the world, covering a cultivated area of nearly thirty million acres.

Assuming a 1.8 per cent annual increase in population (actual rate is 2.32 per cent) and an average rate of growth of per capita power consumption on the most conservative basis of doubling every ten years during the next 40 years, the total requirements of power, in terms of generating capacity, would be of the order of eighteen thousand mw.

The theoretical hydro-electrical potential of the Province is estimated to be of the order of ten thousand mw. Most of this, however, is confined to the inaccessible hilly regions which would make the construction of dams extremely costly. The cost of the energy losses in hundreds of miles of transmission lines to the plains in the south, where power is required for agriculture, industry, commerce and domestic uses, will further add to the cost of power. However, even if the whole of the hydro potential were developed, it would leave a deficiency of about eight thousand mw to be filled by other sources.

Deposits of natural gas have been discovered in West Pakistan which are estimated to be of the order of nine million cubic feet. In terms of heating value, this is equivalent to about five hundred million tons of coal. If half of this quantity of natural gas were reserved for generation of power, it would eventually support two thousand four hundred mw of generating capacity at 60 per cent plant factor. It may be noted that in the U.S.A., where the natural gas reserved are known to be largest in the world, only twenty per cent of gas is used for generation of power. In West Pakistan (Sui-Karachi line), the average consumption of gas at present for power generation amounts to thirty per cent of the gas consumed. This shows that natural gas is being and can be utilized for industrial purposes, other than generation of power. Some of the more important industrial uses are : manufacture of cement, fertilizers,

petro-chemicals, reduction of iron ore, and production of steam for a variety of industrial uses. It is important that the limited deposits of gas in West Pakistan be conserved for the other essential industrial uses, and not more than thirty per cent be allowed to be utilized for the generation of power.

There are some oil fields in West Pakistan, but their total output can hardly meet fifteen percent of the present total oil requirements of the country. Oil cannot, therefore, be considered as a major source of fuel for power generation.

The total deposits of coal are estimated to be of the order of 165 million tons, the bulk of which is in the hilly regions of Quetta and Kalat divisions. This coal contains a high percentage of sulphur, ash and volatile matter and is non-cooking. It is found in thin seems at steep inclines which makes mining an expensive operation. Further, the Quetta and Kalat coals have to be transported down the Bolan Pass for nearly six hundred miles before they can be used for any industrial purposes in the consuming areas of the plains. Indigenous coals, therefore, have very limited potential for meeting the power requirements of the Province.

Imported oil or coal would need to be transported inland over long distances and presently transportation facilities are inadequate.

In the overall picture for West Pakistan, nuclear energy offers the best alternate source of power to meet the growing demands over the next thirty-five years.

Power survey in the West Pakistan Grid Area, which covers Peshawar, Dera Ismail Khan, Rawalpindi, Sargodha, Lahore, Multan and Bahawalpur divisions, shows that in 1966 there will be a deficiency of about two hundred mw between the generating capacity and the predicted demand in this area. This is proposed to be bridged by installing a two hundred mw conventional gas-fired thermal station in the Lyallpur area, near Chiniot. Even after the commissioning of this thermal station, there will be a deficiency of at least 150 mw, between 1965 to 1968 at which time Mangla is scheduled to be commissioned. Studies show that even after Mangla Dam with capacity of three hundred mw is commissioned in 1968 and 1969, a conventional or nuclear power plant of 150 mw capacity could operate at 70 per cent plant factor over most of its lifetime. The conventional plant could only be gas fired and hence comparison of the cost of generation between a nuclear power plant and a gas-fired plant has been made. This shows that the cost of generation of power at 70 per cent plant factor from the nuclear power plant would be 7.22 mills/kwhr as compared to 7.87 mills/kwhr from a gas fired plant.

The future generating capacity requirements in the West Pakistan Grid area depends on (1) The rate at which the tube well programme will actually

be implemented and (2) the rate at which Mangla generating units will be installed and the ultimate plant capacity.

The tubewell programme is vital to the agriculture sector of the country's economy. Waterlogging and soil salinity results in the loss of about 100,000 acres of agricultural land each year. The present tubewell programme calls for 196 mw of peak power demand within the next several years. This programme is inadequate and an expanded programme is being proposed which will add six hundred mw of peak power demand by 1970.

Mangla is scheduled initially to generate 300 mw electrical power. The ultimate capacity of the dam is thought to be nine hundred mw but because of the irrigation requirements, a storage and regulating dam is required downstream from Mangla if its full potential is to be realised. No study has been made on the feasibility of building additional storage and regulating dam downstream. However, based on Mangla construction costs, this secondary dam may also be high in installed cost.

If Mangla should be limited to three hundred mw and the fully expanded tubewell programme is implemented, then by 1964 there should have been a generating deficiency of about two hundred mw (Figures on the tubewell programme and Mangla not yet available. The figures given are based on a study carried out by a consulting company). This deficiency was to be met by installation of a two hundred mw thermal station in Lyallpur area, near Chiniot. This plant is to be commissioned by the end of this year. Even after the commissioning of the Chiniot plant there will be a generating deficiency of at least 150 mw by 1968. Both the two hundred mw plant and an additional 150 mw plant would operate at 70% plant factors over most of their life time and they could be either gas-fired or nuclear power plants. Additional generating capacity would also need to be installed after 1969. If the fully expanded tubewell programme is not implemented, only the two hundred mw Chiniot station would be required but it could operate at a 70% plant factor.

If Mangla can be developed to its full capability and the expanded tubewell programme is implemented, the two hundred mw Chiniot plant would still be required and it could operate at a 70% plant factor over most of its life time. There would be additional generating capacity required between 1964 and 1968 but after Mangla is developed, plants added in the interim period would operate at low plant factors. If the fully expanded tubewell programme is not implemented, then no additional capacity, other than Mangla is required until after 1975.

Construction of the pipe line to the Lyallpur area, which is to serve a proposed gas fired plant at Chiniot, may not be completed well beyond 1966.

If so, a nuclear plant could be commissioned at about the same time and could replace the gas fired plant.

In the economic comparison of 150 mw gas-fired and nuclear power plants at 70% plant factor, the nuclear plant is estimated to produce power at a cost of 7.22 mills/kwhr as compared to 7.87 mills/kwhr from a gas-fired plant.

Karachi Area

Karachi is the only major port of West Pakistan. A very compact complex of industries has grown around Karachi during the past 18 years. This area is served by a 16 inches gas pipe line, which has been laid between Sui gas fie'd and Karachi, a distance of more than three hundred miles. The total dedication of the Sui gas to this pipe line is of the order of 1.2 mill/mill cubic feet, with an ultimate delivery capacity of about 105 mill cub. ft per day with the use of compressors. On the basis of the trend of consumption of gas in Karachi area for power generation and other uses, it appears that the total dedicated reserves to the Sui Karachi gas line, would be exhausted shortly after 1980.

Survey shows that by 1970 there will be a power deficiency of 66 mw. This would require an additional power plant of 100 mw generating capacity. This deficiency can be bridged either by installing another gas-fired plant or nuclear power plant. If it were filled by a gas-fired plant a new pipe line would have to be laid to supply all the power stations and other industrial uses. This would require heavy capital investment, which can be avoided by the installation of a nuclear power plant to fill this deficiency.

Comparative costs of power generation from gas-fired and a nuclear power plant of one hundred mw capacity in Karachi area, show that the cost of generation of power from gas-fired plant will be 7.0 mills/kwhr and from a nuclear plant 7.14 mills/kwhr. This small difference is likely to disappear in the early life of the nuclear plant., because the price of nuclear fuel is likely to come down more rapidly than the cost of the gas. This is supported by the fact that within the last 5 years, nuclear fuel cost has come down by about 20%. Moreover, with competitive bidding on equipment, the price of a nuclear plant may be lower than estimated.

So far we have considered the economic feasibility of nuclear power plants. The additional benefits which the nation will reap are the manifold uses of radioactive isotopes for medicine, industry, etc. Radioactive isotopes are a by-product of any nuclear power plant.