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Simulation of Electric Power Requirements and Supply Strategies: The Case of Bangladesh

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Abstract

This paper presents computer projections of electric energy demand using LEAP and an analysis of electric supply strategies for Bangladesh within the framework of a system dynamics model. Simulated results show that both public and private electricity generation, power demand and power supply increase with time. But, when a policy is adopted to reduce the power shortage within a specified period, the supply never equals the demand and a dream of zero balance or surplus is never realized. Simulated results show that public pressure and preventive measures increase with time and these aid to reduce the system loss and also to improve the quality of life. But, the worst possible load shedding is to be faced during initial period of construction since no electric power is available until the power plants are fully commissioned. Simulated results also show that both public and private generation, power demand and power supply also increase with time for a policy to achieve the projected desired generation capacity which is much more than the actual demand and the total supply meets the demand with a surplus. But, the worst load shedding during the initial construction period still can not be avoided. Finally this model can be used as a useful tool for power supply policy analysis.

Introduction

Energy is needed to meet the subsistence requirements and the basic necessity for the economic development of a country. It is vital for any society. The use of huge amount of energy in the developed countries has resulted in higher agricultural and industrial production, a healthier and more balanced diet and better transportation facilities. As a matter of fact, there is a close relationship between the energy used per person and his physical quality of life. The greater the per capita consumption of energy in a country, the higher the physical quality of life of its people. Per capita consumption of electrical energy is also a measure of physical quality of life [8].

Bangladesh power system

The power system in Bangladesh developed from a number of isolated power systems, totaling only 21 MW, when the British left the sub-continent in 1947, each consisting of a local power plant and a low voltage distribution network to supply local consumer in the then seventeen districts of Bangladesh. The private generation was taken over by the Govt. and the management was entrusted with the newly created Electricity Directorate in 1948.

In 1959 the Government created an autonomous organization called East Pakistan Water and Power Development Authority (EPWAPDA) by promulgation of an ordinance. WAPDA was entrusted with all the activities of the Electricity Directorate and the Irrigation Department. In 1960 the countrywide demand of electricity was less than 50 MW with the largest generating unit of 11 MW at Siddhirganj. Installation of two 40

MW hydro electricity units at Kaptai and a 50 MW unit at Siddhirganj tremendously increased the total capacity.

After the emergence of Bangladesh as an independent country in 1971, EPWAPDA was bifurcated into two autonomous Boards by promulgating an ordinance (P.O. 59 0f 1972). Bangladesh Power Development Board (BPDB) was solely entrusted with the responsibility of generation, transmission and distribution of electricity throughout the country. The installed capacity of electrical power increased from 667 MW in 1975 to 3603 MW in July 1999. The actual capability is 2528 MW and the firm capacity has reached between 2100-2200 MW from an average of 1850 MW in 1998. The highest generation achieved at peak hour was 2601 MW on 8 August, 1999 (BPDB, 1999). The maximum demand increased from 1317 MW in 1988 to 2136 MW in 1998 with an average growth rate of 7.25% while energy generation increased 6541 GWh to 12882 GWh with an average growth rate 8.74% during 1988-1998 [4].

Load shedding

The most debating issue of power management in Bangladesh is load shedding. Power supply is constrained by shortage in generation capacity, inadequate transmission and distribution system and huge amount of system loss. As a result BPDB has to resort to load shedding during peak hours (5 p.m. to 10 p.m.). Moreover, demand has increased over the years but generation has not increased sufficiently to cope with situation. Hence the intensity of load shedding was more than the previous years. The highest number of load shedding was 346 days in 1997-98 while the longest duration was 2872 hours in 1996-97.

System loss

Power sector in Bangladesh is discredited for its high system losses. Both technical and non-technical losses are high. During the last twenty years overall losses have varied between 30.1% and 42.6% of gross generation, including station auxiliary use. During this period T&D losses varied between 27.2% and 40.2% of net generation. This includes a high proportion of theft i.e. under billing, unauthorized tapping of power and pilferage. An analysis of recent data shows that present T&D (technical) loss should be about 19% of net generation or about 18% of gross generation, out of which transmission loss (along with transformers) is about 5.4%. The total loss should not be more than 23.4% including station use [12]. However, the load shedding and hence the loss to PDB can be reduced greatly by reducing the system loss.

Computer modelling of electric power system

Huq [10] initiated energy modelling in Bangladesh. The model proposed by Huq was further developed for integrated rural energy system in Bangladesh using system dynamics approach [5]. Alam et. al. [2] developed a system dynamics model for integrated rural energy system. The potentiality of this model was illustrated in the micro level by using the data of a village in Bangladesh. The system dynamics model for integrated energy system was also applied in agriculture for macro-level policy analysis Alam et. al. [3]; Alam [1]. The model prediction has a great relevance with the historical behavior and it is a very useful tool for policy analysis and planning.

Nail [14] reported an integrated model of U.S. energy supply and demand, which is used to prepare projections for energy policy analysis in the U.S. Department of Energy's Office of Policy, Planning and Analysis. This model represents one of the real success story of system dynamics modelling. This model was implemented at the Department of Energy in 1978 as an in-house analytical tool and has been used regularly for national energy policy analysis since that time. Nail et. al. [15] employed the model to explore a wide range of policy options intended to address the effects of energy use on global warming.

Bala [6,7] presented projections of energy supply and demand and assessed the contributions to global warming for both rural and entire Bangladesh The output of a system dynamics model of energy and environment fed into the LEAP model and over all energy balance was compiled using bottom up approach.

Although energy modelling was initiated by Huq in 1975 and the model was further developed by Bala and Satter (1986 a&b) and Alam et. al. (1990a), these studies do not include electric power. Bala [6,7] projects the demand of electrical energy but this study does not include the analysis of electric supply strategies within the framework of a system dynamics model as a tool for policy planning for sustainable development of electric power sector in Bangladesh. In this paper electric power requirements are projected by using LEAP and supply strategies are assessed by using a system dynamics model. These models are described below:

LEAP model

Demand of electrical energy is increasing day by day. It is increasing at faster rate in the developing countries. In developing countries the demand for electricity doubles at every 7 to 10 years. The forecast of energy demand has to built upon the projected economic development and population growth of a country. This is very crucial for developing economy [11].

The principal analytical tool used here is a Long range Energy Alternative Planning (LEAP) model for the Bangladesh energy system [8]. The LEAP model consists of demand, transformation, biomass and environment modules. These modules provide energy scenarios on final energy demand and supply (transformation and biomass) and environment (CO_2). The demand module calculates the energy demands over time in all sectors of the economy: household, industry, transport, agriculture etc. and the computation is based on bottom up approach.

System dynamics model

The optimal development and management of electric power system is a complex, dynamic and multi-faceted problem depending not only on available technology but also upon economic and social factors. Experimentation with an actually existing electric power system containing economic, social, technological, environmental and political elements may be costly and time consuming or totally unrealistic. Substituting electric power system by a computer model one can conduct a series of studies. The computer models clearly are of great value to understand the dynamics of such complex systems [8]. Owing to the intrinsically complex nature of energy problems, it is necessary to implement various energy policy options only after careful modelling analyses [16]. The analysis involves use of different modelling techniques such as optimization, econometrics, input-output analysis, multi-objective analysis and system dynamics simulation. Forrester's system dynamics methodology provides a foundation for constructing computer models to do what human mind can not do - rationally analyze the structure, the interactions and mode of behavior of complex socio-economic, technological, and environmental systems and hence system dynamics approach is the most appropriate technique to handle this type of complex problems. Several computer packages are now available for system dynamics simulation of complex systems and the widely used packages are STELLA, DYNAMO and DYNOSIM.

The model described here is a theoretical framework for examining the supply strategies of electric power system in Bangladesh. There is a large gap between the generation and peak demand, which results in load shedding during peak period. Both the frequency and duration of load shedding create public annoyance and anger and hence public pressure develops to increase the generating capacity and to reduce system loss. To cope with the crisis the government puts special emphasis on generation by public and private electric authorities to increase the generating capacity. Even special privileges and economic incentives are also provided to the private electric company for reliable supply of electricity. Fig.1 shows the flow diagram of a system dynamics model used to analyze the strategies of electric power supply in Bangladesh.

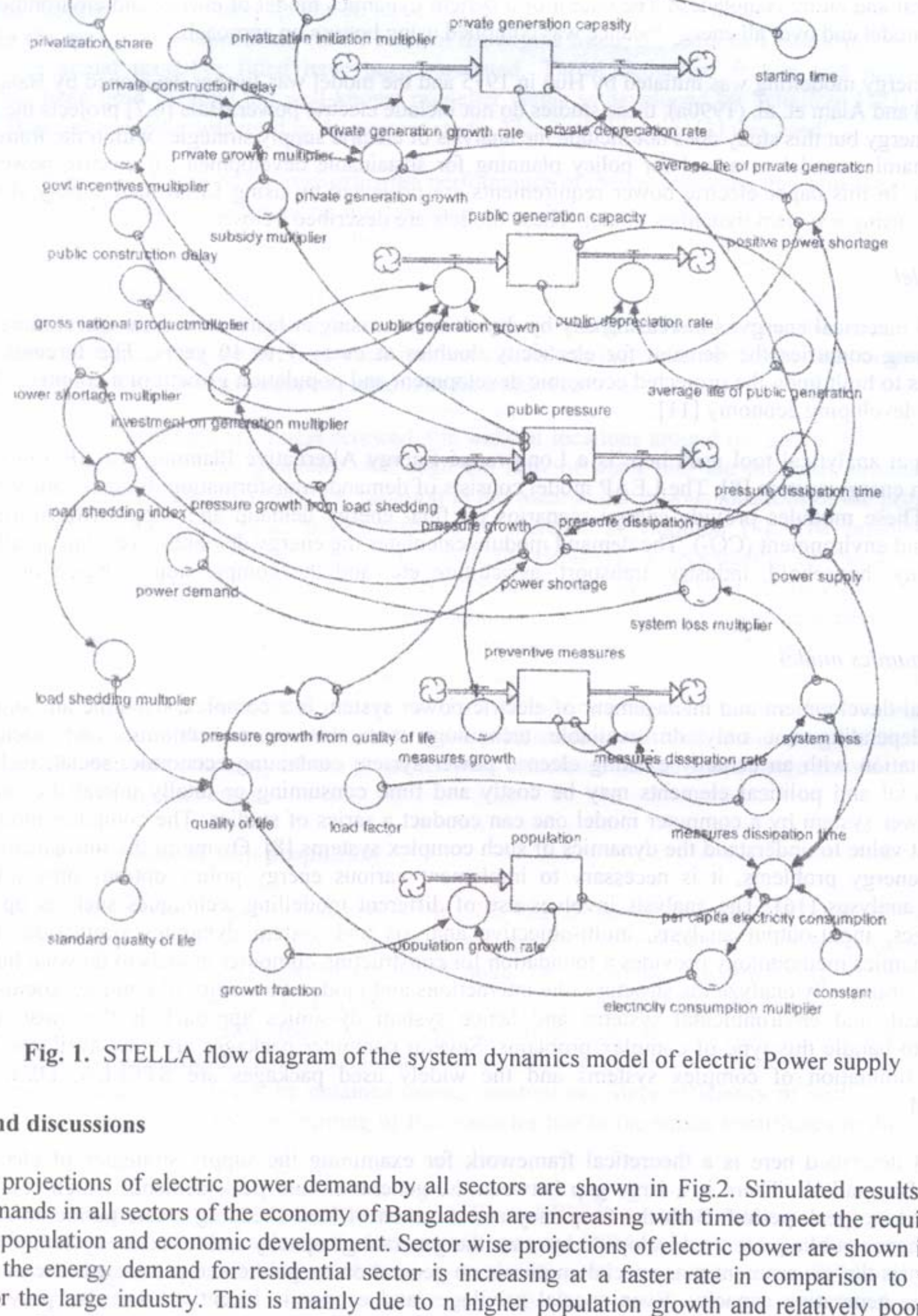

Fig. 1. STELLA flow diagram of the system dynamics model of electric Power supply

Results and discussions

Computer projections of electric power demand by all sectors are shown in Fig.2. Simulated results show that energy demands in all sectors of the economy of Bangladesh are increasing with time to meet the requirements of increasing population and economic development. Sector wise projections of electric power are shown in Fig 3. In this study the energy demand for residential sector is increasing at a faster rate in comparison to the energy demand for the large industry. This is mainly due to n higher population growth and relatively poor industrial development. However, reducing system loss and using the end use efficiency improvement devices can save considerable amount of electric energy used.

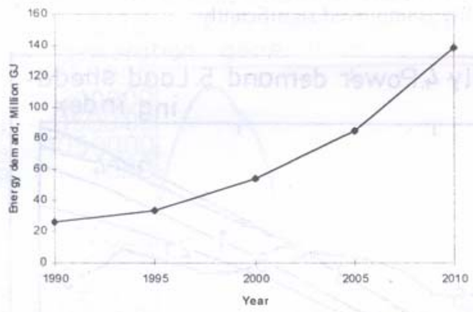

Fig. 2. Electric power demand by all sectors

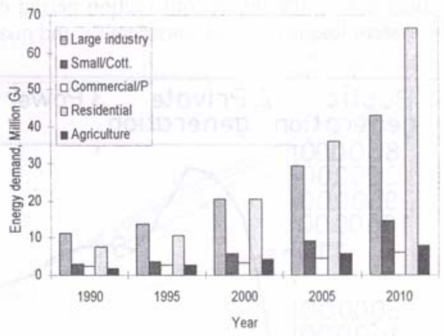

Fig.3. Sector-wise electric power demand

The major shares of electricity for Bangladesh in 1995 for large industry sector, residential sector, small and cottage industries sector, commercial sector and agriculture sector are 41.10%, 31.82%, 11.00%, 8.20%, 7.89% respectively. This indicates that Bangladesh has a small industrial base and electricity on farm is also small.

Various ways of validating a system dynamics model have been considered such as comparing the simulated results with historical data, checking whether the model generates plausible behavior and checking the quality of parameter values. Some of the parameters have been derived from studies, other areas and some were the result of informed guesswork. To judge the plausibility of the model, the behavior of the key variables in the base run were examined. In order to obtain insight into the effects of the alternative policy options, two policy options are considered:

(i) Policy - 1: Increasing the public generation capacity as well as installing and increasing the private generation capacity to minimize the gap between the actual demand and supply within a specified time period and

(ii) Policy -2: Increasing the public generation capacity as well as installing and increasing the private generation capacity to minimize the gap between the projected desired generation capacity and supply.

Policy - 1:

Fig. 4 shows simulated public generation capacity, private generation capacity, power demand, power supply and load shedding index for a time horizon of 30 years. Both public and private generation capacities increase with time. But, the supply never equals nor exceeds the demand since the policy was to reduce the power shortage which is dynamic and dream of zero balance or surplus is never realized. However, the surplus can be realized for a ramp increase of 150 MW or more per year. Fig.5 shows simulated public pressure, preventive measures, quality of life, system loss and per capita electricity consumption. Public pressure and preventive measures increase with time and these aid to reduce the system loss and improve the quality of life. The per capita electrical energy consumption is almost constant during initial period and then it increases for the rest of the period. But, the worst possible load shedding is to be faced during initial period of construction since no electric power is available until the power plants are fully commissioned.

Policy - 2:

This policy is designed to meet the gap between the projected desired generation capacity reported by Mayeed [13] and the actual supply. Fig. 6 shows the simulated public generation capacity, private generation capacity, power demand, power supply and load shedding index for a desired generation capacity and the total supply meets demand with a surplus. Fig. 7 shows simulated public pressure, preventive measures, quality of life, system loss and per capita consumption of electricity. The public pressure initially increases and then it decreases with time because of the zero load shedding while the preventive measures continue to increase with time. But, the worst

Conclusions

- Simulated results show that the electrical energy demand is increasing with time and the residential sector has the largest growth rate for the demand for electricity.
- Simulated results show that power crisis can be minimized by adopting a policy to reduce the gap between the demand and supply within a specified time period by increasing the public generation capacity as well as by installing and increasing private generation capacity. But a zero balance or surplus is never realized. A policy to minimize the gap between the projected desired capacity and the supply provides a surplus power.
- In both these cases severe load shedding in the initial period of implementing these policies is unavoidable and thereafter the system loss is greatly reduced and the quality of life is improved.
- If it is decided to improve the planning and management of electric power management, an analysis of dynamics of electric power system can help to improve the decisions regarding the planning and management.
- Finally this model provides a greater insight and better understanding of the electric power system and it can be used as a useful tool for power supply policy analysis.

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