DYNAMICS OF POWER SUPPLY AND DEMAND

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ABSTRACT

Power demand forecasting methodologies which are currently being used by electricity authorities are end use method, trend method and Scheer's formula. These methodologies being static in nature, do not take into account the future power supply position, while becoming an important instrument of economic change the growth of power generation activity itself is totally dependent upon the overall economic development thus forming an important feedback loop in the economic system.Present paper discusses a power economy system dynamic model for estimation of future demand and supply position of Power.

INTRODUCTION

Unlike early period of development of electric power generation activity, when electric power was primarily used for lighting homes, electricity is now a major input to most of the economic activity. While becoming an important instrument of economic change the growth of power generation activity itself is totally dependent upon the overall economic system. Any shortfall in the availability of electric power has an inhibiting effect on the economic growth, whereas excess power generation is a drain in the limited available resources which could be gainfully used in other sectors of economy. It is, therefore, imperative that the dynamic interdependence of all sectors should be considered while estimating the demand and supply position of power for future.

Thus when palnning for an important sector like power which is both capital intensive and is basically a long gestation activity, methods which give a long prospective should be used. Currently available power planning methods, in contrast have a much shorter time perspective. Forecasting methodologies which are currently being used by electricity authorities in India are end use method and trend method(working group 1979). Parikh did an excellent work in improving upon the work of working group and prepared a more comprehensive model (Parikh 1981, pp. 6-13). Pachauri's model (Pachauri 1975) for a region in U.S.A is also a good attempt to improve upon the conventional methodologies. Though these models go a step ahead then the conventional methodologies, but the feed back loop of supply is not integrated in the model. Rajadhayksha has highlighted the importance for an integrated approach. "It is one thing to arrive at a set of forecasts but it is quite another to arrive at some deeper analysis. As an example one could perhaps relate a number of economic happenings with the occurance of sun spots which may provide us with a good way of forecasting but such a method have little explanatory power. What we really need, it seems is a vehicle that could enable us to find out in which direction the demand for power would move as a result of various changes taking place in the economy of the country. It would, therefore, be desirable to develop detailed and regorous models of demand to give us not only a set of reliable forecasts but a medium through which the effect of various economic demographic changes on the demand for electric energy can be assessed (Rajadhyaksha 1977, pp. 4).

System dynamics developed by Forrestor (Forrester 1961), present a viable alternative by making possible the comprehensive power economy model capable of simulating the total economy of a region to provide reliable demand and supply forecasts (Garga et al. 1982, pp. 59-61). In addition to becoming a medium through which the effect of various economic and demographic changes on the demand and supply of electrical energy could be assessed. This new methodology is able to generate long-term projections and reflect the sensitivity of power supply and demand to various economic demographic variables and vice-versa. System dynamics has been used here to formulate the power economy model to understand the dynamics of power supply and demand for Punjab in India.

Situated as it is, in the northwest corner of India, the state of Punjab is far from the coal-fields of East India. As a result of its proximity to lower Himalyas, however state got a major irrigation-cum-hydroelectric scheme namely Bhakra dam complex which was finally commissioned in the date 1950's. Considering the then economic development of the state, power from this hydroelectric project was found to be far in excess of demand. This succeeded in triggering increased economic activity resulting in the now famous green revolution with matching increase in Industrial activity, which in turn resulted in tremendous increase in demand for electric power with Consequent power shortages. With similar situation also prevailing in other parts of India, shortage of electric power has now become a major constraint on the economic development, despite the fact that a large portion of the Govt. funds now diverted to capital expenditure needed for creating new power generating capacity. As an example, an amount of Rs. 1890 million out of the annual plan budget of Rs. 3850 million for the state of Punjab was spent in 1982-83.

OVERVIEW OF THE MODEL

Before discussing the power demand and supply projection mechanism in some detail,it is useful to present a brief overview of the model. The model may be described as a closed-loop-power-economy-model. Power model projects both demand and supply position having feed back from economy model. Economy model having feed back from power supply and demand model based on the power supply/demand ratio affects the output capital ratio. Output capital ratio in turn affects the state domestic product. Power supply model generates future power supply position from the state plan funds, share of power plan and respective share of generation and transmission. Ratio of money in generation and transmission will increase or decrease the power losses, which will affect the power supply/demand ratio.

The economy sector generates consistent forecasts of variables essential to power demand forecasting viz. Land requiring irrigation, diesel tubewells to be replaced, rural and urban households, rural and urban houses, Industrial capital, state domestic product, savings and capital formation etc. Each sector attempts to capture the basic elements that shape the future dimensions of a region's power and economy position.

In the power demand sector, the projections of various economic parameters are coupled with the power consumption pattern of electricity usage to produce projections on yearly basis. The power demand sector is divided into basic consumer catagories: Domestic, Agriculture, Industries, Commercial and Public Lighting. In the following discussion, the basic loops of the power supply,demand and economy

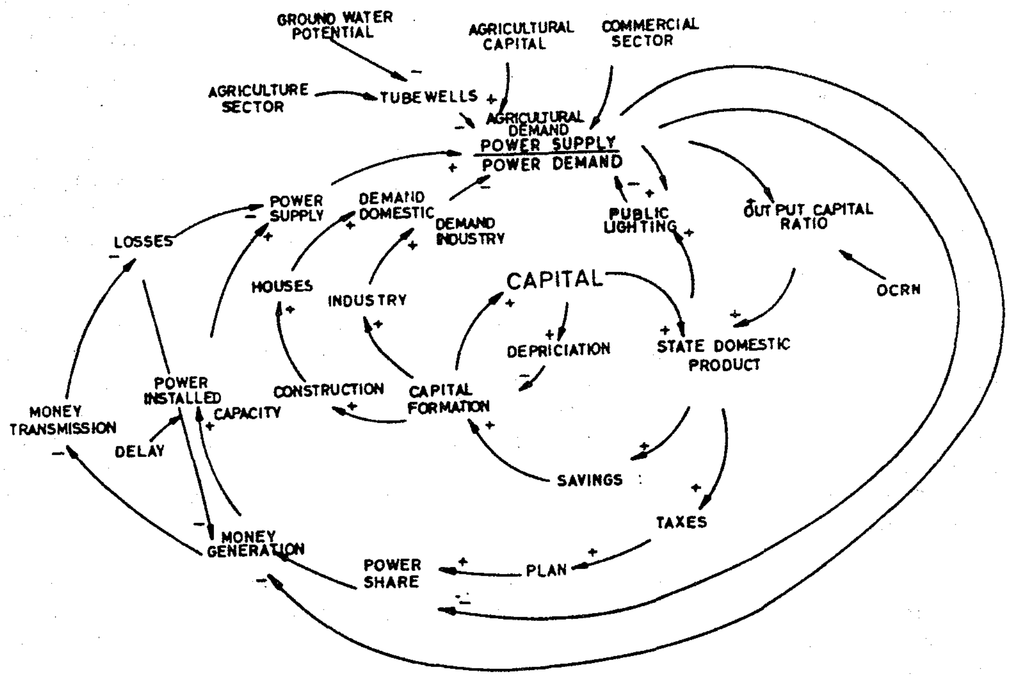

FIG. 1 CAUSAL LOOP DIAGRAM

model are discussed as shown in the causal loop diagram Fig.1. The model has been simulated on DEC 2050 digital computer using Mini Dynamo compiler for running the model.

THE MODEL

The model consists of the following sectors: 1) Population, 2) Agriculture, 3) Manufacturing, 4) Services, 5) Capital Sector, 6) Government revenue and 7) Power Supply and Demand.

Population creates demand of power for domestic sector, for illumination, heating, cooling and other household needs. In the population sector,population is divided into 15 age groups and the birth rates in the infant age group and death rates in all age groups are calculated dynamically from related parameters from all the sectors. As power demand for rural and urban households differ substantially, population is further divided into rural and urban population. As the power is to be used in a residential premises, demand is based on the incoming houses both in rural and urban sectors. Houses are constructed depending upon the capital formation for construction in residential sector and the requirement of houses depending upon the population and family size. New houses constructed each year having feedback from capital sector shown in the cusal loop diagram 1 will determine the demand for new load to be connected. Total connected load with increasing per capita income and consumption for urban and rural domestic sectors computes the demand for domestic sector.

Agriculture sector creates the demand of power for irrigation. Irrigation is one of the most important inputs for the growth of agriculture. High yielding varieties of crops and chemical fertilisers require assured irrigation for giving results. With the increasing population pressure on land creates more demand for food, creates increasing demand for irrigation. Agriculture sector computes total yield of cereals, non cereals and other farm related products, based on yield per hactare and land under cultivation and land double cropped having feedback from capital sector for providing capital for agriculture. Yield per hectare is a function of yield per hactare normal, multiplying factor from irrigation and multiplying factor from agriculture capital, thus completing its major feedback loop from state domestic product.

Major irrigation is provided from tubewells both electric and diesel. As the operating costs of electric tubewells is less than the diesel tubewells, demand for electric connections to convert existing diesel run tubewells into electric tubewells is yet to be fulfilled. This will also result in saving of diesel which is in actual shortage.

Demand for power in agriculture sector is being computed by the number of electric tubewell connections provided and power consumed per tubewell is a function of agriculture capital per hactare of land sown. With increase in agriculture capital per hactare, consumption of power increases. Electric tubewell connections is a level which is increased by the incoming connections. New connections are provided based on the incoming power installed capacity and power share of agriculture which is function of percentage of land irrigated. Ground water potential is a limiting factor for providing the total number of connections for tubewells.

Industrial sector have been partitioned into two main heads: power intensive industry and other Industry. Capital from the capital formation sector as shown in the causal loop diagram 1 is fed back to the two types of industries. Capital is divided among the two industries depending upon the power supply/demand ratio. As power shortage will persist, power intensive industry will be discouraged or it will come with captive power plants. Capital in these sectors converts the capital into value added in Industrial sector, depending upon the output capital ratio. Output capital ratio has been assumed to be a function of power supply/demand ratio and output capital ratio normal. Output capital ratio varies from .5 of the output capital ratio normal OCRN, to one when power supply/demand varies from 0 to 1. Here the demand in industrial sectors is a function of power required per unit of capital and expected variations in power intensiveness of capital, compute the demand of power. Value added of industrial sector is fed to state domestic product.

Service sector creates demand for power in commercial sector for lighting, heating and airconditioning. As industrial sector overtakes the agriculture sector in economy, more and more people start migrating to the urban areas. With increasing urban population, service sector activity starts increasing thus creating more demand for power. Model computes the power demand for commercial sector based on the urban houses and percentage increase in state domestic product.

With increasing economic activity and population migrating to urban areas, density of road use starts increasing with increasing use of road transport, more and more public lighting is required. But in state of power deficits, public lighting is the first to bear the brunt of power cuts. Demand of power for public lighting is a function of state domestic product and power shortage factor. Power shortage factor is a function of power supply/demand.

Capital sector generates capital formation, delayed function of savings. Savings are generated after deducting the consumption from state domestic product. This capital is fed back to Agriculture sector, Industry sector and service sector. Part of the capital is invested in residential construction for housing. Government sector generates revenue from taxes. Taxes determine the plan funds. Share of money from plan funds for power sector is determined by the normal power share and power supply/demand as shown in the causal loop diagram 1.

POWER SUPPLY

Power supply = Power installed capacity x Load factor x (1 - losses) x (1 - power used in auxilaries) x Kwh/Kw.

Power supply is a function of power installed capacity, load factor, losses and power house auxilary consumption. Power installed capacity is a level which is increased by incoming power installed inrate and decreased by derating rate with time. Power in rate is increased by the power in pipe line which is due to the money invested before the starting year of the model and the power inrate from money for power generation. Money power is a level which is increased by money allocated to power sector from plan funds. Money power outrate is a delayed function of level by 9 years gestation period assumed to be for becoming the money effective in generating power. This money outrate is divided into money for generation and money for transmission as per the feed back loops shown in the causal loop diagram 1. Money generation divided by rate for conversion per MW gives the power installed capacity inrate. The money for transmission decides the losses in transmission lines. As losses increase there is much hue and cry to increase the money in transmission as shown by the feedback loop from losses to money generation. Power supply/demand ratio regulates the money for power and further increases the share of money for generation as shown by two feedback loop from power supply/demand, thus counteracting the effect of power losses loop. Delay in construction has been kept constant as having exhausted all the available medium and large hydroelectric sources, further demand has to be met from thermal power houses and agro based mini-thermal power houses having delay period of two years as discussed by authors (Garga et al. 1984, pp. 1250-52). Load factor has been assumed to be 60%.

RESULTS

Model has been validated by comparing the graphical results of various variables viz:- Power Installed Capacity, Power Supply, State Domestic Product, Tubewells Connections etc. from 1970-71 to 1982-83. It seems that the basic structure of power demand and supply feed backs has been captured in the model:

Graphical output of computer results for the demand and supply variables are shown in the figure 2, 3 and 4. Variables plotted are, Demand for agriculture = DEMPW = 1, Demand for industries = DMPIN = 2, Domestic demand = DODE = 3, Commercial demand = COMDE = 4, Public Lighting = PBLIGT = 5, Power installed capacity = PIC = 6, Required installed capacity = RINC = 7. Results are plotted from 1971 to 2011.

Figure 2 shows the results for the model base run, when all the loops are active. Agriculture sector demand increases upto 1999, when the ground water potential limits the tubewell connections to be provided. Thereafter demand for agriculture remains almost constant. Demand for industry overtakes all the demands as the more and more capital starts diverting to industrial sector as the agriculture capital requirements saturates. Power installed capacity chases the demand but gap between supply and demand increases every year. Despite the power supply/demand to money power plan and money power generation loops are active, but power installed capacity remains short of the demand.

Figure 3 shows the results for the normal run, when the feedback loops of power supply/demand and power plan and money generation remains inactive. Here the demand for agriculture sector goes on increasing as the power installed capacity is less

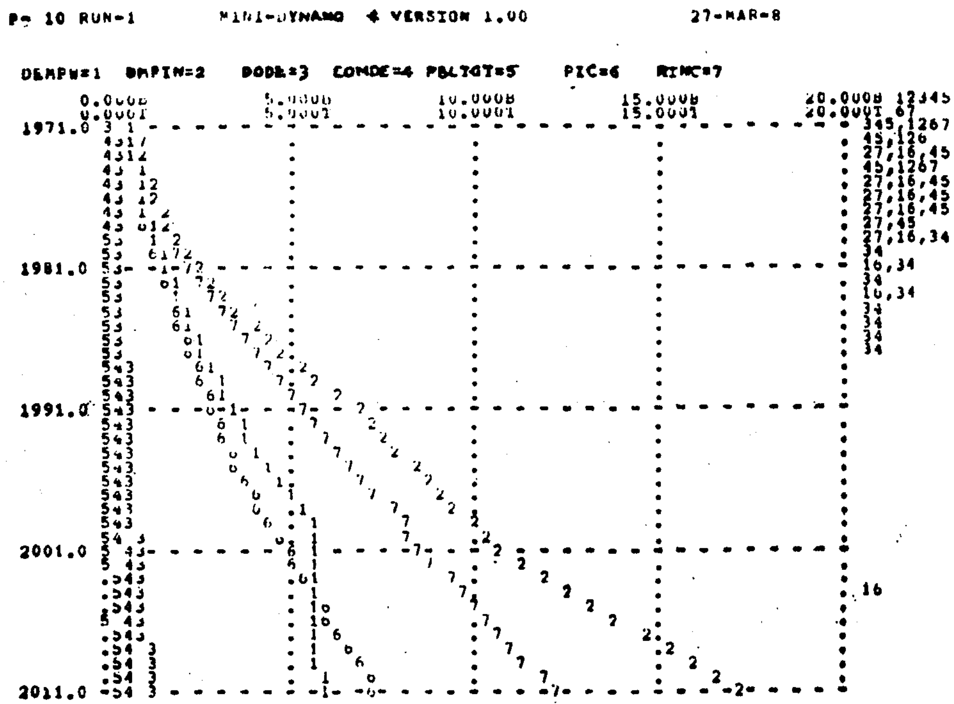

FIG. 2 BASE RUN

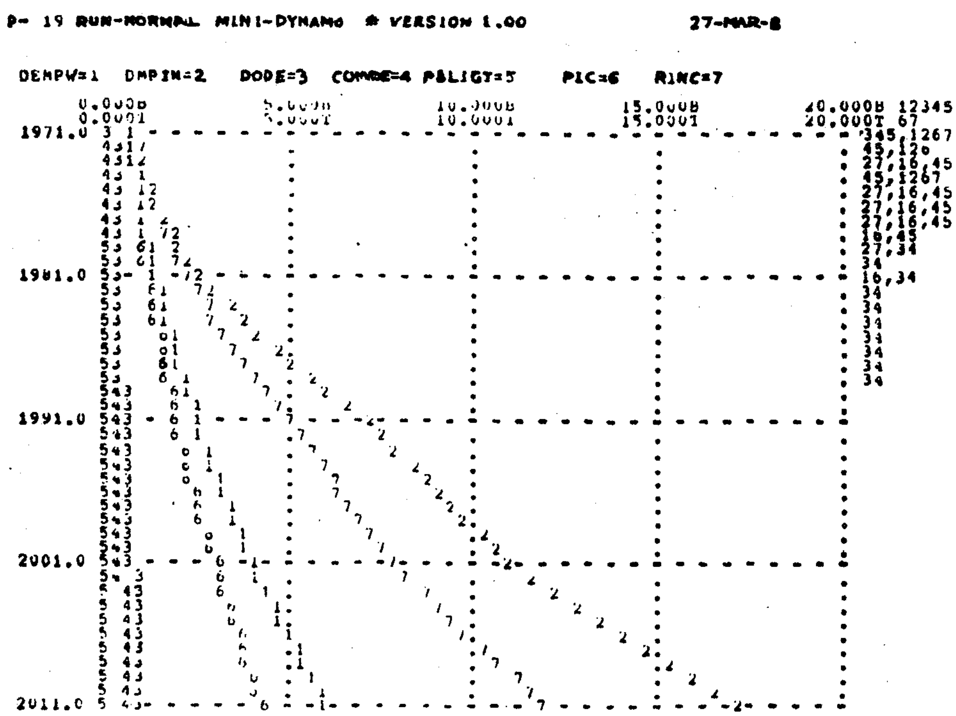

FIG. 3 NORMAL RUN

than the base run and so the tubewell connections provided have still not reached the ground water potential limitation. Power installed capacity reduces drastically, thus affecting the output capital ratio and reducing the state domestic product drastically. Demand for power or required installed capacity has reduced slightly from the base run as the capital which could have gone to power sector is diverted to other industrial activity as there is no feed back from Power supply/ demand thus making a substantial part of the capital unproductive.

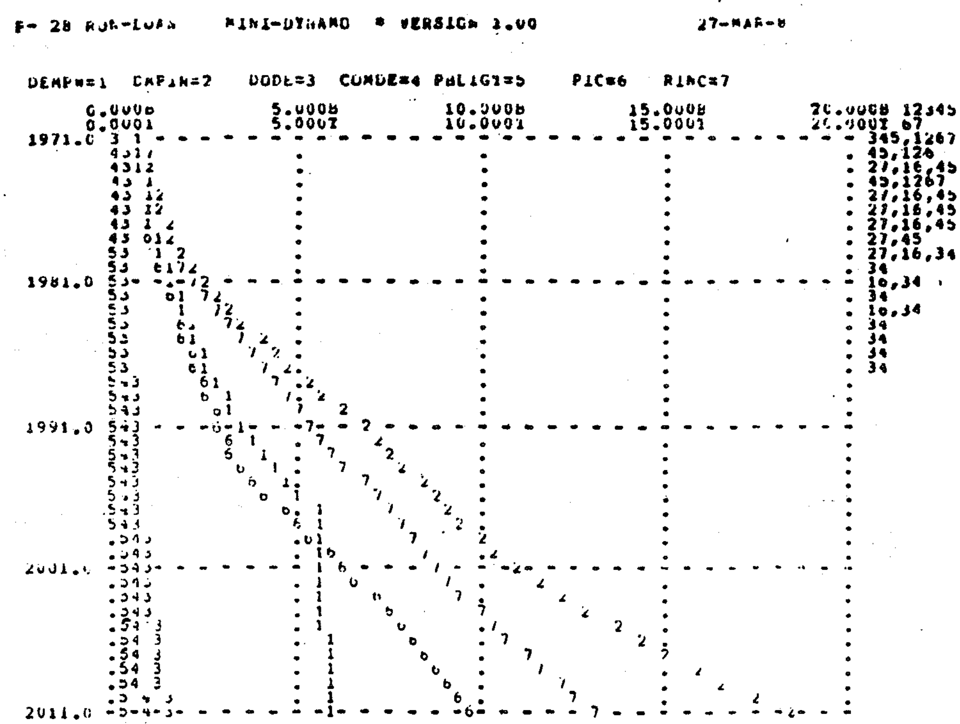

FIG. 4 LOAN RUN

Figure 4 shows the results for a run 3 based on assumption that state will get a loan of Rs. 2000 million in 1990 at 1970-71 prices. This has been able to reduce the gap between demand and supply but gap still persists. Power installed capacity increases substantially but demand for power also increases more than the previious 2 runs.

CONCLUSION

In this paper a system dynamics model to understand the dynamics of power supply and demand has been presented. Feed back loop from power supply/demand for affecting the money in power sector is an important loop, which when effective regulates the money to power sector and generation sector, thus increasing the power supply and increasing the output capital ratio which inturn increases the state domestic product. As even this loop has not been able to bridge the gap between demand and supply, it seems that an alternative to bridge this gap and divert the money from industrial capital to power sector as discussed by the authors (Garga et al.,1984, pp. 1250-52) will be worth mentioning here. That instead of starving the capital of power, capital from the industrial sector will have to be diverted to power sector may be even in private sector. Secondly agrobased mini power thermal stations will also be economical to compensate for the required increasing amount of coal for thermal power houses. It is proved that economy, power supply and demand feedback model can help in understanding the future behaviour of power and economy sectors. Further runs can show the effect of other alternatives viz-a-viz change in power supply,demand and state domestic product.

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