Mansoura Engineering Journal (MEJ) Vol. 16, No. 2, Dec 1991 E.112

POWER SYSTEM PLANNING IN DEVELOPING COUNTRIES
THE CASE OF JORDAN

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تخطيط أنظمة القوى الكهربائية في الدول النامية
حالـــــــة الاردن

الخلاصة

يتناول هذا البحث تخطيط نظام القوى الكهربائي في الدول النامية مع عرض موجز للعديد من الملامح والمشاكل التي تواجهها هذه الدول في عملية التخطيط حيث يتبين ان عملية التخطيط تختلف باختلاف درجة فهم الامور التكنولوجية من قبل المجتمع بشكل عام ومن قبل المخططيـــن وصانعي القرار بشكل خاص. وكذلك فان هذه العملية تتأثر بمعدل النمو الاقتصادي والادارة الاقتصادية السليمه وتبني سياسات صحيحه.

في الجزء الاول من هذا البحث تمت مناقشة المشاكل التي يواجهها مخططو انظمة القوى الكهربائية في الدول النامية. اما الجزء الثاني فقد تناول وصفا مفصلا لتخطيط نظام القوى الكهربائية في الاردن. وفي نهاية البحث تم تقديم بعض الاستنتاجات.

ABSTRACT

This paper deals with power system planning in developing countries. Several features of power system planning in developing countries are presented. These show that the planning process varies with the degree of assimilation of technology by society in general, and by planners and decision makers in particular, as well as the degree of economic growth, sound economic management, adoption of appropriate policies and degree of social development. The problems encountered by power system planners in developing countries are discussed in the first part of the paper. The second part is alloted to a detailed description of the Jordanian case as a good model of fairly successful planning endeavour. In the third and final part, some conclusions are drawn.

I. INTRODUCTION

The authors believe that power system planning processes in developing countries are strikingly different from those used in developed countries due to many reasons such as :

1. Shortage of accurate data, in developing countries, about consumption patterns which makes it difficult to produce accurate demand projections. This difficulty is compounded by the fact that power system sizes in many developing countries are relatively small; hence, any additional unforeseen large load could pose problems to any plan no matter how well conceived or prepared.
2. Development programmes for the electricity sector are usually capital intensive. The investment needed constitutes a financial burden on the governments of developing countries, many of which are poor or need the capital funds for other equally or more important sectors. Yet, electricity plays a major role in the development of country and leads to improved services of other sectors.
3. In many cases it is difficult to plan for power system development which will match the growth in demand. There are several causes for the growth in demand in developing countries as follows: a)natural growth, b)suppressed demand and c)status adjustment growth.

In developing countries the natural growth is rather relatively high because population growth as well as economic growth are high. The suppressed demand, as exemplified by a political decision to connect a village, for example, which is already locally electrified, to the national grid, causes a steep jump in demand. The status adjustment growth is motivated by socioeconomic development. It is rather slow growth in most developing countries except in oil exporting countries where it is phenomenal.

4. Prices for primary energy used in electricity generation are usually fixed by the Government and are rarely affected by price changes that take place in the world market. Moreover, in many instances, electricity entities in developing countries pay a higher price for fuel than the international price. This is a kind of subsidy to the energy sector (or refinery) by the electricity sector.
5. Fixed and rigid tariff structures which are in most cases uneconomic, are heavily subsidized and not dynamic.
6. The lack of trained personnel and necessary hardware and software to implement a proper planning methodology.
7. More weight is given to socio-political issues than techno-economic issues in policy formulations or decision making. This could be manifested by the examples of interconnecting electrical systems of some contiguous developing countries. This decision is usually affected by socio-political factors rather than economic feasibility .

The planning process in general is divided into several activities which are interrelated and are performed in an iterative mode and on a continuous basis. The activities of the planning process include:

- Load research and demand analysis
- Demand and energy forecast

- Generation expansion planning
- Transmission expansion planning
- Distribution expansion planning
- Financial analysis

The planning process cycles through the year whereby each activity is updated once a year at least and its output is used as input for others.
In this paper the authors will discuss the planning process as it pertains to the electrical power system of developing countries.

II. GENERAL DESCRIPTION OF PLANNING ACTIVITIES AND EXISTING METHODOLOGIES :

A brief description of planning activities in developing countries and the relevant methodologies are given below:

1. Load research
Load research involves the measurement and study of the characteristics of electrical loads. The needs and objectives of load research may include requirements in the load management, tariff design, energy conservation, energy-use, load forecasting, transmission and distribution areas [1].

2. Demand forecasting
The load forecast for electrical consumption is an essential element in the energy future of nations.
A developing country will require a different approach from a developed country. The forecast in an open economy will be different from that in a planned economy. Furthermore, not only the methods used in demand forecasting are different in the developing countries but also their purpose may be substantially altered. Industry, in general, is the most intensive energy user in developing countries. Industrial growth can therefore be of strategic importance to both the load forecast and economy development. Village or rural electrification schemes in developing countries also follow this pattern. An active social policy requiring the electrification of vast rural areas of a developing country, is often viewed in terms of the development it may encourage rather than its logistics and the impact upon the utility.
The information required of a load forecast is mainly the maximum power and the total energy to be consumed in the future. Finally load forecasts are also inputs to the financial function in the areas of tariff policy and investment financing.
Usually forecasts are classified as short, medium and long-term as follows:

2.1 Short-Term and Medium-Term Forecasts:
These terms tend to concentrate on the energy aspects of utility operation, such as fuel requirements and equipment utilization. They can also be used to prepare maintenance schedules and develop inter-regional or international power exchange agreements. Furthermore, their predictions are required to incorporate and to

evaluate the effects of uncertainty in the basic elements of the forecast. The effect of weather and other seasonal components of demand are quite relevant in these forecasts.

2.2 Long-Term Forecasts

Nearly 6 to 10 years are required to develop a major generating plant. The process begins with a long-term forecast of expected demands on the system of sufficient detail and extend to allow for accurate system expansion planning.

3. Existing Methodologies

(A) Deterministic Models

These models can be used to forecast the future behavior of a variable on the basis of its past behavior. They are of two general types:

a-Simple extrapolation models: These are of four forms:

(i) Linear trend (ii) Exponential growth (iii) Autoregressive trend (iv) Logarithmic autoregressive trend.

b-Moving average models: There are basically two types of moving average models:

(i) Simple moving average (ii) Exponentially weighted moving average.

(B) Econometric Models

(C) Time-Series Models

(D) End-use (engineering) models

(E) Subjective models

4. Consumer Load Management

An electrical power system is designed and planned to serve the loads imposed by its consumers. This fact affects the overall capacity of the system including generation, transmission and distribution. It also affects the operation of the power system in following the changes in consumer demand and providing for reliable power supply [1].

5. Generation planning

In generation planning the following aspects are studied:

(a) Choice of the optimal mix

(b) Choice of the optimum characteristics of generation plants

(c) Location of new power plants

(d) Use of computer models for planning and analysis

(e) National energy policy

(f) Energy resources in developing country under consideration.

6. Transmission expansion planning

Long-term and medium-term studies are conducted on the following:

(a) Size and location of substations needed

(b) New transmission lines and network structure.

7. Distribution System Planning

The objective of distribution system planning is to assure that the growing demand for electricity, in terms of increasing growth rates and high load density, can be satisfied in an optimal way by additional distribution systems, from the secondary networks through the bulk power distribution, which are both technically adequate and reasonably economical.

8. Financial Analysis

The last task in the planning process is the financial analysis which uses the information from all previous tasks to produce long term financial forecast. Many of the problems of developing countries regarding financial aspects can be solved by introducing this activity within the planning process.

Recently, a new financing scheme called Build, Own, Transfer (BOT), in which a consortium of developers, financiers and local governments share in constructing a new power plant project and guarantee purchase of its output for a period of time after which the plant owenership is transferred to the government, was recently introduced in some developing countries.

III. Problems of Power System Planning in Developing Countries

In this section we summarize and present the main features of power system planning in developing countries:

1. Growth Rate:

The growth rate of power consumption and needs, in developing countries is higher than the same for industrial countries, for example, in Jordan it was 21% in 1980 [2]. The population growth rate is, also, high and the mode of power consumption is high, which imposes a burden on the electric system and requires continuous development. Due to the large rate of growth the planning process is more complex and can be characterized by the following:

a. The planning period is shorter in order to cope with the uncertainty of future demand on power.

b. The mix of power sources (fuels for electricity generation plants) changes from one planning period to another. For example, for relatively small peak load diesel is used, as peak load increases fuel changes to heavy fuel, coal and finally nuclear fuels. This leads to many problems in handling the new technology introduced with each one of the fuel types.

c. The need for skilled technicians and staff to run newly established stations is high due to the high rate of growth in electricity needs. In addition, due to the lack of well developed training programmes and change of technology, shortage of such needed staff results.

2. Inability to use Nuclear Power:

Many of the developing countries are unable to use nuclear power in satisfying their electricity needs due to many reasons, among which is:

a. Industrial countries are hesitant to provide developing countries with nuclear power in order not to help developing countries in aquiring nuclear technology which could be used in developing nuclear weapons.

b. Developing countries, due to lack of trained people in nuclear technology, are hesitant to introduce nuclear technology and in many cases are unable to.

c. Even though the growth rate of power consumption in developing countries is high relative to the rate in industrial countries, the peak load magnitude in developing countries does not economically justify the high initial cost of nuclear stations.
d. The size of the electric power systems in many developing countries is not large enough to warrant an economic addition of a nuclear power plant. This is because commercially available nuclear power plant sizes are in the range 600 - 1200 MW and since any new plant should not exceed 10% of existing installed capacity it means that the minimum system size for considering nuclear power is 6000 MW.

3. <u>Problems with Rural Electrification in Developing Countries:</u>
The rural areas in most developing countries are not connected to national electricity grids. However, many countries have already started connecting rural areas to their national grids. Many problems arise from not connecting rural areas as well as connecting them:
a. Average income level in rural areas is low compared to urban areas, hence, not all people in rural areas can afford to use the puplic power supply.
b. Due to the nature of the rural economy (low income, unindustrialized) electricity consumption is low, hence, electrification cannot be justified on economic basis. In many cases, the decision to electrify a certain village is justified by social reasons. In addition, the spread of consumption points in rural areas over a large area compared to the same in urban areas make long transmission lines needed and hence cost of electricity distribution is high. Combining the above characteristics together, we find the capital cost of connecting rural areas to national grid is high compared to capital cost of using autogenerators. On the other hand, the running cost of generating one KWh is much higher by using autogenerators rather than connecting to the national grid.
c. Although consumption level in rural areas is low, but growth rate, once an area is connected, is sustained.
d. Many developing countries have a long way to go in their rural electrification programmes.
Although two thirds of the people of the developing countries live in rural areas, less than one third of them have access to electricity, and less than 5 - 10% of investments in the electricity sector are allocated to rural electrification [3]
e. Rural electrification projects are characterized by low benefits and low productivity gains. This is due to the fact that electricity in rural areas is used primarily for domestic puposes and not in productive fields [4]. Moreover, many of the benefits gained by rural electrification can be classified as social benefits which are difficult to measure or quantify, for example : modernization, improved quality of life, additional community services, income redistribution and social equity, employment creation and other sociopolitical effects [5].

4. <u>Lack of and Quality of Information:</u>
Many developing countries are becoming aware of their need and the importance of data banks and availability of information. However, at the present time, both the availability and the quality of

available information are not as good as the same in industrial countries. Thus, forecasting future demand or planning power expansion has to take the quality of information into consideration [5].

5. Environmental Issues:
Concern with environmental issues is not as high as it is the case in developed countries. However, it is observed that there is a growing concern in the developing countries with this issue, for example in India [7].

6. Institutional Problems:
Many factors including quality of information, political instability, centralization of the decision making, inadequate use of computers and lack of trained personnel have lead researchers to believe that the success of applying results of planning studies or management science are limited in developing countries [8 and 9].

7. Financial Burden:
Power system development programmes in developing countries require huge investments and constitute a heavy financial burden to their fiscal policies. The World Bank [5], for example, estimates that the required investment approaches US $60 billion annually in order to keep up with a 7% growth rate in demand. Typically, about 1/3 of these investments requires payments in foreign currencies. Moreover, these expenditures typically account for about 25% of public capital investments or about 2% of Gross National Product.

8. Lack of National Capabilities:
Many developing countries electric utilities have outgrown their internal management, technical and administrative capabilities [5]. Corruption and reliance on incompetent people have also added to the problems of developing the power systems of some developing countries. Furthermore, the dependence, for many years, on expatriate personnel and foreign consultants has caused the highly qualified nationals to seek better job oppurtunities elsewhere.

9. Absence of National Plans:
It is essential that developing countries adopt a power system planning methodology that fits within an integrated and comprehensive national energy planning methodology [10]. Moreover, the national energy should be part of a global national development plan that encompasses all future development scenarios for all sectors. Unfortunately, the norm in developing countries regarding energy planning does not always serve the national development plans. For example, the financial requirement of the energy sector burdens the national economy and at the same time is developed in isolation from national development plans.

10. Absence of interregional connected networks:
Many contiguous developing countries can enhance the reliability

and continuity of supply of their electric networks by connecting with each other. However, due to political and other factors this opportunity is not utilized.

IV. POWER SYSTEM PLANNING IN JORDAN

1. INTRODUCTION

About 85% of electricity supply is provided by the Jordan Electricity Authority (JEA) which is a government-owned utility. The remaining 15% is produced by autoproducing large industries. JEA is the only entity which is entitled by the "Electricity Law" to generate, transmit, distribute and sell electricity to consumers according to preapproved electricity tariff.
Two other companies are allowed to buy electricity from JEA and sell to consumers according to certain concession laws as follows:
-Jordan Electric Power Company (JEPCO) is responsible for the distribution of electricity in Amman, Balqa and Zarqa Governorates.
-Irbid District Electricity Company (IDECO) is responsible for the distribution of electricity in Irbid and Mafraq Governorates.

The Ministry of Energy and Mineral Resources (MEMR) is responsible for the energy sector which includes the electrical power sector.

2. Power System Planning Organization in Jordan

All the electric utilities participate in the planning of the electrical power system in Jordan. This paper will focus on the planning as practiced by JEA since its responsibility covers all aspects of the power system.
The planning staff at JEA is about 10 professionals half of which are engineers and the rest are economists, accountants and statisticians. The planners of JEA constitute about 0.5% of total staff of JEA (about 2000).

3. Planning Methodology

The planning methodology used for the planning of the power system in Jordan is depicted in Figure 1.

The main activities of this methodology are:
-Demand and energy forecast
-Generation system planning
-Transmission and distribution system development planning
-Financial planning

These main activities are performed once a year within the planning cycle which starts with the demand forecast and ends with the financial analysis. Some of the activities are performed more than once a year to cover for any variations in the most essential factors affecting the planning process.

In addition to the main activities mentioned above there are other activities that are performed on a continuous basis and provide valuable input to the main activities of the planning cycle. These are :
-Load research and demand analysis

-Investment programme definition
-Tariff design issues
-Demand and supply side data bases

The first activity is a purely planning activity while the others involve other departments. Load research and demand analysis function has proven to be a very valuable tool for planners. It can be defined as follows:

- study of the characteristics of electrical loads to provide a thorough and reliable knowledge of trends in, and the general behavior of, the load characteristics of the electrical usage of consumers.

-is a process by which utilities measure the consumption of the different consumer categories and the pattern of consumption.

-time related energy usage combined with demographic, socioeconomic and weather data comprise the basis for load research studies.

-it provides valuable input to:
 -Load forecast.
 -Load management strategies
 -Tariff structure design

The load research and demand analysis activity is very essential for the planning process and has therefore been incorporated among the planning activities of JEA.

The following sections give some detail of the main planning activities as practiced by the technical planning department of JEA.

A. Demand and Energy Forecast

Two forecasts are prepared annually by JEA and are updated as required, these are:

A.1. Medium term forecast: which covers a period of 24 months and produces monthly peak loads and energy projections at the main transmission substation level as well as total system level.
It is used for: maintenance scheduling, power system analysis studies, operation policies, medium term financial analysis and cash flow.

A.2. Long term forecast: which covers a period of 10-15 years and produces annual peak loads and maximum energy demand for each sector of consumption and for the total system.
It is used for system expansion studies and long term financial analysis.

The methodology used for the long term forecasting is the sectorial analysis of demand whereby the consumption for each category of consumers having the same homogeneous pattern of consumption and are affected by the same driving forces is determined separately. Methods as regression analysis, time series analysis, econometric analysis and market survey are used. For each sector a suitable equation (specification) is determined by defining the relationship between consumption and certain variables that affect consumption. The most significant variables are determined (through statistics and load research) and thus the future consumption is determined through the evolution of these driving forces.

JEA has also acquired and uses a computer programme for long term energy demand forecasting from the International Atomic Energy Agency (IAEA a UN Organization) . The programme is called "Model for Analysis of Energy Demand" (MAED). It is an end use model which basically provides demand projections based on selected scenarioes. It is a useful tool, however, it requires an extensive data base. The input data includes all information regarding all energy forms and the associated driving forces. These variables cover socioeconomic, demographic, technological and life style factors.

B. Generation System Planning

Historically, JEA has depended on outside consultants to provide for the long term generation expansion plan. This is due to the fact that the investment programme needed for the realization of the expansion plan is too important to risk in not having experience.

However, this trend has shifted gradually in recent years where JEA staff work as part of a team with the consultants.

Furthermore, certain parts of the work are done completely by JEA planners. As a matter of fact the whole exercise of generation expansion planning is done by JEA prior the joint study with the consultants. The results are independently verified and JEA is surer to have a sound expansion plan in addition to that JEA planners have gained invaluable experience in the process.

JEA had acquired from the IAEA a computer programme for generation expansion planning called Wein Automatic System Planning (WASP). JEA planners use the WASP-III at least twice a year to verify the plan or upon any changes in forecast, capital costs, fuel costs, discount rates etc.... Very recently the WASP programme was used to study and analyze benefits of the interconnection between Jordan and Egypt in the prefeasibility study which was carried out jointly by the two electricity authorities.

Figure (2) shows the interface between the MAED and WASP computer programmes which together form an integral planning tool.

JEA has other computer packages which are used in the generation system planning studies and are based on production costing and reliability analysis. These are the PSIM/P programme from Power Technologies Inc., USA, and PC/CUM from META Systems,USA.

C. Transmission and Distribution Development

The development process starts by identifying the needs of the network and ends by designing the reinforcements. Recently, this planning activity has been augmented by including the development of interconnections, improving reliability of supply and enhancing system conditions. JEA uses the standard tools for the technical planning studies.These include load flow, short circuit, overvoltage and stability studies. In recent years, JEA has moved into a new direction towards technology transfer. Through

cooperation agreements between JEA and sister utilities in other developing countries, studies are carried out using the facilities or computer software/hardware jointly by JEA staff and experts from such utilities.
There are several computer programmes available at JEA which are used in carrying out the different technical studies including those conducted for the planning of the power system. These include :

- PSS/E from Power Technologies Inc., USA.
- ERACLES from EDF, France.
- Load Flow from Electrocon, USA.
- Short Circuit, Electrocon, USA.

D. Financial Planning

JEA uses a computer programme which was developed in-house with the aid of a local Jordanian consultant. This programme is a very versatile financial planning tool and has been acknowledged by most of the international financing agencies which lend JEA.

Recently, JEA has developed a PC version of the financial analysis programme which will enhance the financial studies due to the versatility and availability of personal computers.

The use of the financial analysis programme is not limited to the financial forecast but it can be used to conduct analytical studies. These include tariff studies and comparison between sources of financing.

V. CONCLUSIONS

The following main conclusions can be drawn from this paper:

1. Power system planning in developing countries is different from that in developed countries due to :
   a. lack of accurate data.
   b. lack of capital funds.
   c. high growth rates.
   d. primary energy pricing is not dynamic and does not follow market price changes.
   e. fixed and rigid tariff.
   f. shortage of skilled personnel.
   g. more weight is given to socio-political issues rather than techno-economic issues.
2. There are many problems facing power system planners in developing countries such as :
   a. planning processes are influenced by socio-political issues more than techno-economic issues.
   b. very high growth rates (and sometimes phenomenal) make it extremely difficult to plan and implement system development.
   c. inability to use nuclear power plants which could be one viable option for power generation for some power systems.
   d. financial burden of many electric utilities in the developing countries which makes it difficult to undertake the capital intensive programmes for the development of the power system.
3. Although Jordan is one of the developing countries, it has overcome many of the difficulties facing electricity sector and thus can be considered as a model for other developing countries to follow in progressing in this domain.
4. Many of the problems facing developing countries in the electricity sector planning can be categorized as institutional rather than analytical.
Developing countries should develop their in-house competent staff in order to be able to perform the planning activity properly. This can be achieved by the active participation of the in-house staff in the portion of the planning process carried out by the outside consultants.
5. Problems in developing countries concerning power system planning are unique and thus require special attention.
6. Developing countries should be careful in selecting planning methodologies and computer programmes to meet their requirements. In other words, complicated programmes, for example, may lead to additional problems, such as unavailability of data and uncertainty of results.

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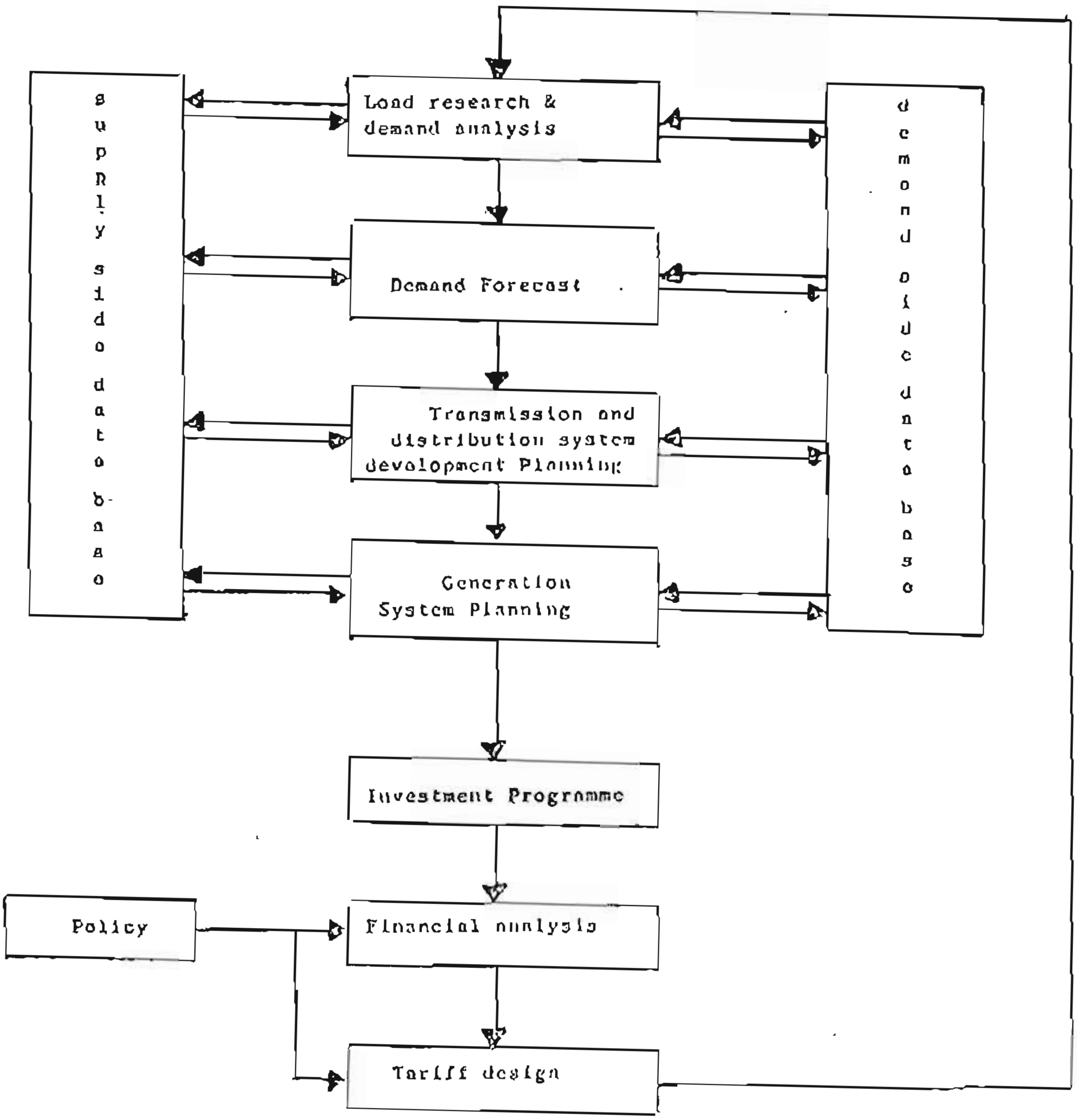

Fig:(1) JORDAN ELECTRIC POWER SYSTEM PLANNING METHODOLOGY

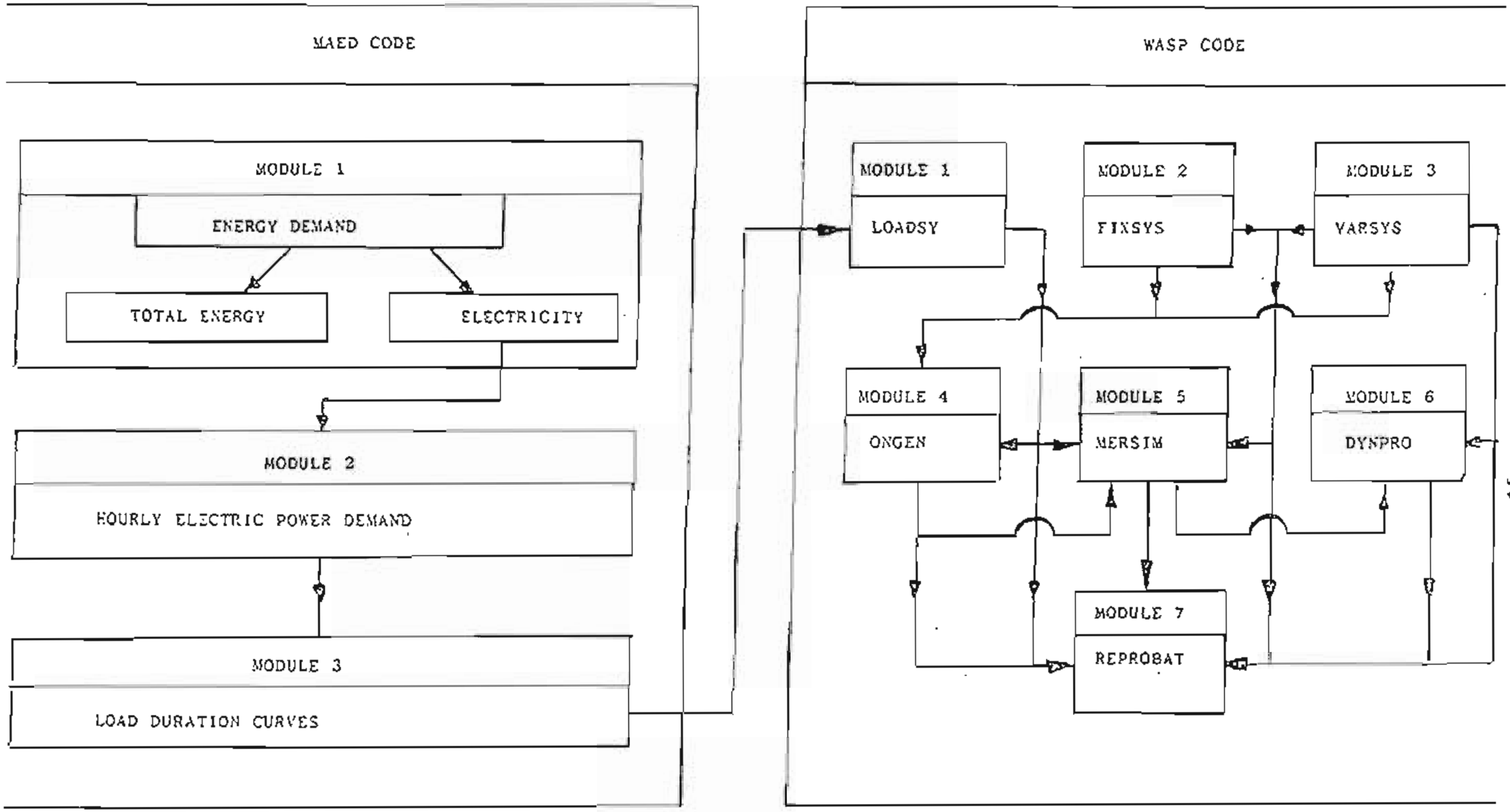

Fig.(2): INTERACTION BETWEEN MAED AND WASP PROGRAMMES