EFFECTIVE POWER SYSTEM PLANNING FOR OPTIMUM SYSTEM EXPANSION IN SOUTH – WEST NIGERIA

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DEDICATION

This thesis is dedicated to my beloved Lord and Saviour, Jesus Christ, who is the Shepherd and Bishop of my soul, the King eternal, Immortal, Invisible, the only wise God, to Him be glory and majesty, dominion and power, both now and ever. Amen.

APPROVAL

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EXPANSION IN SOUTH –WEST – NIGERIA.

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This is to certify that this thesis has been read and approved as meeting the requirements of the Department of Electrical and Electronic Engineering, School of Engineering and Engineering Technology, The Federal university of Technology, Akure for the award of Master of Engineering (Electrical Power System) degree.

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DECLARATION

I hereby declare that this thesis is a record of my research work. It has never been presented nor accepted in any previous application for a higher degree.

All sources of information have been specifically acknowledged.

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Adu, M.R.

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ABSTRACT

The importance of power system planning cannot be over emphasised, therefore the planning for the optimum expansion of South – West Nigeria power system was considered in this research work.

The four generating plants in the south – west Nigeria were visited to assess their present level of performance and their effectiveness. Useful information on total installed capacity as well as monthly (MW) availability were collected from these stations. Also, the monthly peak demand and operational report as well as load flow diagram were collected. The mineral fuels available in the South West Nigeria were also itemised. The peak demand from 1997 – 2020 AD were forecasted using the least square method. The available generation were diligently compared with the peak demand in south west.

As at 1998, from operational report, 1285MW was the actual machine capability, while the available installed capacity was 1395MW out of the 3317MW original installed capacity. And the peak demand in 1996 was 1376MW.

It was discovered that the power generation was far below the demand of the consumer. And this accounts for the incessant power outages and load shedding problems.

To solve this problem, it is required that more power stations should be constructed in Ondo, and Edo States as well as Kogi State where we have oil/gas and coal respectively.

The existing power stations should be rehabilitated. The newly constructed stations should serve the base load, while the old rehabilitated steams stations should be used for intermediate load, and gas turbine plant should be reserved for peak load periods.

TABLE OF CONTENTS

CHAPTER TWO

LIST OF FIGURES

LIST OF APPENDICES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

Planning is the most critical element in providing adequate service at minimum cost. It is the foundation for construction and operation criteria, the timing, quantity and sizing of plant additions and modifications and the type and quality of service.

Electric utilities exist to supply the power needs of their customers, and it is only logical that these needs should form the foundation for system planning. The power system planning is vital to assume that the growing demand for electrical energy can be satisfied. Electricity should be supplied continuously to the consumer at voltages within statutory limits, the total installed capacity must invariably be able to meet the total demand, and the system must be able to meet the maximum peak demand without any disturbance. Therefore, the task of system planning is that of defining the optimum expansion programme that will provide for orderly system growth, achieving a balance between technical adequacy and long-term investment costs (Toshiaki, O. 1992).

Depending on the type of power plant, a total of 8 to 10 years can elapse from the time of conception to completion of a large electric generating station; system planners must therefore study this power system 10 to 20 years in the future in order to have sufficient time to predict and correct future energy problems. Through a combination of examining historic trends and making futuristic predictions, the planner estimates future generation requirements and recommends facility construction.

1.1 TYPES OF PLANNING

The planning being carried out in utility company can be sub-divided into two major groups:

(i) Short-term/range planning

(ii) Long-term/range planning

Short - range planning is defined as the analytical process that includes an assessment of the near future by evaluating alternative causes of action against desired objectives with the selection of a recommended cause of action for the time period requiring immediate commitments. While the long - range planning is defined as the analytical process that includes an assessment of the future by evaluating alternative causes of action against desired objectives with the selection of a recommended cause of action extending beyond the time period requiring immediate commitments.

The long - range forecasting has a time horizon of 15 - 20 years, whereas the time horizon of short- range forecasting is somewhere between 1 and 5 years.

1.2 POWER SYSTEM PLANNING ACTIVITIES

Power system planning activities include

- load forecasting
- generation planning
- transmission planning
- sub-transmission planning
- distribution planning
- operation planning
- research and development planning

This write-up focuses mainly on load forecasting and generation planning, with other activities briefly described.

Generation planning helps to identify the technology, size, the timing of the next generating plants to be added to the power system in order to ensure that adequate generation capacity is available to meet future demand for electricity and that the future cost of power generation is economical (Gonen, T. 1988).

1.3 LOAD FORECASTING

One major tool used by system planners is load forecasting. The basic function of the load forecasting is to analyze the raw historical load data to develop models of peak demand for capacity and of energy for production costing. It is an important part of planning because it determines the timing, and magnitude of system additions needed.

The risk of planning based on too low load projections is poor system reliability, whereas the risk of planning based on too high load projections is an uneconomical operation (Gonen, T. 1988).

Preparation of a forecast entails more than just using historical data and mathematical formulas to projects into the future. The key to realistic forecasting is the inclusion of informed judgment and intuition into the methodological framework being employed in order to minimise uncertainty associated with the future development or event in question (Sullivan W.S. and Wayneclay C.W. 1977).

1.4 THE SOUTH WEST NIGERIA

The South West Nigeria considered in the course of this project is made up of ten states: they are: Lagos, Oyo, Ogun, Ondo, Osun, Delta, Edo, Ekiti, Kogi and Kwara States.

This part of the country happens to be the most developed and highly industrialised areas especially Lagos state. The electric power consumption in this area is enormous compared with other parts of the country. The total land mass of the south west Nigeria is about 1700 square kilometres; and the population (as given by 1991 population census) is as shown in Table 1.1 below.

Table 1.1 Population of South West Nigeria

S/N	STATE	POPULATION
1.	Lagos	5,725116
2.	Oyo	3,452720
3.	Delta	2590491
4.	Ogun	2333726
5.	Ondo	2249548
6.	Edo	2,172005
7.	Osun	2,158143
8.	Kogi	2,147756
9.	Kwara	1,548412
10.	Ekiti	1,535790
Total		25,913707

The total population of the south west Nigeria is about 29% of total Nigeria population (88,992,220).

Although the electric power stations in Nigeria – Kanji, Jebba, Shiroro, Eghin, Afam, Sapele, Delta and Ijora are all interconnected into the national grid: for the purpose of this project, the south west power stations are only being considered as if they are separated from other power stations; while the rest of the country is being viewed as if it is being supplied by the rest of the power stations.

1.5 GENERATING STATIONS IN THE SOUTH-WEST REGION OF NIGERIA

The four basic generating stations in the South-west region of Nigeria are:

1. Egbin-Thermal power station, located at Ikorodu in Lagos State
2. Ijora Thermal power station, located at Ijora in Lagos state
3. Sapele Steam and Gas power station, located at Ogorode-Sapele, in Delta State.
4. Delta Gas power station, located at Ughelli in Delta state.

The total installed capacity of the generating stations are as stated in the table 1.2 .

Table1.2: Installed capacity of Generating stations in South West Nigeria

S/N	STATION	TOTAL MW INSTALLED
1	Egbin Thermal	1320
2	Sapele Gas & Steam	1020
3	Delta Gas	912
4	Ijora Thermal	65
	TOTAL	3317MW

1.6 ELECTRIC UTILITY POWER PLANT DESIGN

Designers of electric utilities are constantly thinking about the generating facilities that must be in operation 10 or more years in the future. The final design and construction of new capacity will typically require not less than 4 years. For these reasons, all basic decisions must be made at least that long before the capacity is needed.

Management must find the best practical answers to four fundamental questions about the provision of added capacity. When? How big? Where? What kind? (Ellioth T.C. 1989).

The answers to when? and How big? are approached by forecasting future electric demand.

The location of an electric generating station is determined by analysis of many factors that influence the selection in diverse ways. The object is to make an engineering economic analysis that will disclose the best choice, which in general is the location that will result in the lowest total cost to the owner in the long run. The following are some of the factors to be considered.

- Availability of natural sites for example, large capacity of water with good head (for hydro-station)

- Condensing water supply

- Availability of cheap conventional fuels.

- Environmental pollution or the ecological factors.

Once the size, timing and location of the plant have been determined, the question arises what kind? In practice, the steps are not taken separately and in succession; they overlap considerably.

The primary choice is among the several plant fuel cycles; conventional fuel, nuclear energy, and internal combustion (diesel or gas turbine). Strictly on the basis of total economy, steam with coal frequently is preferred in the larger sizes, with internal combustion having an advantage for smaller units.

Capacity installed for peaking purposes may be subject to very different economic evaluation than is the case for base load generating equipment. Heat rate economies dominate the latter, while availability of peak shaving capacity for short periods is most important in the former.

1.7 ELECTRIC RELIABILITY REGIONS

Power systems are established to supply electrical power to a specific geographic area. With the trend toward large power plants, smaller utility systems cannot afford sufficient backup power in the event that some of the large units are taken off line.

In order to ensure sufficient reserve electrical power, a country such as Nigeria can be divided into reliability regions. Regional planning now supplements projections by individual systems to assure that each region will be able to meet the requirements placed on it. For the purpose of this project, the South - West Region of Nigeria is being considered.

1.8. OBJECTIVES OF THE RESEARCH

The following are the major objectives of this research work.

- To investigate the various type of power generating station and their total capacity available in the South-West region of Nigeria.

- To investigate the stations present level of performance and their effectiveness
- To determine the type and size of power plants to be added and their citing.
- To optimize the facilities necessary to provide an adequate electrical energy supply at low cost.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 DEFINITIONS OF SOME IMPORTANT TERMS IN POWER SYSTEM STUDIES

The load curve is characterised by the maximum ordinate (being referred to as the maximum demand), the average ordinate (known as the average demand) and the load factor (defined to be the ratio of the average demand to the maximum demand.

Let P_{max} = maximum demand

P_{av} = average demand

Then load factor is given by the relationship

$$\text{Load factor, L.F} = \frac{P_{av}}{P_{max}} \qquad \text{.......... (1)}$$

The average demand, of a given curve, multiplied by the time base (in hours) represents the area of the load curve. The area under the load curve also stands for the total energy supplied to the system during the period for which the load curve has been plotted. Adequate power (generating) capacity needs to be provided in order to meet the demand of the consumers. And very often, the capacity provided (i.e. the installed capacity) is more than the maximum demand on the system. In order to take into account the above facts, another quantity is needed to be defined, which is the capacity factor, and is defined to be the ratio of the average demand to the installed capacity in the system.

$$\text{Capacity factor} = \frac{P_{average}}{P_{installed}} = \frac{P_{av}}{P_{inst}} \qquad \text{.......... (2)}$$

where P_{inst} = Installed capacity of the systems.

For a system with no reserve or standby set, the load factor is equal to the capacity factor. Normally the capacity factor is less than the load factor.

Plant Running load factor is defined to be the ratio of the average unit output at the busbar to the sum of the product of the capacity and running hours of the individual generators in the power station.

Plant running load factor (PRLF) = $\frac{(Pav \times h)}{Pihi}$ .... (3)

where Pi = capacity of the i^{th} unit

hi = running hours of the i^{th} unit

h = period for which the load curve has been plotted.

The plant running load factor would be greater than the capacity factor and the load factor calculated for the given system. Another factor being often needed is the plant use factor. It is defined as the ratio of energy produced per annum to the product of the installed capacity and the number of hours for which the plant was in operation.

i.e. Plant use factor P.U.F = $\frac{E_a}{Pinst \times h}$ .... (4)

where E_a = Energy produced per annum

P_{inst}= Installed capacity

h = Number of hours for which the plant was in operation

Berry (Jha R.S. 1980) studied different systems and load curves. He suggested a relationship for the loss load factor in terms of the load factor given as

(Loss load factor) = a (load factor) + b (load factor)^2 ....(5)

He has also suggested the values of 'a' and 'b' as 0.20 and 0.80 respectively from the detailed studies of large number of load curves.

Availability factor = $\frac{\text{Service hours of a plant or unit}}{\text{Total hours during the period}}$

The availability factor is always greater than or equal to the capacity factor.

NEPA define Availability factor = $\frac{\text{Average MW Availability}}{\text{Installed (MW) capacity}}$

Average MW Availability = This is a measure of average usable MW capacity of each station putting gas presence constraints and other external factors into consideration.

Installed capacity: This is the sum of the manufacturer ratings of all installed generating equipment in the system.

Capability: Capacity or capability of a power system is defined as the maximum KW output ability of the system with all power sources available with no allowances for outages.

Firm Capacity: It is the capacity of the system arrived at after allowing for maintenance and for system operating requirements.

Peak load: It is the maximum simultaneous ultimate customer demand which occurs during a period (day, week, month or year), as measured by actual supplies at bulk power sources.

Gross Margin: This represents the difference between capability and peak load as defined above. Gross margin of a system, therefore should be of sufficient magnitude to provide for scheduled maintenance, emergency outages and system operating requirements if practical operating conditions are to be maintained.

Surplus (Deficit): This is the difference between firm capacity and peak load on KW demand side and between energy available and energy required on the energy side.

Energy Available: This is the total energy that can be produced on firm basis (about 90% availability) for hydro installations and at normal availability of thermal plants.

Energy requirements: This is the aggregate of the energy consumption of all ultimate customers as measured at the busbar of the generating stations.

Diversity factor: This is the ratio of the sum of the individual substation/feeder maximum demand to the maximum demand on the system/substation.

D.F. = $\frac{\text{sum of maximum demand on individual feeder}}{\text{maximum demand on the system}}$

The diversity factor is always greater than unity.

2.2 WHY INSTALLED CAPACITY LAGS BEHIND THE LOAD GROWTH IN NIGERIA

In the developed countries, there is normally a stable capital market and the vital power sector is never allowed to suffer due to shortage of funds. In Nigeria as in other developing countries, demand for power for the exploitation of minerals, modernisation of agriculture and for rapid industrialisation is growing by leaps and bounds. Consequently the installed capacity always lags behind the load growth and frequent power shortages are the order of the day. The reasons for these epileptic conditions may be many. Long term plans may be ambitiously drawn up, but the availability of finances may be limited, as the power sector has to compete with other sectors like industry, transport, agriculture, education, health and defence.

In the power sector itself, there are competing claims of different models of generation and between generation, transmission and distribution. Power project implementation is a lengthy process spread over several years and unless sufficient financial resources are made available and at the required intervals, the completion of a project gets delayed.

Apart from these, most of the developing countries do not have the manufacturing facilities for the power plants and equipment needed and therefore have to resort to imports. This requires a large amount of foreign exchange. Moreover, they are also beset by a shortage of sophisticated technical personnel and they have to be brought from other countries (Jog, M.G. 1989).

2.3 FUEL SOURCES FOR MODERN POWER PLANTS

The potential fuel sources of electric power generation at present are fossil - coal, petroleum, and natural gas - together with nuclear fuel and hydroelectric power. And these except nuclear fuel represent the only well-developed means of generating large quantities of electric power in Nigeria. Research, development, and construction of experimental facilities are progressing in fusion, solar, wind and ocean thermal power programmes. All these new concepts appear to be a number of years away from making possible the production of significant quantities.

2.4 POWER GENERATION

This is based on electro-mechanical energy conversion principle, (using synchronous generator). This takes place when the change in flux is associated with mechanical motion. Voltages are hereby generated in windings or groups of coils by rotating these windings mechanically through a magnetic field, or by mechanically rotating a magnetic field past the winding or by designing the magnetic circuit so that the reluctance varies with rotation of the rotor. By any of these methods, the flux linking a specific coil is changed cyclically, and a time-varying voltage is generated.

The principle of electromagnetic induction is used for the generation of electric power with the help of synchronous generator. All modern types of alternating current generators essentially consist of a fixed stator and revolving rotor. The stator emf is induced when the shaft of the rotor is revolved with the help of the prime-mover. The rotor carrying field magnet and coils which provide the magnetic flux of the machine. The field is excited by a direct current brought into the field circuit by means of two rotor slip-rings and set of brushes riding on them.

The magnitude of the induced voltage in the single phase of the stator winding depends upon the strength of the magnetic field, the speed of rotation and number of stator coils in series.

2.5 POWER SYSTEM IN THE SOUTH-WEST REGION OF NIGERIA

The supply system consists of the network conductors and the associated equipment over which energy is transmitted from the generating station to the consumer. It may be divided into two distinct part: the transmission system and the distribution system. The former may again be divided into primary and secondary transmission; while the latter may be divided into primary, secondary and tertiary distribution.

In general in an ac system, there would be a change in voltage at each point where the sub-division takes place, the change being effected by transformers usually at a substation, and therefore, there are several working voltages in the same system.

For equipment manufacturing reason and in order that corresponding sections of adjacent system may be inter connected, it has been found necessary to standardize voltages, the voltages in Nigeria are as indicated in the figure 2.1.

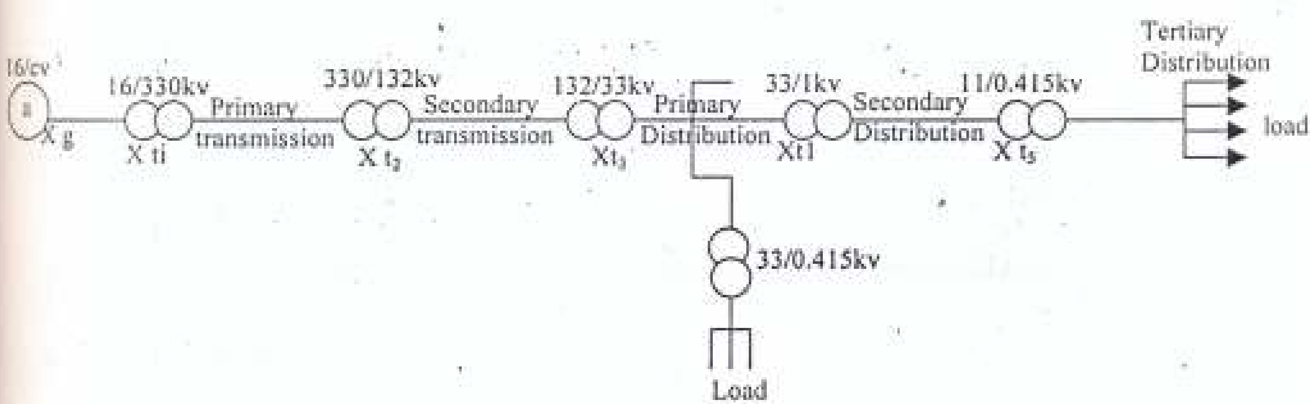

Fig. 2.1 Standardized Voltages in Nigeria.

Electric power is generated at a voltage of about10kv - 16KV which then is stepped up to a national grid value of 330Kv. The first step down of voltage from primary transmission level is at the bulk power sub-station, where the reduction is to 132KV. This step down is from the primary transmission and grid level to sub-transmission or secondary transmission level.

The next step-down in voltages is at the distribution substation; broadly speaking, two distribution voltage levels are employed.

(i) The primary or feeder voltage (33 or 11KV)

(ii) The secondary or consumer voltage (415V three phase/ 230V single phase).

The distribution system, feed from the distribution transformer stations supplies power to the residential or domestic, industrial and commercial consumers. Thus, the power system operates at various voltage levels separated by transformers.

2.5.1 EGBIN THERMAL POWER STATION

Egbin Thermal power plant is one of the latest and biggest additions to the electricity industry in Nigeria. Often seen as the biggest single generating power station in Black Africa; it was built to meet the ever rising demand for electricity in Lagos and its environs.

Location: Egbin Thermal power station was conceived and located at Ijede village, on the outskirts of Ikorodu town. It is situated on a low-rise land and bounded by the Lagoon to the South, Mangrove swamp to the North and Ijede village to the West.

Capacity of the plant: Egbin Thermal power station has a generating capacity of 1320MW. It consists of six fuel reheat steam electric units with nominal rating of 220MW (6 x 220 = 1320MW).

Fuel and gas: In constructing Egbin Thermal power station, there was special provision so that it can depend on High Pour Fuel Oil (HPFO) for its operations. There was the provision as well that will guarantee that the plant conveniently converts from using HPFO to Natural Gas. For the purpose of using the cheap natural gas of the Niger Delta

Region of the country, the Escravos Lagos pipeline (ELP) was linked directly to Egbin Thermal power station.

Cost of the plant: Egbin Thermal power station was built at a cost of about N5 billion given the then exchange rate of N7 to one United States Dollar.

Commissioning of the power station: Egbin Thermal Power station was commissioned on May 13, 1986 by the President, General Ibrahim Badamasi Babangida.

Contractors: The Marubeni Corporation of Japan, a consortium of consulting engineers was the main contractor in charge of the whole electrical installations while Shawmount Limited of Canada whose sister company in Nigeria is MONECO was concerned more with environmental and ecological input.

2.5.2 SAPELE POWER STATION

The conception and subsequent construction of Sapele Power Station was an outcome of the load forecasts for Nigeria in 1972, compared with the installed capacity at that time, which showed the need for the provision of large additional power plants.

Location: Sapele power station was located at Ogorode, Sapele in Delta state. This area was chosen because of the large reserves of natural gas presently being flared off, acceptable foundations, and sufficient cooling water.

Capacity of the plant: Sapele power station has a generating capacity of 1020MW. It consists of 6 x 120MW = 720MW steam turbine and 4 x 75MW = 300MW Gas turbines.

Fuel and gas: The Sapele power station depends on High Pour Fuel oil (HPFO) for its operations. The HPFO is often supplied to the station through the small jetty at the power station. The power station also depends on natural gas for its operations. The power station gets its cheap supply of natural gas from NNPC compressor station at Ogboni-Koko, Sapele.

Cost of the plant: Sapele power station, Ogorode, was constructed at a cost of over N259.2 million.

Commissioning of the power station: The first of the Sapele power station was commissioned in September, 1978; while the last Unit was commissioned in 1980.

Contractor: Shawmount Limited a firm of consulting engineers was responsible for the overall design and management of the power station. Actual construction started in January 1976.

2.5.3 DELTA GAS POWER STATION

The necessity for the construction of Delta Gas power station became obvious as a result of the ever-growing rise in the load demand for the supply of electricity in and around Warri where heavy industries like Aladja steel complex and Nigerian National petroleum Corporation, are located. More was the growing demand around the whole nation due to the ever-increasing number of enterprising Nigerians in various social, commercial and industrial activities.

Location: Delta gas power station was located at Ughelli, Delta state, because of the availability of natural gas in abundance. More, the cheapness in utilizing gas for the generation of electricity was another obvious point, that influenced and justified the location of the power station off that scope in that environment.

Capacity of the plant: The plants were not constructed and commissioned at the same time; but the total installed capacity was 912MW. It consists of:

GT_1 - GT_2	-	2 x 36MW	=	72MW
GT_3 - GT_8	-	6 x 20MW	=	120MW
GT_9 - GT_{14}	-	6 x 20MW	=	120MW
GT_{15} -	-	1 x 100MW	=	100MW
GT_{16} - GT_{20}	-	5 x 100MW	=	500MW
		TOTAL	=	912MW

Gas consumption: The Delta gas power station depends solely on natural gas for its generation.

Cost of the plant: The National Electric Power Authority spent about N2.5billion for the construction of Delta gas power station.

Commissioning of the power station: Delta I which consists of GT_1 and GT_2 was commissioned in 1966 Delta II which consists of GT_3 - GT_8 was commissioned in 1975 Delta III, which consists of GT_9 - GT_{14} was commissioned in 1978. Delta IV, which consists of GT_{15}, was commissioned in 1989 while GT16 - GT20 was commissioned in 1990.

Contractor: Consortium of General Electric of the United States and Marubeni of Japan were the two major contractors.

2.5.4 IJORA THERMAL POWER STATION

This is one of the oldest power plant in the country.

Location: Ijora Thermal power station was located at Ijora in Lagos State.

Capacity of the plant: Ijora Thermal power station has a generating capacity of 65MW.

Fuel: Ijora Thermal power station depends on High Pour Fuel Oil (HPFO) for its operation.

Commissioning of the power station: Ijora Thermal power station was commissioned in 1978

2.6 PATTERN OF DEMAND

The power demand by the consumer does not remain constant, but it fluctuates from minute to minute, day to day, season to season. To study the pattern, the graph of load against time is plotted which is called a load curve.

LOAD CURVE: A curve showing the load demand (variations) of consumer with respect to time is known as load curve. If the time is in hours then the load curve is known as daily curve. If the time is in days, the load curve is known as monthly load curve and if the time is in months, the load curve is known as annual load curve. This is illustrated in figure 2.2.

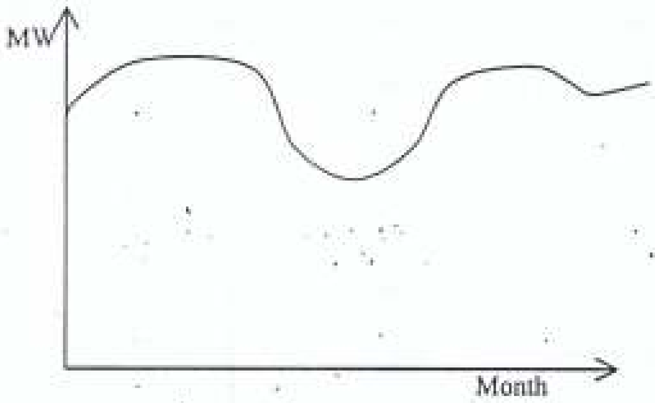

Fig. 2.2 Annual Load Curve

The load curve shows how the load varies with time. It is useful in predicting the annual requirements of energy and capacity of the power plant required to take the peak load.

The area under the load curve gives total energy consumed by the customer.

The energy consumption of the customer is given by an expression

$E = \int(kw)dt$ -.. (6)

If the load curve is drawn on yearly basis:

The problem in designing the power plant is not only the energy consumed by the customer but the way adopted to use it. Take for example two consumers X and Y that consume the same amount of energy as shown in fig. 2.3, but their consumption patterns are different.

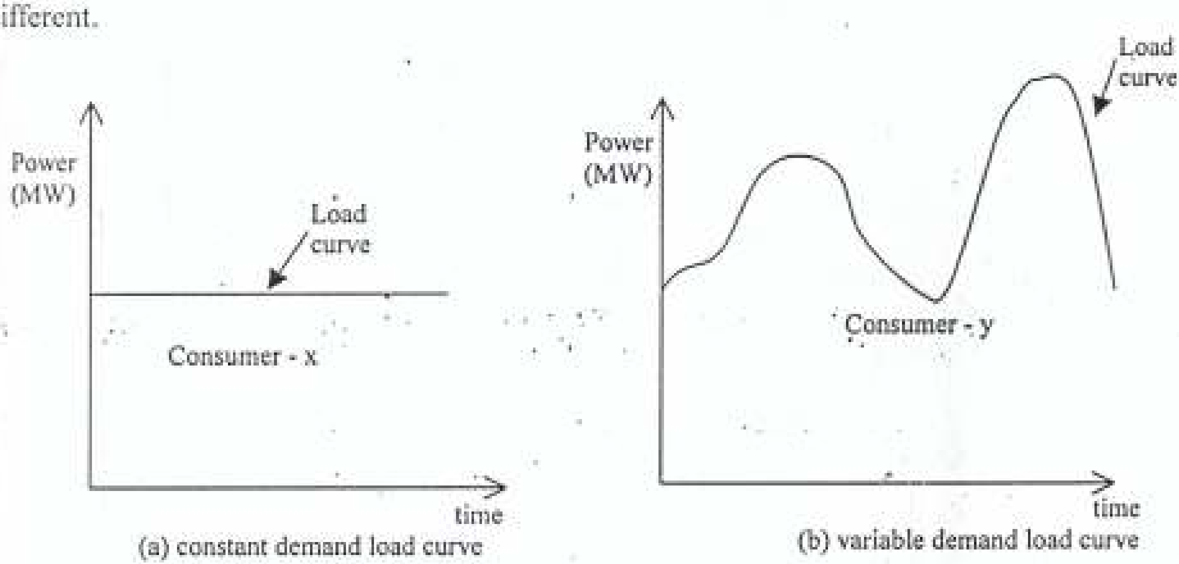

Fig 2.3: Constant and Variable Demand Load Curve

Considering the two load curves above, the peak load of consumer Y is far greater than that of consumer X, therefore, the generating capacity of the plant required to supply the load of Y is greater than the capacity required to supply the load of X. The plant designed for consumer Y is not only bigger in size but it also runs underload (part load) conditions for majority of the period. Therefore, the cost of energy supplied to Y may be 100% greater than the cost of energy supplied to X, although the total energy consumed by both consumers is the same. Most of the completion of present day modern power plants operation arise from the inherent variability of the load demanded by the consumers according to the requirements with respect to time. For economical and better operation of the power plant, constant magnitude load is always desirable as it allows the plant to work at highest efficiency and require simplified control and regulating devices. The magnitude of peaks and valleys in load curve generally depends upon the nature of the load connected, pattern of activities of the concerned population, time of the day, the climate etc.

LOAD DURATION CURVE: This is the plot of load demand against the period or time for which the load persists on the system. It is simply a re-arrangement of daily load curve with loads set-up in descending order of magnitude. The areas under the load duration curve and corresponding load curve are equal and measure KW-hr of energy for that period.

To get the load duration curve from chronological load curve, we cut the daily load curve into many vertical strips and then arrange them in descending order. This is illustrated in figure 2.4.

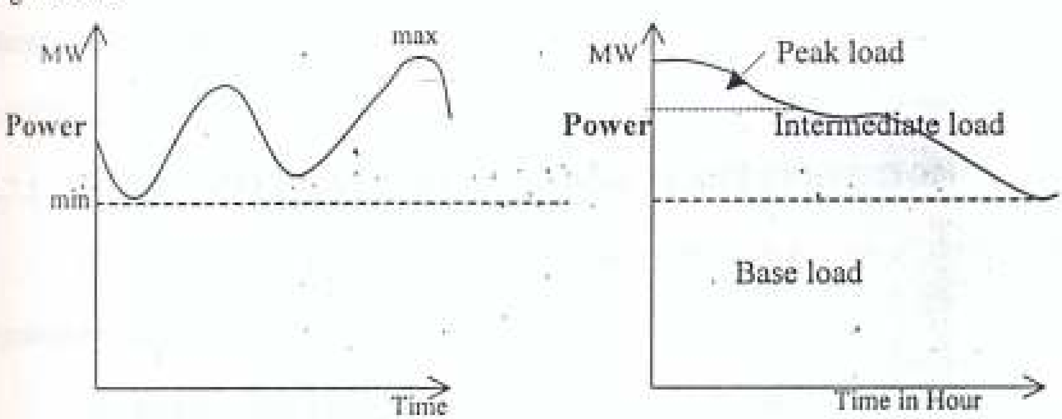

Fig 2.4 Preparation of load duration curve from load curve.

Load duration curve offers the advantage of summarising loads for a day, weeks, month or year. This is advantageous for power plant design as in one simple curve, a whole year can be summarised showing peak demand, the variations in demand down to minimum, the length of the time they existed and total energy involved.

From Fig. (b) above, the loads under the load duration curve can be divided into three:

(i) Base load: This is the load which the demand never falls and is supplied 100% of the time.

(ii) The peak load: This is considered the region to the left of the sharply sloping portion of the curve and usually represents loading seen less than 15% of the time.

(iii) The medium or intermediate load: This represents the remaining load region.

2.7 CATEGORIZATION OF POWER STATIONS

In order to meet the varying power demands, different categories of power stations have to be provided for in the grid. They are divided into three categories:

(i) Base load plants

(ii) Intermediate or medium load plants

(iii) Peak load plants.

Base load plants work for a period 6,000 hours or more in a year. Medium load plants work between 2,000 and 6,000 hours a year and peak load plants work for less than 2,000 hours in a year (Jog, M.G. 1989).

2.7.1 THE LOAD DURATION CURVE AND PLANT SELECTION

The pattern of load demands from the utility leads to the use of three types of power generating plants:

(a) **BASE LOAD PLANTS:** These plants have to run continuously, they are heavily loaded, therefore they must be very efficient plants with a low cost of power generation, though they may need initial heavy capital investment, which is economically justifiable.

Most new, large coal and nuclear power stations are based loaded plants, due to the low operating costs of these units, although their capital costs are very high.

(b) <u>MEDIUM/INTERMEDIATE LOAD PLANTS:</u>

The cost of generation may be higher than base load plants, but more reasonable than that of peaking units. These plants tend to be somewhat smaller and older units. For most parts, they are older coal plants, where thermal efficiencies are significantly below those of the modern units. They may also include older petroleum and gas fired stations in those areas of the country where petroleum and natural gas have been used for base-loaded plants.

(c) <u>PEAK LOAD PLANTS:</u> These plants are run for a small fraction of the time, and because of this, fuel costs of these plants are not of major importance. Capital costs, on the other hand, must be charged whether the station is or is not used. Therefore, in building a new plant for peaking service, it will be built in a way that will minimize capital costs. Commonly used plants are: Gas turbine plants, pumped storage plants, compressed air storage plants. An exception to the case of low-capital cost plants for peaking service is the use of hydroelectric plants for this purpose. This is due to the fact that, the total quantity of water that can be impounded by a hydroelectric plant dam is limited. In many cases it is impossible to run the plant at rated load for most of the year, as the water required will exceed the total available. Therefore, the plants may then be used only during those portions of the year when the load is highest (Weisman J. andd Eckart R. 1985).

Intermediate and peaking - load plants are often termed load-following plants. This terminology is used because the output of these plants responds to the diurnal variations of load on the system.

2.8 DETERMINATION OF LOAD MAGNITUDE

The power system is expected to discharge its main function by supplying the power or energy to the consumer connected to the system. Its performance largely depends upon the correct evaluation or assessment of its load magnitude.

For the proper assessment of the load magnitude, it is always advisable to refer back to the statistical data of load growth of the past. These past data are statistically related by methods of curve fitting, utilizing proper numerical analysis techniques and checking the extrapolated results by various checks and counter checks.

The forecast of demand for electricity is expected to assess:

(a) Increase in generating capacity required year by year in the future to meet the growth in demand and the best geographical location for the new plants;

(b) Provision of new main transmission links between generating plant and the supply points;

(c) Necessity for establishing new supply points and

(d) Extension and reinforcement of the distribution system and connecting the supply points to consumers.

It is desirable that for forecasting demand, the period required to design and commission or extension to the supply system should be taken into consideration. It takes up to 5 to 7 years between forecasting a future demand and bringing in the new plant at the best geographical location to meet it. Forecasting beyond this period need not have great degree of accuracy (Jha R.S. 1980).

2.9 HYDRO STATION

The generation of electrical energy in bulk quantity is possible by utilizing the potential energy of water stored in reservoirs and passing it over the blades of turbines. Thus the potential energy of water is converted into mechanical energy by the water turbine which, with the aid of an electric generator, gets the mechanical energy converted into electrical energy.

World's water power resources are considerable and are replenishable every year by the nature. Despite its disadvantage that the water available for generation of electrical energy may vary from year to year or even during the year, water power resources provide one of the cheapest form of energy available to mankind.

Hydropower schemes can either be single-purpose, having as their only purpose the production of electricity, or multipurpose, having hydropower production as just one aspect of total utilisation of the facility.

The quantity of water available and head are important in the generation of power. The available head depends upon the selection of site for hydraulic power plant. The site of the power plant is always selected for the highest available head when other things are in favour of site selection.

The quantity of water available at the selected site depends upon the hydrological cycle of nature. As the availability of water depends on the natural phenomenon of rain, the maximum capacity of hydraulic generating plant is usually fixed on the basis of minimum quantity of water available (Jha R.S. 1980).

The typical scheme of hydro-electric power stations is given in Figure below.

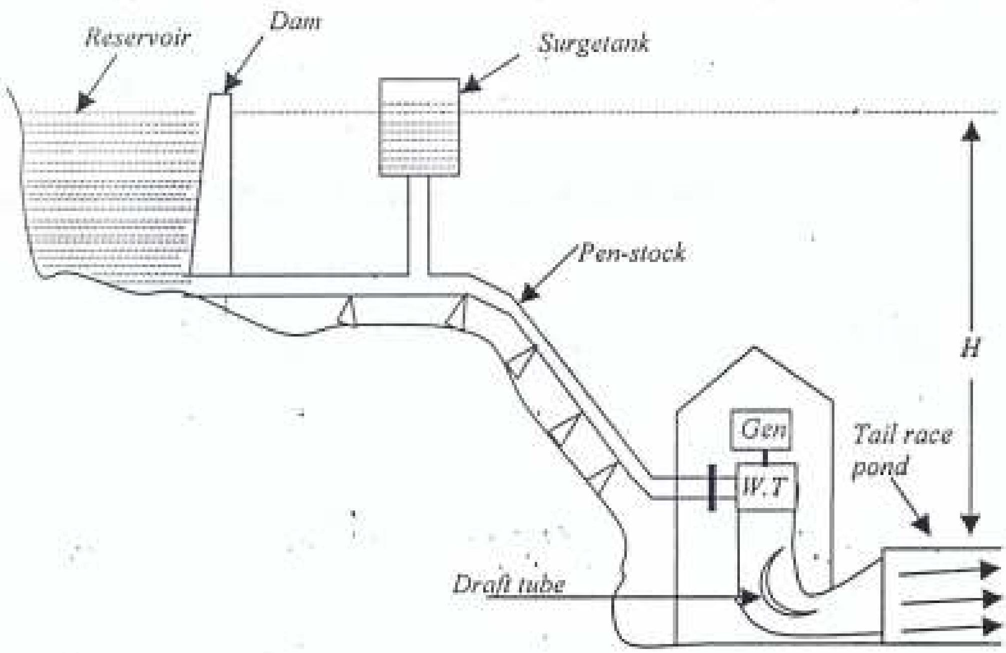

Fig. 2.5 Hydro Electric Power Generation

Water available from rainfall over an area (catchment area) is stored in the reservoir. This stored water is led to the turbine in a power station through a penstock. The variable flow of water through the penstock, depending upon the condition of operation of a power plant, is regulated through a surge tank. The water after releasing its potential energy to the rotating blades of the water turbines reaches tail race pond via the draft tube.

Let the catchment area = $A(km)^2$

Let the Annual rainfall = f(m)

∴ Volume of water available per annum

$$= Af \times (1000)^2 m^3$$

Let K = factor of availability.

This takes into account evaporation, consumption of water by trees and plants etc.

∴ Actual amount of water available per annum

$$= (1000)^2 \ AfK m^3$$

$$\text{Discharge per second} = \frac{(1000)^2}{8760 \times 3600} AfK.m^3/sec$$

(No of hours/year = 8760).

$$Q = \frac{AfK}{31.5} m^3/sec$$

Where Q = amount of water available for power generation

let the gross head in m = H

Then, work done/sec = $Q\rho H$ Kg.m/sec

Where ρ = density of water = $1000 Kg/m^3$

$$\therefore \text{H.P generated} = \frac{Q\rho H}{75}$$

(One metric H.P = 75Kg.m/sec)

$$\therefore \text{H.P. generated} = \frac{1000}{75} QH = 13.33QH$$

Since one metric HP = 736 watts or 0.736KW, we have

Average amount of electric power available

$= 13.33 \times 0.736\ QH$

Pav. = 9.8 QH KW.

Let the penstock efficiency be ηp

the turbine efficiency be η t and

the generator efficiency be η g

:. Net Kw available = 9.8 QH $\eta p\ \eta t\ \eta g$

:. Pav = 9.8 QH η_o

where η_o = overall efficiency of the hydroelectric generation.

2.10 GAS TURBINE POWER PLANTS

This is most satisfactory power developing unit among various means of producing mechanical power due to its exceptional reliability. It is relatively free from vibration and is capable of producing large powers from units of comparatively small size and weights.

In the last two decades, the rapid progress had been observed in the development and improvement of the gas turbine plants for electric power production. The major progress has been observed in three directions viz: (a) increase in unit capacities of gas turbine units (50 - 100MW); (b) increase in their efficiency (37%) and (c) Drop in capital cost (RS.500 -7000 per KW installed).

The economics of power generation by gas turbine is proving more attractive in all parts of the world due to its low capital cost and high reliability and flexibility in operation. Apart from these, another outstanding feature of gas turbine plant for power generation is its ability of quick starting and capability of using wide variety of fuels from natural gas to residual oil or powdered coal.

Gas turbine plants is mainly used for peaking loads, due to its relatively low installed cost per KW of installed capacity. The world largest peaking installation 480MW is at Astoria Power Station in USA (Arora S.C. and Domkundwar S. 1992).

GAS TURBINE PLANT

The gas turbine plant basically consists of (a) compressor, (b) combustion chamber and (c) turbine as shown below.

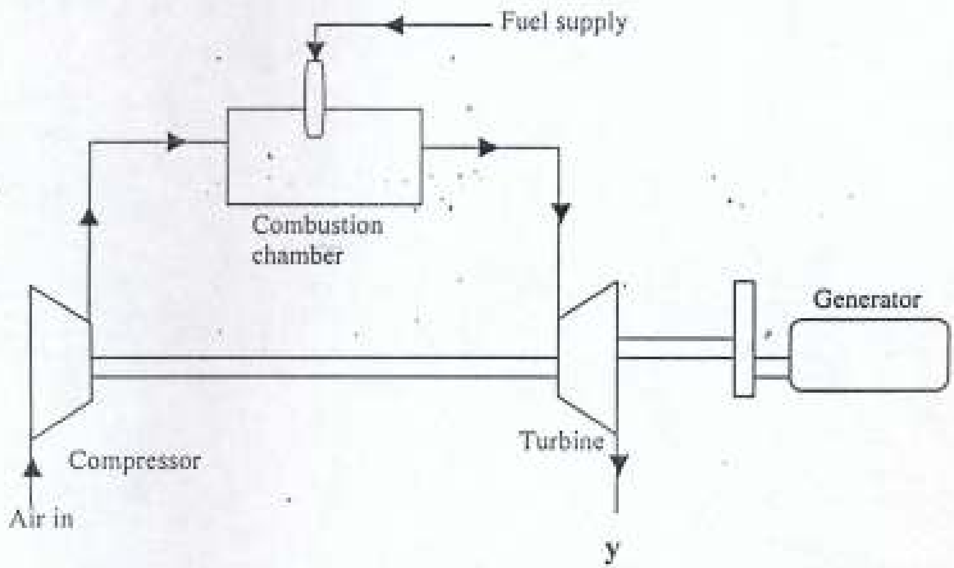

Fig 2.6 Gas Turbine Plant

The air is compressed in a compressor (which can either be centrifugal or axial flow type) and the fuel is burned in the combustion chamber when the compressed air is supplied from the compressor. The burned high temperature gases are passed through the turbine. The part of the work developed by the gases passing through the turbine is used to run the compressor and remaining (30 - 35%) is used to generate the electrical energy.

2.11 THERMAL POWER PLANTS

A thermal power station using steam as working fluid works basically on the rankine cycle. Steam is generated in a boiler, expanded in the prime mover and condensed in condenser and fed into the boiler again.

Thermal power plant consists of four main circuits, they are:

(i) Coal and ash circuit

(ii) Air and gas circuit

(iii) Feed water and Steam flow circuit

(iv) Cooling water circuit.

COAL AND ASH CIRCUIT: In this circuit the coal from the storage is fed to the boiler through coal handling equipment for the generation of steam, and the ash produced due to the combustion of coal is removed to ash storage.

FEED WATER AND STEAM CIRCUIT

The steam generated in the boiler is fed to the steam prime mover to develop the power. The steam coming out of prime mover is condensed in the condenser and later fed into the boiler through the aid of pump.

Feed water is supplied from external service to compensate for some of the steam water lost through different components of the system. The feed water from external source is passed through the purifying plant to reduce the dissolved salts to an acceptable level and to avoid the scaling of the boiler tubes.

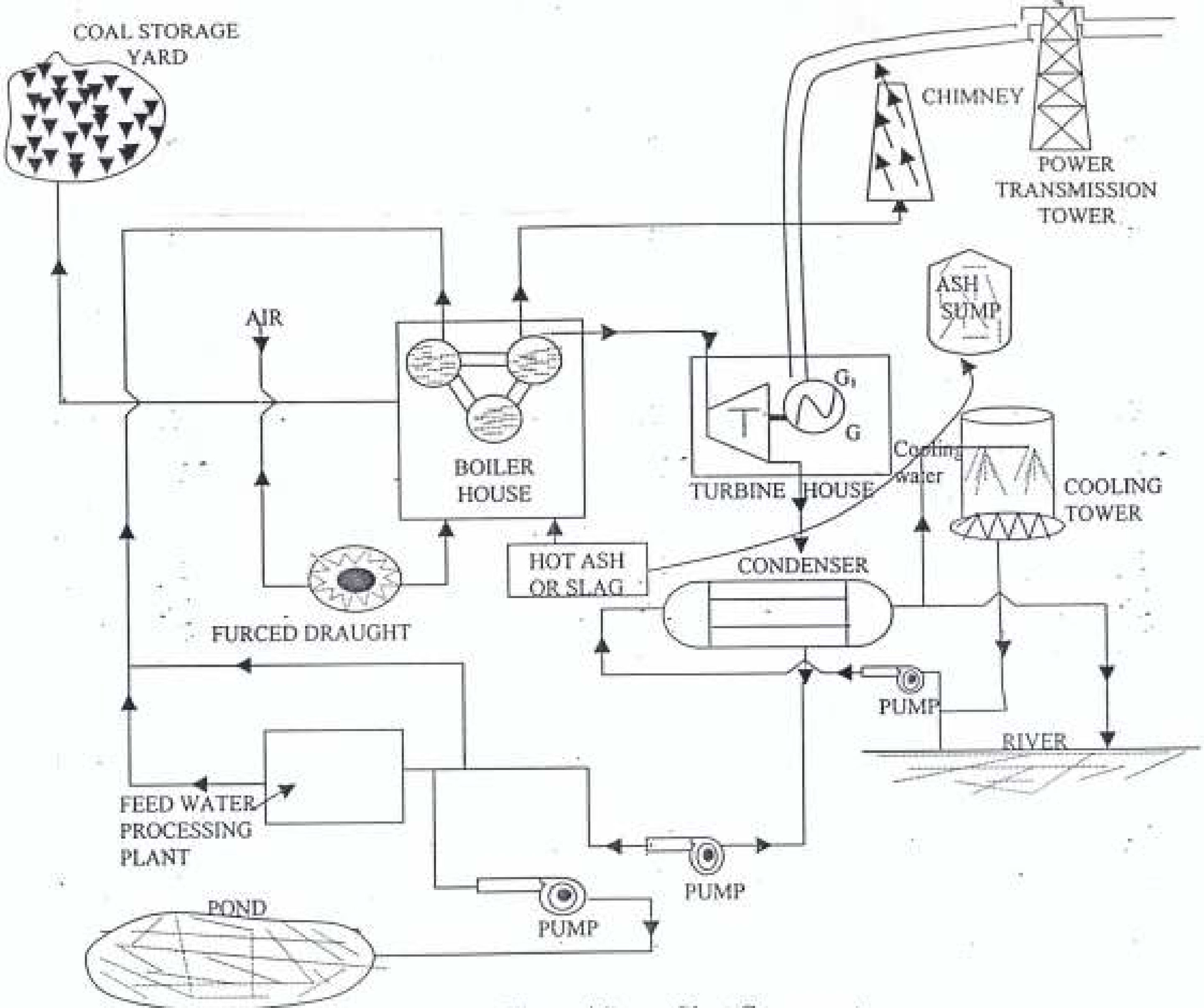

Fig. 2.7 Thermal Power Plant Components

AIR AND GAS CIRCUIT

Air is supplied to the combustion chamber of the boiler through fan. The dust from the air is removed before supplying to the combustion chamber.

COOLING WATER CIRCUIT

Due to the fact that the quantity of cooling water required to condense the steam is considerably large, lake or river is being employed to pass through the condenser and heated water is discharged to the lower side of the river. This is known as open system. When adequate water is not available, then the water coming out from the condenser is cooled either in cooling pond or cooling tower. The cooling is effected by partly evaporating the water. When the cooling water coming out of the condenser is cooled again and supplied to the condenser, then the system is known as closed system.

2.11.1: SITE SELECTION FOR THERMAL POWER STATION

The location of the thermal power stations should be made with full considerations not only of the trends in the development and location of demand but also of the availability and location of the cheapest sources of primary energy.

Some of the important factors to be considered for the selection of site for thermal plants are as follows:

(i) **AVAILABILITY OF COAL:** It is necessary to install the power station as close as possible to source of coal (e.g. coal mines for coal) so as to minimize transport charges.

(ii) **ASH DISPOSAL FACILITIES** (when using coal): A 400Mw power station requires nearly 10 hectares area per year if the ash is dumped to a height of 6.5metres. The ash handling problem is more serious than coal handling because it comes out in hot condition and it is highly corrosive. Its effects on atmospheric pollution (fly ash) are more serious as the human health is concerned. The ash can be easily disposed to river, sea or lake economically if such facilities are available at plant site, or used for other industrial processes.

(iii) **SPACE REQUIREMENT:** The space and building requirements by the power station is another point that must be considered. The average land requirement is 3 to 5 acres per MW capacity (where coal is used) which includes the space required for coal storage, ash disposal, stall-colouring, market facilities and the space required for whole machines.

(iv) **NATURE OF LAND:** The selected site for the power plant should have good bearing capacity as it has to withstand the dead load of the plant and forces transmitted to the foundation due to the machine operations.

(v) **AVAILABILITY OF WATER:** Large quantities of water are required for condenser, for disposed of ash, and as feed water to the boiler.

A 60mw capacity plant requires about 20 to 30 thousand tons per hour to condense the steam coming out from the turbines.

(vi) **TRANSPORT FACILITIES:** It is always necessary to have a good road and railway line linking thermal power station for bringing in heavy machinery for installation and for bringing in fuels.

(vii) **PUBLIC PROBLEMS:** The proposed site should be far away from the towns to avoid the nuisance from smoke, fly ash and heat discharged from the power plant.

2.12 NUCLEAR POWER STATION

The rapid increase,industry and living standard of the people with the gradual depletion of fossil fuel resources and oil being a high priced commodity, have dictated reconsideration of exploring new sources of energy. The nuclear energy has the potentiality to offer a solution to the problem because of the large amount of energy that can be released from a small mass of active material.

The discovery of the fission of uranium was of tremendous importance as it opened the prospects of using the energy stored in the atomic nucleus for the production of electric power.

"The first nuclear reactor was built under the strict security arrangements in the squash court under the University of Chicago's Stagg Field Stadium by Fermi and his collaborators. The Chicago pile diverged on 2nd December 1942 which was an epochal event in the history of power development.

The first electricity from nuclear power was generated by the experimental breeder reactor (EBR) in 1952. While the World's first atomic power plant of 5MW capacity for industrial purposes was commissioned in U.S.S.R on June 27, 1954 and this date is regarded as the birth of new source of power generation. The next nuclear Calder Hall power plant in Cumberland was commissioned in October 1956 to feed the electricity to the national grid of USA (Arora S.C. and Domkundwar S. 1992).

The natural substance used as a nuclear fuel is Uranium. In pure form it is heavy, hard nickel-white metal. It oxidizes in air and water. Natural Uranium wherever found consists of its three isotopes, which are Uranium 238, 99.3%, Uranium 235, 0.7% and Uranium 234, trace of all these three natural isotopes, only Uranium 235, (U-235) fission in a chain reaction. A small portion of Uranium 238 (U-238) would fission but is cannot sustain a chain reaction.

During the fissioning process, the binding energy of the nucleus of an atom is released under the action of a fast moving neutron or a high energy particle. During the fissionary process, two or three new neutrons are also produced. These neutrons are used subsequently for maintaining the continuous process. Such process is known as the chain reaction and it is characterised by the continuous release of heat at a steady rate.

2.12.1 GENERAL COMPONENTS OF NUCLEAR REACTOR

The nuclear reactor may be regarded as a substitute for the boiler firebox of steam plant or combustion chamber of a gas-turbine plant. The nuclear power plant may be of steam driven turbine or gas driven turbine as per the choice of the fluid.

The general arrangement of Nuclear power plant with essential components using steam as working fluid is shown on figure below.

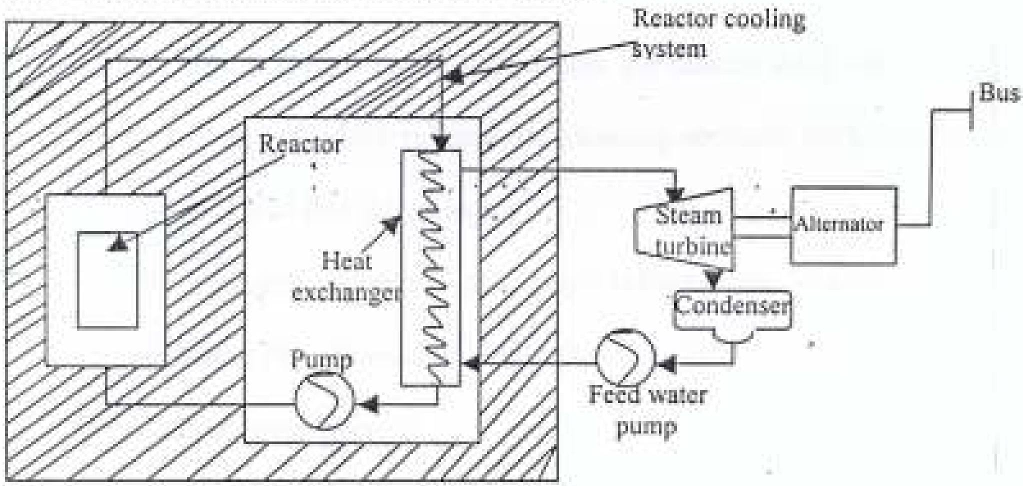

Fig 2.8: Nuclear Power Plant

(1) **Fuel:** The nuclear fuels which are generally used in rectors are $92U^{235}$, $94Pu^{239}$ and $92U^{233}$. Among the three, the $92U^{235}$ is naturally available up to 0.7% in the Uranium ore and the remaining is $92U^{238}$ ore formed in the nuclear reactors during fission process from $92U^{238}$ due to the absorption of neutron without fission.

(2) **Moderator:** The moderator is a material which reduces the kinetic energy neutron (1 Mev or 13200Km/sec) to slow neutron (0.25ev or 2200m/sec.), and this is done in a fraction of second. The function of the moderator is to increase the probability of reaction. The slowing down of neutrons is effectively done by the light elements as H_2, D_2, N_2, O_2, C.

(3) **Reflector:** It is always necessary to conserve the neutrons as much as possible in order to reduce the consumption of fissible material and to keep the size of the reactor small. The neutrons which are released in fission process can be absorbed by the fuel itself, moderator, coolant or structural materials. Some neutrons may escape from the core without absorption and will be lost for ever.

In other to reduce the loss of escape, the reactor inner surface is surrounded by a material which reflects the escaping neutrons back into the core. This material is called the reflector.

The required properties of a good reflector are low absorption and high reflection for neutrons, high resistance to oxidation and radiation as well as high radiation stability.

(4) **Coolant:** The main purpose of the coolant in the reactor is to transfer the heat produced inside the reactor. The same heat carried by the coolant is used in the heat exchanger for further utilization in the power generation.

(5) **Control rods:** The control of the chain reaction is possible by removing the fuel rods or the neutrons continuing the chain reaction from the core of the reactor. But it is always easy to get rid of the neutrons. It is done by inserting the control rods into the fuel tubes. The control is necessary to prevent the melting of fuel rods, disintegration of coolant and destruction of reactor as the amount of energy released is enormous.

The materials used for control rods must have very high absorption capacity for neutrons e.g. cadmium, boron etc.

(6) **Shieldings:** The reactor is a source of intense radioactivity, and these radiations are very harmful to the human life. The common radiations from the reactor are Xrays, βrays, Y-rays and fast neutrons. To prevent the

effects of these radiations on the human life, it is necessary to absorb them before emitting to the atmosphere.

These radiations are effectively absorbed by concrete and steel.

(7) **Reactor vessel:** The reactor vessel encloses the reactor core, reflector and shield. It also provides the entrance and exit passages for directing the flow of coolant.

For the purpose of power generation, pressurised water reactor (PWR) and boiling water reactor (BWR) are the two main types of reaction used.

2.12.2 LOCATION OF NUCLEAR POWER PLANT

Some factors which control the site of nuclear power plant are:

1) **AVAILABILITY OF COOLING WATER:** The plant requires huge quality of cooling water, therefore, it must be located near a river, lake or sea so that ample quantity of water will be available.

2) **TRANSPORTATION FACILITIES:** The power plant should be nearer to the transport facilities as much as possible as heavy equipment are to be transported to the site.

3) **DISTANCE FROM LOAD CENTRE:** It should be located near the load centre. This will reduce the power loss as well as the cost of long transmission lines.

4) **SAFETY:** The power plant should be located at a reasonable distance from the populated area to avoid the radiation hazards.

5) **RADIOACTIVE WASTE DISPOSAL FACILITY:** The wastes of the nuclear plant are highly radio-active and therefore sufficient space must be available near the plant for short time storage as well as for long-time burial of the radioactive waste.

6) **FOUNDATION REQUIREMENT:** The site selected for the plant must be suitable for foundation and should be strong enough to support the reactor and auxiliary equipment.

2.13 FOSSIL FUELS

2.13.1 NATURAL AND PETROLEUM GAS

Current geological theories indicate that natural gas was formed from decaying vegetable matter in the same manner, and generally along with petroleum. In some regions, wells drilled into the geologic formation containing the gas and trapped oil release gas predominately. In other regions, both oil and gas are released together. Even today, in some fields, the natural gas is flared or burned at the wellhead because of lack of facilities to transport the gas.

Most natural gas is used as domestic or commercial heating fuel. However, in regions close to the source of natural gas, it has also been used as a power plant fuel.

Composition and Properties of Natural Gas Fuels

Natural gas is the cleanest burning of all the fossil fuels. It is free of ash and mixes well with air to undergo complete combustion and producing very little smoke.

Natural gas consists primarily of a mixture of the most volatile paraffins - methane through pentane with high proportion of methane.

2.13.2 LIQUIFIED NATURAL GAS AND PETROLEUM GAS

Since the major constituent of all natural gas is methane (critical temperature - 83°C), cryogenic temperatures are requires to maintain the gas as a liquid at moderate pressure (e.g. - 100°C at 36 bar). Storage and shipment of the liquid has a large advantage in that $1 m^3$ of liquid is equivalent to more than $600 m^3$ at standard atmospheric conditions.

Liquefied petroleum gas (LPG) refers to hydrocarbons (such as propane, propylene, butane, butylene and isobutane) which are liquefied under moderate pressures and at normal temperatures but which are vapours at the usual atmospheric conditions

Liquefied petroleum gas is widely used to supplement natural gas flow during peak usage periods. In a few cases, natural gas flow may be supplemented by "Oil gases". These gases are made by thermal decomposition of petroleum fractions ranging from naphtha to residual fuel.

Transportation:

Oil is transported by tanker, rail, truck or pipeline.

2.13.3 COAL

This is a generic term that describes a rather wide variety of solid hydrocarbon products formed from pre-historic terrestrial vegetation. It comes in four different types: Peat, lignite or brown coal, bituminous and Anthracite coal.

There are several properties of coal that are important in power plant applications: These includes:

(a) Sulfur content: This is an important consideration in the selection of coal. Sulfur is one of the combustible constituents of coal. However, the product of combustion, sulfur dioxide, (SO_2) is considered to be a major source of atmospheric pollution. It is difficult and expensive to remove the sulfur dioxide from the combustion products. In selecting a coal source. detailed assessment must be made considering current environmental regulations covering plant SO_2 emissions, the sulfur content of the coal, the cost of the coal, and the capital cost and operating cost of SO_2 removal equipment.

(b) The combustion properties: This are related to how well the coal burns.

(c) Weatherability: This is a measure of how well coal can be stockpiled for long periods of time without crumbling.

(d) Grindability: This is another important consideration when selecting coal. Grindability of a standard coal is defined as 100. The index is established to be inversely proportional to the power required to grind the coal to a specified particle size for burning.

(e) The ash softening temperature: This is the temperature at which the ash softens and becomes plastic. This is usually somewhat below the melting point of the ash. This coal characteristic is important to the ash discharge system.

Some of the characteristics of coals that determine its selectivity for plant use are:

Moisture content

High heating value

Grindability index

Ash content

Ash fusion temperature

Sulfur content

Coals with high moisture content will increase most boiler components sizes and reduce boiler efficiency. It will also require a larger air heater. The burning of coal with a high moisture content results in a higher flue gas dew point, and raises the stack temperature needed to prevent corrosion.

The high heating value of the coal is another property that greatly affects plant design. The high heating value (HHV) establishes the rate at which coal is fed into the furnace (firing rate). Since the HHV can vary from 19,000KJ/Kg (8000Btu/lb) to well over 28,500KJ/Kg (12,000Btu/lb) and since the firing rate for a given furnace or boiler output is inversely proportional to the HHV, thus, the HHV will affect the design of the boiler combustion zone, burners and coal feeders and coal-handling equipment (Arora S.C. 1992).

Transportation: Coal is mainly transported by rail shipment, truck or overload conveyer.

2.14 CHOICE OF FUEL

The selection of fuel is based on a combined investigation of availability, cost, and operating requirements. Most individual power plans use solid, liquid or gaseous fuels either singly or in combination. When company fuel costs, one must consider these expenses; the base price of fuel, fuel delivery, handling and, reclaims, labour, plant services, and fixed charges on fuel handling and fuel burning equipment.

Careful study of these expenses, adjusted to an annual basis, will provide a foundation for fuel selection. Other less tangible factors should also be evaluated, such as reliability of supply, future availability, individual fuel cost trends, ease of conversion from one fuel to another, and extent of future plant expansion (Dbuath K. 1995).

CHAPTER THREE

METHODOLOGY OF POWER SYSTEM PLANNING

This project among other things involved visiting and collecting relevant data from the four basic power generating stations in the South-West region of Nigeria namely:

- Egbin Thermal Power station, Ikorodu - Lagos;
- Ijora Gas Power station, Ijora - Lagos;
- Sapele Steam and Gas Power station, Ogorode, Sapele
- Delta Gas Power station, Ughelli.

These data include:

Average monthly MW availability from January to December in each utility from 1988 to 1996; Thermal Fuel cost from January to December in each utility from 1988 - 1996; capacity of the plants, type of fuel, cost of installation as well as date of commissioning each generating station.

I also visited NEPA National Control Centre (NCC) Osogbo as well as NEPA former headquarters in Marina - Lagos to collect data on monthly Peak demand (MW) for South West Nigeria from 1988 - 1996, operational report, load flow diagram as well as summary of generation capabilities of NEPA Power Stations as operated in January to December from 1988 - 1996.

Moreover, I visited the Bitumen Project Work, at NIDB house Akure and office of Solid Minerals, Federal Secretariat, Oda Road Akure to collect Data on mineral fuels available in the South-West region of Nigeria, states where it is being mined and total reserves available.

With the aids of past data records collected, using (least square method), I was able to forecast the peak demand expected from 1997 - 2020AD. When these figures are compared with the installed capacity it is possible to see if there would be need to provide for additional power plants, when this addition is to be effected, the size of the plants and the best citing.

Furthermore, assessment of the utilities present level of performance and their effectiveness was made by considering the operational report as well as the availability factor of these generating stations, and also by comparing the commissioning date of these plants with their life spans, which is averagely about 30 - 40years, to see how long they can still be in service. The available generation were diligently compared with the peak demand as shown in table 4.3.

3.1 FORECASTING METHOD

The various techniques for forecasting demand can be divided broadly into two groups:

(a) Mathematical and statistical methods which attempt to forecast future demands by determining trends of past results and using the trends to extrapolate the curve of demand into the future.

(b) Synthesis of demand determined by:

  (i) Either on a local basis and taking into consideration knowledge of new development affecting demand, or

  (ii) On a national basis, applying the techniques of market research to estimate future changes in each class of load.

Apart from these, graphical methods are used when the demand is plotted as a function of time. The demand versus time curve is then extrapolated to obtain what would be the value of the demand in future. This method affords an approximate idea about the probable demand in the future.

In the graphical method of load forecasting, it is assumed that the power increases in an exponential manner over a limited number of years. This assumption is found to be very near to the actual conditions in practice for short-term growth of electrical load. In real power system planning, electrical power demand almost doubles itself within every seven to eight years period.

3.2 MATHEMATICAL THEORY FOR FORECASTING POWER DEMAND USING THE METHOD OF LEAST SQUARES

Let D = demand of electrical power (KW or MW)

y = the year in which the demand is considered

y_o = base year

Then the exponential growth of demand with time would be expressed as:

$D = e^{a+b(y-yo)}$ .... (7)

where e = Naperian base of logarithm

a, b = constants.

To evaluate the constants a and b, based on actual demand data over a number of years,

Put $y - y_o = Y$

:. $D = e^{a+bY}$ ....(8)

:. $\ln D = a + bY$ ....(9)

Let $V = \ln D$

:. $V = a + bY$ ....(10)

Equation (10) is an equation relating V and Y in a linear fashion.

Assuming that the demand for consecutive years are given as

$D_1, D_2, D_3 ....D_n$

:. $V_1 = \ln D_1; V_2 = \ln D_2; ....V_n = \ln D_n$

The plot of V = f(Y) is shown in Fig. 3.1 below:

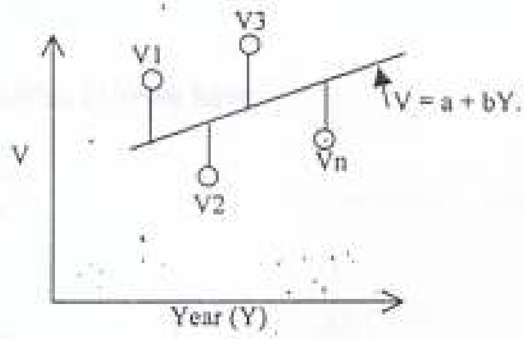

Fig. 3.1 Plot of V versus Y

Corresponding to various values of Y_i's there are V_i's. All the V_i's are randomly distributed as shown in Fig. 3.1. In order to correctly asses the demand, the sum of the squares of the errors committed by such approximation should be minimum, that is,

$$S = \sum_{i=1}^{n}[v_i - (a + bY_i)]^2 \quad \text{.......... (11)}$$

Should be minimum

And the conditions for S to be Minimum are:

$$\frac{\partial S}{\partial a} = o \text{ and } \frac{\partial S}{\partial b} = 0 \quad \text{..........(12)}$$

$$\therefore \frac{\partial S}{a} = \sum_{i=1}^{n} 2\,[v_i - (a+bY_i)]\,(-1) = 0$$

$$\therefore \sum_{i=1}^{n} V_i = n_a + b \sum_{i=1}^{n} Y_1 \quad \text{.......... (13)}$$

$$\text{Also } \frac{\partial S}{\partial b} = \sum_{i=1}^{n} 2[V_i - (a+bY_i)]\,(-1)Y_i = 0$$

$$\therefore \sum_{i=1}^{n} Vi\,Yi = a \sum_{i=1}^{n} Yi + b\sum_{i=1}^{n} Yi^2 \quad \text{..........(14)}$$

Thus, equation (13) and (14) provide the conditions for the sum of the least squares of the deviation to be minimum.

For simplifying further, let

$$\sum_{i=1}^{n} Yi = 0$$

From equation (10) we have

$$a = \frac{1}{n}\sum_{i=1}^{n} vi \quad \text{...(15)}$$

and

$$b = \frac{\sum_{i=1}^{n} YiVi}{\sum_{i=1}^{n} Yi^{2}} \quad \text{...(16)}$$

Thus equation (15) and (16) would enable us to evaluate the constants a and b so as to minimize the error in load forecasting.

Year	Demand (MW)	Vi = InDi	Yi	YiVi	Yi^2
1988	1036	6.9431	-4	027.7725	16
1989	1109	7.0112	-3	-21.0336	9
1990	1234	7.1180	-2	-14.2360	4
1991	1232	7.1164	-1	-7.1164	1
1992	1257	7.1365	0	0.0000	0
1993	1262	7.1405	1	7.1405	1
1994	1318	7.1839	2	14.3677	4
1995	1352	7.2093	3	21.6280	9
1996	1376	7.2269	4	28.9077	16
n = 9		ΣVi= 64.0858	ΣYi = 0	ΣYiVi = 1.8854	ΣYi^2=60

From equation (15)

$$a = \frac{1}{n}\left(\sum_{i=1}^{n} Vi\right)$$

$$= \frac{1}{9} \times 64.0858$$

$$= 7.1206$$

From equation (16)

$$b = \frac{\sum_{i=1}^{n} YiVi}{\sum_{i=1}^{n} Yi^2}$$

$$= \frac{1.8854}{60}$$

$$= 0.0314$$

Using equation (7), that is $D = e^{a+b(Y-Y_0)}$

Where Y = the year in which the demand is considered

And Y_0 = base year, (this is equal to 1992 from the table above)

Equation (7) can further be written as $D = Ae^{bx}$

Where $A = e^{a} = e^{7.1206} = 1237.2$

And $x = Y - Y_0$

Where x = 0 → 1992

1 → 1993

2 → 1994

3 → 1995

:

:

28 → 2020

Starting from the base year the forecast for 1992 would be $D = Ae^{bx}$ → here x = 0

$D = Ae^{0}$

$= 1237.2$ MW

The forecast for 1993 would be

$$D = Ae^{bx} \rightarrow \text{ here } x = 1,\ b = 0.0314$$

$$D = 1237.2e^{0.0314}$$

$$= 1276.7\text{MW}$$

The forecast for 1994 would be

$$D = 1237.2e^{0.0314 \times 2}$$

$$= 1317.4\text{MW}$$

The forecast for 1995 would be

$$D = 1237.2e^{0.0314 \times 3}$$

$$= 1359.4\text{MW}$$

The forecast for 1996 would be

$$D = 1237.2e^{0.0314 \times 4}$$

$$= 1402.8\text{MW}$$

The forecast for 1997 would be

$$D = 1237.2e^{0.0314 \times 5}$$

$$= 1447.5\text{MW}$$

The forecast for 1998 would be

$$D = 1237.2e^{0.0314 \times 6}$$

$$= 1493.7\text{MW}$$

The forecast for 1999 would be

$$D = 1237.2e^{0.0314 \times 7}$$

$$= 1541.3\text{MW}$$

Now that the country is passing through a period of democracy, more investors both from local and foreign individuals/organisation are being envisaged, many industries will be established in various parts of the South West Nigeria. In addition to this is the government plans to increase the salaries of the workers, which will invariably bring about an increase in the purchasing power of the people, and many of the industries that have not been operating to their full capacity (due to low purchasing power of the people) will be revived again. Therefore, the demand for power by the year 2000 will be greater than the normal trend of the forecast. As analysts believed that annual growth rate of 7% would be a maximum upper bound (Weisman, S. and Eckart R. 1985) assuming twice the maximum upper bound for the year 2000 i.e. 14% growth rate, this can be achieved by introducing an accelerating factor "$\alpha = 1.4$" to cater for this, and which is gradually being reduced by 0.05 until year 2008 when it is totally removed.

The forecast for 2000 would be

$D = Ae^{\alpha bx}$

Where α = accelerating factor, which is taking to be equal to 1.4

$D = 1237.2\, e^{1.4 \times 0.0314 \times 8}$

$D = 1758.6$ MW

The forecast for 2001 would be

$D = 1237.2\, e^{1.35 \times 0.0314 \times 9}$

$D = 1811.9$ MW

The forecast for 2002 would be

$D = 1237.2\, e^{1.30 \times 0.0314 \times 10}$

$D = 1860.9$ MW

The forecast for 2003 would be

$D = 1237.2\, e^{1.25 \times 0.0314 \times 11}$

$D = 1905.2$ MW

The forecast for 2004 would be

$D = 1237.2\, e^{1.30 \times 0.0314 \times 12}$

$D = 1944.5$ MW

The forecast for 2005 would be

$$D = 1237.2\, e^{1.15 \times 0.0314 \times 13}$$

$$D = 1978.4 \text{ MW}$$

The forecast for 2006 would be

$$D = 1237.2\, e^{1.10 \times 0.0314 \times 14}$$

$$D = 2006.5 \text{ MW}$$

The forecast for 2007 would be

$$D = 1237.2\, e^{1.05 \times 0.0314 \times 15}$$

$$D = 2028 \text{ MW}$$

The forecast for 2008 would be

$$D = 1237.2\, e^{0.0314 \times 16}$$

$$D = 2044.7 \text{ MW}$$

The forecast for 2009 would be

$$D = 1237.2\, e^{0.0314 \times 17}$$

$$D = 2109.9 \text{ MW}$$

The forecast for 2010 would be

$$D = 1237.2\, e^{0.0314 \times 18}$$

$$D = 2177.2 \text{ MW}$$

The forecast for 2011 would be

$$D = 1237.2\, e^{0.0314 \times 19}$$

$$D = 2246.7 \text{ MW}$$

The forecast for 2012 would be

$$D = 1237.2\, e^{0.0314 \times 20}$$

$$D = 2318.3 \text{ MW}$$

The forecast for 2013 would be

$$D = 1237.2\, e^{0.0314 \times 21}$$

$D = 2392.3$ MW

The forecast for 2014 would be

$D = 1237.2\,e^{0.0314 \times 22}$

$D = 2468.6$ MW

The forecast for 2015 would be

$D = 1237.2\,e^{0.0314 \times 23}$

$D = 2547.3$ MW

The forecast for 2016 would be

$D = 1237.2\,e^{0.0314 \times 24}$

$D = 2628.6$ MW

The forecast for 2017 would be

$D = 1237.2\,e^{0.0314 \times 25}$

$D = 2712.4$ MW

The forecast for 2018 would be

$D = 1237.2\,e^{0.0314 \times 26}$

$D = 2798.9$ MW

The forecast for 2019 would be

$D = 1237.2\,e^{0.0314 \times 27}$

$D = 2888.2$ MW

The forecast for 2020 would be

$D = 1237.2\,e^{0.0314 \times 28}$

$D = 2980.4$ MW

Table 3.1: Forecasted Peak demand from 1997 – 2020

Year	Forecast Demand (MW)
1997	1447.5
1998	1493.7
1999	1541.3
2000	1758.6
2001	1811.9
2002	1860.9
2003	1905.2
2004	1944.5
2005	1978.4
2006	2006.5
2007	2028.7
2008	2044.7
2009	2109.9
2010	2177.2
2011	2246.7
2012	2318.3
2013	2392.3
2014	2468.6
2015	2547.3
2016	2628.6
2017	2712.4
2018	2798.9
2019	2888.2
2020	2980.4

This is further shown graphically in Fig. 3.2 below

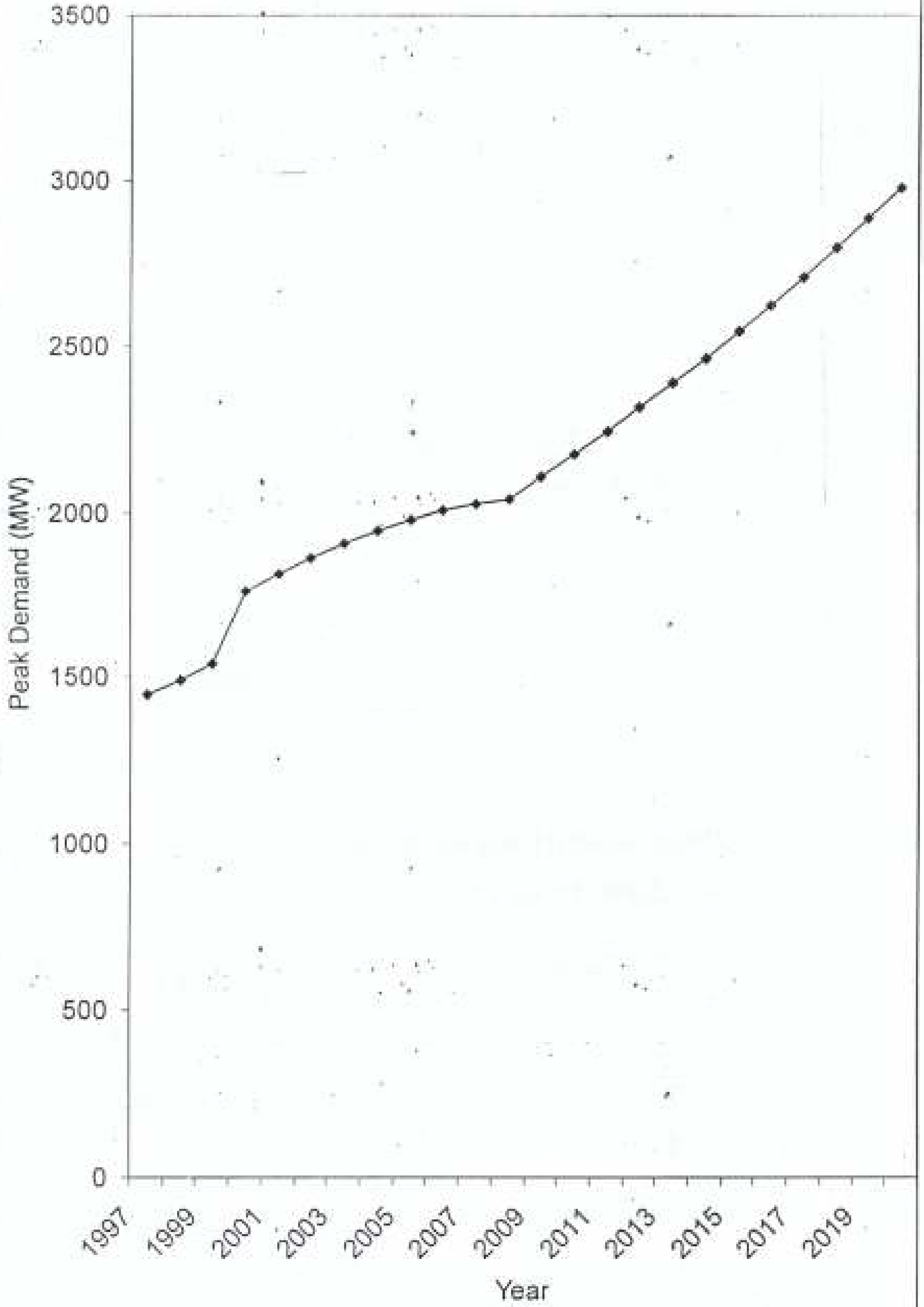

Fig. 3.2: Forecasted Peak Demand from 1997 - 2020 AD

CHAPTER FOUR

RESULT AND DISCUSSION

The available mineral fuels in the South West Nigeria as well as operational report of South West power stations are as shown in Table 4.1 and Table 4.2 respectively.

Table 4.1 SOUTH WEST MINERAL FUELS

S/N	Mineral	Location	Estimated Reserved	User Industries	Exploitation
1	Coal	Kogi Edo	500000000 tonnes	As fuel for production of tar, gases & oils, cement, industrial boilers, carbonation plants	Annual production is around 25000 tonnes.
2	Oil/Gas	Delta Edo Ondo	N.A.	Generating electricity	N.A.

Table 4.2 OPERATIONAL REPORT OF SOUTH WEST POWER STATIONS GENERATION AVAILABILITY AS AT APRIL 1998.

Power Station	Units	Installed available capacity (MW)	Actual Machine Capability (MW)	Remark
Egbin	St1	220	220	
	2	220	220	
	3	220	220	
	4	---	---	Distorted furnace, needs foreign exchange
	5	220	220	
	6	---	---	Distorted furnace, needs foreign exchange
sub total		880	880	

Sapele	st1	120	90	
	2	---	--	High turbine vibration 25/03/98
	3	---	--	generator transformer problem 28/05/96
	4	---	--	stator high winding temperature
	5	---	--	awaiting fund for rehabilitation
	6	120	75	
sub total		240	165	
Sapele	gt1	---	---	Tripped on shaft posi- Tion high 26/03/98
	2	75	60	
	3	---	--	Foreign exchange re- Quires to resume sus- Pended rehabilitation Since Nov.1991
	4	---	---	Foreign exchange re- Quired to replace dam- Aged generator trans- Former since 26/4/90
sub total		75	60	
Delta	gt1	---	---	Scrapped. 09/06/80
	2	---	---	Overdue for major overhaul 23/08/88
	3	---	---	Overdue for major overhaul 24/03/89
	4	---	---	Damaged no.2 bearing 12/02/87
	5	---	---	Vibration trouble 15/07/88
	6	---	---	Under rehabilitation.
	7	---	---	Inlet guide valve actuator problem 23/04/84. awaiting rehabilitation.
	8	---	---	Unable to exceed 22.25 speed 31/7/92 awaiting rehabilitation.
	9	---	---	Compressor blade failure 21/3/93. Awaiting rehabilitation.
	10	---	---	Tripped on overspeed.
	11	---	---	Awaiting rehabilitation 11/4/88
	12	---	---	Field ground problem.
	13	---	---	oil leakage from no.1

				bearing & control problem in house rehabilitation in progress
	14	---	---	rehabilitation awaiting 20/10/96
	15	---	---	damaged first stage compressor blade 01/8/96
	16	100	90	
	17	100	90	
	18	---	---	bearing problem, requires hot gas path inspection 10/01/94
	19	---	---	tripped on combustion trouble 25/4/98
	20	---	---	compressor blade failure 20/09/97
sub total		200	180	
Ijora	gt4	---	---	Awaiting recommissioning
	gt5	---	---	Generator breaker being cannibalised for gt4
	gt6	---	---	high vibration units, awaiting hot gas path inspection.
sub total		nil	nil	
Total		1395	1285	

The load duration curve from 1988-1996 are as shown in figures 4.1 – 4.9 below.

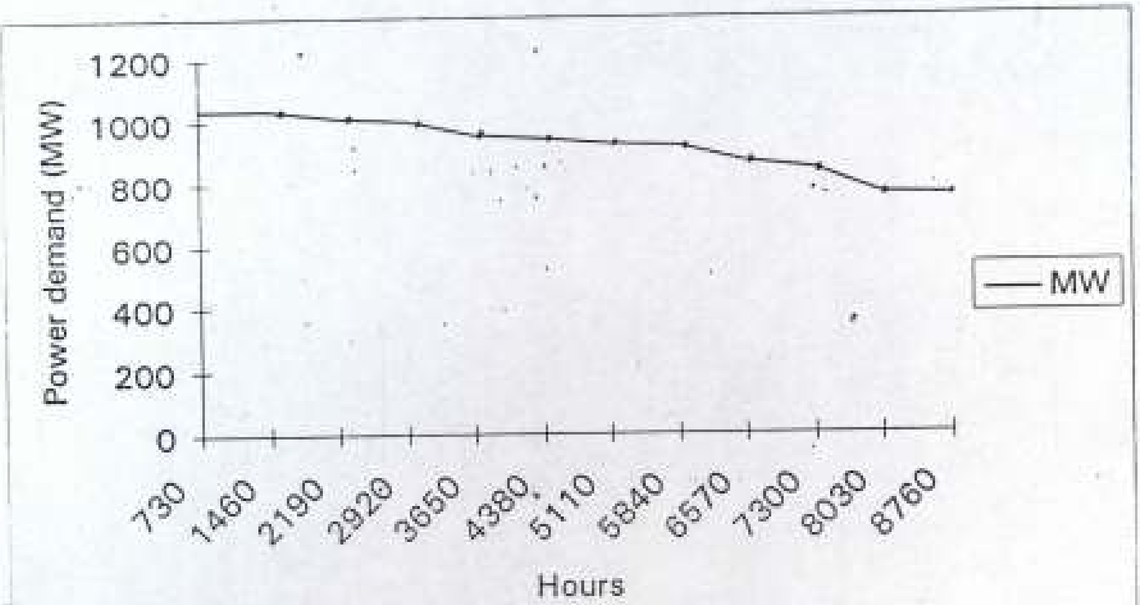

Fig. 4.1: 1988 Load duration curve

Load duration curve spread out linearly, bulk of the power generation is needed for base load.

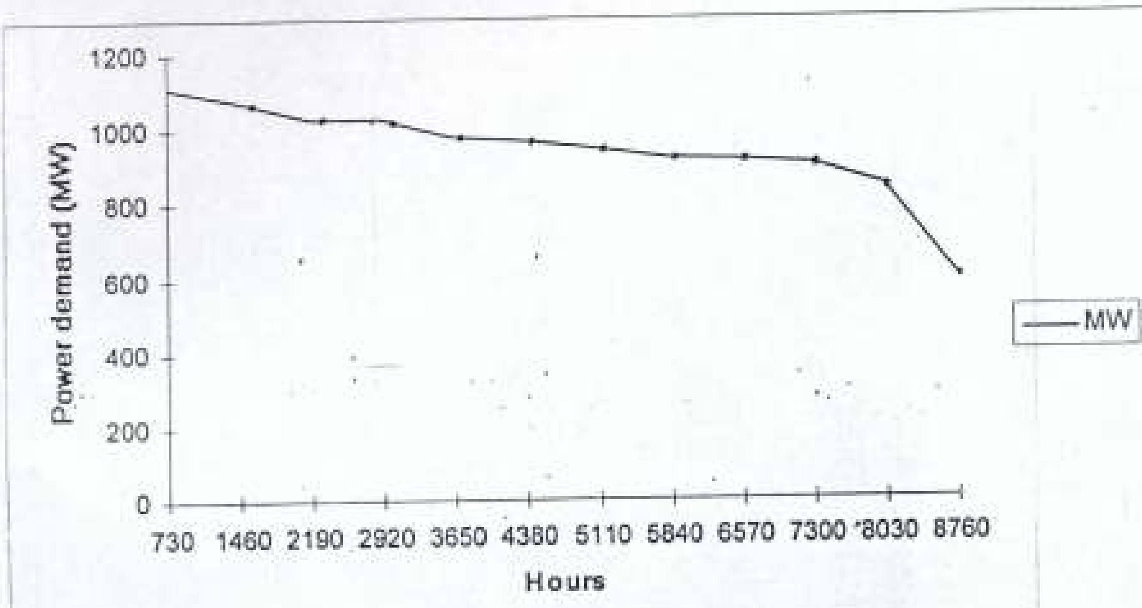

Fig. 4.2: 1989 Load duration curve

Curve drop down sharply at the tail end, more power is needed for intermediate load.

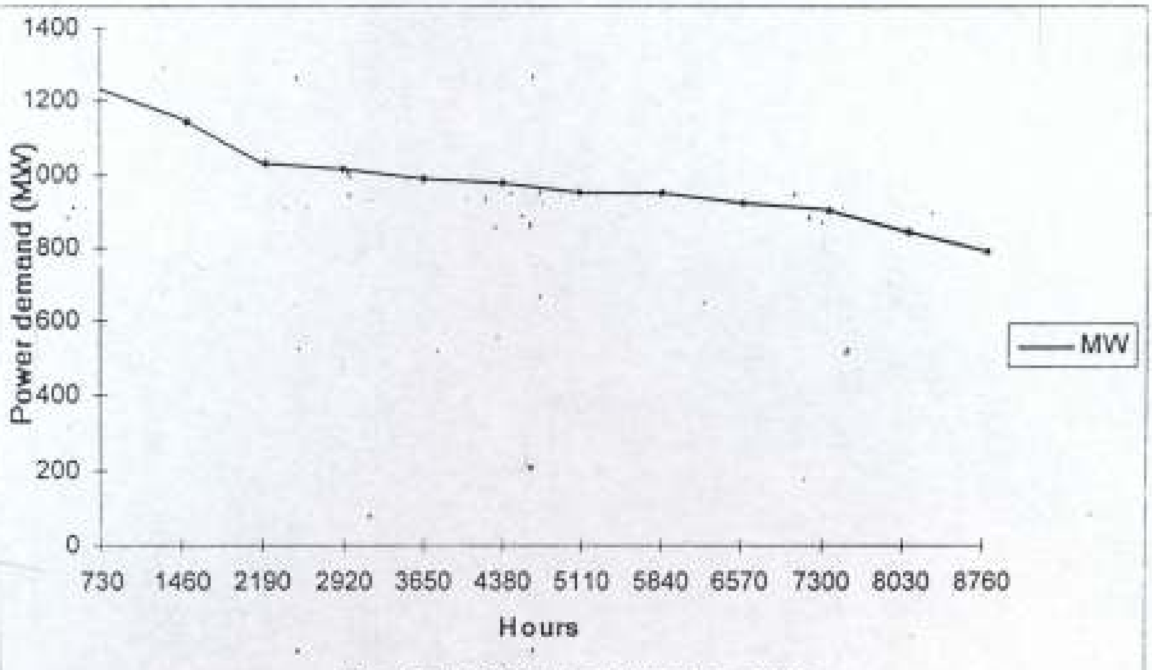

Fig. 4.3: 1990 Load duration curve

Curve drop sharply at the initial stage and later spread out linearly.

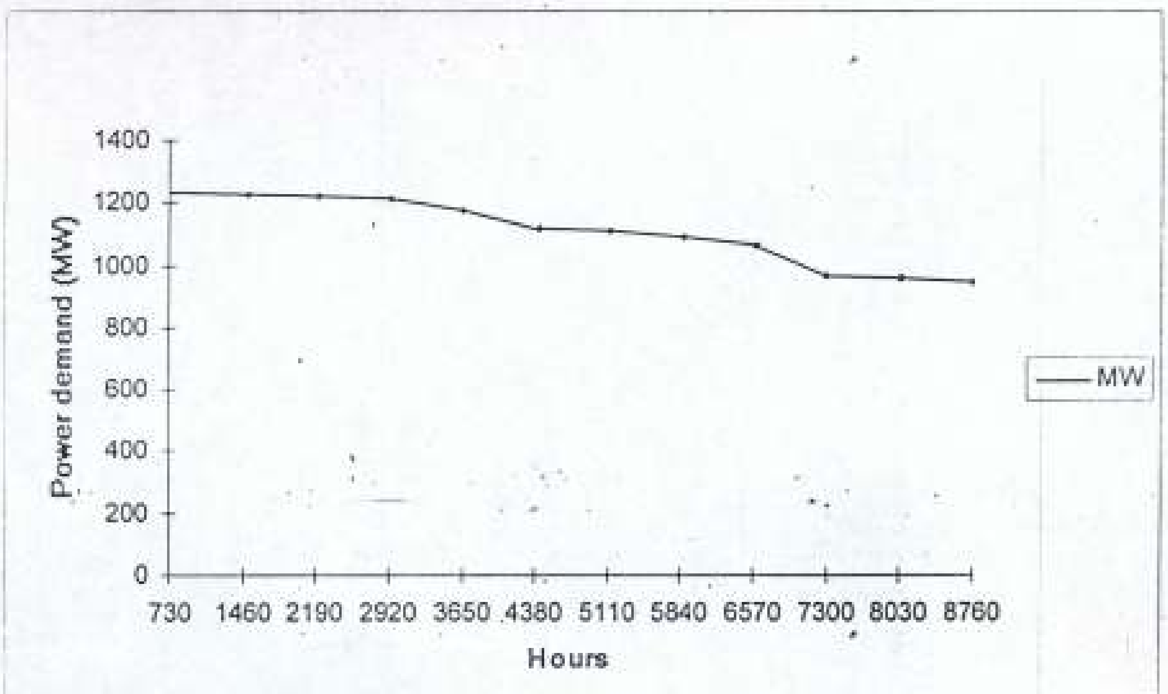

Fig. 4.4: 1991 Load duration curve

The peak load spread out linearly for a longer period.

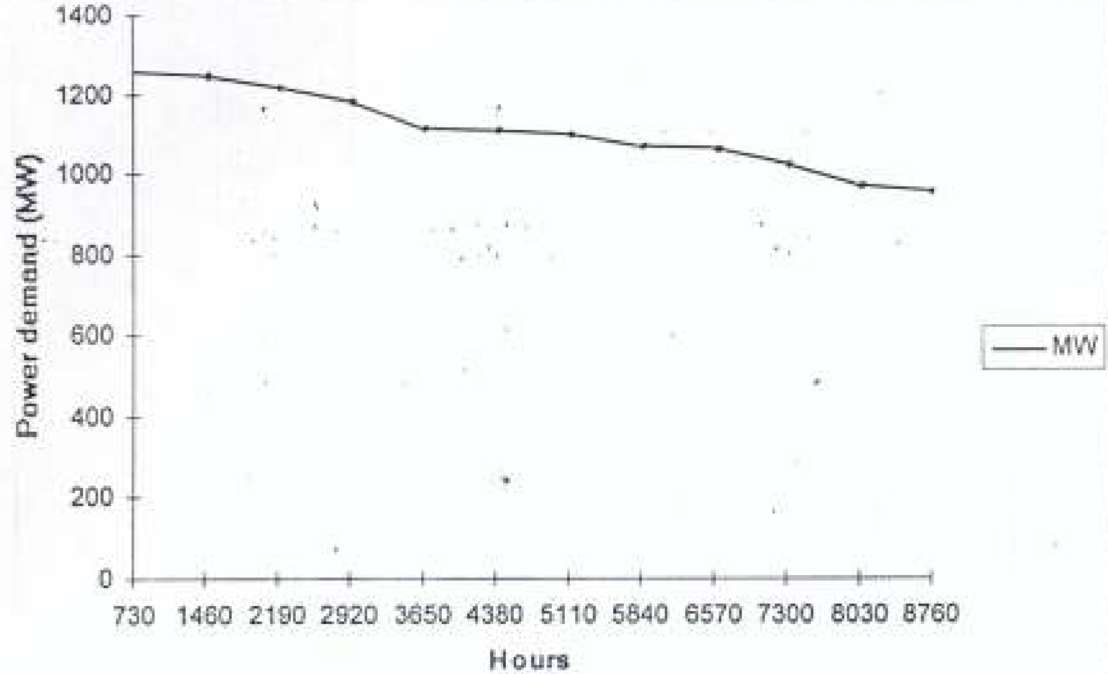

Fig. 4.5: 1992 Load duration curve

Peak load covered higher period, with intermediate load very low.

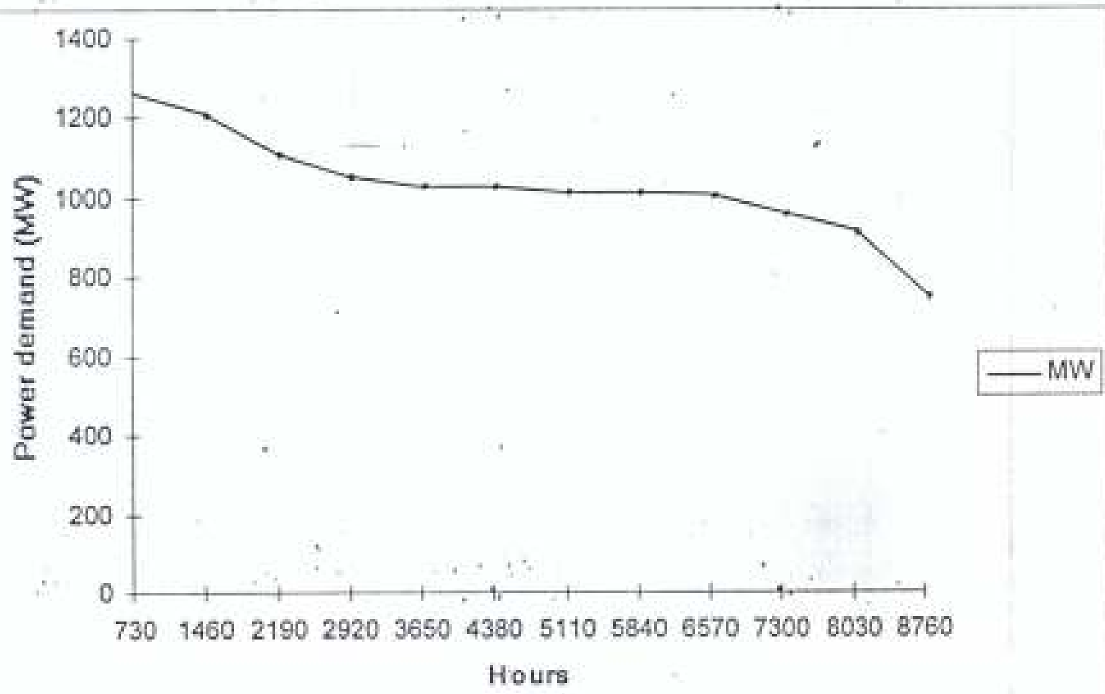

Fig. 4.6: 1993 Load duration curve

Peak load, intermediate and base load are clearly demarcated out

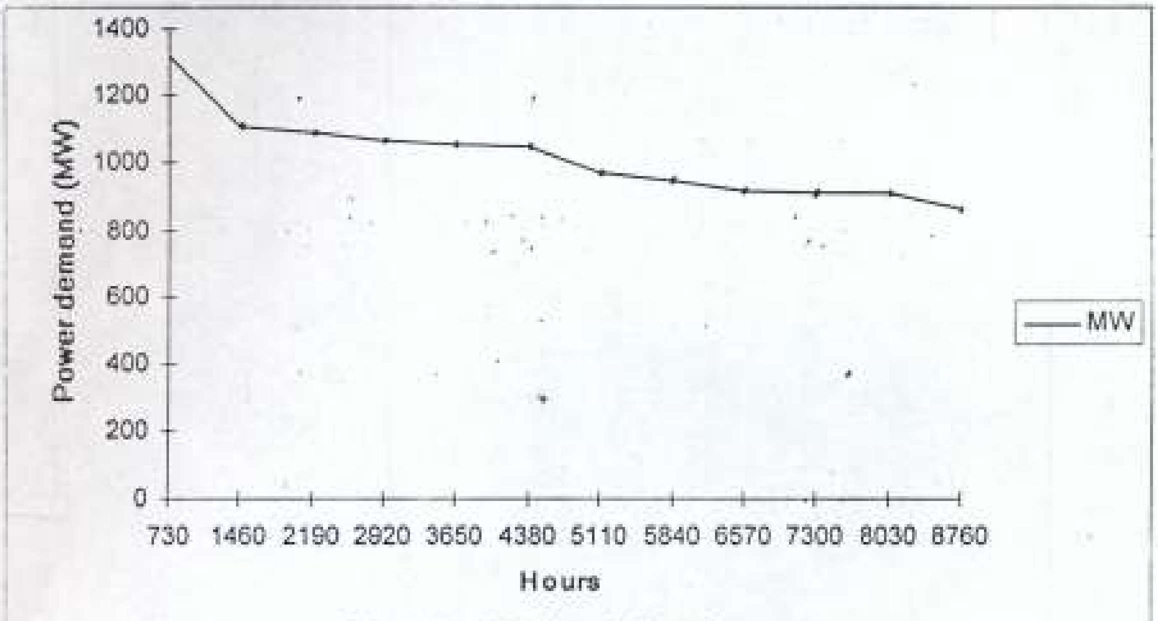

Fig. 4.7: 1994 Load duration curve

The peak load drop sharply, while the intermediate load is very low.

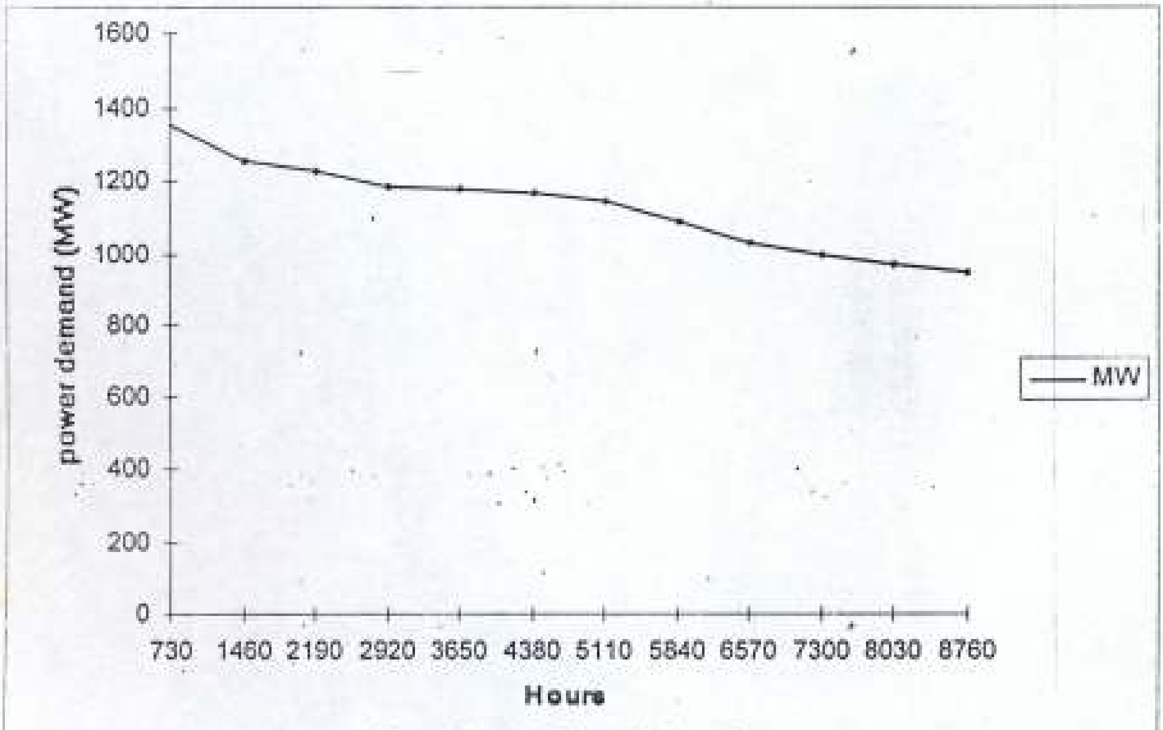

Fig. 4.8: 1995 Load duration curve

The curve progressively fall down linearly from the peak to the base load.

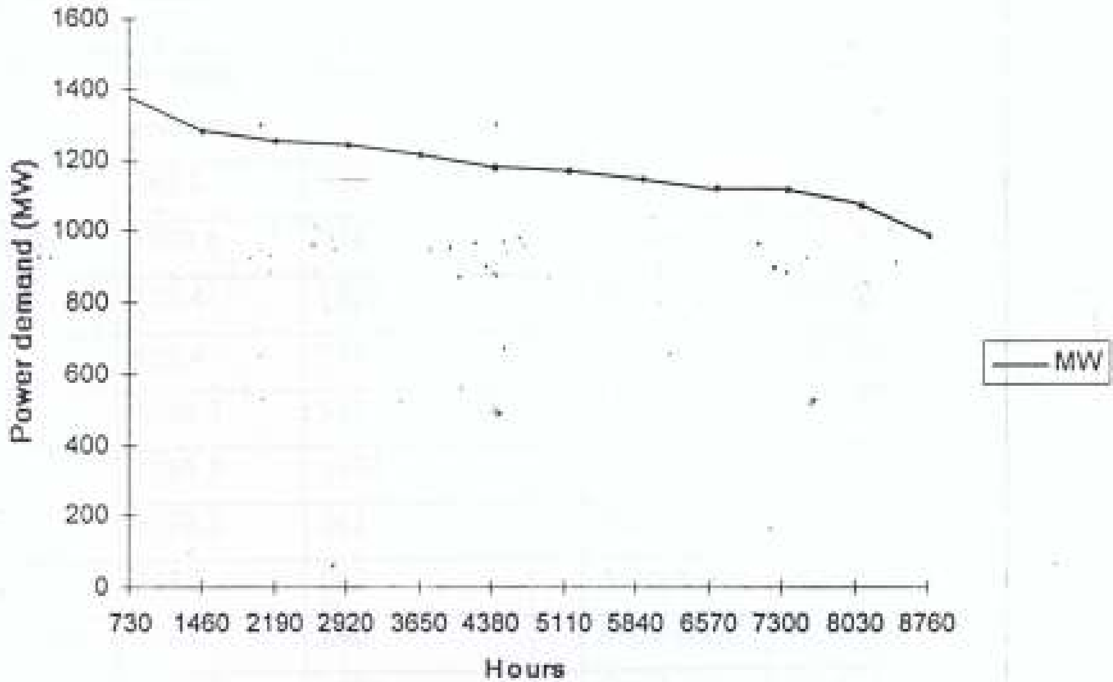

Fig. 4.9: 1996 Load duration curve

Base load is very high, with moderate intermediate and peak load.

Table 4.3: Comparing the available generation in South West with the peak demand from 1988-1996

1988				1989		
Month	Average generation	Peak Demand		Month	Average generation	Peak Demand
January	762.2	923		January	1234.33	917
February	1004.6	918		February	1323.15	943
March	728.4	1010		March	1415.03	842
April	859.4	751		April	1307.48	1109
May	1086.3	957		May	1258.42	968
June	1185.5	1034		June	1327.43	1025
July	1193.3	761		July	1311.64	1071
August	948.5	943		August	1374.9	602
September	826	840		September	1450.56	900
October	1144.8	1036		October	1214	974
November	1278.7	869		November	1284.07	1025
December	1261.3	999		December	1427.32	914
1990				1991		
January	1520.84	924		January	872.81	957
February	1154.25	1014		February	1104.32	1215
March	1150.65	952		March	1322.26	1230
April	978.21	907		April	1105.64	1092
May	851.48	1029		May	1298.9	1179
June	840.43	989		June	1088.53	1120
July	1278.54	1234		July	1350.07	1221
August	1306.61	1155		August	1090.78	1111
September	1172.47	796		September	1383.17	1066
October	1039.26	976		October	1371	1232
November	882.9	847		November	1386	948
December	1050.35	948		December	1398.83	967

1992				1993		
January	1385.32	1023		January	1102.91	1031
February	1339.76	1257		February	1067.5	1282
March	1531.19	1245		March	914.03	1008
April	1295.13	1067		April	880.49	965
May	1246.33	1115		May	1010.8	918
June	1306.61	1070		June	1128.61	754
July	1329.04	1183		July	1243.61	1211
August	1423.26	1220		August	1190.61	1016
September	1527.6	958		September	1115.23	1028
October	1428.15	1110		October	1195.4	1017
November	1385.5	971		November	1264.07	1056
December	1289.06	1097		December	1385.99	1112
1994				1995		
January	1290.67	910		January	1223.68	1178
February	1060.42	948		February	1229.36	1352
March	1009.01	860		March	1212.78	1256
April	1189.86	907		April	1268.83	1185
May	1188.08	971		May	1103.03	995
June	995.47	1086		June	1251.17	970
July	901.85	1318		July	1215.51	1228
August	412.75	1063		August	1263.12	1144
September	837.8	917		September	1105.23	948
October	962.3	1104		October	1078.32	1028
November	1106.57	1044		November	1228.43	1168
December	1166.83	1053		December	1195.48	1088
1996						
January	1390.29	1281				
February	1594.07	1081				
March	1425.13	1212				
April	1657.44	1252				

May	1490.62	1180				
June	1536.29	1376				
July	1539.97	1118				
August	1367.4	1168				
September	1405.47	1241				
October	1213.81	990				
November	1131.03	1119				
December	1266.93	1145				

From the available data, giving rooms for reserves, the present total installed capacity in the south west Nigeria which from table 1.2 equals 3317MW should normally be able to take care of the region effectively till year 2019 AD which according to forecast shall be about 2888.2MW so that 428.8 MW should be for reserves (in case of outages and maintenance).

But from the operational report it is vividly clear that some of the units in all the utilities are not operational due to lack of fund for rehabilitating them and some have been scrapped due to old age.

The total installed available capacity from the operational report is 1395MW while the actual machine capability is 1285MW, which can no longer cope with the peak demand of 1996 which was 1376MW. No wonder the epileptic supply of electricity at this period of time and the incessant load shedding problems.

65MW out of the 3317MW or 2.2% of installed capacity are over 30 years old 1397MW out of the 3317MW or 42.1% of total installed capacity are over 20 years old while 2817MW out of the 3317MW or 84.9% of total installed capacity are over 10 years old.

Now considering the long time required to construct a new power station, it is high time therefore for the authority in the South West to rise up to save the power system in this area from imminent acute power shortage.

Looking back at the period between 1966 and 1990, new power generating units had been commissioned at the average of one in every 3 years, but from 1990 up to date, no new generating unit has been commissioned. It is either that the power sector has been grossly neglected or vision for adequate power generation has been blurred. Priority must again be shifted toward construction of new generating station starting from this year; while fund must also be made available to rehabilitate the existing ones.

But in planning for new power stations, the question is how big, where and what kind?

From the forecast, by year 2020AD, the peak demand would have risen to about 2980.4MW, or approximately 3000MW. Making provision for reserves (maintenance and outages), there must be planning toward 3500MW. From the present total installed available capacity this gives a shortfall of 2105MW. Therefore, machinery must be put in motion in planning for additional 2105MW.

Now in locating new stations, we must consider the areas having mineral fuels as well as water for condensing unit. Therefore, Edo, Ondo and Kogi states would be the most appropriate as given in table 4.1.

In determining the type, hydrostation would not be suggested in this report, due to the fact that no detail investigation was carried out concerning the rivers in the South West. Thermal power station using coal and gas/oil would be the most appropriate since these are readily available in the south west. Nuclear power station would not fit in because of lack of the nuclear fuel in the South West, as well as for safety consideration in the handling the technicalities involved..

In order to minimize the cost of transportation of fuels, 480MW plant consisting of 80MW unit each using coal should be constructed at Kogi State while 880MW plant made up of 220MW unit each using gas/oil should be constructed at Edo and Ondo state respectively.

The mode of transportation of this fuel will be through pipe in case of oil/gas and lorry/train in case of coal.

lorry/train in case of coal.

Because of the large amount of money that will be required by the authority in the south west to meet this task, the construction must be in phases, so that by year 2020 AD, the south west would be self sufficient of adequate power generation and the consumers demands would be effectively satisfied.

The newly constructed power station should serve the base load, while the old rehabilitated steam power stations should be used for intermediate load, and gas turbine plant should be reserved fot peak load periods.

4.1 CONFIDENCE INTERVAL

A 95% confidence interval for the forecasted peak demand by the year 2020 AD is found to be equal to (2980.4 ± 43.096)MW. Thus, we can be 95% confident that the peak demand by the year 2020 AD is between 3023.496MW and 2937.304 MW. Any variation from these, however, must be as a result of peculiar local factors such as illegal tapping, vandalisation of facilities and the loadsheding problem which makes it practically impossible to know the true peak demand of the consumers.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This research work clearly revealed to the public that the power generation in the South West Nigeria is far below the consumer's demand. And at this period of democracy in the country in which more investment from both local and foreign (individuals/organisations) are being envisaged, more industries will be established in various parts of the South West Nigeria. Coupled with this, is the planned increase in the salary of workers, which will invariably increase the purchasing power of the people. Many industries that have been operating below their full capacity (due to low purchasing power of the people) will be revived again. All these factors coupled with deregulation process will eventually lead to increase in power demand by the people (since the demand for electricity is closely tied to the gross national product).

In order for the dream of the people of having adequate and sufficient power supply be met, proper attention should be placed on the power sector in the South West Nigeria. Funds should be made available by the authority in South West Nigeria to rehabilitate all the existing units in the utilities of this area; apart from this, new generating stations should be constructed in Ondo, Edo and Kogi States where we have mineral fuels and water in abundance to minimise the cost of transportation.

5.2 RECOMMENDATION

In order to improve the South West power system as well as saving it from epileptic supply pattern, the following recommendations are made to the authority of the South West Nigeria; which if they are carried out, it will go a long way to ensure sufficient and adequate power supply by the year 2020 AD and even beyond.

1. Efforts should be made now to construct more power stations of about (2105MW) to compliment existing ones.
2. Funds should be made available to replace all old units in the power stations.
3. Private sector participating in the generation of electricity, (similar to the one being proposed by Lagos, Ekiti and Ondo States governors) should be encouraged.
4. Radial distribution system should be replaced with ring type to ensure reliability of supply.
5. Old transformers should be upgraded or replaced with new ones.
6. Power system in the South West should be computerised so that, new information available on computer technology can be incorporated into the power system for metering, measurement of data, processing data and overall supervision of the transmission and distribution system.

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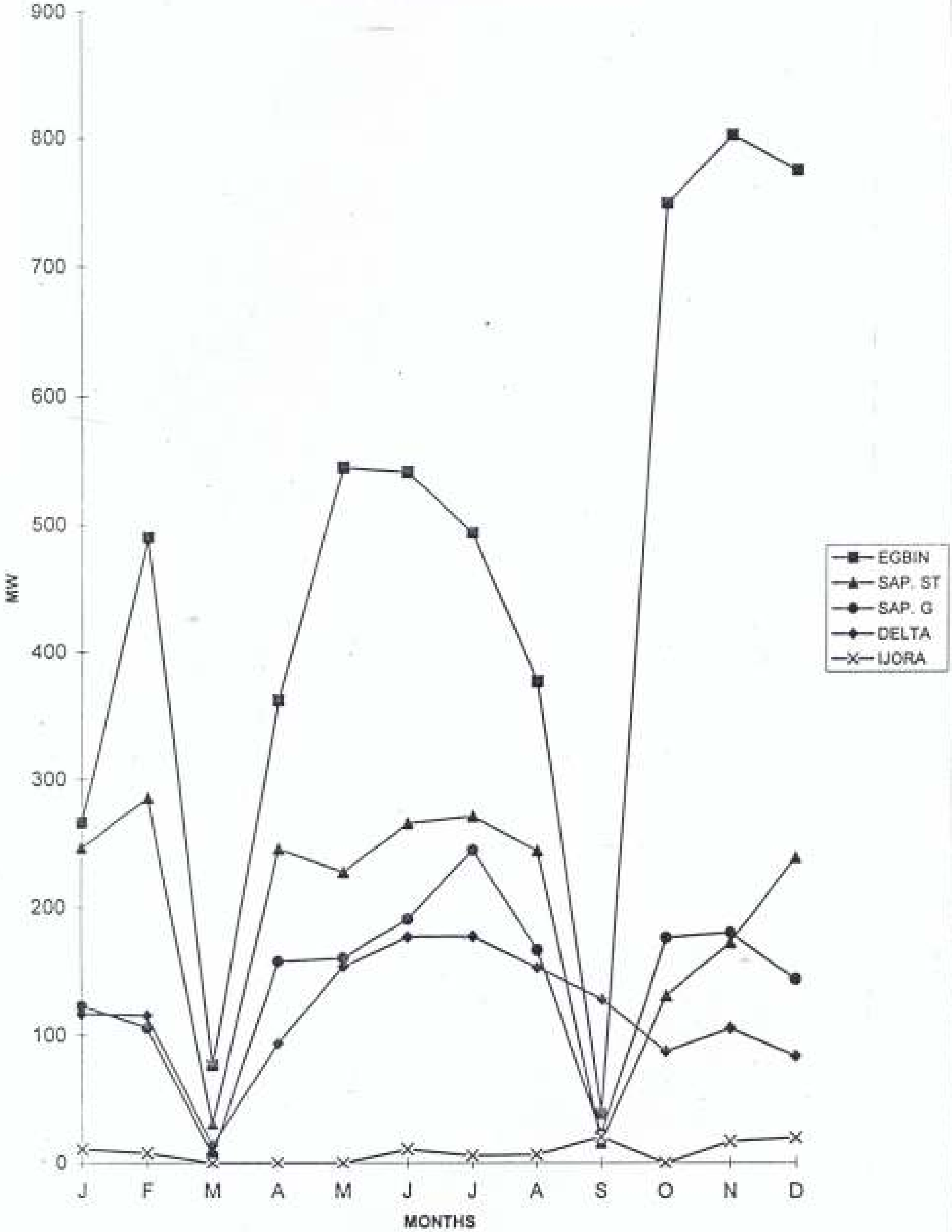
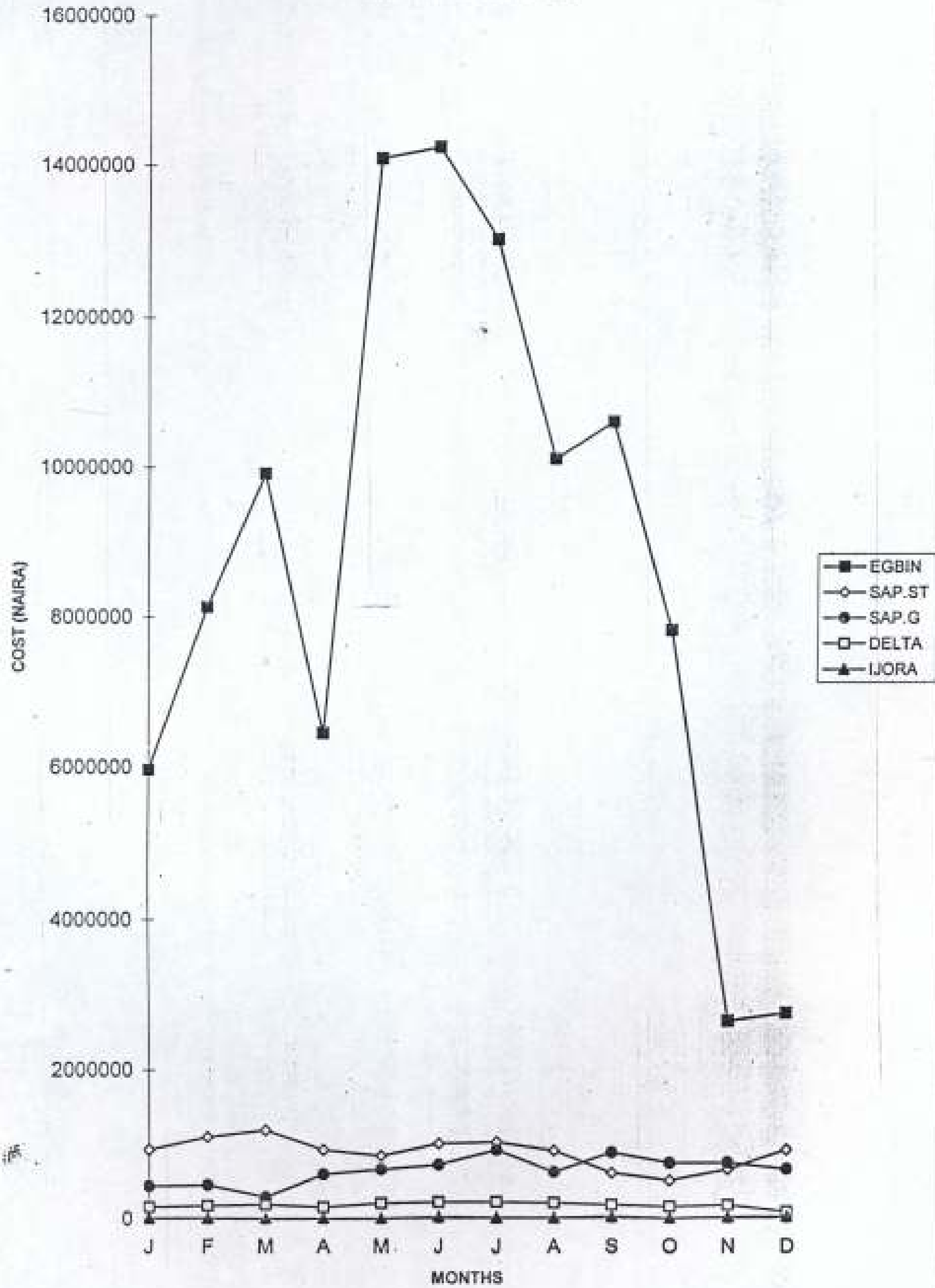
APPENDIX A1

1988 AVERAGE MONTHLY MW AVAILABILITY



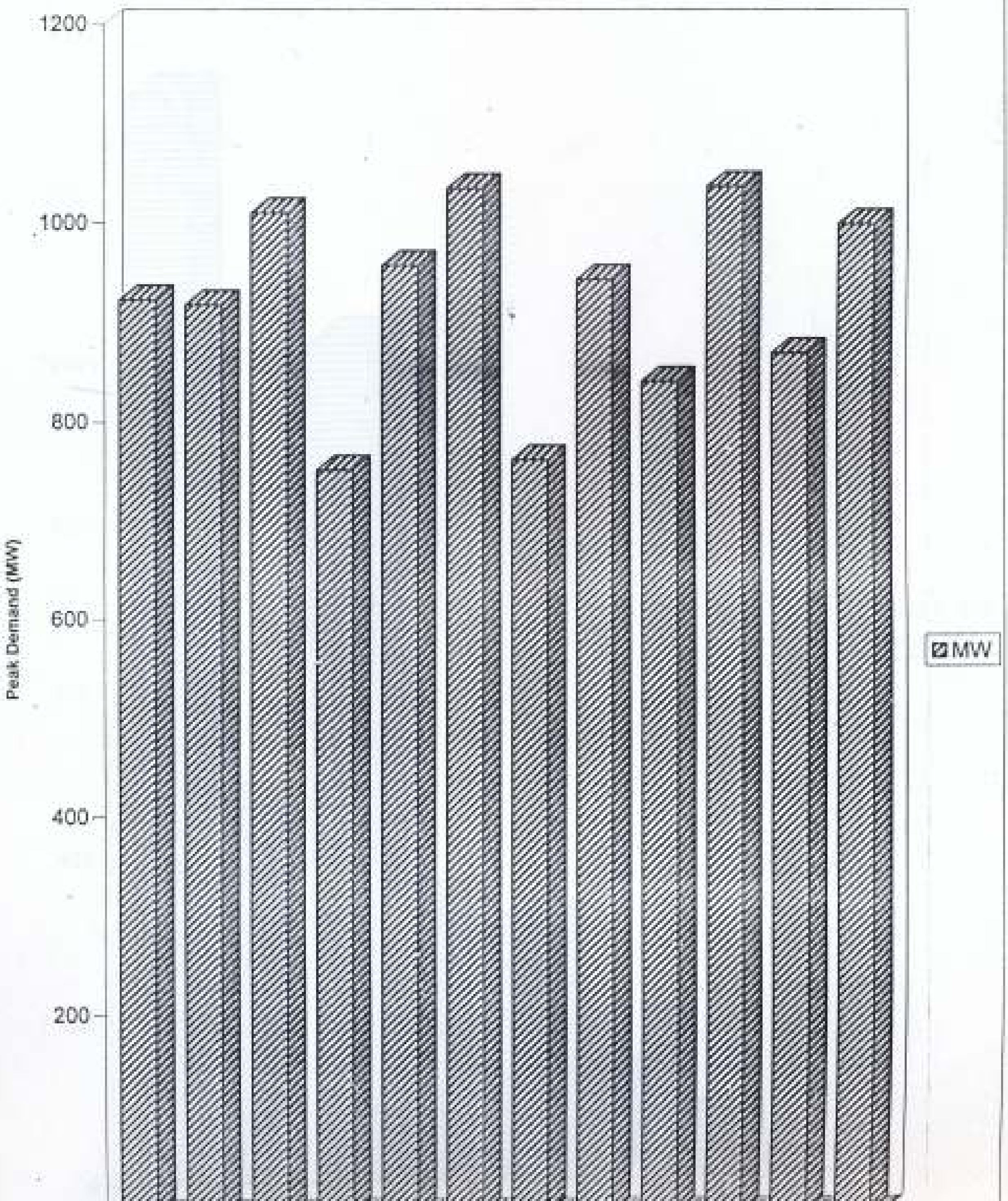
APPENDIX A2:

1988 THERMAL FUEL COST



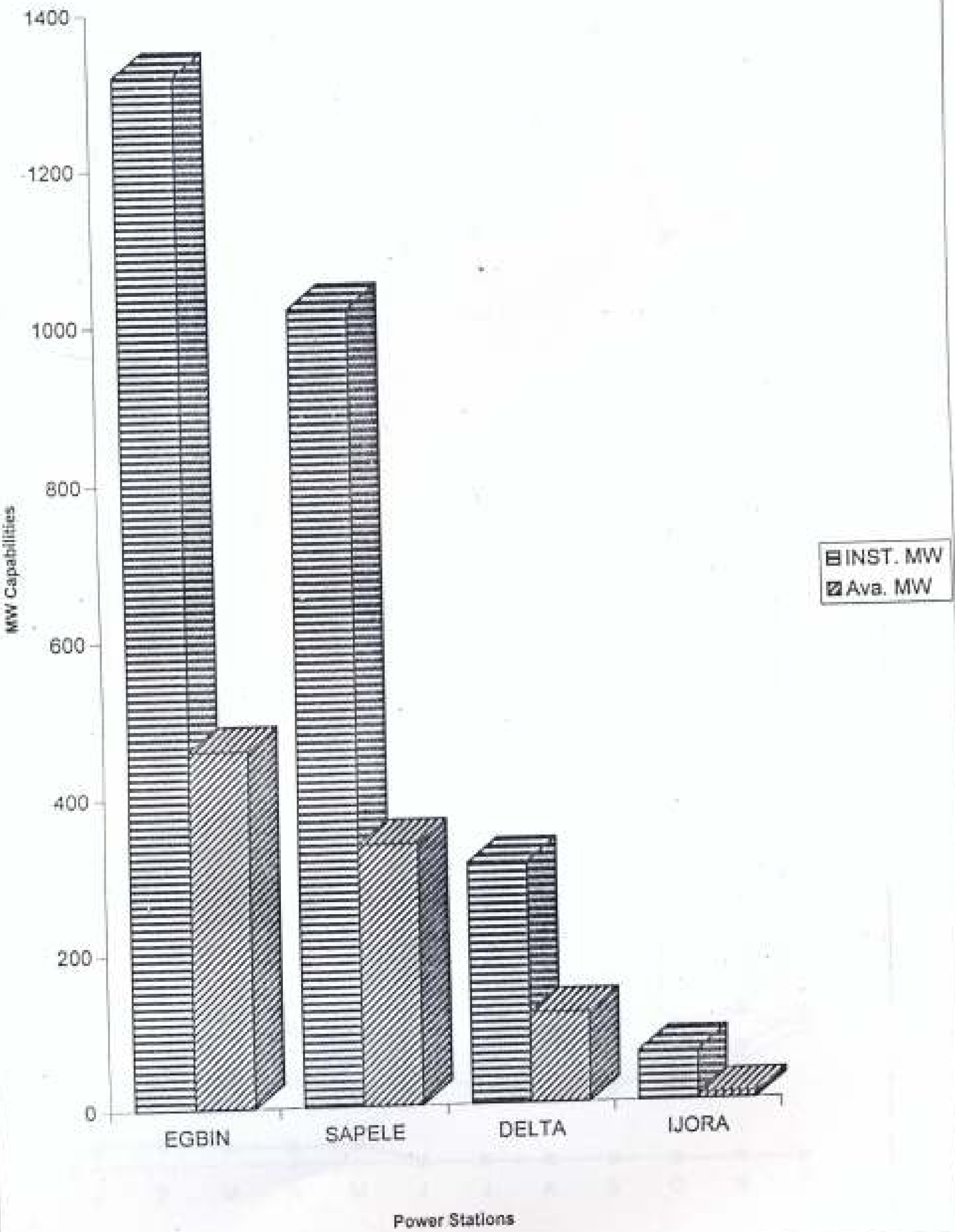
APPENDIX A3

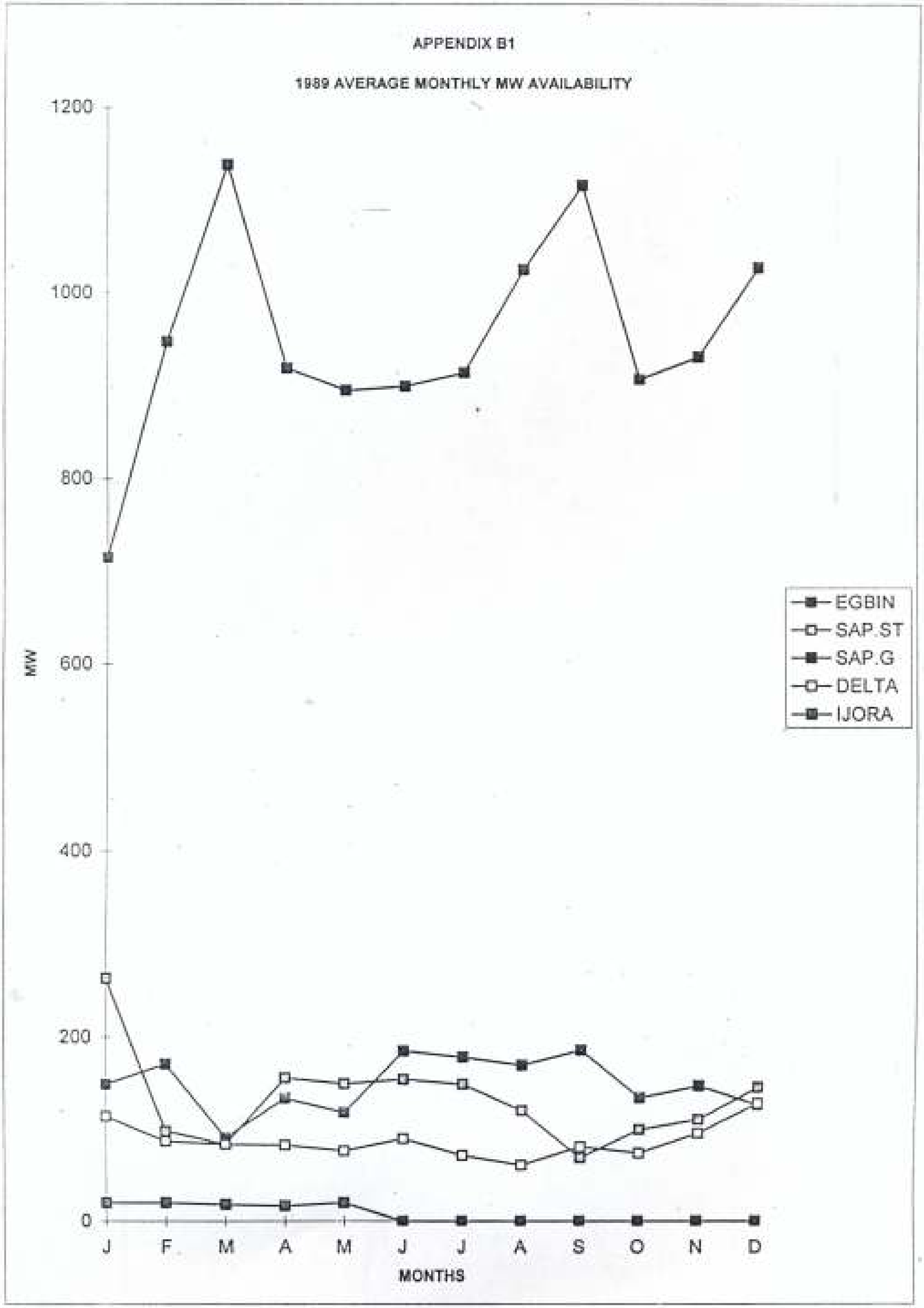
1988 Region Monthly Peak Demand (MW)

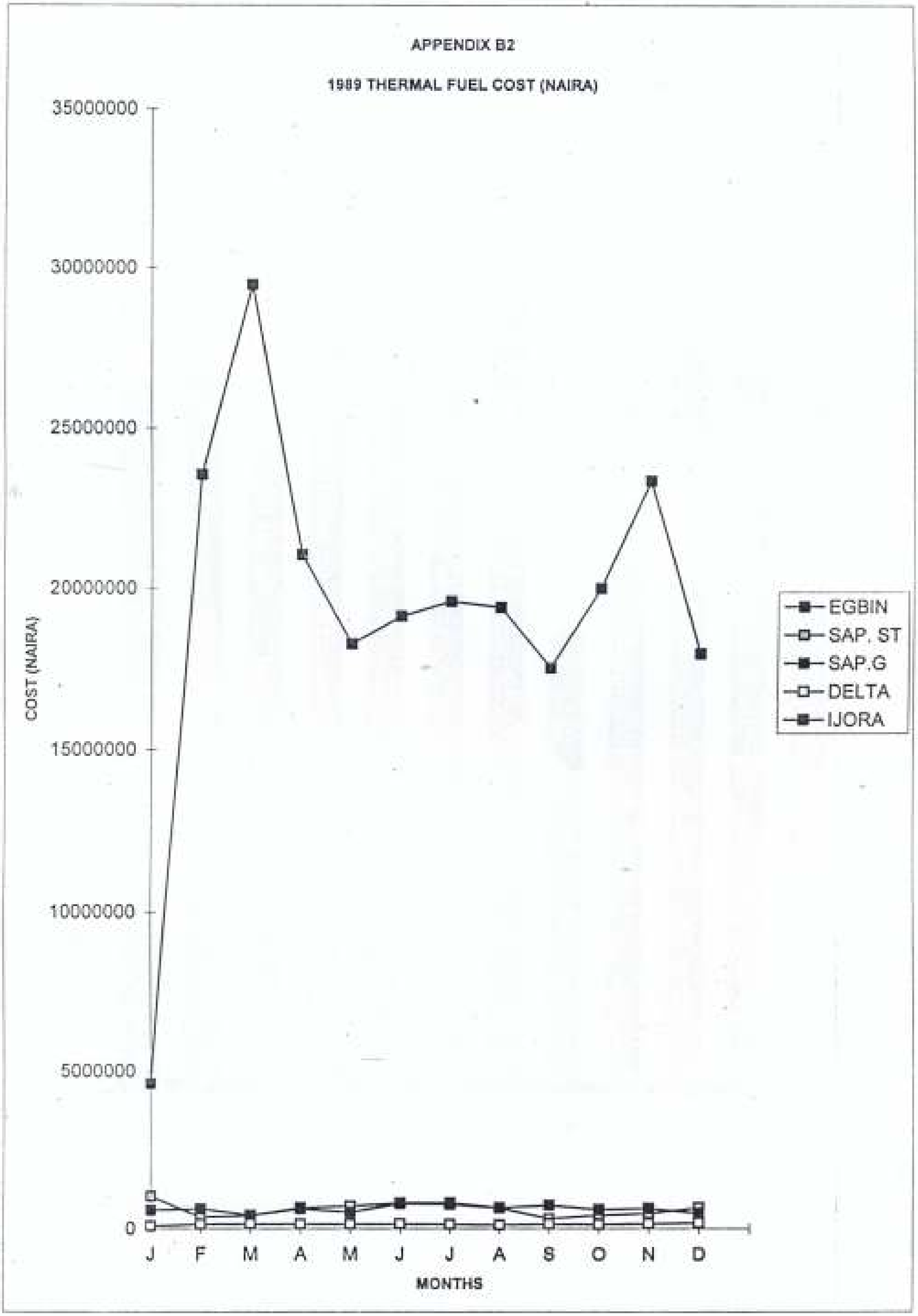


APPENDIX A4

1988 Generation Capabilities of NEPA Power Stations

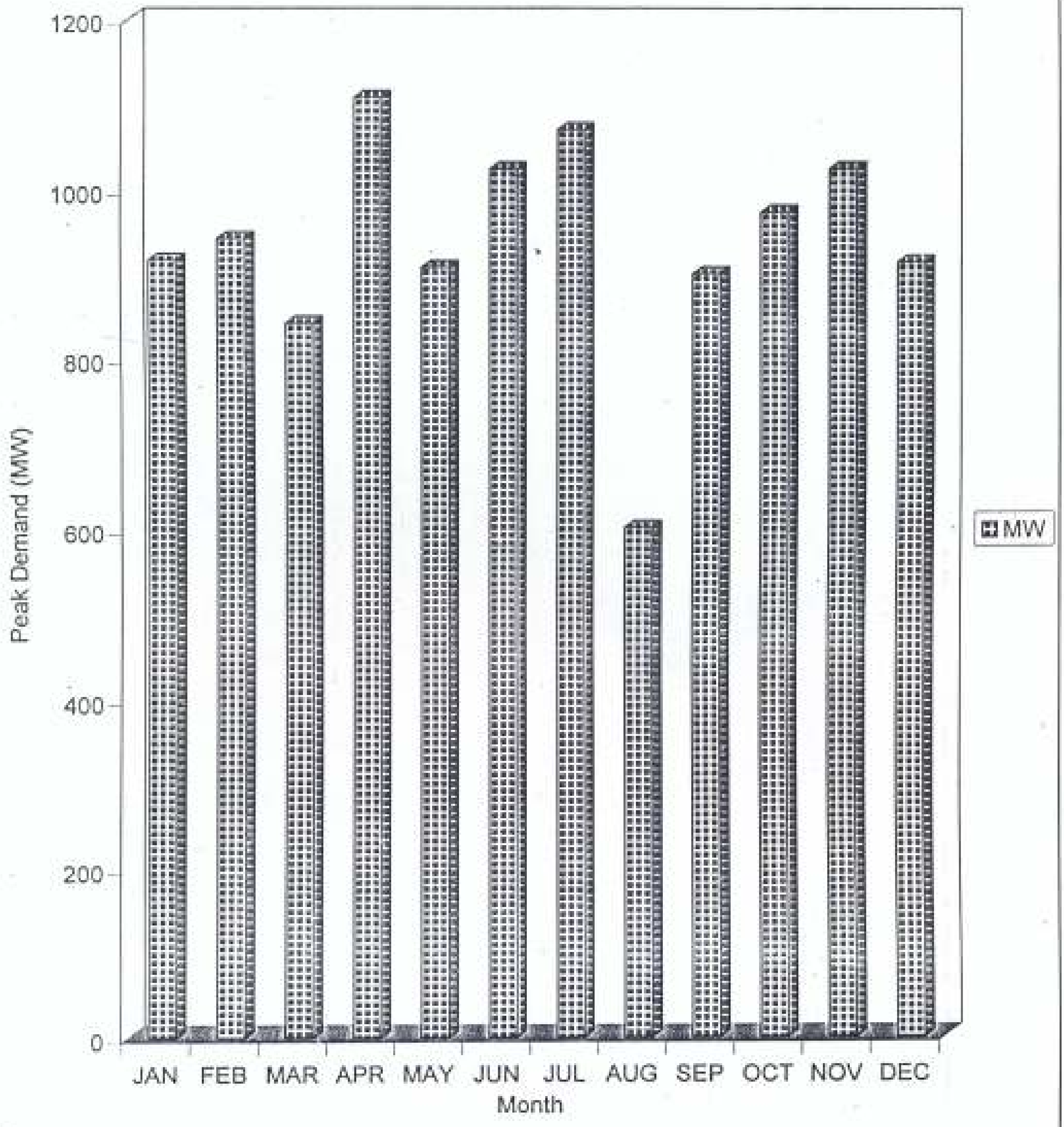



APPENDIX B1
1989 AVERAGE MONTHLY MW AVAILABILITY
1200
1000
800
600
400
200
0
MW
J
F
M
A
M
J
J
A
S
O
N
D
MONTHS
EGBIN
SAP.ST
SAP.G
DELTA
IJORA


APPENDIX B2
1989 THERMAL FUEL COST (NAIRA)
35000000
30000000
25000000
20000000
15000000
10000000
5000000
0
COST (NAIRA)
J
F
M
A
M
J
J
A
S
O
N
D
MONTHS
EGBIN
SAP. ST
SAP.G
DELTA
IJORA

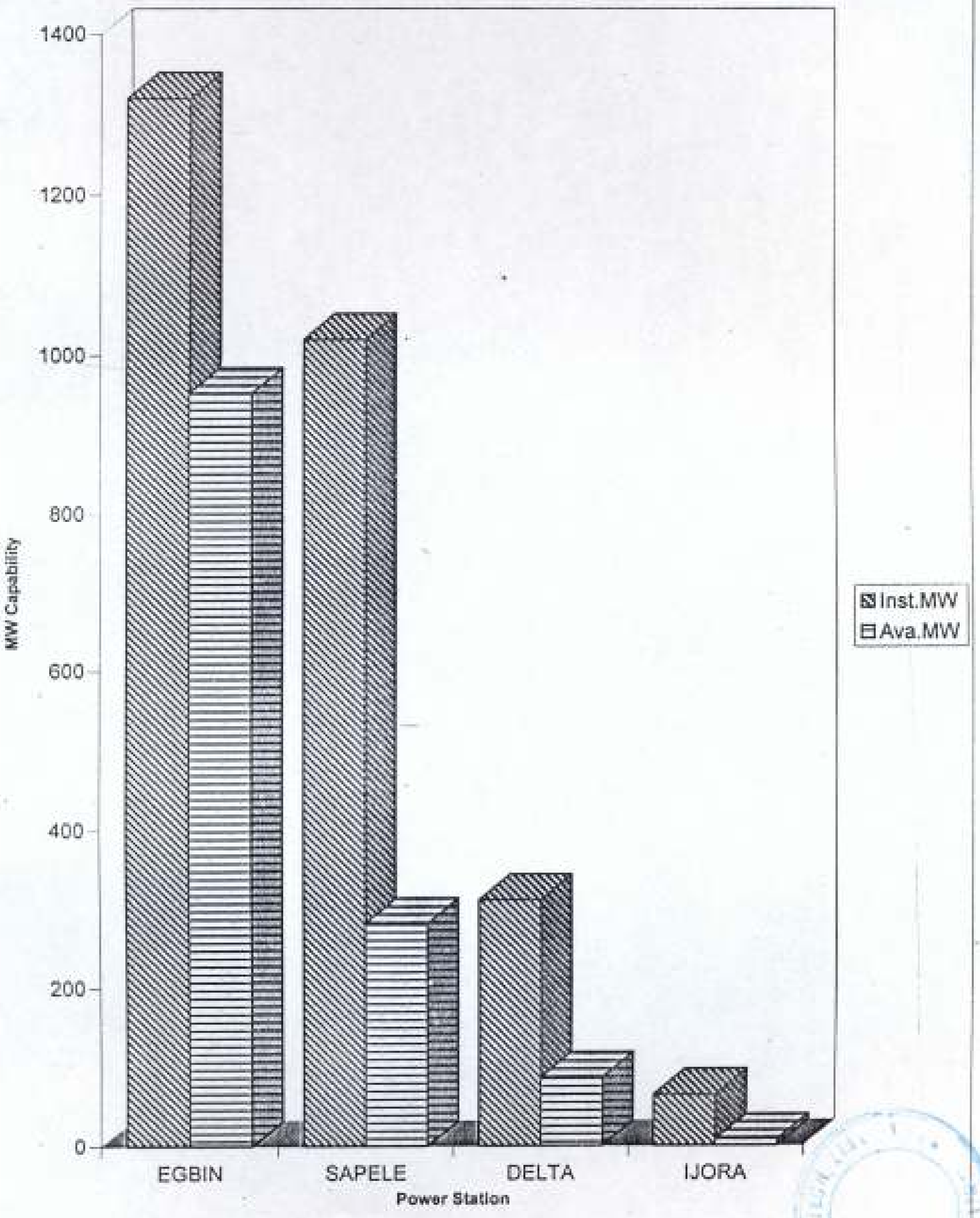
APPENDIX B3

1989 South West Monthly Peak Demand (MW)

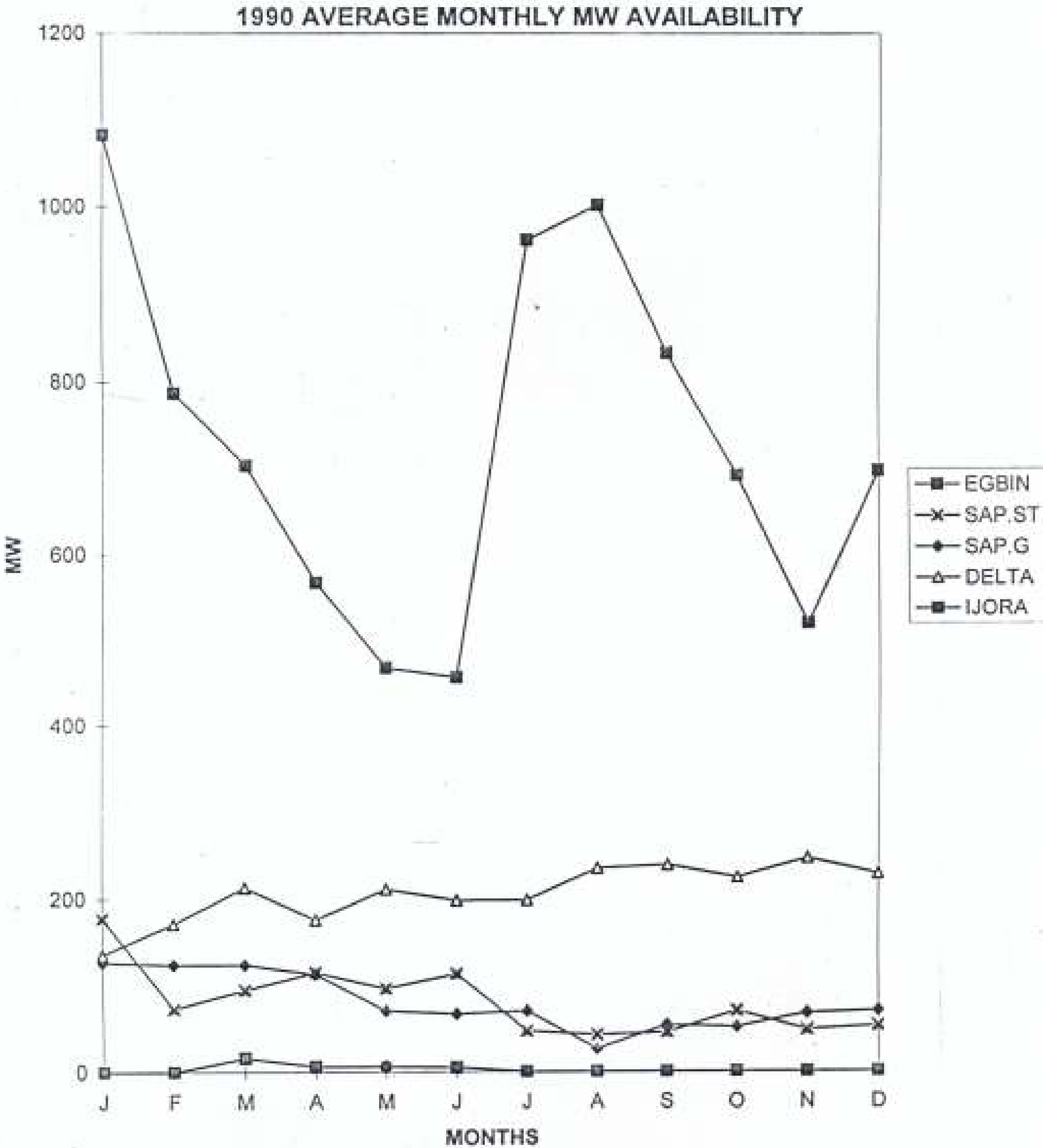


APPENDIX B4

1989 Generation Capabilities of NEPA Power Station

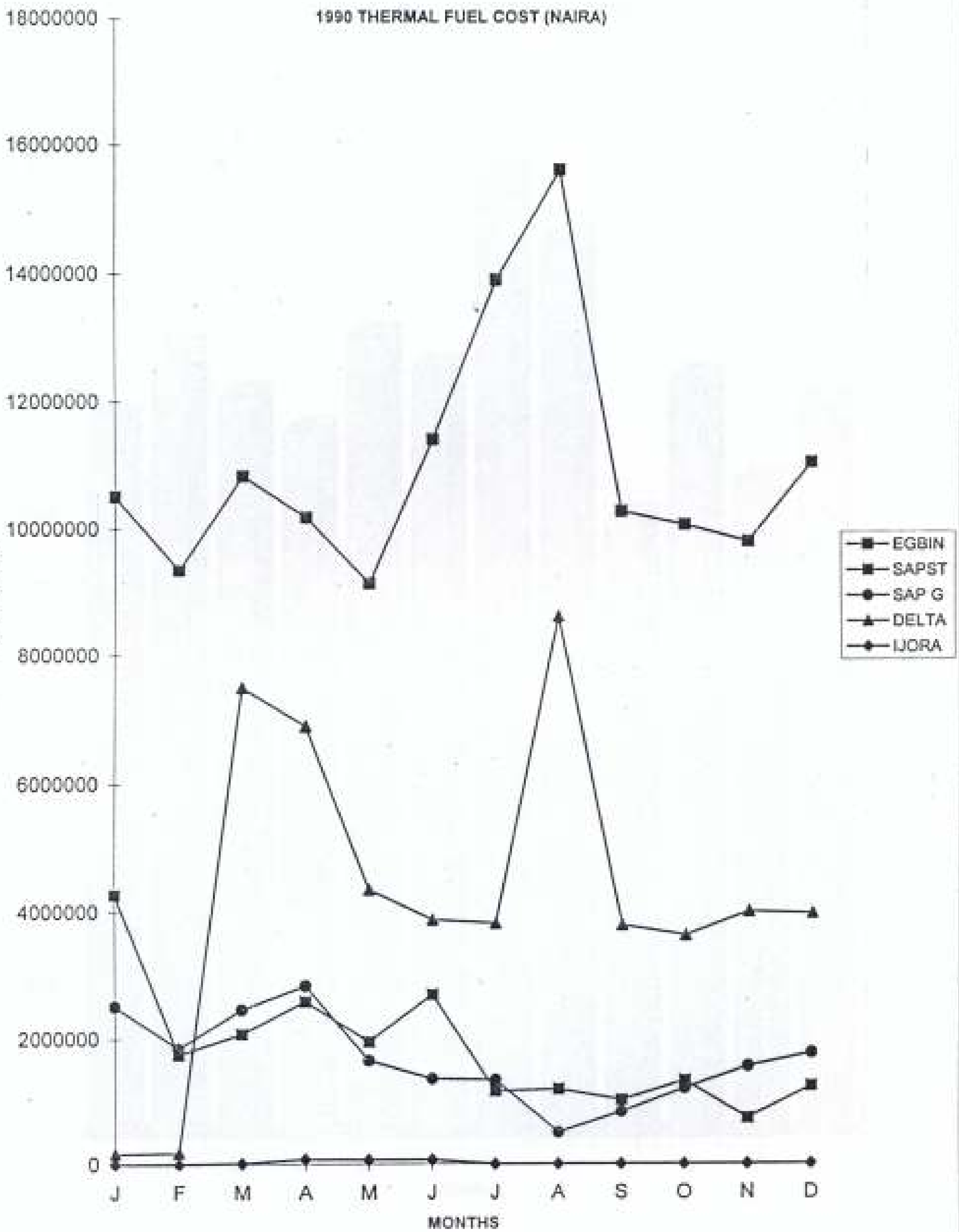


APPEDIX C1



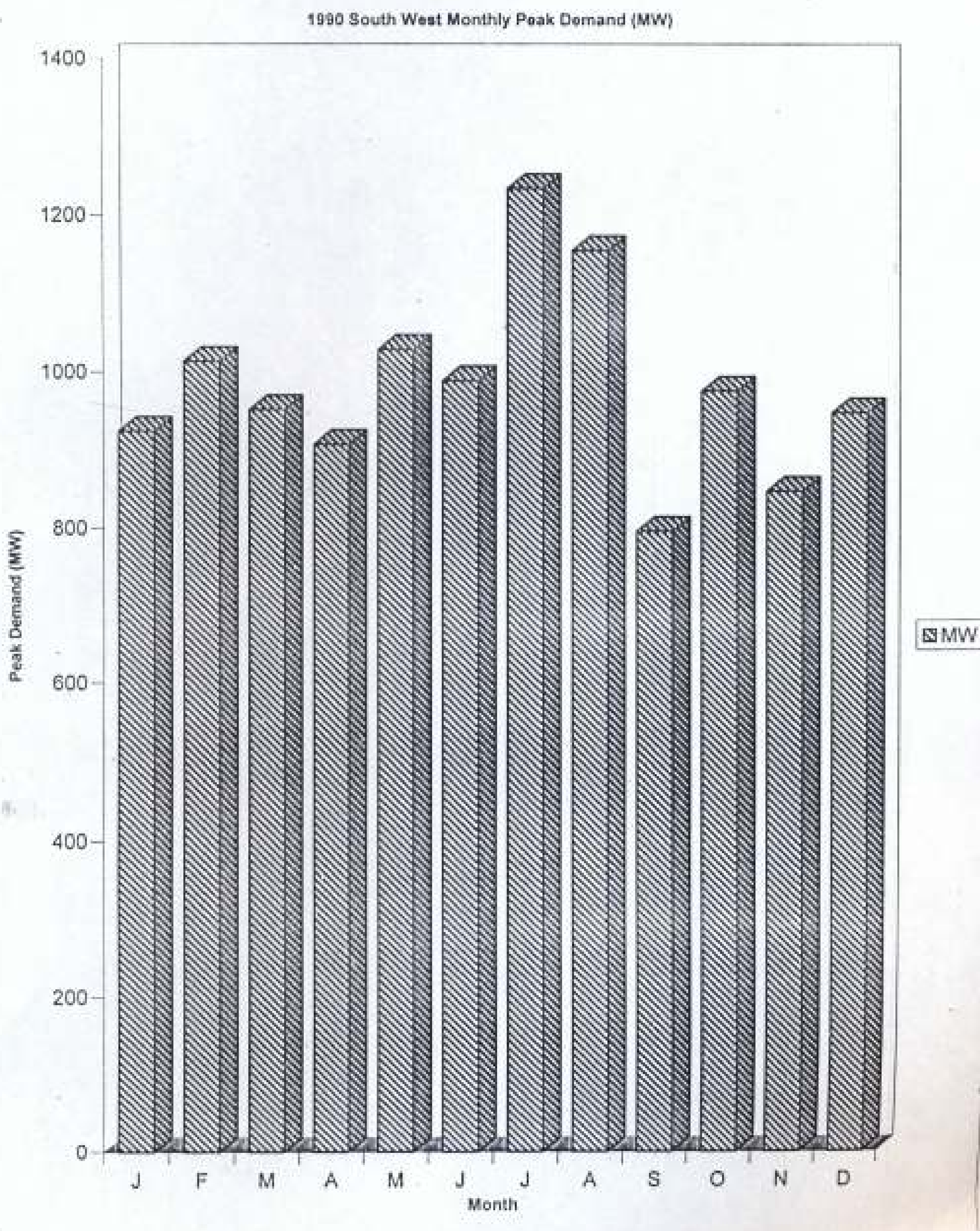
1990 AVERAGE MONTHLY MW AVAILABILITY
1200
1000
800
600
400
200
0
MW
J
F
M
A
M
J
J
A
S
O
N
D
MONTHS
EGBIN
SAP.ST
SAP.G
DELTA
IJORA

APPENDIX C2

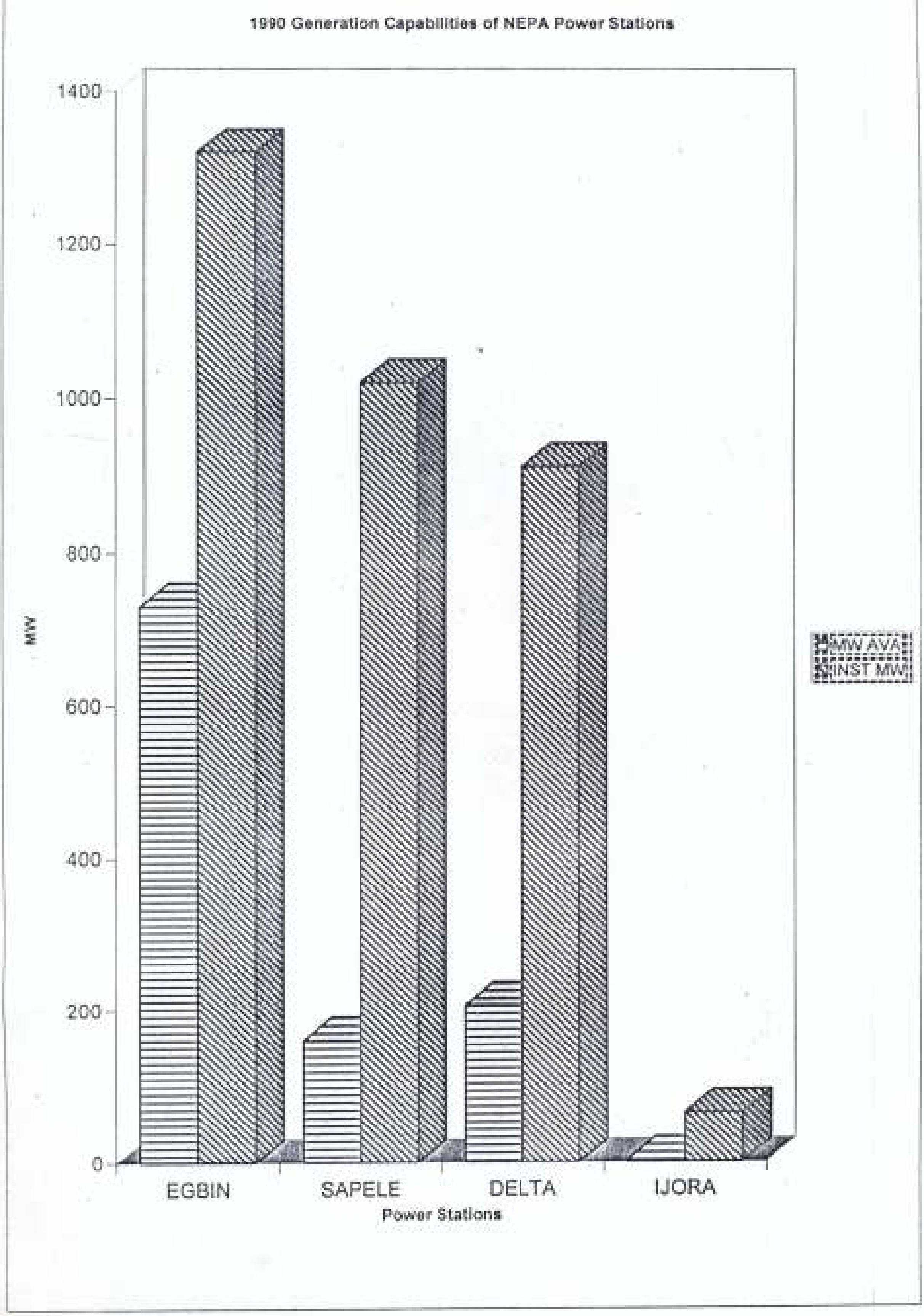


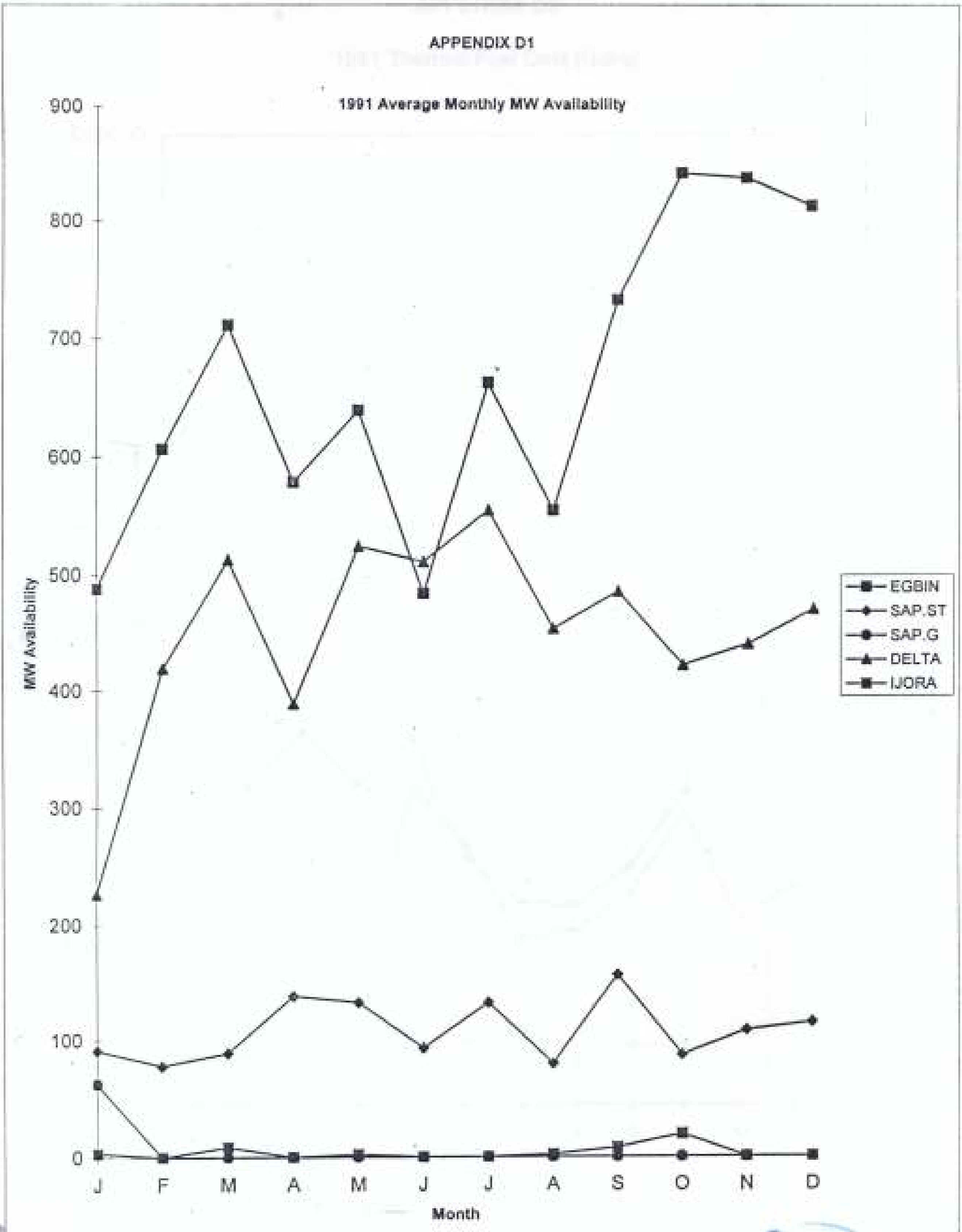
1990 THERMAL FUEL COST (NAIRA)
18000000
16000000
14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
COST (NAIRA)
J
F
M
A
M
J
J
A
S
O
N
D
MONTHS
EGBIN
SAPST
SAP G
DELTA
IJORA

APPENDIX C3

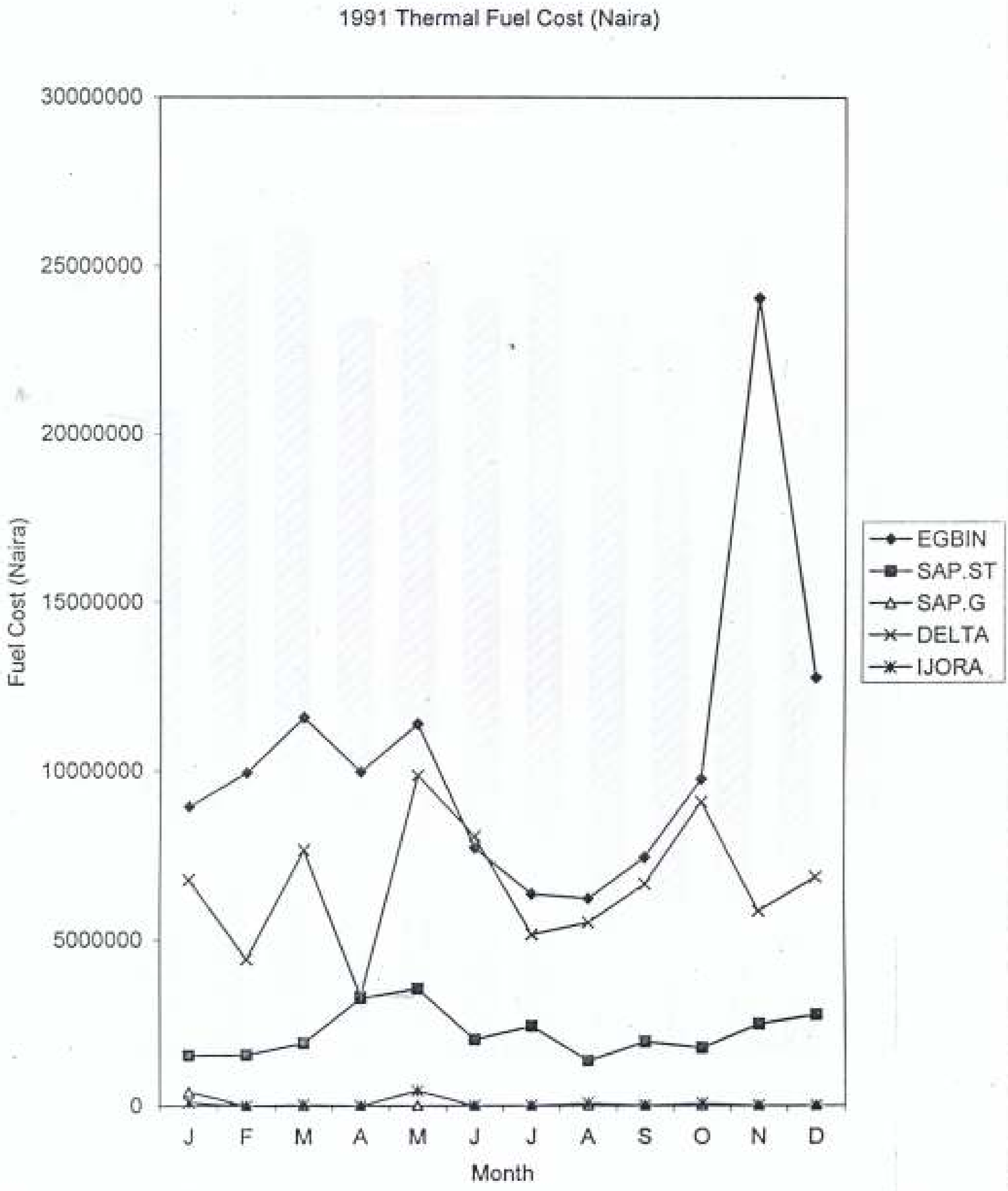

1990 South West Monthly Peak Demand (MW)
1400
1200
1000
800
600
400
200
0
Peak Demand (MW)
J
F
M
A
M
J
J
A
S
O
N
D
Month
MW

APPENDIX C4


1990 Generation Capabilities of NEPA Power Stations
1400
1200
1000
800
600
400
200
0
MW
EGBIN
SAPELE
DELTA
IJORA
Power Stations
MW AVA
INST MW

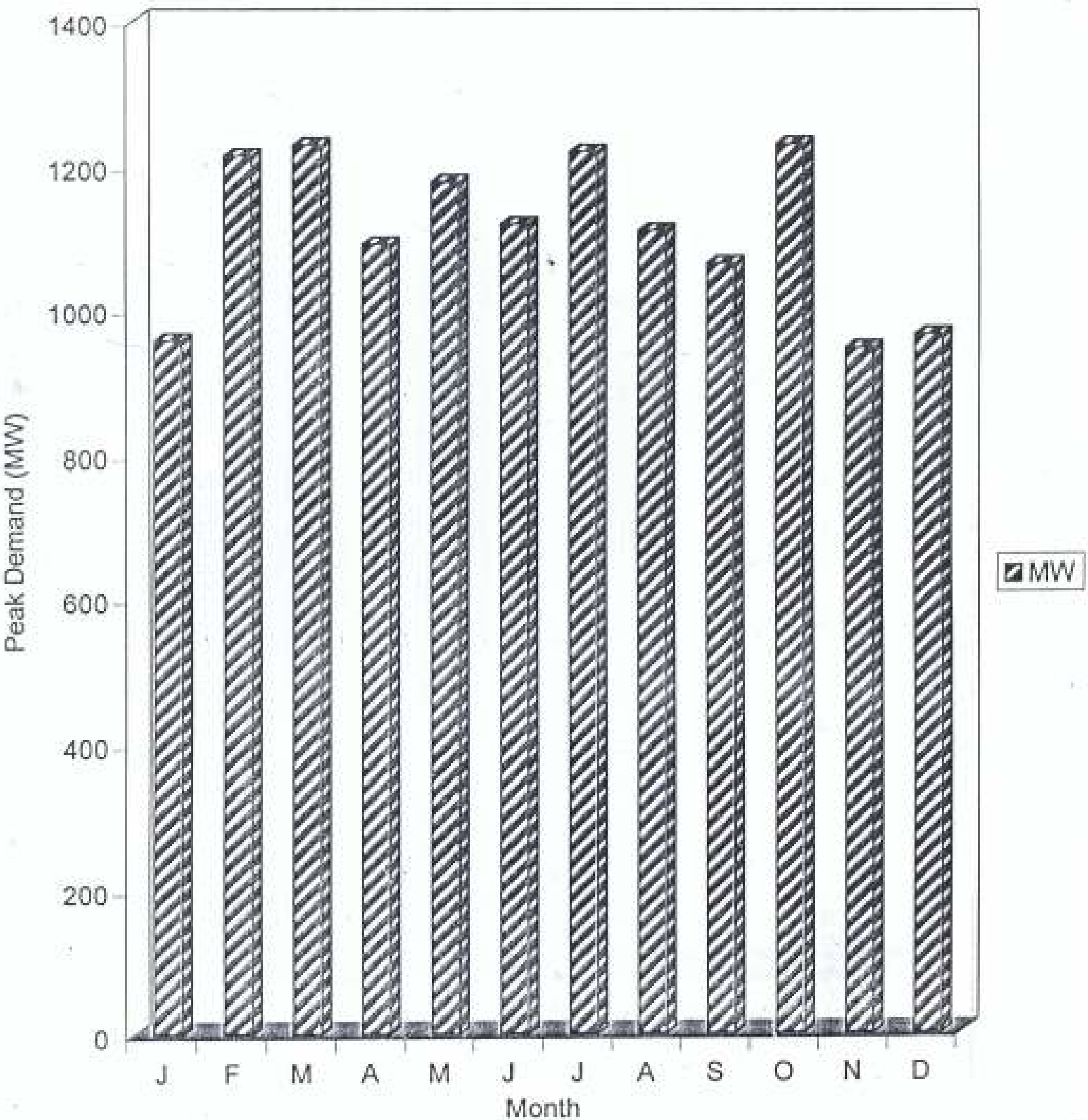

APPENDIX D1
1991 Average Monthly MW Availability
900
800
700
600
500
400
300
200
100
0
MW Availability
J
F
M
A
M
J
J
A
S
O
N
D
Month
EGBIN
SAP.ST
SAP.G
DELTA
IJORA

APPENDIX D2


1991 Thermal Fuel Cost (Naira)
30000000
25000000
20000000
15000000
10000000
5000000
0
Fuel Cost (Naira)
J
F
M
A
M
J
J
A
S
O
N
D
Month
EGBIN
SAP.ST
SAP.G
DELTA
IJORA

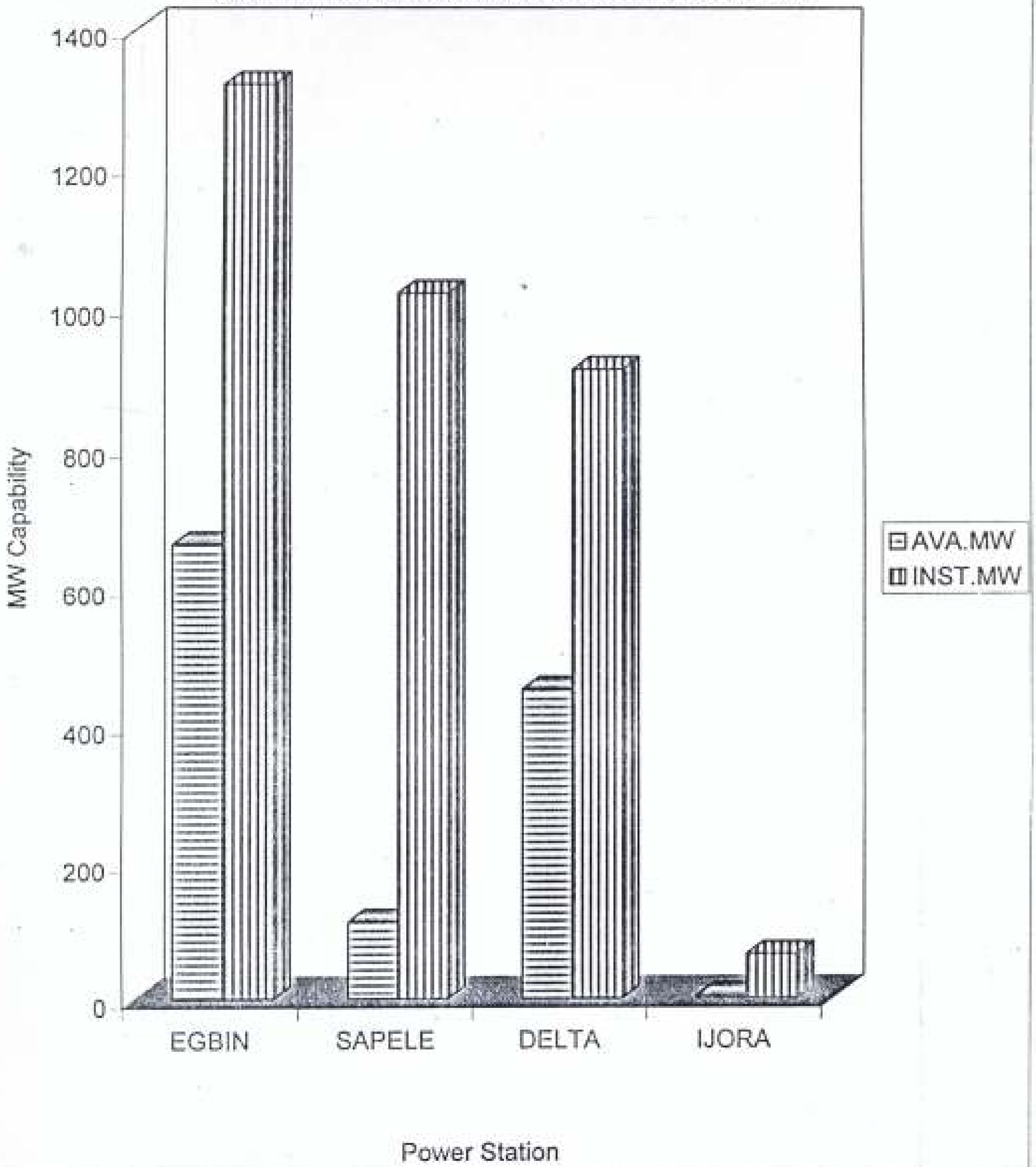
APPENDIX D3

1991 South West Monthly Peak Demand (MW)

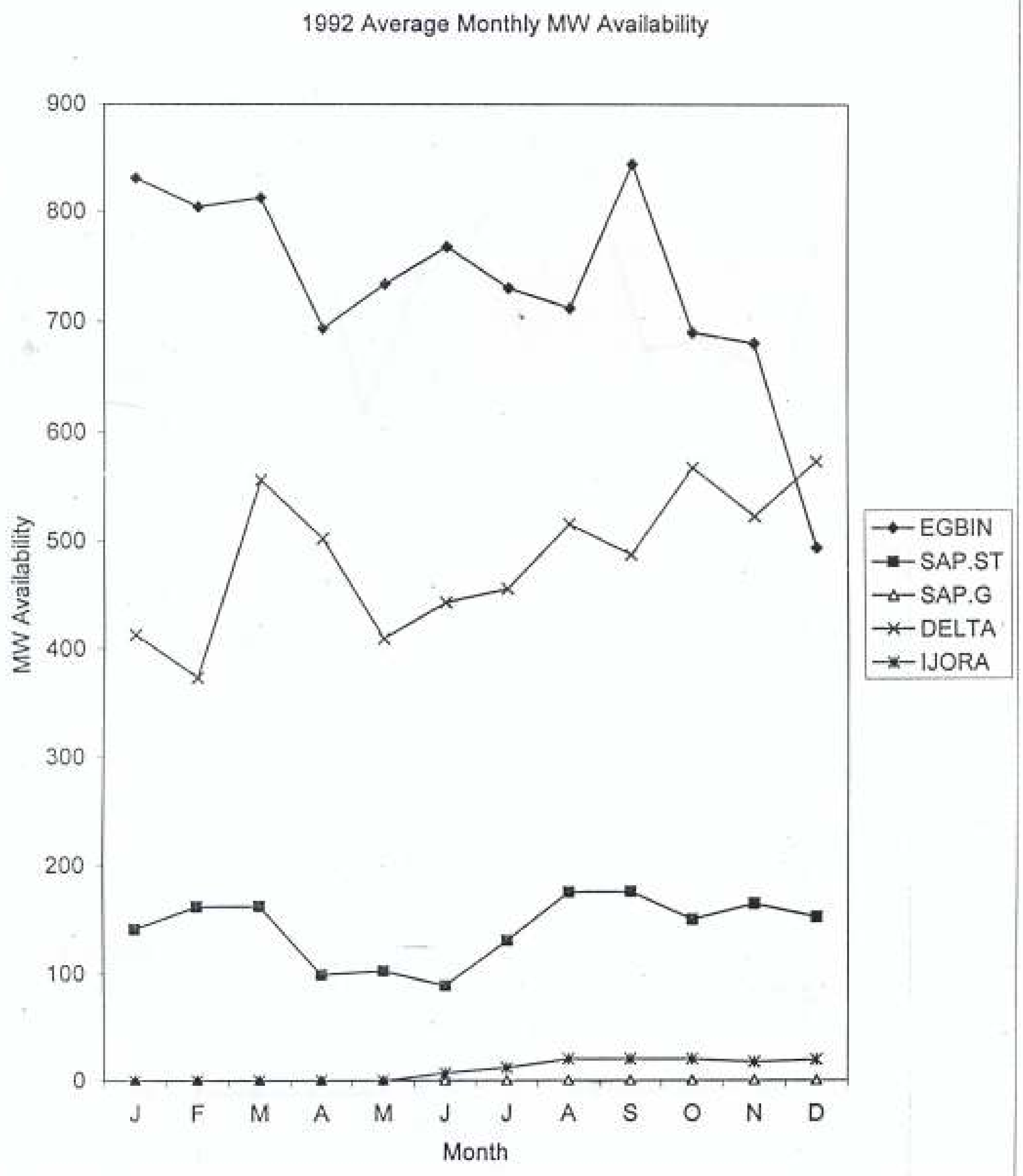


APPENDIX D4

1991 Generation Capabilities of NEPA Power Station

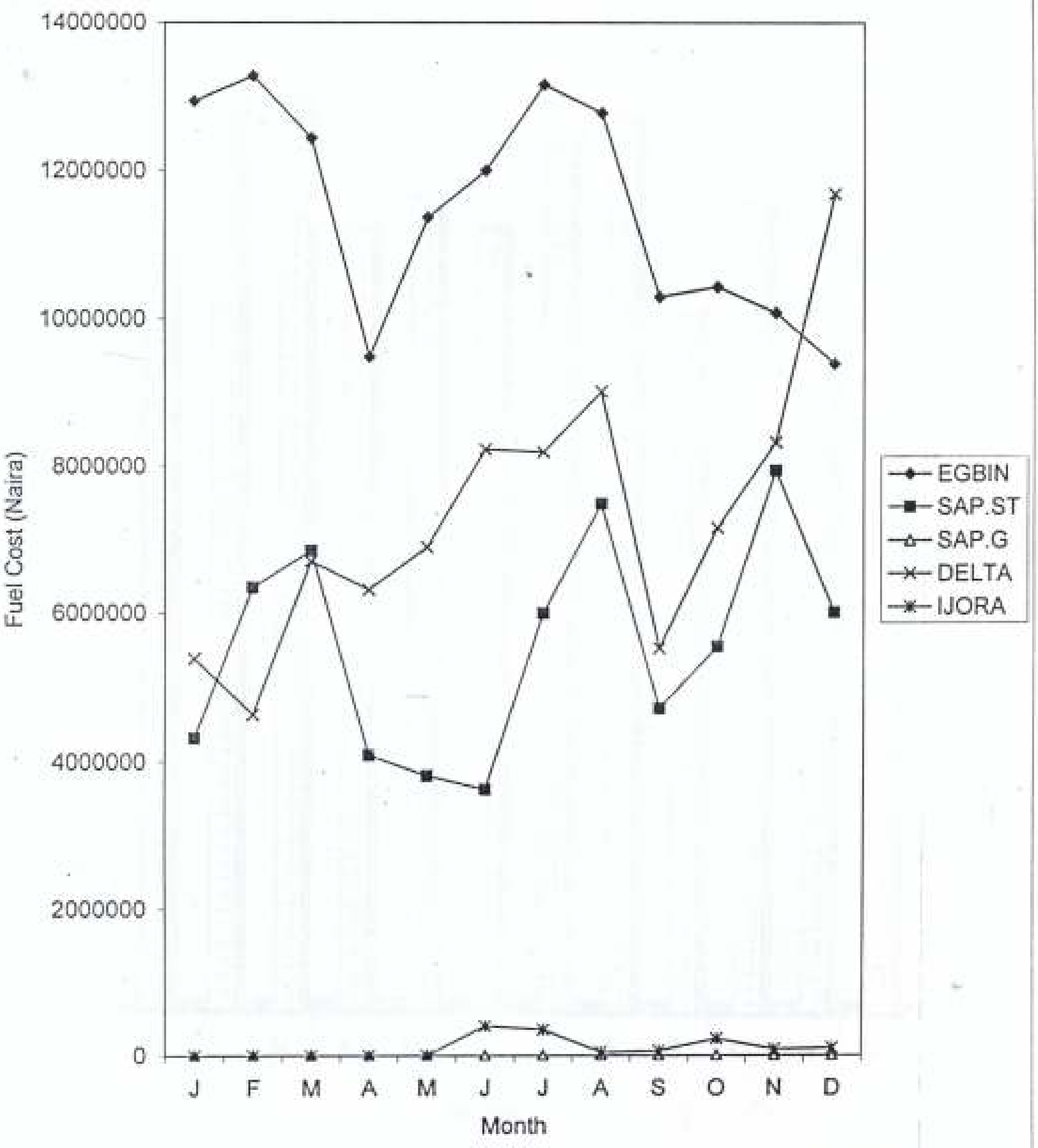


APPENDIX E1

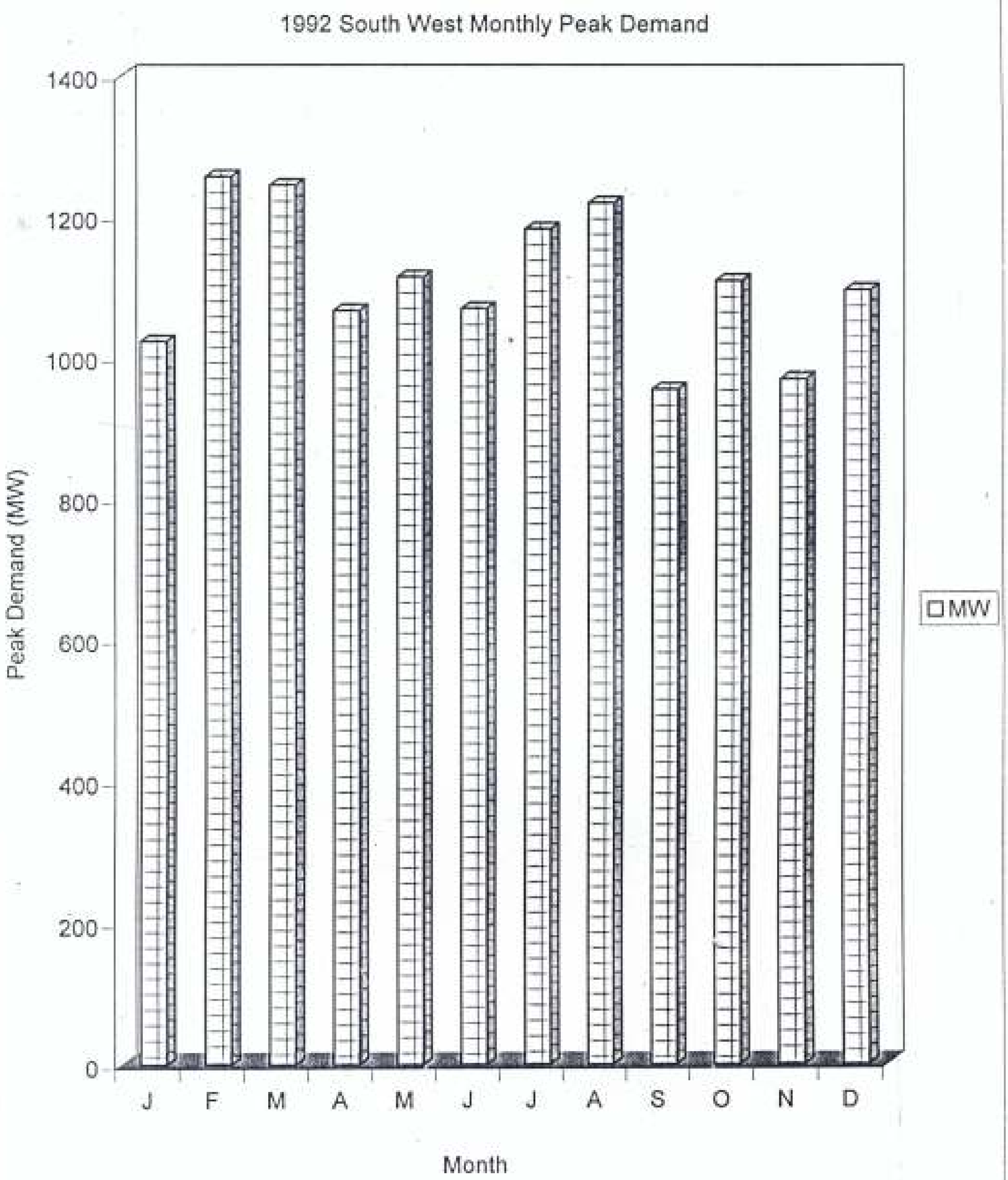

1992 Average Monthly MW Availability
900
800
700
600
500
400
300
200
100
0
MW Availability
J
F
M
A
M
J
J
A
S
O
N
D
Month
EGBIN
SAP.ST
SAP.G
DELTA
IJORA

APPENDIX E2

1992 Thermal Fuel Cost (Naira)



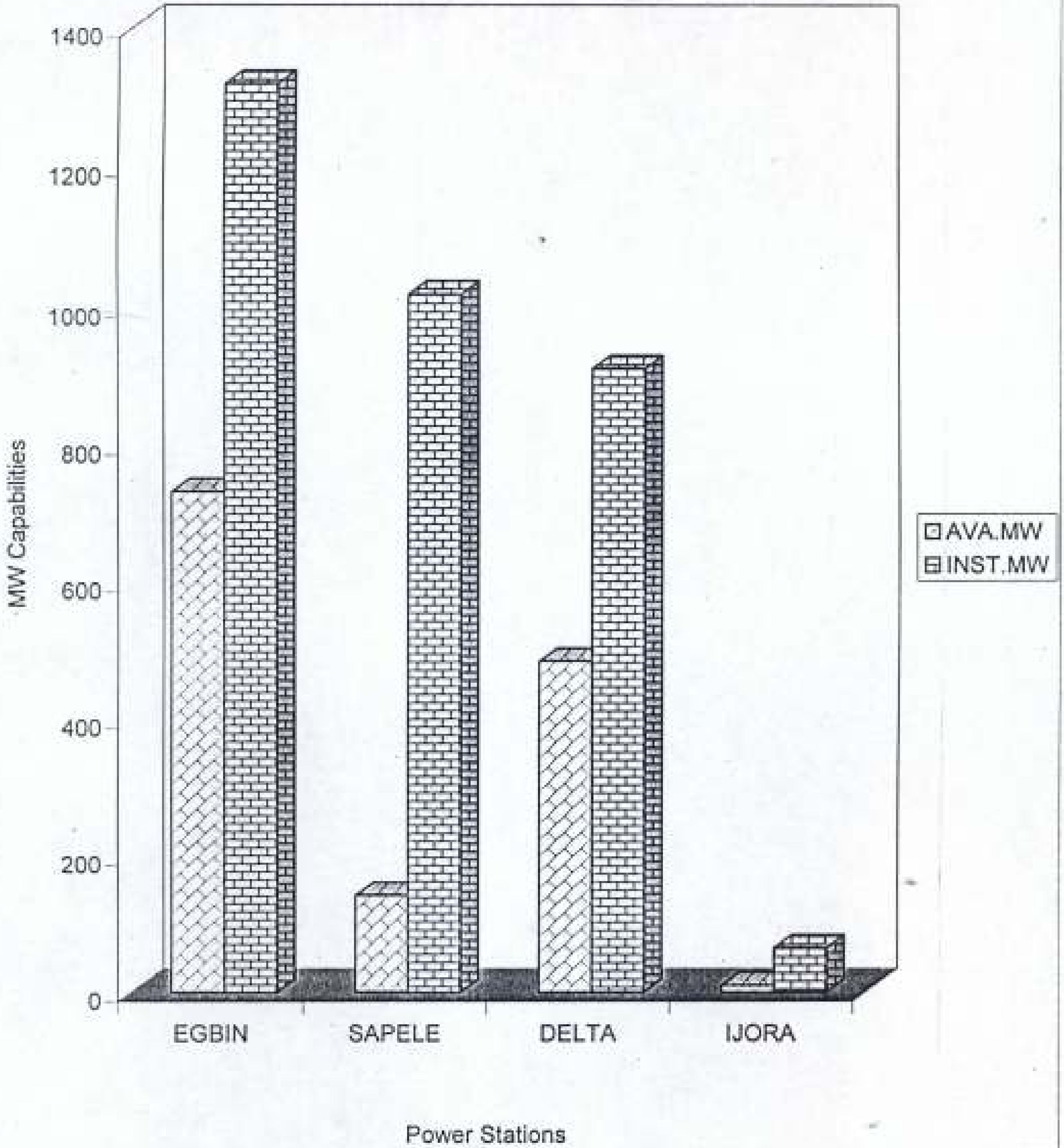
APPENDIX E3



1992 South West Monthly Peak Demand
1400
1200
1000
800
600
400
200
0
Peak Demand (MW)
J
F
M
A
M
J
J
A
S
O
N
D
Month
MW

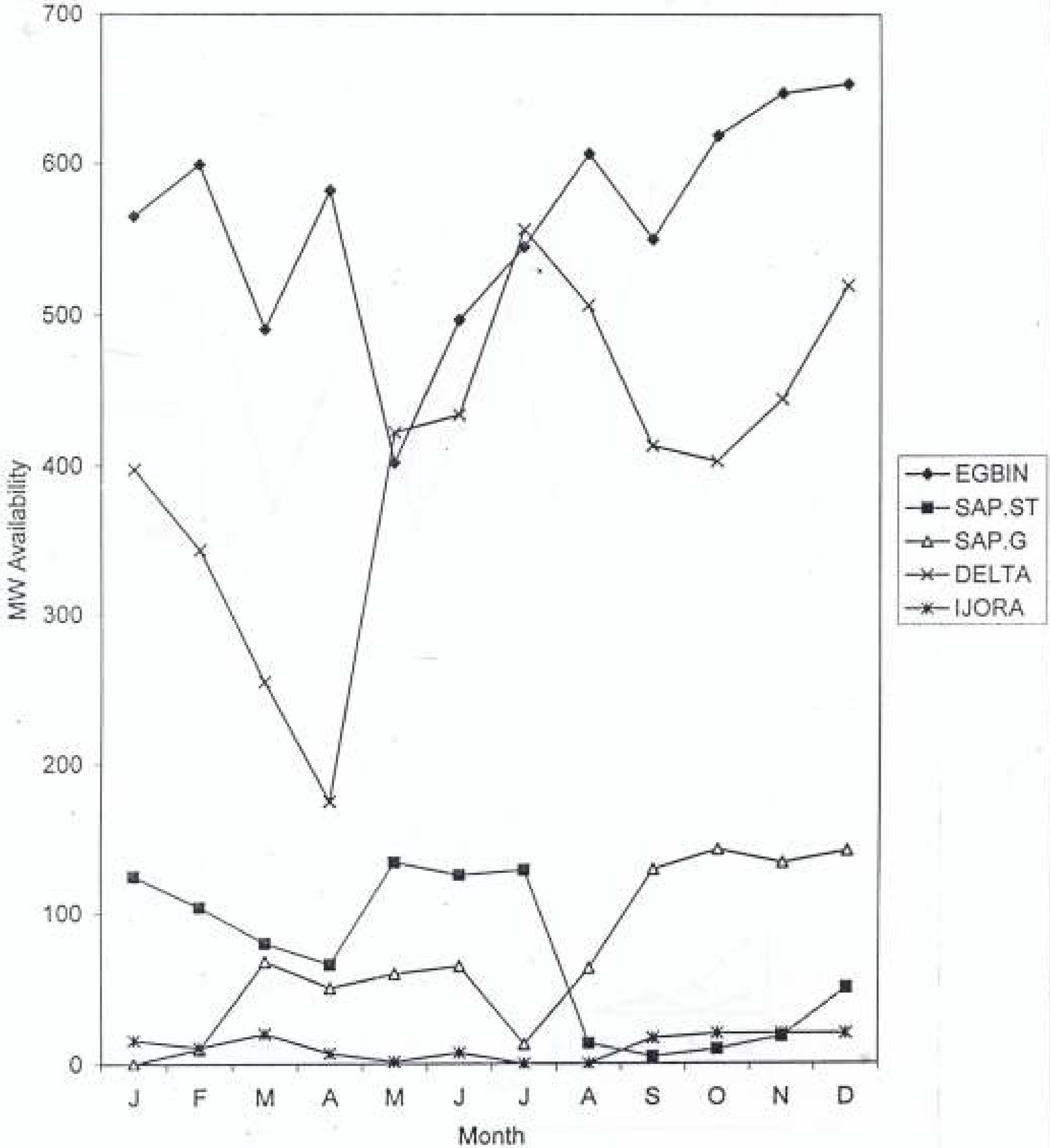
APPENDIX E4

1992 Generation Capabilities of NEPA Power Stations



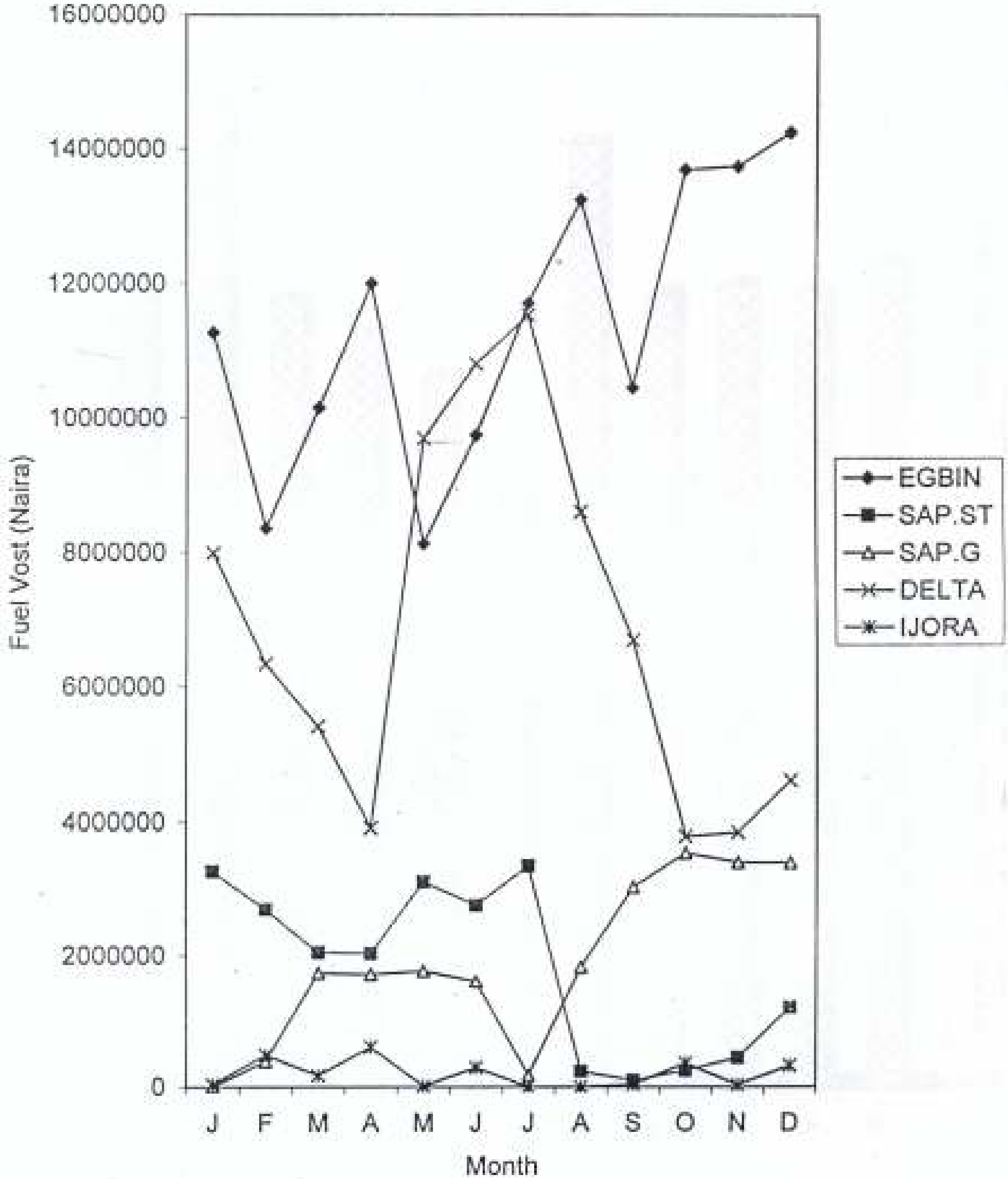
APPENDIX F1

1993 Average Monthly MW Availability



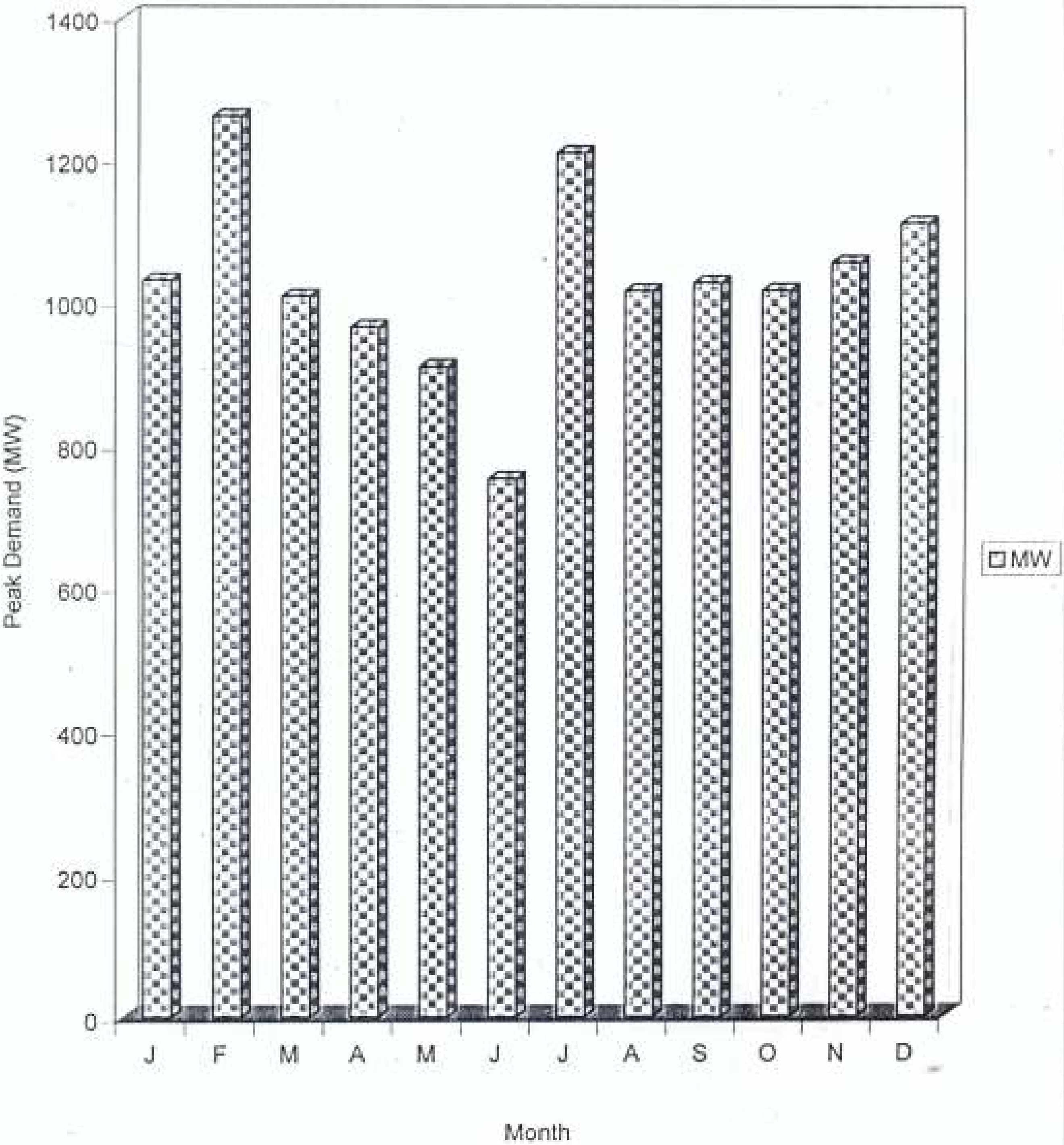
APPENDIX F2

1993 Thermal Fuel Cost (Naira)



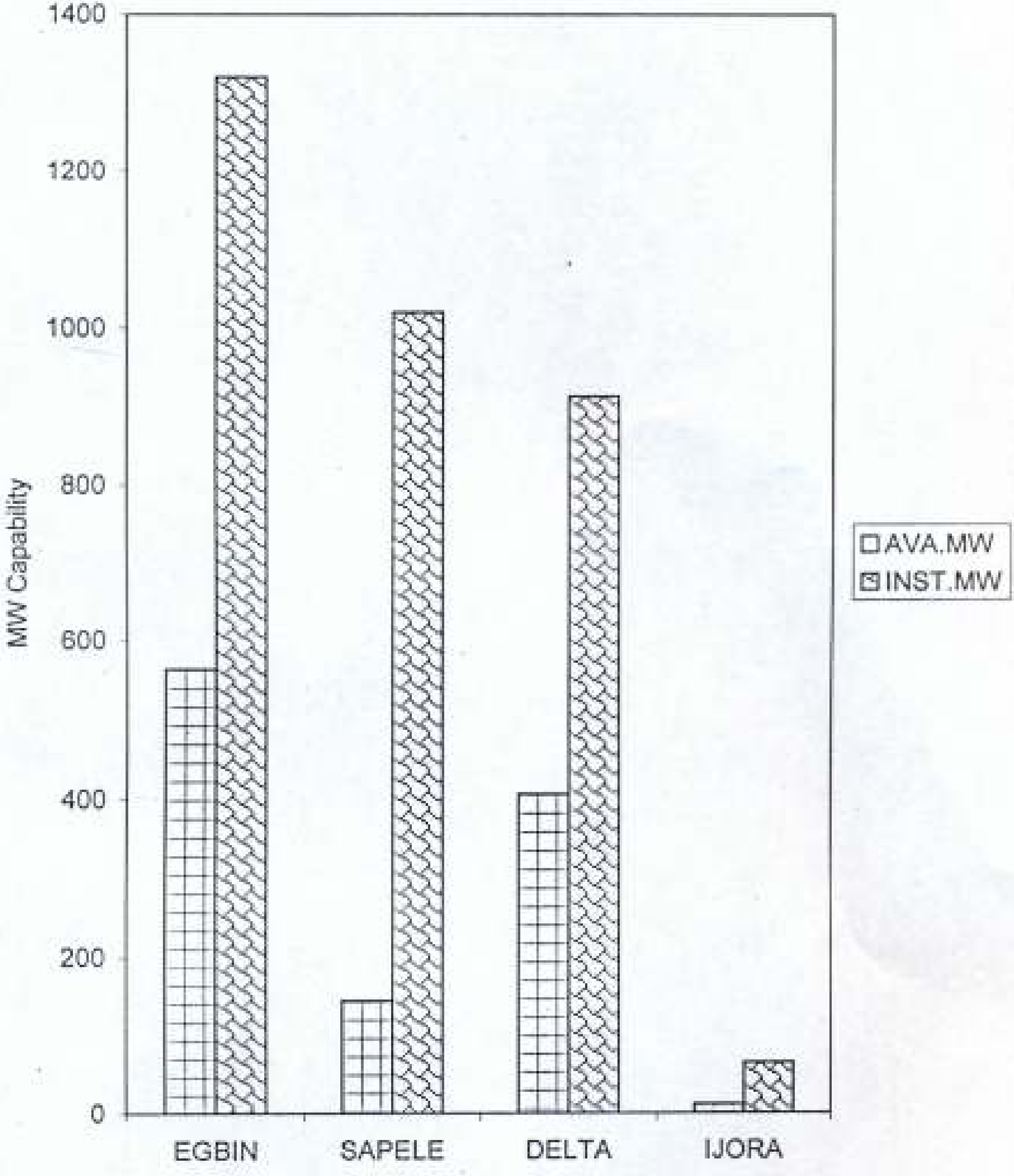
APPENDIX F3

1993 South West Monthly Peak Demand (MW)



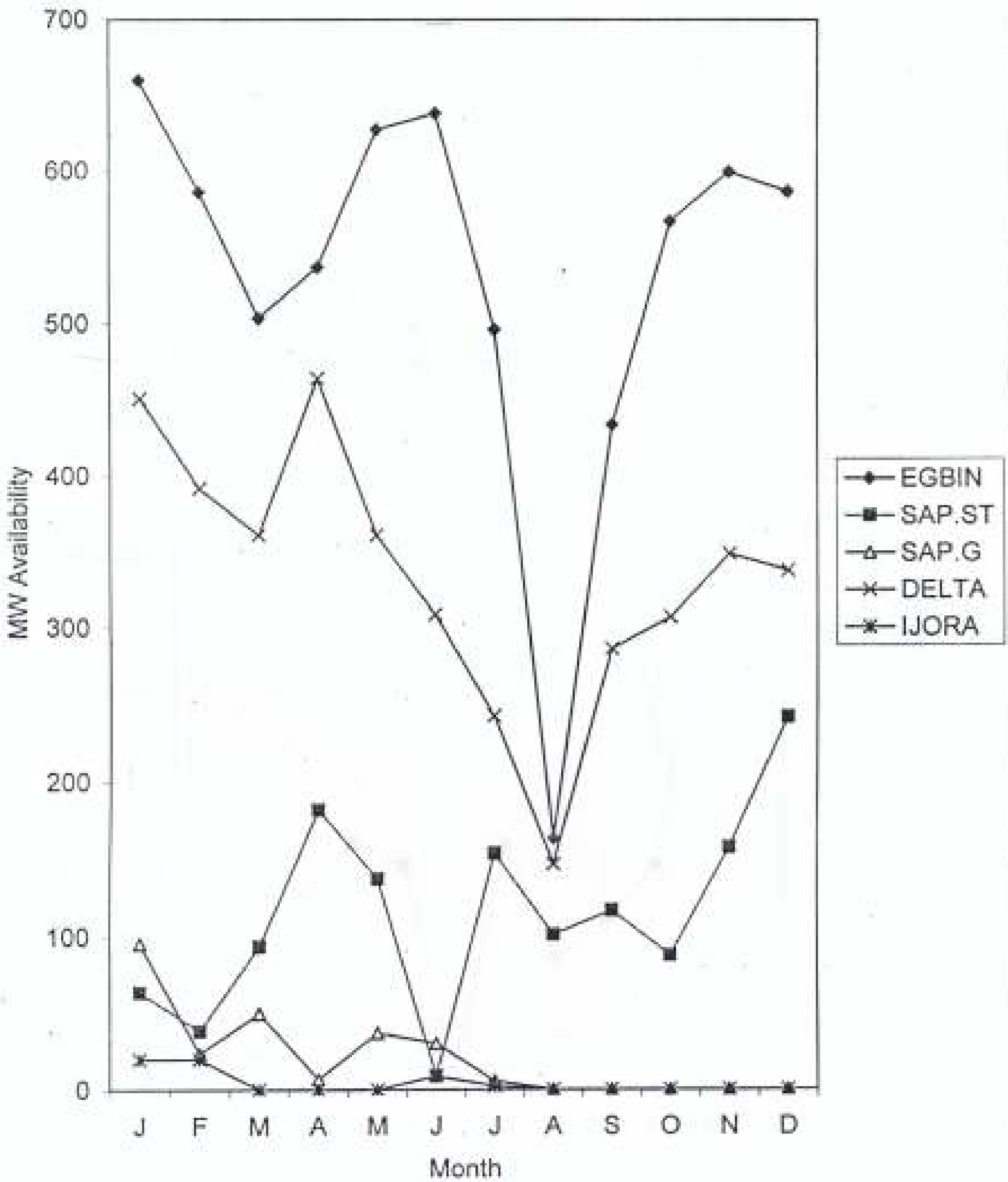
APPENDIX F4

1993 Generation Capabilities of NEPA Power Stations



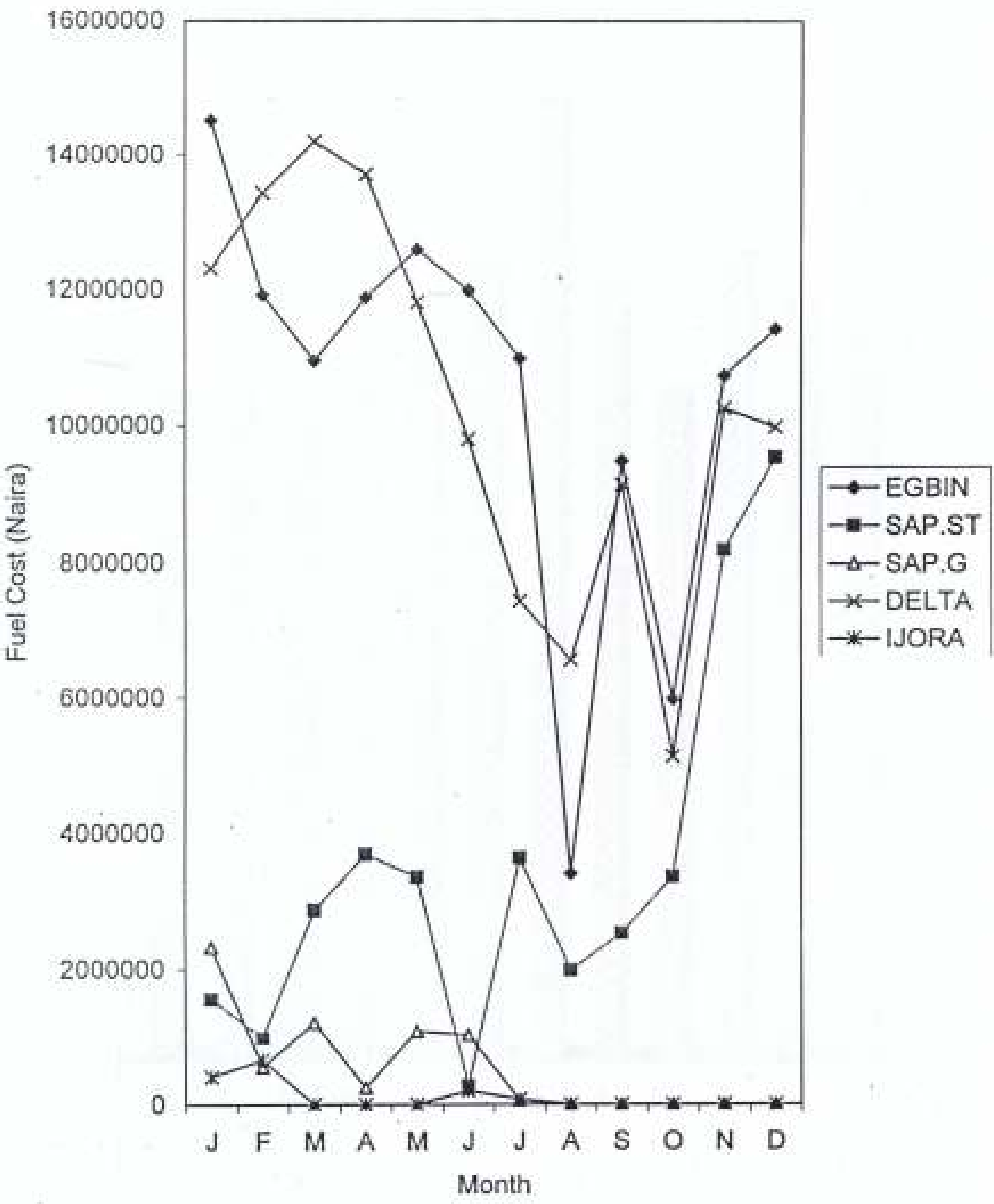
APPENDIX G1

1994 Average Monthly MW Availability



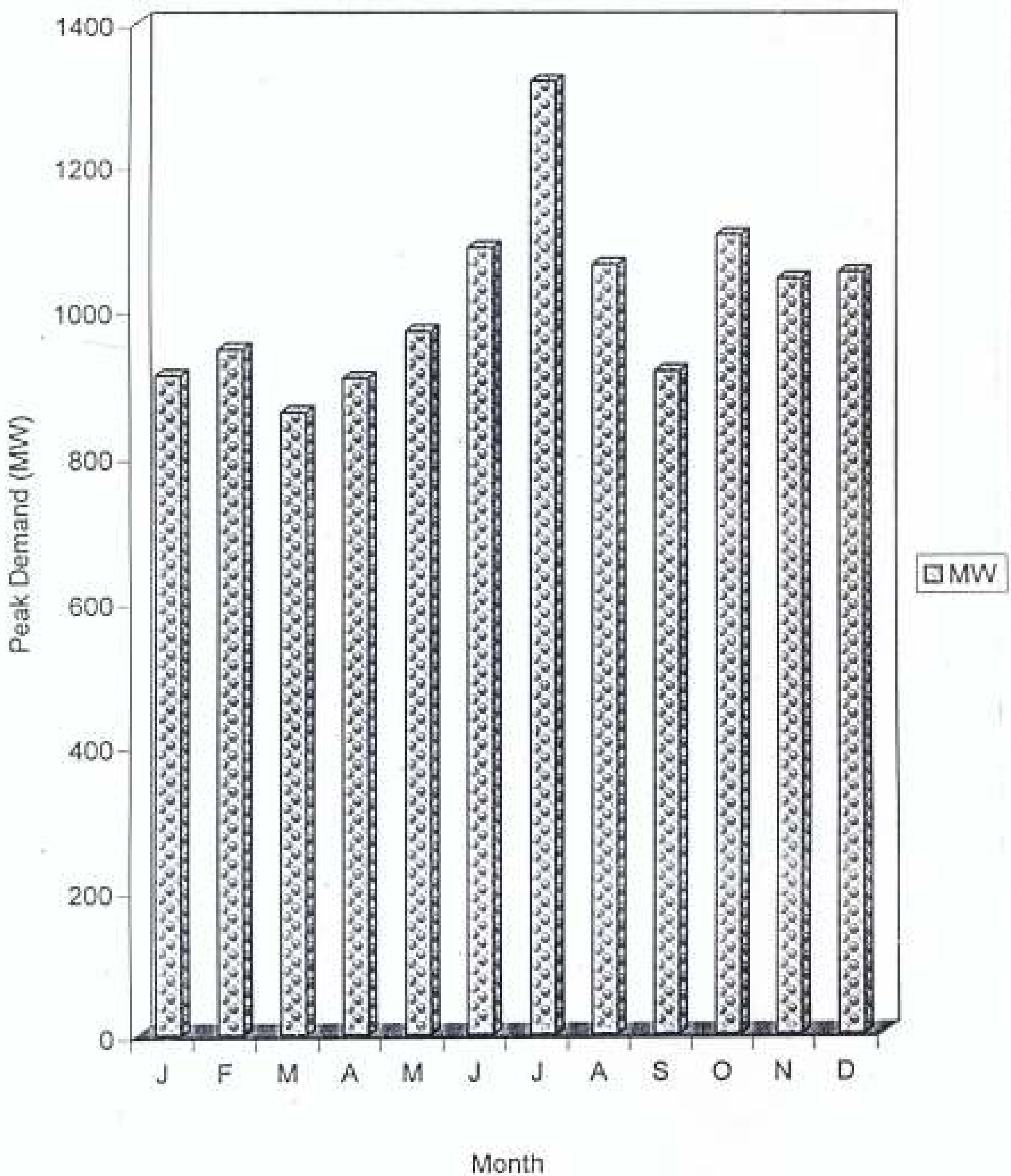
APPENDIX G2

1994 Thermal Fuel Cost (Naira)



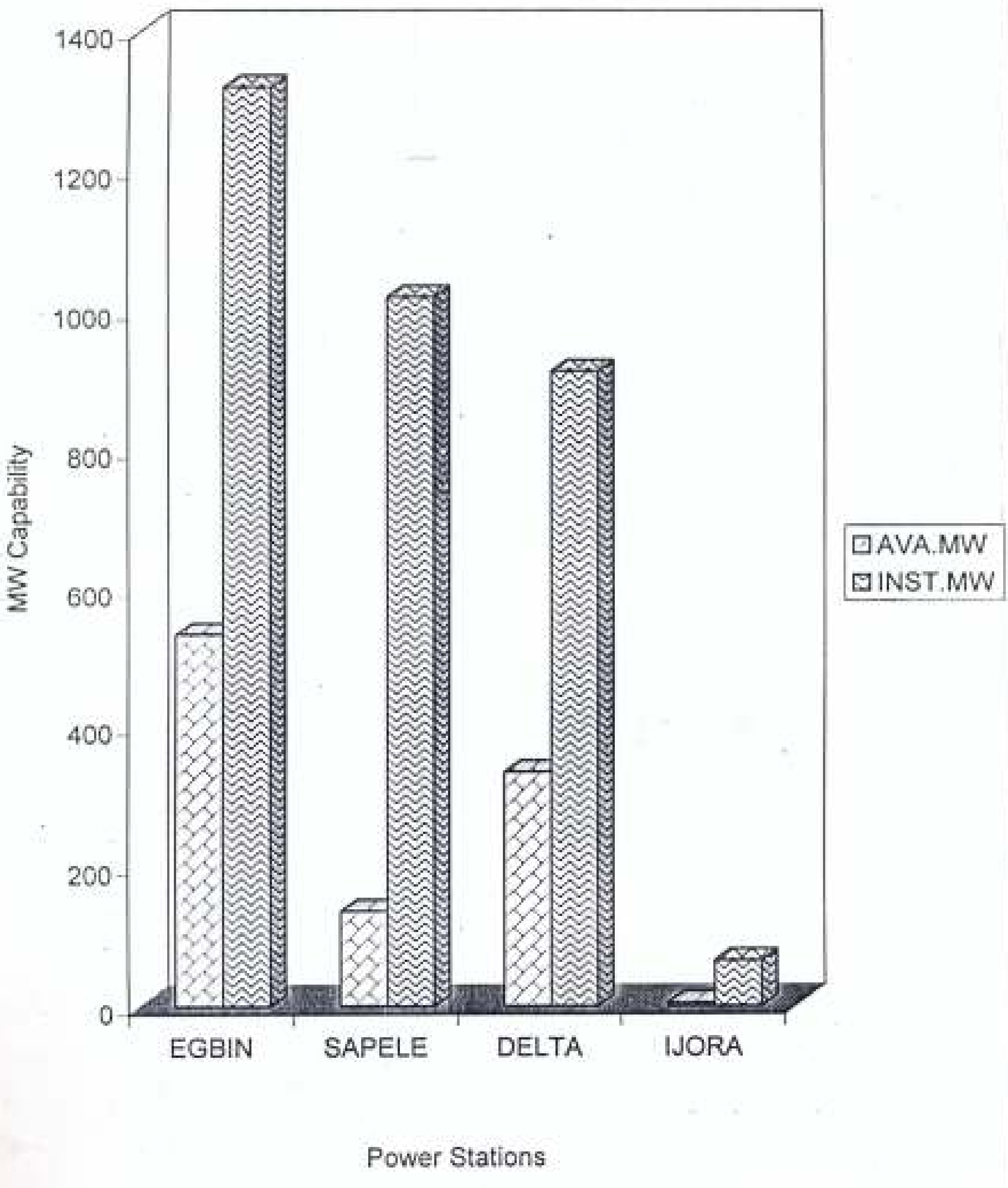
APPENDIX G3

1994 South West Monthly Peak Demand (MW)



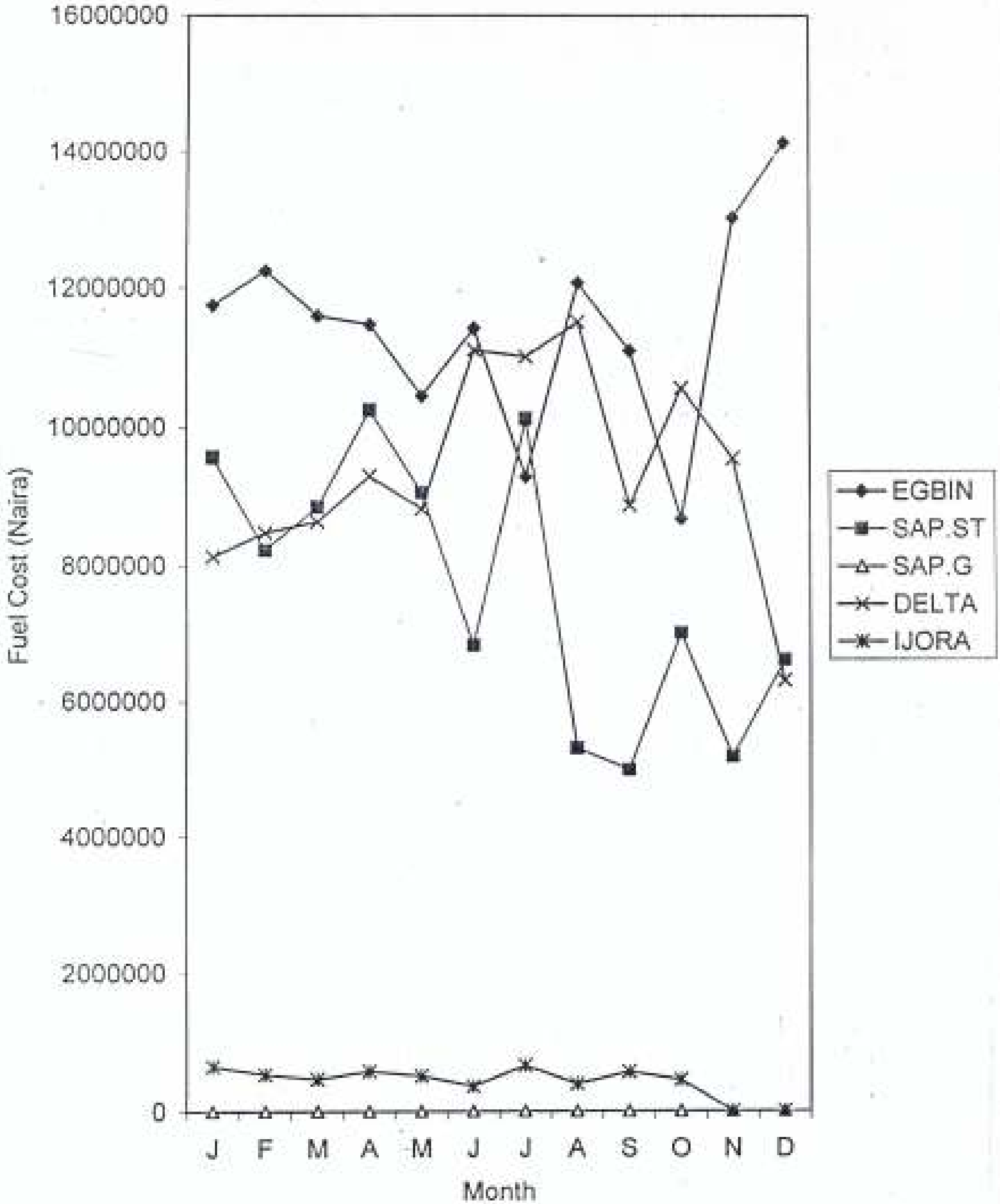
APPENDIX G4

1994 Generation Capabilities of NEPA Power Station



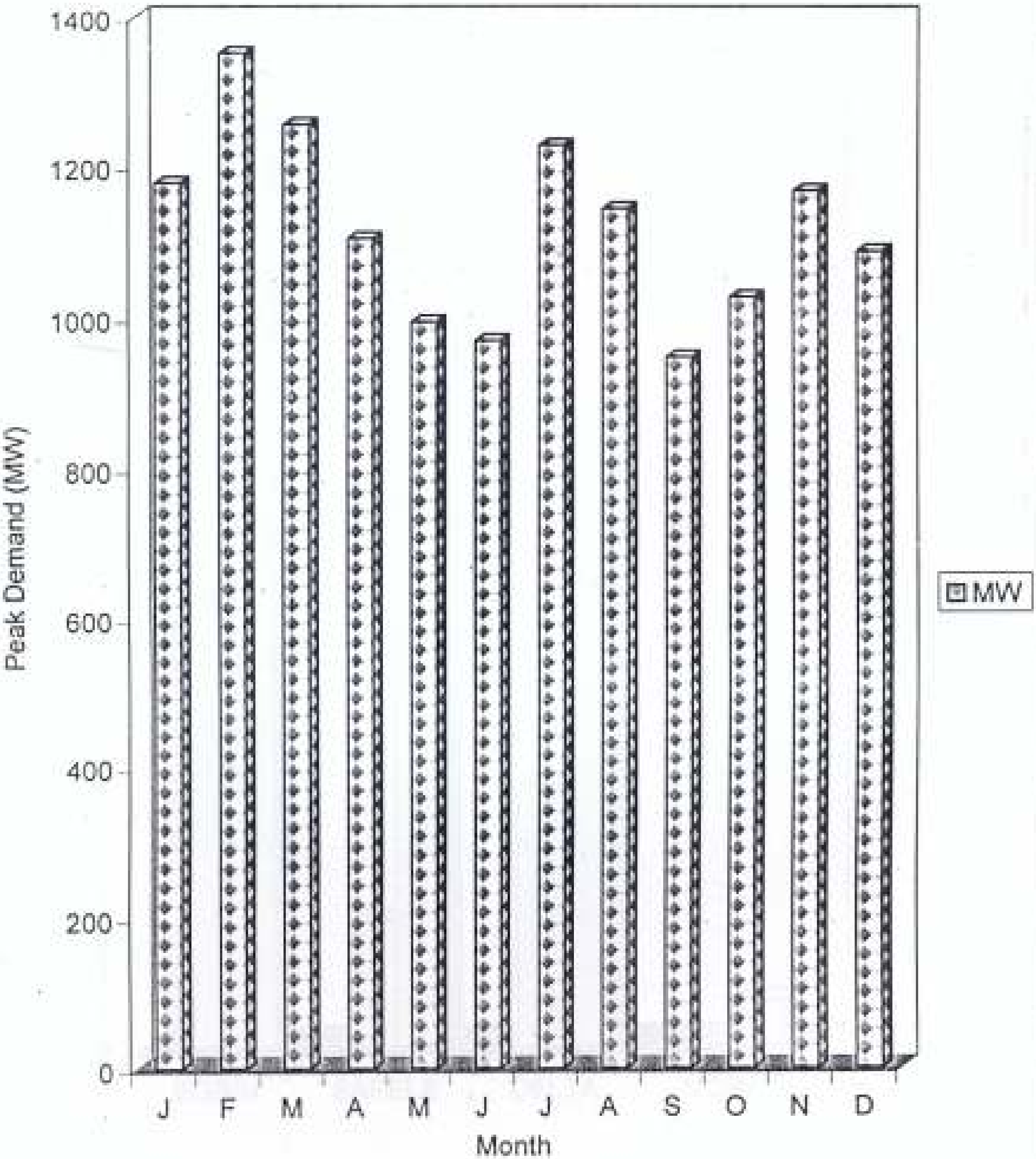
APPENDIX H2

1996 Thermal Fuel Cost (Naira)



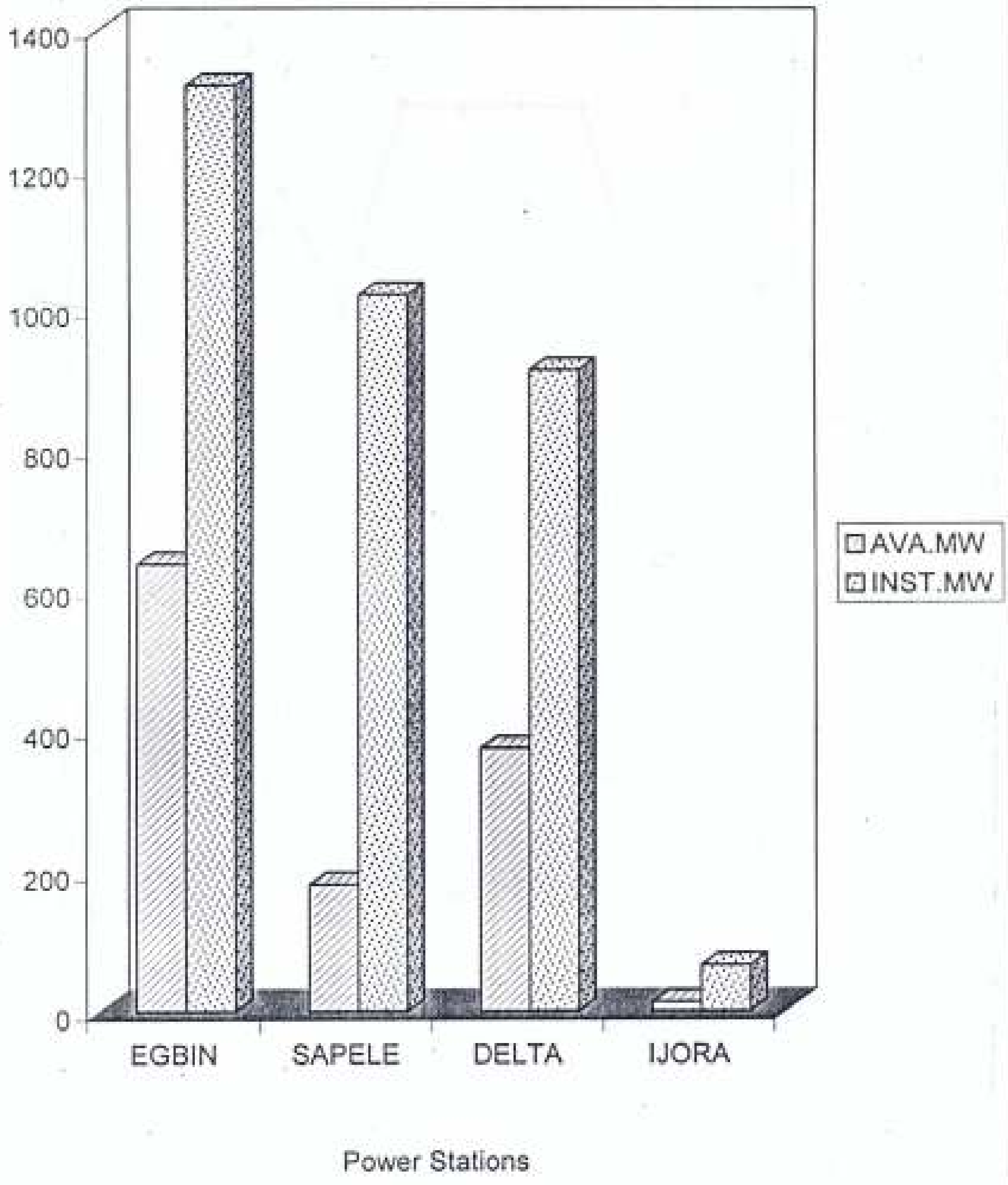
APPENDIX H3

1995 South West Monthly Peak Demand (MW)



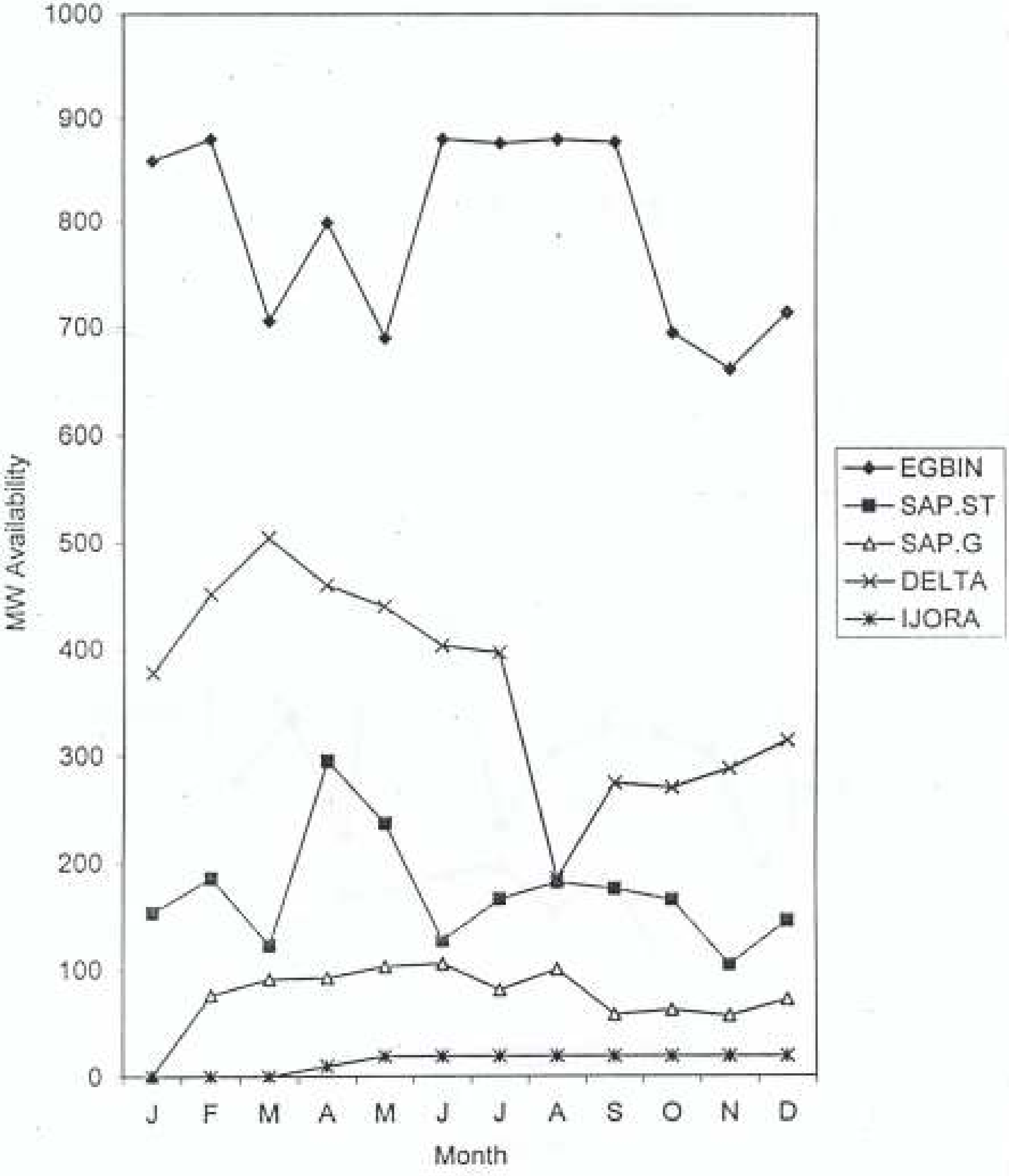
APPENDIX H4

1995 Generation Capabilities of NEPA Power Stations

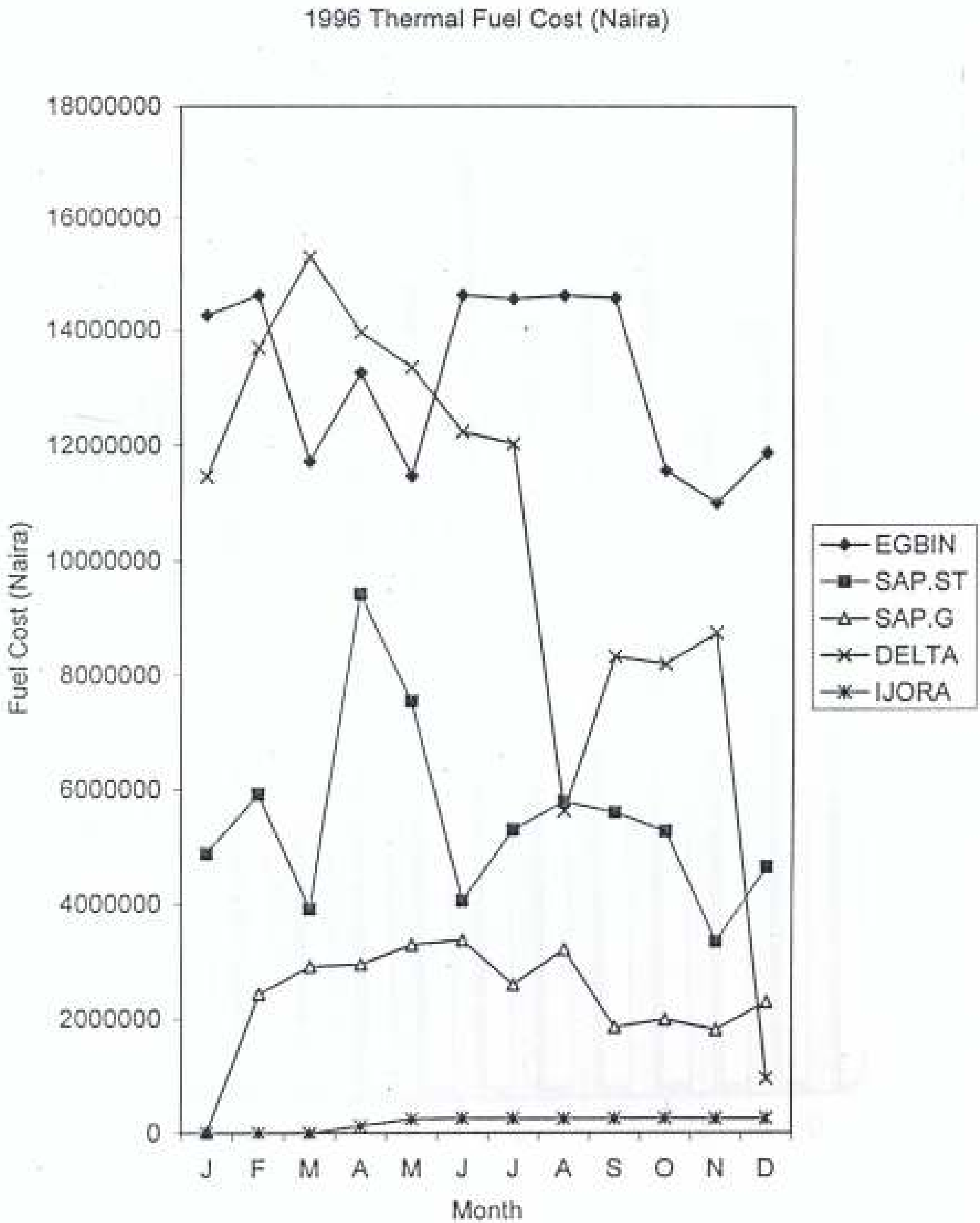


APPENDIX I1

1996 Average Monthly MW Availability

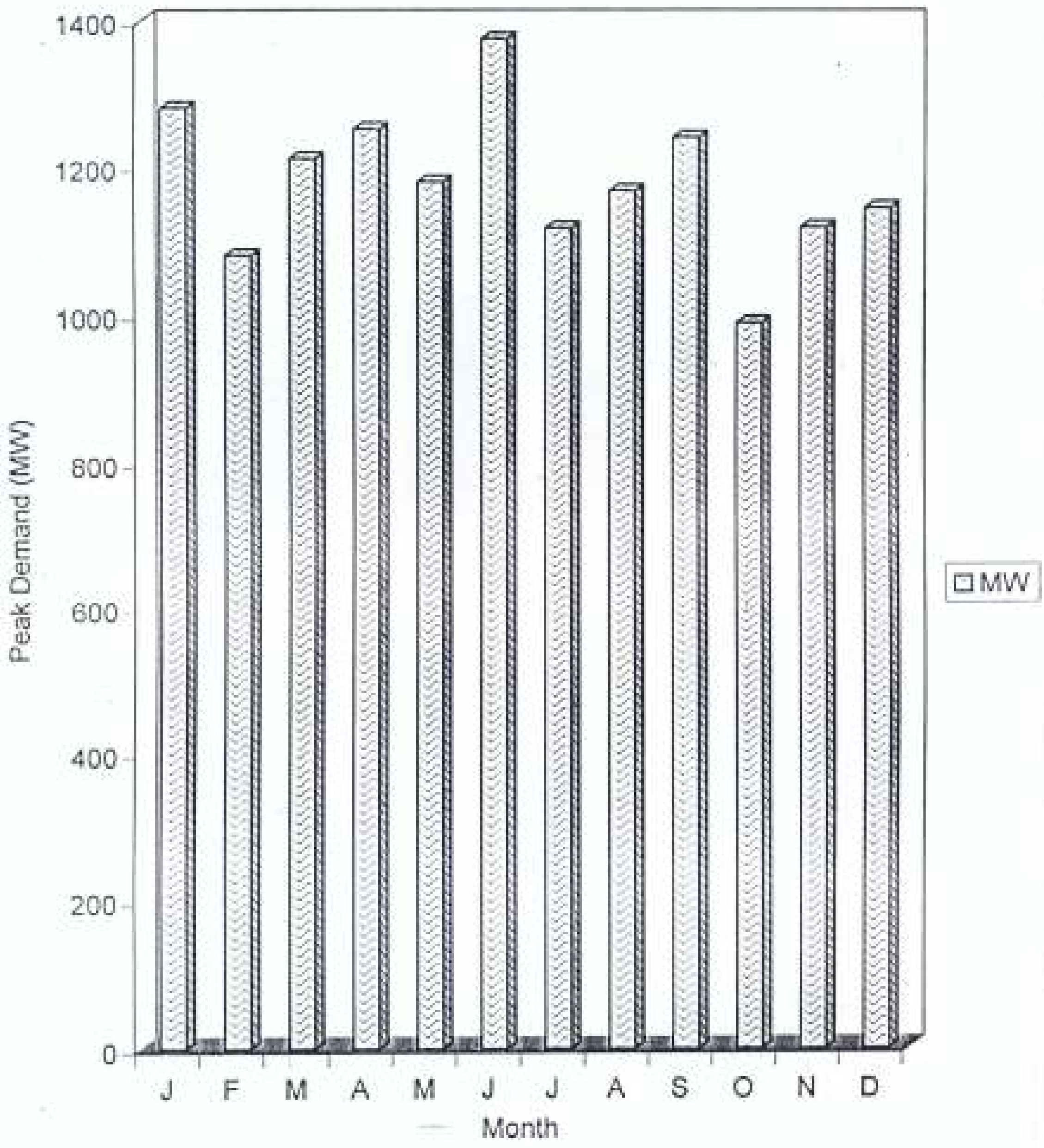


APPENDIX I2


1996 Thermal Fuel Cost (Naira)
18000000
16000000
14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
Fuel Cost (Naira)
J
F
M
A
M
J
J
A
S
O
N
D
Month
EGBIN
SAP.ST
SAP.G
DELTA
IJORA

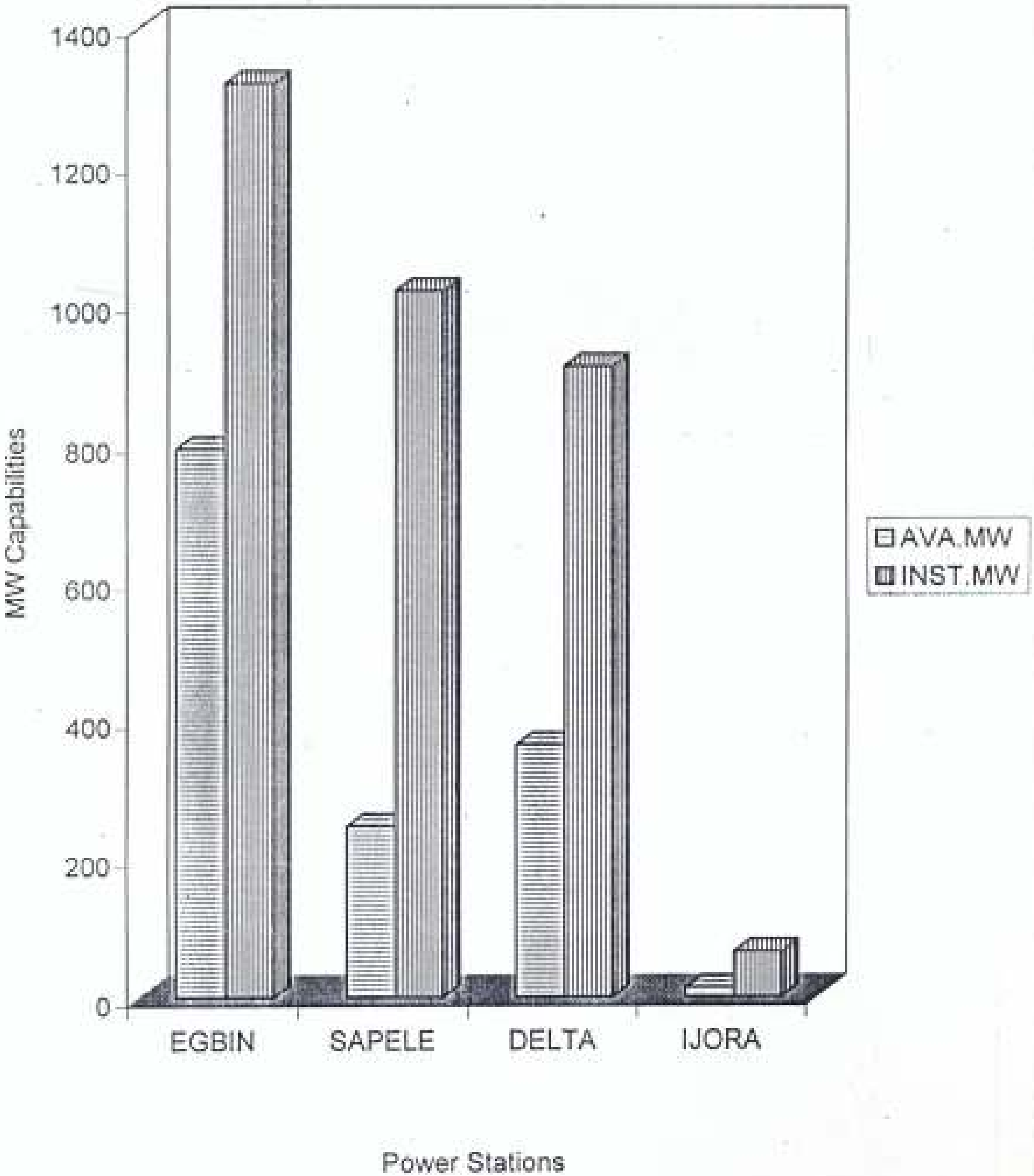
APPENDIX I3

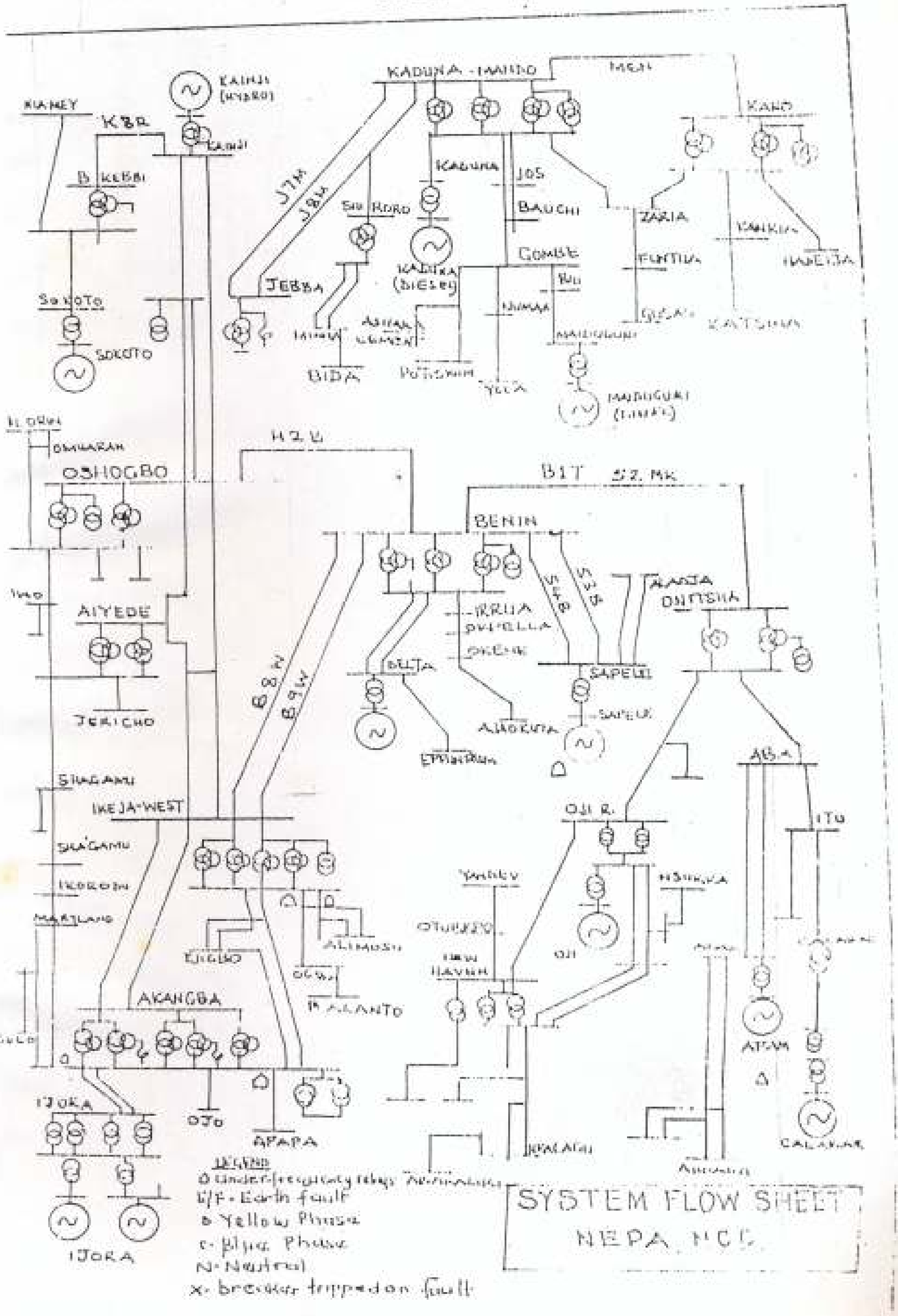
1996 South West Peak Demand (MW)



APPENDIX I4

1996 Generation Capabilities of NEPA Power Stations




KADUNA
KAINJI (HYDRO)
K8R
B. KEBBI
SOKOTO
J7M
J8M
JEBBA
KADUNA
JOS
BAUCHI
GOMBE
ZARIA
KANO
BIDA
OSHOGBO
AIYEDE
JERICHO
BENIN
IRRUA
DELTA
SAPELE
AJAOKUTA
ONITSHA
ABA
ITU
IKEJA-WEST
AKANGBA
IJORA
OJO
APAPA
AFAM
CALABAR
LEGEND
x- breaker tripped on fault
SYSTEM FLOW SHEET
NEPA NCC