THE REPUBLIC OF TUNISIA

REPORT

ON

ELECTRIC POWER DEVELOPMENT PLAN

OCTOBER 1977

JAPAN INTERNATIONAL COOPERATION AGENCY

REPORT ON ELECTRIC POWER DEVELOPMENT PLAN IN THE REPUBLIC OF TUN

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PREFACE

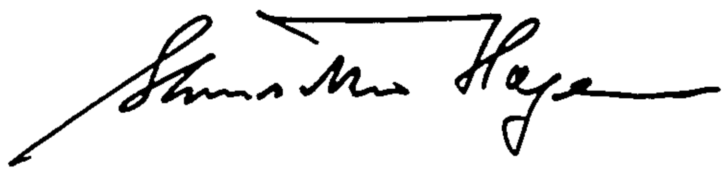
The Government of Japan, in response to the request of the Government of the Republic of Tunisia, agreed to conduct a study of the electric power development program of Tunisia in relation with plans for installation of new power generation facilities to cope with peak demands which have become prominent in recent years. The Government of Japan entrusted this study to the Japan International Cooperation Agency (JICA).

The Agency, in consideration of the importance of the electric power situation of Tunisia in relation to the Social and Economic Development Plan of the country, dispatched a mission of six members headed by Mr. Masashi Koike (EPDC International Ltd.) to Tunisia for a period of thirty (30) days from February 8 to March 9, 1977. The mission, carried out field investigations with the cooperation of government agencies of the Republic of Tunisia, and on returning to Japan, examined the data collected in Tunisia and the results of field reconnaissance to prepare this Report.

It would be truly rewarding if this Report were to contribute to the long-range electric power development of the Republic of Tunisia and hence to the prosperity of the country's society and economy, to enhancing the economic relation between Tunisia and Japan, to further deepen the friendship and goodwill between the two countries.

In closing, I express my deep appreciation to the members of the mission for their efforts, and to sincerely thank those persons concerned in the Government of Tunisia and in the Société Tunisienne de l'Electricité et du Gaz (STEG), the agency directly concerned with accomodating the mission, the members of the Japanese Embassy in Tunisia, and the Ministry of Foreign Affairs and Ministry of International Trade and Industry of the Government of Japan for their assistance in dispatching of the mission.

October, 1977



Shinsaku Hogen
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Mr. Shinsaku Hogen, President
Japan International Cooperation Agency

Herewith submitted is a Study Report on a long-range electric power development plan considering the entire national territory of the Republic of Tunisia, and the Kasseb Pumped Storage Power Project to be incorporated in the development scheme which would meet the peak electric power demand which has become conspicuous in recent years.

The Mission, for 27 days from February 9 to March 7, 1977 collected data and information at Socifé Tunisienne de l'Électricité et du Gaz (STEG), the Ministére du Plan, etc., carried out field reconnaissances of the Kasseb Pumped Storage Power Project site and investigations of related power demand areas.

The principal purpose of the survey is to determine the position to be occupied by the Kasseb Pumped Storage Power Project being considered in Tunisia through formulation of an optimum electric power development scheme by a comprehensive study of the present circumstances of the electric power system, electric power development plans and the energy situation of Tunisia.

The electric power industry of Tunisia is a monopoly of STEG which has the entire country as its service area, and an interconnected system is comprised of 150-kV and 90-kV transmission lines connecting power stations which are mainly thermal power generation facilities. As for the substance of the electric power development scheme, it is considered to be optimum to develop from the year 1983 150-MW steam thermal units as base supply capability in combination with the Kasseb Pumped Storage Power Project, 350 MW (first stage 75 MW x 2 units, second stage 100 MW x 2 units) as peaking power, in addition to the power generation facilities already ordered.

With regard to the Kasseb Pumped Storage Power Project, when compared with gas turbines which would serve as alternative facilities, it was concluded that the benefit-cost ratio, B/C, would be 1.06 (discount rate 10%), and when the secondary benefits to be obtained according to the socio-economic analysis are added, the economics would be improved further. The Kasseb Pumped Storage Power Project will have secondary merits such as the capacity to serve as a hot reserve in a power system comprised mainly of thermal power generation facilities, maintenance of normal frequency through load-following operation, reduction in start-up losses and start-up faults due to reductions in the number of times of start-up and stopping, improvements in operating thermal efficiencies of base thermal units by which freedom and dependability in power system operation would be enhanced.

Further, when considerations are given in relation to the offshore natural gas development project being promoted in Tunisia at present, the Kasseb Pumped Storage Power Project will improve the utilization factors of base thermal power stations using natural gas as fuel, and in effect, improve the utilization factor of the gas pipeline, and therefore, it is thought to be desirable for the natural gas development project also.

The economy of Tunisia is showing rapid development as a result of four "Socio-Economic Development Plans" implemented in the past and this year a Fifth Plan has been initiated. As the base for supporting this economic development, electric power development has always been pursued as a top-priority program in the past, and is scheduled to be carried out forcefully in the future also. It is hoped that the study just made on electric power development will eventually lead to even greater economic and technical cooperation between the two governments.

In submitting this Report, I wish to express the deepest appreciation to the government agencies of Tunisia which gave us the utmost cooperation, and to those persons concerned at the Japanese Embassy in Tunisia, the Ministrry of International Trade and Industry and the Ministry of Foreign Affairs, Japan.

October 1977

Masashi Koike, Chief
Mission for the Survey on
Electric Power Development Plan
in the Republic of Tunisia

INTRODUCTION

(Purpose of Study)

The purpose of this study made at the request of the Government of the Republic of Tunisia is to determine the position to be occupied by the Kasseb Pumped Storage Power Project, which has been under contemplation and examination for some time to cope with the rapidly increasing peak power demand of recent years, in the future electric power development program which will play an important role in development of the Tunisian economy. In order to achieve this purpose, the necessary load forecasts, electric power development plans, general economic analyses of the Kasseb Pumped Storage Power Project, and power system analysis are to be made, thereby establishing a base for a feasibility study of the Kasseb Project to be conducted hereafter.

(Circumstances Prior to Dispatching of Survey Mission)

The Government of the Republic of Tunisia is presently pursuing a path to industrialization based on abundant underground natural resources in accordance with its Fifth Socio-Economic Development Five-Year Plan (1977–1981). In order to comply with the brisk electric power demand accompanying this industrialization, Société Tunisienne de l'Électricité et du Gaz (STEG), a government agency, is proceeding with a 454-MW electric power development program as a link in the abovementioned Socio-Economic Development Plan. To succeed this Fifth Five-Year Plan, STEG has been considering realization of the Kasseb Pumped Storage Power Development Project as one of the supply capabilities to carry peak portions of power loads, and has been proceeding with preparations for execution of a feasibility study. In July 1976, the Tunisian Government requested the Japanese Government to conduct a feasibility study for the Kasseb Project.

The circumstances described below make up the background for such a request having been made. Peak power demand has been increasing rapidly in recent years and meeting this demand with power generation facilities such as gas turbines would mean that the number of units would be greatly increased making maintenance and operation troublesome, whereas it would be convenient for power system operation if hydroelectric supply capability were to be increased. In case of pumped storage hydro, power for pump-up would be supplied from base-load thermal power stations in the midnight and there would be a number of merits such as raising of the utilization factors of base thermal stations, while this would also be desirable for the effective utilization of natural gas to be developed offshore of Gabes Bay that would be used as fuel for the base thermal stations.

The Japanese Government, on receiving the request, examined relevant existing reports, and proposed to the Tunisian Government that as a first step of technical cooperation a survey would be conducted on the full particulars of the electric power development program of Tunisia and the position to be occupied by the Kasseb Pumped Storage Power Project in that power development program determined, after which, as the second step, a feasibility study of the Kasseb Project would be carried out. This proposal of the Japanese Government was accepted and the Survey Mission was thus dispatched.

(Investigation Schedule of Survey Mission)

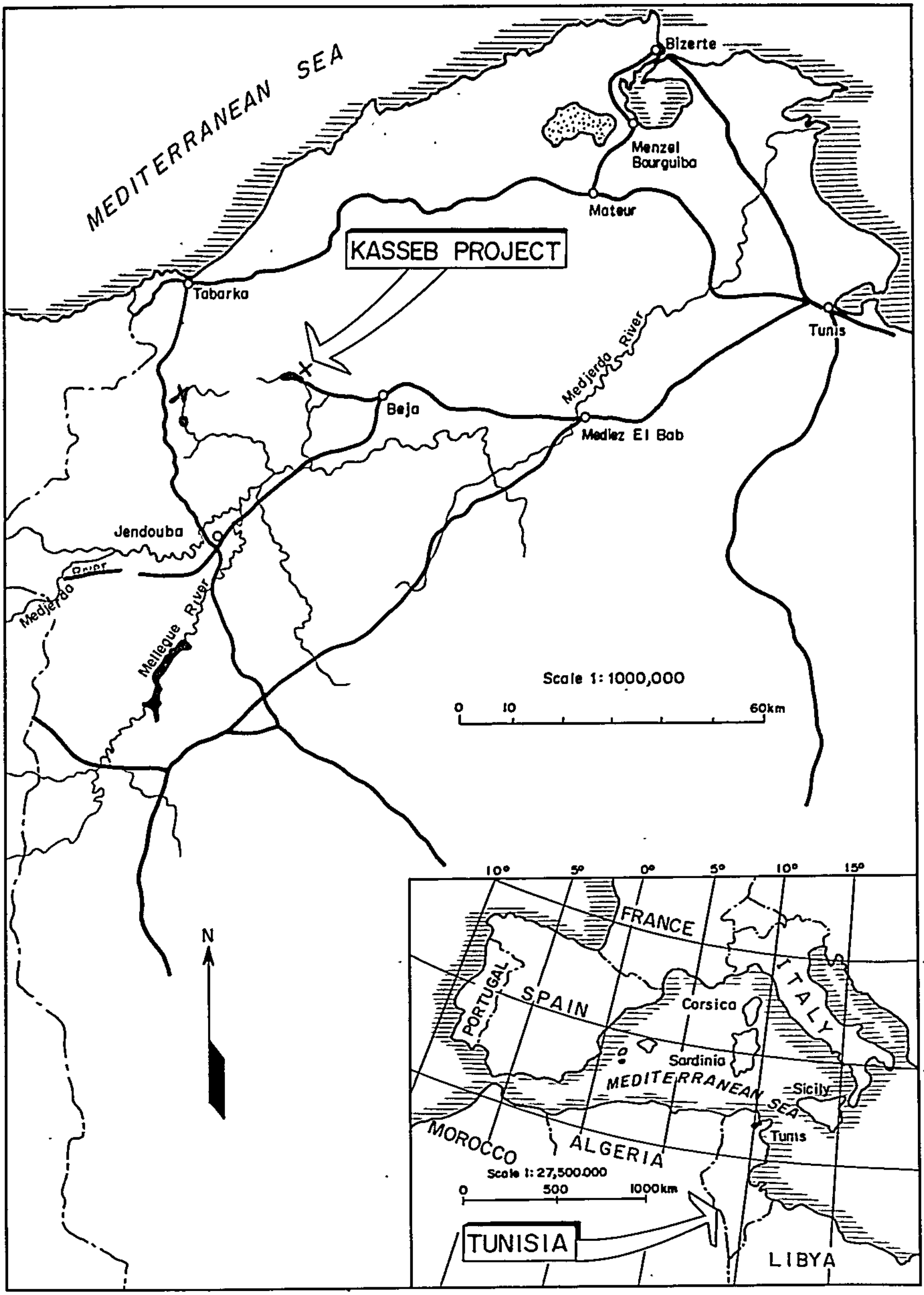
The Mission carried out field investigations based on a 30-day schedule departing from Japan on February 8 and returning on March 9, 1977, and during the 27 days of stay in Tunisia, 12 days were spent in surveys of existing power generation, transmission and substation facilities, reconnaissance of the Kasseb Pumped Storage Power Station site, inspection of the Sousse Thermal Power Station site, and investigation of actual situations in power demand areas. The remainder of the period of stay was spent chiefly in discussions with STEG based on the results of these field investigations and the results of preliminary investigations made in Tokyo.

(Organization of Survey Mission)

The Mission was comprised of members from EPDC International Ltd., the Ministry of International Trade and Industry (MITI) and the Japan International Cooperation Agency (JICA). The names and assignments of the members are given below.

Chief	Masashi Koike, EPDC Int'l, General Supervision
Member	Ichiro Inoue, MITI, Facilities Planning
"	Tetsuro Kobayashi, EPDC Int'l, Electric Power Economics
"	Tatsuo Tomabechi, EPDC Int'l, Power System Planning
"	Hiroshi Kagami, EPDC Int'l, Demand and Power Supply Planning
"	Yuichi Ebita, JICA, Work Coordination

KEY MAP OF KASSEB PROJECT



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CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 1 CONCLUSIONS AND RECOMMENDATIONS

1.1 CONCLUSIONS

1.1.1 Background of Economic Development and Outlook for Development

The Fifth Economic and Social Development Plan of Tunisia with the target of achieving a GNP growth rate of 7.5% annually, aims to promote various industries and related service sectors by putting two thirds of the total investment of 4,200 million Dinars in the production sector with particular emphasis on the manufacturing industry and energy sectors.

As energy resources of Tunisia, hydrocarbons such as petroleum and natural gas are abundant, and especially, the recoverable quantity estimated to be 50 billion to 80 billion m^3, of offshore natural gas is scheduled to be extracted from 1981 under the Fifth Plan, and besides offering a base for developing a gas chemical industry in the future, it brightens the outlook for securing fuel for the electric power industry over a long term.

It is expected that in the long run the Tunisian economy will continue to develop in the future while approaching the projected goals with the country's abundant resources and the extensive system of education as a background.

1.1.2 Electric Power Demand Forecast

The power demand was divided into high-voltage and low-voltage demands and the former was calculated based on the growth rate adopted in the current five-year plan of Société Tunisienne de l'Electricité et du Gaz (STEG) and taking into account the actual growth rate up to 1976, while the latter was forecast estimating the electrification rate in 1990 as 85% and also taking into account the actual growth rate and the rate adopted in the current five-year plan.

Further, based on the general correlation data between GNP and electric power consumption, the above calculated power demand figures were checked by the estimated GNP of Tunisia to examine whether they were appropriate. As a result, the following forecast figures were obtained as electric power demand up to 1990 (see Fig 1-1).

	Actual	Forecast			
	1976	1980	1985	1990	Growth Rate,%
Annual energy production (GWh)	1,350	2,230	3,940	6,760	11.3
Maximum power (MW)	280	445	775	1,330	11.0
Annual load factor (%)	55.0	57.2	58.0	58.0	–

(Note) STEG Power System demand only, private power generation not included.

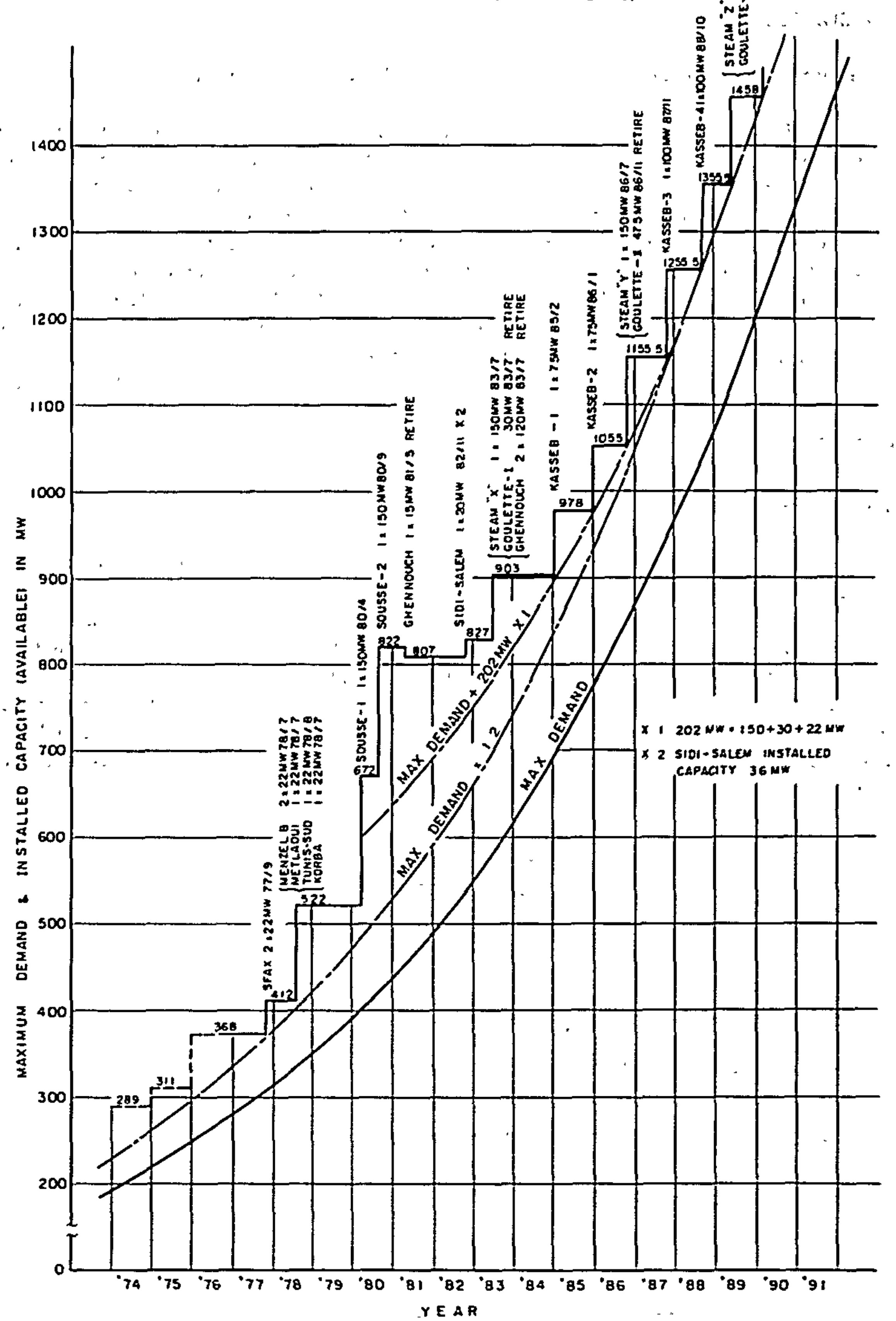
1.1.3 Long-Range Electric Power Development Program

(1) Concept of Reserve Capacity

The criteria of STEG regarding reserve supply capacity are the following:

(a) Assumption of simultaneous outage of unit of maximum capacity (150 MW) + unit

Fig. 1-1 MAXIMUM DEMAND & INSTALLED CAPACITY (AVAILABLE)



of second largest capacity (30 MW) + unit of third largest capacity (22 MW) or a total of 202 MW.

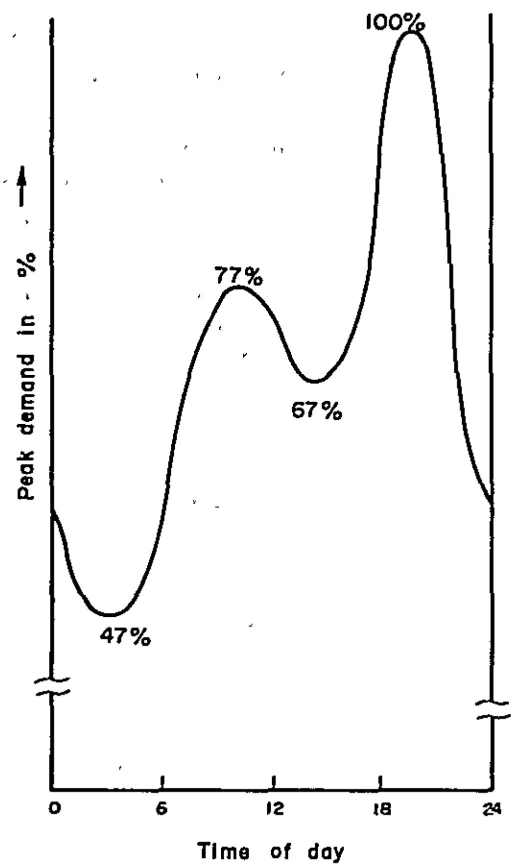
(b) 20% of peak demand

Of (a) and (b) above, whichever is larger is taken as the reserve capacity. Applying this concept, reserve capacity of 202 MW according to (a) would be necessary between 1980 and 1987, while (b) would be applicable thereafter. In order to examine whether this reserve would be reasonable, calculations were made of the probability of supply failure occurring assuming outages of thermal units at an appropriate rate. As a result, the probability of power failure was estimated at 0.0185 (6.7 days annually) and it was found this was fairly bad compared with the value generally targeted in electric power enterprises. However, providing reserve capacity beyond this level will pose an economic problem, and therefore, it was decided to adopt the criteria of STEG.

(2) Daily Load Curve

Regarding the daily load curve, the one provided by STEG estimated from that of the present system was adopted, and it was assumed that the form of this load curve would show almost no variation for the period studied. The shape of this daily load curve is as shown in Fig. 1-2.

Figl-2 Daily Load Curve



(3) Idling and Retirement Plan for Existing Power Stations

An idling and retirement plan was formulated assuming that the service lives of existing steam thermal power stations to be 22 years and that existing gas turbine stations would be retired in 11 years judging from the present state of the facilities.

(4) Formulation of Supply Capability Plan (Long-Range Development Scheme)

The development program of STEG up to Sidi Salem Hydroelectric Power Station scheduled to be commissioned in 1982 has already been decided according to the current five-year plan. Consequently, the period studied by the Survey Mission was that after Sidi Salem. The result of the study may be outlined as follows:

- It will be necessary for new supply capability to be added in 1983.
  The nature of this supply capability, as indicated in the study of Item 1.1.5(1), would be that of base power, and it was considered that a steam thermal should be newly provided.
  "X" Thermal Power Station: 150 MW
- New supply capabilities are to be added further in 1985 and 1986.
  At this point, peaking power will become necessary, and this is where Kasseb Pumped Storage Power Station would be introduced. Determination of unit capacities for this power station is as described in Item 1.1.5(2).
  Kasseb Pumped Storage Power Station, First Stage: 75 MW x 2
  The timing of start-up would be made 1 unit in 1985 and another in 1986 from the viewpoint of balance of demand and supply, but taking into account economy in construction work, in reality it will be advantageous to install the No. 2 unit 6 months after the No. 1 unit, and in this case, both units will be scheduled for start of operation in 1985. The work schedule and construction cost by year have been calculated based on start-up of two units in 1985.
- A new base supply capability will be necessary at the end of 1986.
  "Y" Thermal Power Station: 150 MW
- Peak supply capabilities will again be needed in 1987 and 1988.
  Kasseb Pumped Storage Power Station, Second Stage: 100 MW x 2
- Introduction of a base supply capability will need to be planned for 1989.
  "Z" Thermal Power Station: 150 MW

The manner in which these new supply capabilities are to be introduced is as indicated in Fig. 1-1 cited previously.

1.1.4 Power Demand and Supply Balance

The forecast of increase in demand and the manner in which the required supply capabilities are to be introduced are as shown in Fig. 1-1, while curve A in Fig. 1-3 indicates the actual ratios of supply capabilities to power demand in each of the years.

Further, Fig. 1-3 also indicates the ratios of base and peak supply capabilities to maximum demand, and it can be seen that base and peak capabilities are more or less secured at all points of time matching the load curve of STEG.

(Note) Appropriate ranges of base and peak supply capability ratios demanded by daily load curve of STEG (Fig. 1-2).

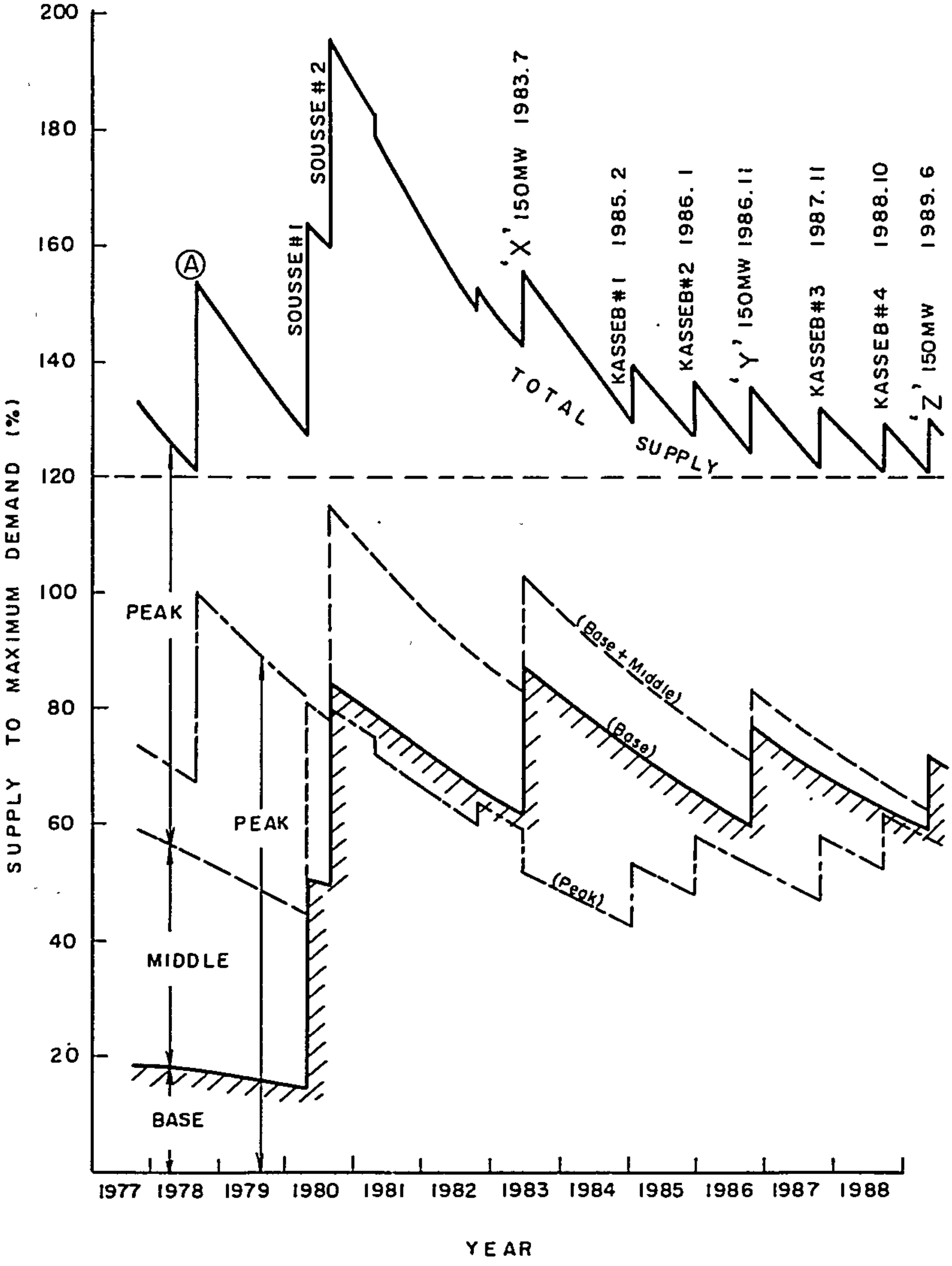
Base supply capability .... Max. 80%, min. 60%
Peak supply capability .... Max. 60%, min. 40%

1.1.5 Items of Study in Power Development Scheme

(1) Nature of Base Supply Capability to be Introduced in 1983

As a result of the studies indicated below, it was concluded that 150 MW of steam thermal should be introduced in 1983.

Fig. 1-3 RATIO OF BASE, MIDDLE & PEAK SUPPLY CAPABILITY



(a) The ratio of base supply capability possessed by STEG at this point is too low.

(b) As base supply capability, steam thermal is of much higher efficiency than gas turbine.

(c) Although a special type of alternative is conceivable wherein a group of gas turbines is newly installed in 1983 and used for base power operation at the beginning, and after a steam thermal is newly built in 1985, the group of gas turbines is diverted to its proper role of a peak load supply capability (in which case Kasseb Pumped Storage Power Station will not be constructed), but as a result of examining the economics of this alternative, it was found not to be advantageous in comparison with the regular proposal described in Item 1.1.3.(4).

(d) In case realization of a pumped storage power station is planned for a later year, it will be necessary for a high-efficiency steam thermal power station to be constructed in advance from the aspect of supplying power for pump-up.

(2) Unit Capacity of Kasseb Pumped Storage Power Station to be Introduced in 1985

As a result of examining the unit capacity of Kasseb Pumped Storage Power Station under the condition that system frequency variation produced when there is sudden increase in load at the time of starting pump-up is to be held within ±0.5 Hz, it was confirmed that 75 MW would be allowable in 1985.

1.1.6 Kasseb Pumped Storage Power Project
(Planned as a daily-circulated type pumped storage power station)

(1) Power Station Output

From the viewpoint of economy, it is preferable to make the output as large as possible, but depending on following two reasons the installed capacity of the power station was decided at 350 MW.

- With regard to the scheduled upper reservoir, the site of the dam is naturally fixed, while it will be topographically unavoidable for high water level to be set within a certain limit (EL 430 m), and therefore, the effective storage capacity will be limited to around 4.5×10^6 m^3.
- The duration time of supply for peak load required of Kasseb Pumped Storage Power Station, as stated in (4) below, is thought to be about 3.3 hours, but considering some allowance, this was set at 4 hours.

(2) Effective Head

The effective head was planned as indicated below.

Water Level	Upper Reservoir	Lower Reservoir
High water level	EL 430 m	EL 290 m
Low water level	EL 410 m	EL 280 m

Gross head	
Maximum gross head:	150 m
Minimum gross head:	120 m
Normal gross head:	135 m

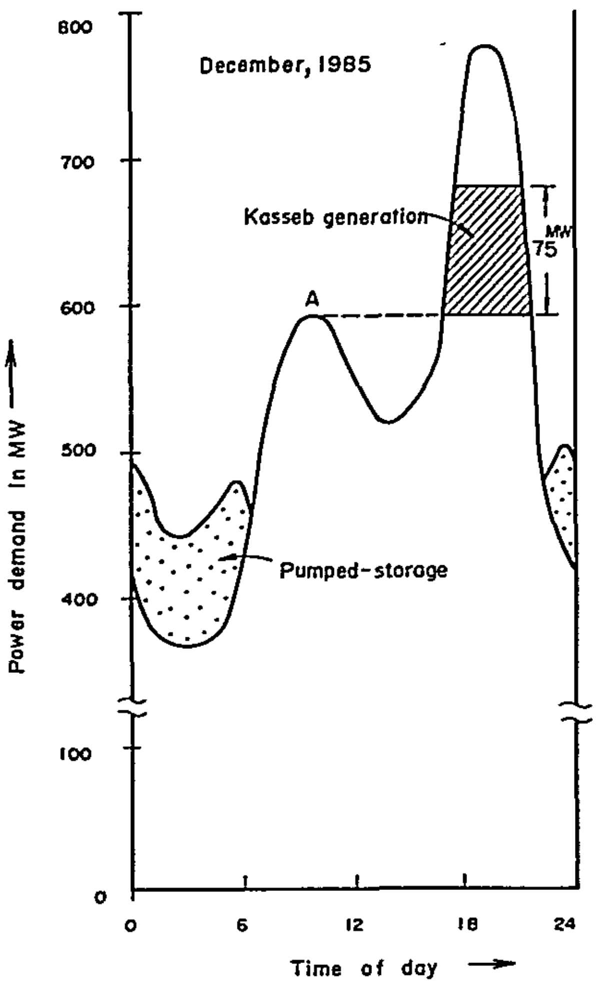
As the standard effective head, 129 m was calculated.

(3) Development in Stages

Since it will not be necessary for a peak supply capability of 350 MW to be available at one time, a two-stage plan was formulated where development of the total installed capacity of 350 MW would be divided into two stages, with 75 MW x 2 units commissioned in 1985 under the first stage project, and 100 MW x 2 units commissioned approximately 2 years after the first stage.

(4) Form of Operation Anticipated

Although it is difficult to anticipate a given form of operation for a pumped storage power station since actual operations are generally of varying types, it was assumed for the purposes of this study report that operation of Kasseb Pumped Storage Power Station would be for peaking power as indicated in the figure below. In effect, it was considered that power generation would be performed limited to lighting-time peak hours and supply would be made as a rule with the full installed capacity for peak load above point A.



The pumped storage energy generation for each year was calculated with the above as a basis. The power and electric energy required for pump-up were also checked and it was determined there would be no shortage in any of the years. Under this form of operation, the peak duration time when Kasseb Power Station is completed will be 3.3 hours.

1.1.7 Economic Analysis of Kasseb Pumped Storage Power Project

(1) Benefit-Cost Ratio and Economic Internal Rate of Return

If the Kasseb Pumped Storage Power Project were not to be implemented as a peak power supply capability, it will be necessary for gas tubrine power stations to be constructed in its stead. Therefore, a gas turbine project was considered as the benefit of Kasseb Project, and an economic comparison was made for the entire service life (50 years) of Kasseb Power Station in terms of the total present worth costs of the two projects. As a result, the benefit-cost ratio B/C, was, found to be 1.29 in case of a discount rate of 6%, 1.06 in case of a discount rate of 10%, and 0.96 in case of a discount rate of 12%, and the economic internal rate of return (equilibrium point between benefit and cost) was calculated as 11.8%. In this respect, since the social rate of discount to be applied in evaluating the economics of a project in Tunisia is put as 10% per annum, in the relation with the economic internal rate of return, the Kasseb Project may be said to have ample economic superiority (see Table 1-1).

(2) National Economic Effect

The economic analysis of the Project will not be adequate unless examinations are made not only from the aspect of benefit-cost ratio, but also from the aspect of the influence of the Project on the national economy as a whole. In this case, the ratio of the domestic currency requirement in the construction funds for the Kasseb Project is estimated to be large (approximately 44%), part of which will become savings of local contractors, materials suppliers and others, and this will have a large effect on the national economy along with the net profit of STEG to be obtained from sales of electricity of the Kasseb Project through the immense reinvestment. This secondarily induced effect is computed in this present study report by a certain technique according to which the aggregate national consumption brought about in the case of a discount rate of 10% converted to present worth is estimated at approximately 14,590,000 Dinars which corresponds to about 32% of the present worth of the total cost of the Kasseb Project. In contrast, in case of the alternative gas turbine project, the foreign currency portion is extremely large (approximately 90%) so that the greater part of the funds will only flow out to foreign countries, and almost no propagation effect as described above can be looked forward to. As described above, when seen from the standpoint of effect on the national economy, the Kasseb Project will bring about an incomparably greater effect than the gas turbine project.

(3) Other Economic Effects

In addition to the above, as will be described later in Item 1.2.1, and Item 1.2.2, the Kasseb Project, when compared with the alternative gas turbine project, will have various merits in the aspect of operating equipment such as rapidity of starting, and moreover, will be highly effective in improving the equipment load factor of the offshore natural gas pipeline to be constructed at great expense.

Table 1-1 Resumen of Economic Evaluation of Kasseb Project

Item	Gas-turbine Plan (B)	Kasseb Plan (C)
Installed capacity	380 MW	350 MW
Year to be put into service and output	82 MW 1985.2 " 1985.8 108 MW 1987.11 " 1988.5	75 MW 1985.2 " 1985.8 100 MW 1987.11 " 1988.5
Construction cost of power station	38,000,000 Dinars	44,966,000 Dinars
Related transmission and transforming facilities	Substation 103 MVA 1985.2 " 1985.8 135 MVA 1987.11 " 1988.5	Transmission line Kasseb~M'Nihla 1985.2 Kasseb~Tajerouine 1987.11
Construction cost of related transmission and transforming facilities	5,260,000 Dinars	3,510,000 Dinars
Total construction cost including administration cost etc.	47,500,000 Dinars	54,823,000 Dinars
Operation and maintenance cost	1,101,000 Dinars/year	567,000 Dinars/year
Unit fuel cost	32.5 Dinars/TEP	22.5 Dinars/TEP
Fuel cost per kWh	10.2 Dinars/kWh	5.2 Dinars/kWh
Annual fuel cost	3,653,000 Dinars/year	2,699,000 Dinars/year
Equipment replacement cost	Gas turbine 15 years Substation 30 years	Civil facilities 50 years Electrical equipment 30 years
Total cost during service live (50 years)	405,434,000 Dinars	218,578,000 Dinars
Present worth of total cost at discount rate of 10%	48,462,000 Dinars	45,723,000 Dinars

B/C=1.06

1.1.8 Preliminary Design of Kasseb Pumped Storage Power Station

The power station is designed as a daily pump-up power station using the existing Kasseb Dam to form the lower reservoir, and pumping up to a basin spread out in the mountainland near the left bank of the lower reservoir, utilizing this basin as the upper reservoir.

However, the real design would of course be the task of the next survey team for the feasibility study to follow, and here, a rough preliminary design will be provided mainly in relation to power station equipment which differ greatly from the report of a past study by TECSULT International to calculate the construction cost. The principal specifications of the power station are as follows:

Name of river:	Kasseb
Max. available water:	321.4 m^3/sec
Gross head	
Maximum:	150 m
Minimum:	120 m
Normal:	135 m
Power station capacity	
First stage:	75 MW x 2 units
Second stage:	100 MW x 2 units
Upper reservoir	
High water level:	EL. 430.00 m
Low water level:	EL. 410.00 m
Available drawdown:	20.00 m
Impoundment area:	1.3 km^2
Total storage capacity:	5.1×10^6 m^3
Effective storage capacity:	4.5×10^6 m^3
Lower reservoir (existing Kasseb Dam)	
High water level:	EL. 290.00 m
Low water level:	EL. 280.00 m
Available drawdown:	10.00 m
Effective storage capacity:	34×10^6 m^3
Headrace tunnels	Circular section, pressure type
Inside diameter x Length:	5.8 mϕ x 1,110 m (No. 1 & No. 2 Gen)
	6.7 mϕ x 1,270 m (No. 3 & No. 4 Gen)
Surge tank	
Main chamber	
Inside diameter:	8.00 mϕ
Height:	81.00 m
Water chamber:	7.0 mϕ x 50 m
Penstocks:	850 m (No. 1 & No. 2 Gen)
	770 m (No. 3 & No. 4 Gen)
Main generating equipment	
Pump-turbine:	Francis, single-stage, reversible pump-turbine
Number of units:	2 units (No. 1 & No. 2)
	2 units (No. 3 & No. 4)
Output (turbine):	77,400 kW, 103,400 kW (No. 3 & No. 4)
(pump):	83,000 kW, 111,000 kW (No. 3 & No. 4)
Speed:	214 rpm, 188 rpm (No. 3 & No. 4)

Generator-moter	3-phase, AC, synchronous generator-motor
Number of units:	2 units (No. 1 & No. 2)
	2 units (No. 3 & No. 4)
Output:	84,700 kVA, 113,300 kVA (No. 3 & No. 4)
Voltage:	13,200 volt
Frequency:	50 Hz
Main transformer:	3-phase, FOA, outdoor type, with on load tap changer
Number of units:	2 units (No. 1 & No. 2)
	2 units (No. 3 & No. 4)
Capacity:	84,700 kVA, 113,300 kVA (No. 3, & No. 4)
Voltage:	225 kV/13.2 kV
Frequency:	50 Hz
Connection:	$\lambda - \Delta$

1.1.9 Power System Analysis

Chiefly in order to select the method of transmitting power generated at Kasseb Pumped Storage Power Station, system analyses were made of the three sections of 1985, 1986 and 1989, and power flow distributions, power losses, reactive power equipment requirements and voltages at various stations were examined. The results are as indicated below.

- The following two alternatives are conceivable as methods of power transmission from Kasseb Power Station:

  Alternative A: Lead out 1 circuit each from Kasseb to M'Nihla and Tajerouine
  Alternative B: Connect 2 circuits from Kasseb to M'Nihla

  Of the two, Alternative A is more advantageous in every respect such as power loss, stability, reactive power equipment, and this transmission method should be adopted.

- Regarding the locations for the 150-MW "X" and "Y" thermal stations, the following two alternatives were studied:

  Alternative 1: Concentration at Sousse
  Alternative 2: Installation in vicinity of Tunis

  Although there is not very much difference between the two, Alternative 2 is more advantageous by about 5 MW in terms of power loss and 50 MVA in terms of reactive power equipment requirements, and it may be said to be desirable for the future 150-MW thermal units of "X" and "Y" to be installed in the vicinity of Tunis from the standpoint of system configuration. However, locating of these thermal plants should be studied comprehensively, not only from the aspect of system configuration, but also with reagrd to the situation in availability of construction sites and the relation with pipeline facilities for natural gas which will be the fuel, and a separate detailed examination will be necessary. Finding a solution to this problem is considered to be outside the scope of our study this time.

1.2 RECOMMENDATIONS

1.2.1 Necessity for Kasseb Pumped Storage Power Project

(1) Necessity as Seen From Aspect of Power System Operation

As previously described, the technical and economic feasibilities of the Kasseb Pumped Storage Power Project have been verified. Moreover, the following merits of pumped storage power generation in operation should also be considered. In effect, to meet the greater part of power demand by means of thermal power generation facilities would involve considerable restrictions in freedom and dependability of power system operation, and these should be relieved through realization of the Kasseb Pumped Storage Power Project.

i) Pumped storage power generation is extremely effective as hot reserve for maintaining supply during faults or when there are abrupt changes in demand since starting and output increase are rapid.

ii) Operation following load variations is easy.

iii) Alleviation in frequent start-up and stopping of gas turbines and middle thermal are possible leading to reductions in start-up losses and start-up faults.

iv) Receiving power for pump-up from base thermal stations makes possible high-efficiency operation of the base thermal stations.

v) It is possible to play a role as a reactive power supply facility to maintain system voltage.

(2) Relation with Natural Gas Development Project

It is thought that the Kasseb Pumped Storage Power Project will have an extremely desirable effect on the offshore natural gas development project presently planned as the greatest national project of Tunisia.

It may be considered that the feasibility of a natural gas project will depend to a great extent on whether a large-scale and permanent demand for the gas will quickly appear, and in this sense, the method of supplying gas to base thermal power stations which are the largest consumers of gas should be established at the earliest, while efforts should be made to improve the load factor.

Note: It is estimated that of the initial annual production goal of 1.5 billion m^3 of the natural gas development project, 1 billion m^3 will be used by three 150-MW steam thermal plants which STEG will possess by 1983.

Development of a pumped storage power station will improve the load factors of these base thermal stations and will have the effect of lowering the unit cost of the fuel gas supplied.

Also, since supply of gas for pump-up power is made during the midnight when loads of base thermal stations are light, and supply of pump-up power will be done within the range of installed capacities of these thermal stations, there will be no accompanying increases in gas supply facilities necessitated.

On the other hand, it will generally not be advantageous to use the gas for small-capacity gas turbine power stations for peaking power which are provided at a number of locations. The reasons for this are as follows:

- Long, branch pipeline facilities to numerous small-capacity stations will be required, which is not economical.

- Gas turbines for peaking power will be operated only several hours daily and the utilization factors of the above-mentioned pipeline facilities will be low.

- To have a large difference in peak and off-peak gas consumption will require the long offshore trunk pipeline facilities to be designed for the quantity of gas pumped at peak hours, and this will cause a large economic demerit.

The disadvantages of gas turbine are as mentioned above, and if a group of gas turbine stations were to be constructed as an alternative to Kasseb Pumped Storage Power Station and gas were to be used as fuel, numerous adverse conditions would be forced on the natural gas project, and in this respect also it is considered more advantageous to proceed with the Kasseb Pumped Storage Project.

1.2.2 Proposal on Available Drawdown of Existing Kasseb Reservoir

The existing Kasseb Reservoir which will comprise the lower reservoir for the pumped storage power station is presently being operated with its main purpose the supply of drinking water to Tunis and the available darwdown is said to be 22 m from high water level of 290 m to low water level of 268 m. The Mission, in planning this reservoir as the lower reservoir for the pumped storage power station, made a study on whether some amount of restriction could be placed on the available drawdown from the standpoint of power station construction.

As a result of the study, it was considered possible for the reasons given below to hold low water level at EL 280 m, in effect, restrict available drawdown between high and low water levels to 10 m, and the preliminary design for Kasseb Pumped Storage Power Station was made on this basis.

- Ever since construction except for the initial year of water impoundment, Kasseb Reservoir has always been operated at high water range, and there is no record of the water level having fallen below EL 280 m.

- Assuming that 1.20 $m^3/$ sec, the limit of capacity of the water main, would be supplied to Tunis as municipal water, the water level variation was calculated from the inflow records of six years in the past (1970–1975), and it was found there would be no objectionable points in operation of the existing Kasseb Reservoir with the regulating capacity in this range even in dry years.

- In 1982, the large-capacity Sidi Salem Dam (effective storage capacity 900 x 10^6 m^3) will be completed on the mainstream of the Oued Medjerda and the impounded water will be utilized for irrigation, power generation and drinking water. It should be permissible to anticipate that the importance of Kasseb Reservoir in supplying city water will be lessened as a result.

Meanwhile, such restriction of available drawdown will bring about the following benefits to the Kasseb Pumped Storage Power Project.

— It will not be necessary to make the powerhouse an underground type and an access tunnel to the powerhouse will not be required.

— Construction of a tailrace will be made easy.

— It will not be necessary to greatly lower the water level of Kasseb Reservoir for construction of the powerhouse and the work will be much easier.

— The problem of the impounded water of Kasseb Reservoir being agitated by pump-up and discharge will be alleviated.

As described above, the Survey Mission proceeded with the preliminary design setting the low water level of Kasseb Reservoir at EL 280 m, but essentially, this is a matter which must be decided on discussion between the Tunis Municipal Water Bureau, the operator and administrator of Kasseb Reservoir, and STEG, and it is necessary for a separate detailed study to be made.

However, when considering how this proposition will lower the construction cost of the Kasseb Pumped Storage Power Project and make construction easy, it is hoped that this proposal will be pushed ahead insofar as possible.

1.2.3 Timing of Construction of 150-MW Steam Unit "X"

The first-stage work of the Kasseb Pumped Storage Power Project will be completed in 1985, and seen from the size of the demand forecast, the power required for pump-up will be lacking at this time unless three 150-MW units of base thermal are operated. Meanwhile, from the balance of power demand and supply, a 150-MW steam thermal unit will become necessary in July 1983 as a new supply capability.

When the supply reliability of the electric power system, power loss, increase in reactive power facilities for voltage regulation are considered, it will be desirable for the 150-MW "X" thermal unit to be constructed in the vicinity of Tunis. When the construction period required for a steam thermal power station is considered, it will be necessary to decide on the construction site by the end of 1978 and start preparatory work requried in case of a new location in the Tunis District. When it is difficult to secure such a loation, or in consideration of the relation with the natural gas pipeline, it will be possible for additional installation at the Sousse Thermal Power Station site. In any event, the location of the 150-MW "X" thermal unit should be decided at an early date, and equipment must be ordered by the middle of 1980.

1.2.4 Kasseb Pumped Storage Power Project and Necessity for Next Survey

The purpose of this long-range electric power scheme is to establish a general outlook technically and economically whether the Kasseb Pumped Storage Power Project can emerge on the scene as a feasible project. The Survey Mission made examinations based on the preliminary study report submitted previously by the TECSULT International Ltd., and changed the scale of power generation and revised items such as the construction cost. However, since the present study was not made upon detailed field reconnaissances, the following items must be clarified through investigations to be made hereafter.

i) Design of upper reservoir dam at the feasibility level.

ii) Design of intakes, waterways, surge tank, powerhouse and outlet at the feasibility level.

iii) Confirmation of geology.

iv) Selection of turbine center heights at the powerhouse and confirmation of conditions for operation of lower reservoir.

v) Determination of work quantities and unit prices.

vi) Establishment of parameters for socio-economic analyses.

As indicated above, in order for the Kasseb Pumped Storage Project to be realized it is necessary for the economics to be confirmed after carrying out analyses in higher precision, and for the feasibility of the Project to be verified through financial analyses. A second study of the Kasseb Pumped Storage Power Project is needed in this way, and in order to complete the first-stage work by February 1985, it will be necessary to finish a feasibility study by the autumn of 1978.

CHAPTER 2

ECONOMIC BACKGROUND

CHAPTER 2 ECONOMIC BACKGROUND

2.1 TERRITORY AND NATURAL CONDITION

The Republic of Tunisia which became independent from France in 1956 is located at the northern coast of Africa with its northern and eastern parts facing the Mediterranean Sea, southeastern part bordering Libya and its western part Algeria. The national territory from 6° to 9° east longitude, and 33° to 38° north latitude covers an area of 167,000 km², while the coast line has a length of 1,200 km.

The national territory may be broadly divided into the Northern Region and Southern Region.

2.1.1 Northern Region

The Northern Region which has large and small rivers such as the Medjerda, Mellegue (upstream stretch of the Medjerda), Bizerte and others running through it may be subdivided into the following three areas. These are the Northwest Area covered largely by cork oak, the Central Area comprising a fertile plain, and the Northeast Area well known for livestock, citruses and horticultural products which spreads from Tunis to Cap Bon.

The important mountain ranges of the Northern Region are the Medjerda Mountain Range, an extension of the Atlas Mountain Range which reaches to Bizerte and the Tebessa Mountain Range to the south, and the largest river of the country, the Oued Medjerda, which has its source in Algeria, crosses the land from west to east and feeds the Mediterranean Sea.

2.1.2 Southern Region

The Southern Region is divided into the Central Plateau Area and the Western Desert Area which is an extension of the Sahara Desert. These areas have scattered oases with date palms and lakes and marshes of high salt content, but these are all dry lakes in the summer.

2.1.3 Temperature and Rainfall

The climate of Tunisia is a sunny Mediterranean type divided into the four seasons of spring, summer, autumn and winter, and every year from May to September is hot and dry, while during the rainy season from October to April of the following year it is temperate. Mean annual temperatures are 18°C at Tunis, Sousse and Sfax, 17°C at Bizerte and 19°C at Gabes.

The average annual rainfall is only about 900 mm in the Northern Region and 200 mm in the Southern Region, and as will be described later, the effective utilization of water is one of the greatest concerns of this country.

2.2 POPULATION AND MAJOR CITIES

2.2.1 Population and Population Growth Rate

According to the results of the national census of May 8, 1975, it is estimated that the total population of the country is 5,577,000. Compared with the figure of 4,533,000 in the census carried out in 1966, the average growth rate would be 2.3%, but when emigration of 180,000 persons during this period is considered, the real growth rate is 2.65%.

As for the number of persons per household, since the total number of households in the 1975 census was 1,009,000, there are 5.5 persons per household.

The future population is one of the basic factors in forecasting electric power demand. According to the outlook established by I.N.S. predicted on future decrease in the birth rate due to family planning, the future population growth rate is forecast to be 2.36% in 1975–1980, 2.24% in 1980–1985, 2.10% in 1985–1990, 1.79% in 1990–1995 and 1.48% in 1995–2000.

2.2.2 Major Cities

The entire country is divided into 18 administrative districts or "Gouvernorats," and although there are 152 municipalities, those which may be cited as particularly important cities are the followings:

Tunis (capital)	Population more than	800,000
Sfax	"	120,000
Sousse	"	75,000
Bizerte	"	60,000
Kairouan	"	50,000

2.3 ENERGY RESOURCES

2.3.1 Water Power Resources

The annual rainfall of the country is an average of 900 mm in the Northern Region and an average of about 200 mm in the Southern Region and cannot be said to be abundant, and many of the rivers and stream are so-called oueds which flow in the rainy season but dry up in the dry season. Topographically, there are very few sites where high heads can be obtained, and the country cannot be said to be favored very much in the way of water power resources.

As existing dam facilities, there are large dams such as Nebeur, Ben Metir, El Aroussia, Kasseb and Bou Heurtma, but the main purposes of these are to supply city water or irrigation water, and the appurtenant power stations, such as Nebeur, Fernana, El Aroussia and Kasseb are no more than small-scale power stations for peak supply with installed capacities of 13,000 kW, 10,200 kW), 4,900 kW and 600 kW, respectively.

The existing hydroelectric power stations are only the five mentioned above. Besides these, there will be Sidi Salem Power Station (installed capacity 36,000 kW, dependable output 20,000 kW) with construction started under the Fifth Economic and Social Development Plan beginning in 1977 and scheduled to be commissioned in 1982, but even including this, the dependable output to cope with peak power demand will be only about 45,000 kW.

For this country which is not favored very much with water power resources, the effective utilization of hydro power is naturally a nationwide requirement, and the conception of the Kasseb Pumped Storage power Project was born with this nationwide demand as the background.

2.3.2 Petroleum Resources

Compared with water resources, petroleum resources are abundant. Since petroleum was discovered in 1964 at El Borma by SITEP established under an agreement between the Government and ENI of Italy, there have been petroleum reserves discovered in succession at El

Doureb, El Couech, Sfax, Asthart (Gabes Bay) and ISIS, and as a result, the amount of crude oil exports since 1969 has overtaken phosphorite and risen to first place.

In this way, the increase in crude oil production in recent years has become a factor in providing a bright outlook for the Tunisian economy which until then had been troubled by large deficits in the balance of payment, but the production quantity itself, after a peak of 4.6 million tons in 1974, has leveled off at more or less 4 million tons. (The performance reported for the Fourth Plan was 4.1 million tons as an annual average for 1973–1976.)

Meanwhile, with regard to petroleum refining, there is Bizerte Oil Refinery of annual refining capacity of one million tons established in 1963 as a joint venture with ENI, where light oils are mainly being produced. The annual average production during the Fourth Plan from 1973 through 1976 was slightly higher than a million tons. Further, in order to cope with the increase in demand for petroleum products, it had been scheduled in the Fourth Plan for an additional refinery to be newly constructed, but construction of this new refinery has been pending due to the effects of changes in international prices of petroleum products and discovery of offshore natural gas at Gabes Bay.

2.3.3 Natural Gas

Along with petroleum, production of natural gas is a large mainpost supporting the Tunisian economy. This production of natural gas was started with completion of an oil pipeline between El Borma and Gabes. In addition, there is a small quantity of natural gas being produced at Cap Bon. The production quantity in 1976 was 212 million Nm^3 at El Borma and 2 million Nm^3 at Cap Bon, a total of 214 million Nm^3.

Of the above 212 million Nm^3 of natural gas production at El Borma, 196 million Nm^3 are consumed by Ghannouch thermal power station and gas turbine power stations, while the remainder of 16 million Nm^3 is consumed by the ICN, ICF, MAP and Al KIMIA chemical plants and brick factories in the Gabes district.

Initially, the capacity of the pipeline from El Borma was 2,970,000 Nm^3/yr (34,000 Nm^3/yr), but in order to cope with the growing demands by gas turbines and chemical industry, compression stations have been additionally constructed to increase the supply capacity from 34,000 Nm^3/hr to 58,000 Nm^3/hr.

Although the reserves of natural gas at El Borma are comparatively small, an extremely large natural gas field estimated to have reserves of 50 to 80 billion cubic meters was discovered offshore at Gabes Bay, and the development of this field is presently being studied. According to the Fifth Economic and Social Development Plan, it is being planned for this natural gas to be supplied to the Gabes, Sfax, Sousse, Tunis and Bizerte districts by laying submarine and overland pipelines to supply fuel for future large-scale thermal power plants and for developing a gas chemical industry. The success of this development plan of offshore natural gas depends on the procurement of required funds, but the Fifth Plan has targeted 1981 to 1982 for starting operation and it is scheduled for annual production to be 1.5 billion Nm^3 initially and 3 billion Nm^3 ultimately.

2.4 NATIONAL ECONOMY

Since the independence in 1956, the Tunisian economy fell into a stagnation until the 1960s just like as in other Maghreb countries due to economic confusions caused by the repatriation of approximately 300,000 European immigrants who had comprised the mainstream of the economy, but in 1961, a Ten-Year Plan for Long-Range Development (1961–1971) was formulated, and as a result of implementation of the 1st and 2nd Economic and Social

Development Plans mainly based on government investments, in contrast to the annual growth in real GNP of 3% in the 1950s, there were fairly large increases which came to be seen in the latter part of the 1960s.

During this period, from around 1963, when exports of primary products such as minerals and agricultural products were stagnant while there were large increases in imports, an imbalance in supply and demand in the form of increased foreign trade deficits and increased rate of inflation was brought about. In order to cope with such a viscious economic cycle, devaluation was carried out in 1964 and a series of credit tightening policies enforced, as a result of which since 1968 the Tunisian economy has been notably improved. It was also about this time that the previously-mentioned petroleum reserves were discovered and developed, and a balanced economy has begun to be brought where acceleration of the economic growth rate is accompanied by improvement in the balance of payment.

The above-mentioned Long-Range Development Plan of 1961 aims for an average annual growth of 6% in real GNP, and the First Plan (1962–1964), the Second Plan (1965–1968) and the Third Plan (1969–1972) were implemented within the framework of this Long-Range Plan, in succession to which the Fourth Plan (1973–1976) with the average annual growth rate in GNP targeted to be 6.6% was implemented. In the Fourth Plan, because of the international economic crisis felt especially in 1976, in effect, the sharp rise in import prices and the difficulties of principal commodities, the shortage in supply of domestic construction materials and shortage of labor of contractors on building and public works projects, the planned goal of 6.6% for GNP was not reached, but even then, while a world-wide recession was going on, a high level of 6% in real growth rate was achieved, and the Fifth Plan was newly implemented from 1977.

2.4.1 GNP Growth Rate and Industrial Structure

The performance in the Fourth Plan with regard to GNP and the targets for the Fifth Plan from 1977 are indicated in the table 2-1.

The present situation in economic activities of the various sectors comprising GNP are the following.

(1) Agriculture

The weight of the agriculture and marine products sector is 21.5% of GNP, second to the tourism and service sector, while approximately 45% of the total population is engaged in this sector. In this sense, it may be said that the agriculture and marine products sector is a nucleus of economic activities of the nation. The principal agricultural products are grains such as wheat and barley, and fruits such as olive, grape, citruses, date and almond. Approximately 40% of these agricultural products become raw materials for the food processing industry and contribute to exports.

(2) Mining, Energy

Tunisia is one of largest phosphate rock producing countries in the world and there are nine mines in the Sfax-Gafsa area. These mines owned by Compagnie des Phosphates et du Chemin de Fer (CPCF) produce approximately 3,800,000 tons annually. Other than the above, approximately 700,000 to 800,000 tons of iron ore are being produced annually by Société de Djebel Djerissa, while there are small quantities of lead, tin and fluorine ore, but the weights of these in GNP are extremely small.

Besides the above, there are more than 4 million tons of crude oil and 250 million Nm^3 of natural gas produced annually, mainly at El Borma, and when these are aggregated, the weight of the mining and energy sector in GNP in 1976 was 6.1%.

(3) Manufacturing Industries

The manufacturing industries make up 11.2% of GNP, of which the most important part is the food processing industry, in which there are 7 large-scale sugar refineries, a number of flour milling and vegetable oil plants, and numerous canned fish factories.

Manufacturing industries other than the above which are of importance are steel, metal and construction materials industries.

Firstly, in the steel manufacturing sector, there is the El Fouladh Steel Complex at Menzel Bourguiba, which is operating at full capacity to produce 180,000 tons of pig iron, 195,000 tons of steel, 110,000 tons of reinforcing steel, 25,000 tons of wire and 8,000 tons of steel structures. In the machinery sector, there are passenger car and truck assembly plants at Tunis, Sousse, etc., while there is a shipyard at Menzel Bourguiba. In the electrical equipment industry, assembly plants for television sets, radios, refrigerators, etc., and small-sized transformer, cable and household electrical appliance factories are engaged in production at various localities.

Next, in the construction materials industry, the most important of the various materials is cement, but with the present production capacity of 600,000 tons of Cimenterie Portland de Bizerte, the sharp increase in demand cannot be kept up with and importation of large quantities has been unavoidable. Therefore, besides doubling the production capacity of the above company, it is planned for Cimenterie de Gabes (700,000 ton/yr) and Cimenterie de l'Ouest (1,000,000 ton/yr) to be newly established during the period of the Fifth Plan.

Although its weight in the GNP is still small, the recent development of the chemical industry in the Gabes-Sfax area is worthy of special note. In essence, the abundant domestic phosphorite and labor force are being utilized to increase added value, and to reduce imports amounting to vast sums, and during the past several years there has been an enormous construction investment made in the Gabes-Sfax area, and phosphate production plants and others have been constructed by ICM (Industries Chimiques Maghrébines) at Gabes and SIAPE, NPK, etc. at Sfax, while besides these, construction plans for a phospate-nitrate fertilizer plant of SEPA (Société des Engrais Phosphates et Azotés) are progressing.

(4) Tourism and Services

Tourism and services comprise one of the most important industrial sectors of Tunisia, and of the total exports in 1976, 22.5% were made up by this sector. There are many modern hotels which have been constructed at Tunis, Sousse and Jerba Island, and these are serving as major foreign currency earners.

2.4.2 Production Targets and Investment Requirements for Fifth Plan

(1) Principal Targets

The principal targets of the Fifth Plan, when compared with the performances of the Fourth Plan which realized GNP/Capita of 222 Dinars (US$517) in the final year (1976), are as indicated below:

(a) By the total investment of 3,500 million Dinars (1976 value) the annual growth rate of 7.5% in real GNP is to be achieved to increase GNP/Capita to 285 Dinars (US$663) in 1981.

(b) A progression of the consumption in public and private sectors is to be held to 6.6% during the Fifth Plan, against 8.3% registered during the Fourth Plan, in order to realize a national saving rate of 23.1% (saving rate during the fourth Plan was 22.5% against GNP for the four-year average).

(c) The export growth rate of 9.5% (both in quantity and amount) is to be planned, against the import growth rate of 5.5% in quantity and 11.5% in amount, in order to held the balance of payment to a deficit of 457 million Dinars in 1981.

(d) With respect to employment, new employment to be achieved in the non-agricultural sector is to be 233,000 persons (157,000 in the Fourth Plan), of which 100,000 are to be for the manufacturing sector (60,000 persons for the Fourth Plan).

(2) Production Goals of Principal Sectors

The production increase goals of the major sectors of the Fifth Plan, compared with the actual figures for the final year (1972) of the Third Plan and the final year (1976) of the Fourth Plan, will be as indicated in Table 2-2. Those points which should be specially noted regarding these production goals are the following:

(a) Production of crude oil is to be increased by 35%, the petroleum refining capability by 3 times, according to which it is to be aimed for increase in added value.

(b) In addition to the production of natural gas at El Borma, there will be 1.5 billion Nm^3 annually of offshore natural gas (ultimate plan of 3 billion Nm^3 annually) amounting to production of 17 billion Nm^3.

(c) Against the average annual growth rate of 10.7% in electric power generation for entire Tunisia including STEG and private power generation from 1970 through 1975, the growth rate during the Fifth plan is to be increased to 13.3% reflecting the vigorous economic activities in various manufacturing industries and other sectors.

(d) In manufacturing industries, particularly construction materials and chemicals, large increase in production capacities is to be planned in order to create a large-scale industrial area in the Gabes-Sfax district.

(3) Investment Required

The total investment amount for the Fifth Plan in terms of 1976 value has been estimated at 3,500 million Dinars. Assuming rises in commodity prices of 6% annually, the funds required in terms of current prices would be approximately 4,200 million Dinars, and further adding increased inventories of stored goods of 8.5 million Dinars, the total will be 4,208.5 million Dinars.

Meanwhile, with average annual growth rate in GNP at 7.5%, by suppressing the rate of increase in the total demand of the public and private sectors at an annual average of 6.6%, it is planned to achieve national savings of 3,012.5 million Dinars during the period of the Fifth Plan. Accordingly, the procurement of the required investment amount is planned to be as follows:

Procurement	Amount
National savings	3,012.5 million Dinars (71.5%)
External finances	1,196.0 million Dinars (28.5%)
Total	4,208.0 million Dinars (100%)

The principal aims of investment under the Fifth Plan are the following:

- Two thirds of funds required are to be invested in productive industries.
- Of the productive industries, special emphasis is to be laid on investment in the manufacturing industries with the aim of increasing employment.

The investment amounts scheduled for the various sectors are as indicated in Table 2-3.

2.4.3 International Balance of Payments

The general situation in the international balance of payments as planned under the Fifth Plan will be as follows:

(a) The balance of trade of goods will be an average annual deficit of 325 million Dinars.

(b) The balance of trade of services, with increased revenues from tourism, is expected to be an average annual surplus of 150 million Dinars.

(c) The balance of transfers will be an average annual deficit of 64 million Dinars.

(d) The overall international balance of payments will be an average annual deficit of 239 million Dinars and the cumulative deficit for the period of the Fifth Plan will be 1,196 million Dinars. This cumulative deficit, as indicated in the preceding item 2.4.2 (3), will be covered by external finances.

Indicating the above balance of payments by year, the results will be as shown in Table 2-4.

Of the service revenues in the above table, the revenues from tourism makes up approximately 65%, while in export of goods, the weights of the various sectors are as indicated below.

Export products	Fourth Plan	Fifth Plan
Agricultural and marine products	4.6%	6.3%
Mining products (mainly phosphorite)	12.1%	10.0%
Petroleum products	37.9%	35.8%
Food products	18.9%	10.3%
Industrial products	20.8%	36.0%
Total	100 %	100 %

Table 2-1 Performance and Predictions in GNP Growth Rate (in 1976 Price)

Item	Fourth Plan (million Dinars)				Fifth Plan (million Dinars)			
	1973	1976	Annual growth rate (%)	Weight (%)	1977	1981	Annual growth rate (%)	Weight (%)
Agriculture and fishery	206.7	272.8	1.6	21.5	260.0	324.3	2.4	17.7
Mining and energy	70.4	77.3	5.2	6.1	88.8	134.2	11.9	7.3
Mining	10.1	12.4	9.9	1.0	13.7	21.9	10.6	1.2
Petroleum	43.1	43.3	1.7	3.4	50.4	75.4	12.3	4.1
Electricity	12.3	14.8	10.2	1.2	17.0	27.1	13.3	1.5
Water supply	4.5	6.8	13.2	0.5	7.7	9.8	8.3	0.5
Manufacturing industries	98.2	142.6	6.9	11.2	160.0	257.3	13.3	14.1
Buildings and public works	63.2	100.0	10.6	7.9	110.0	161.1	10.0	8.8
Transportation and telecommunication	60.9	79.5	9.0	6.3	85.6	115.5	7.8	6.3
Turism	32.2	50.6	4.3	4.0	55.1	73.2	8.0	4.0
Commerce and various services	283.8	365.6	8.9	28.7	382.4	514.0	7.7	28.0
Administrative services	128.2	181.9	10.2	14.3	193.4	253.4	6.8	13.8
GNP (Factor costs)	944.4	1,270.3	6.0	100	1,335.3	1,833.0	7.4	100

Table 2-2 Production Capacity Expansions in Principal Industrial Sectors

Item	Unit	1972	1976	1981	Goals of 5th Plan	
Mining industries					10.6%	
Phosphate rock	1,000 tons	3,387	3,400	7,130		
Iron ore	1,000 tons	884	535	480		
Lead	1,000 tons	32.6	16	18.7		
Tin	1,000 tons	20.5	16.2	27.4		
Fluorine ore	1,000 tons	40.5	38	71.0		
Petroleum industry					12.3%	
Crude oil	1,000 tons	3,977	3,900	5,300		
Natural gas	$10^6 \times Nm^3$	20	214	1,700		
Light oil	1,000 tons	1,043	1,050	3,500		
Electricity					13.3%	
High and middle tensions	GWh	515	745	1,360		
Low tension	GWh	222	377	730		
Total	GWh	737	1,116	2,110		
Manufacturing indust.					13.3%	
Food processing					3%	
Construction mate.					28.7%	
Machinery					16.2%	17.5%
Chemical					27.6%	
Textile and leather					13.8%	
Others					11.9%	

Table 2-3 Investments scheduled for the Fifth Plan

(Million Dinars)

Item	Fourth Plan	Fifth Plan
Agriculture and fishery	201.5	500
Mining	50.0	120.0
Energy:	280.1	710.0
Investigations	(95.4)	(105.0)
Crude oil production	(100.1)	(97.3)
Light oil production	(1.4)	(49.6)
Natural gas product.	(9.7)	(248.1)
Electricity	(73.5)	(210.0)
Water supply	42.4	130.0
Manufacturing industries	283.2	950.0
Buildings and public works	235.7	600.0
Transportation and telecommunication	281.4	600.0
Turism	52.8	80.0
Other services	8.1	60.0
Public facilities	187.8	450.0
Total	1,578.0	4,200.0

Table 2-4. International Balance of Payments under Fifth Plan

(Million Dinars)

Item	1976	1977	1978	1979	1980	1981
Trade of goods						
Export	346	375	410	440	500	560
Import	556	640	714	780	847	931
Balance	– 210	– 265	– 304	– 340	– 347	– 371
Export of services	223	256	283	314	348	387
Import of services	122	139	156	166	181	196
Balance	+ 101	+ 117	+ 127	+ 148	+ 167	+ 191
Transfers						
Incoming	77	82	86	89	92	95
Outgoing	98	120	134	150	168	190
Balance	– 21	– 38	– 48	– 61	– 76	– 95
Total						
Incoming	646	712	779	843	940	1,042
Outgoing	776	899	1,004	1,096	1,196	1,317
Balance	– 130	– 187	– 225	– 253	– 256	– 275

CHAPTER 3

PRESENT STATE OF ELECTRIC POWER INDUSTRY

Table 2-4. International Balance of Payments under Fifth Plan

(Million Dinars)

Item	1976	1977	1978	1979	1980	1981
Trade of goods						
Export	346	375	410	440	500	560
Import	556	640	714	780	847	931
Balance	– 210	– 265	– 304	– 340	– 347	– 371
Export of services	223	256	283	314	348	387
Import of services	122	139	156	166	181	196
Balance	+ 101	+ 117	+ 127	+ 148	+ 167	+ 191
Transfers						
Incoming	77	82	86	89	92	95
Outgoing	98	120	134	150	168	190
Balance	– 21	– 38	– 48	– 61	– 76	– 95
Total						
Incoming	646	712	779	843	940	1,042
Outgoing	776	899	1,004	1,096	1,196	1,317
Balance	– 130	– 187	– 225	– 253	– 256	– 275

CHAPTER 3

PRESENT STATE OF ELECTRIC POWER INDUSTRY

CHAPTER 3
PRESENT STATE OF ELECTRIC POWER INDUSTRY

3.1 ELECTRIC POWER COMPANY

3.1.1 Present State

Electric power supply in Tunisia is being provided from power generation to distribution by Société Tuniseienne de l'Électricité et du Gaz (STEG) which has the entire country as its service area, and there is no other electric power enterprise. The STEG Electric Power System covers the greater part of the service area with 150-kV and 90-kV transmission lines and 30-kV distribution lines except for the southern desert area. The country has a border with Libya to the east but there is no interconnection with the Libyan electric power system. On the other hand, at the western side, it is possible for interconnection by 90-kV transmission lines at two locations with the Algerian electric power system and power interchange is carried out when necessary. The maximum power interchange between the two countries in the past was recorded in 1973 and 1974 when 11 GWh were transmitted in both years.

Other than STEG, oil refining, steel manufacturing and chemical industries have private power generation facilities, the amount of power generated by them estimated to have been 185 GWh in 1976, and compared with the 1,350 GWh power generation performance of STEG, the proportion made up by private power generation is small at 12%.

The electrification rates of Tunisia as a whole are presently 65% for urban areas and 23% for agricultural areas (rural communities), but if the Fifth Five-Year Plan from 1977 through 1981 is accomplished as targeted, these will be increased to 85% and 56% (rural communities), respectively. As a result, the electrification rate for the entire country will be increased from the 45% in 1976 to 60% in 1981. Approximately 60% of the electric power consumption of Tunisia is in Northern Tunisia centered around the capital of Tunis and the greater part of the remainder is consumed in the Mediterranean coast area from Sousse and south.

The per capita electric power consumption of Tunisia compared with other countries is as shown below.

	Per Capita Consumption (kWh)	Per Capita GNP (US$)
Sweden	9,206	6,150
Germany, Fed. Rep.	5,023	5,461
Japan	4,201	3,559
France	3,436	4,486
Italy	2,658	2,442
Spain	2,302	1,605
Brazil	676	–
Tunisia	198	363
Morocco	164	290
Algeria	161	425

Remarks: These consumption figures are for 1974 while per capita GNP are at 1968 prices.
Source: United Nations Statistics Yearbook, 1975.

3.1.2 STEG Activities and Organization

STEG is a government agency established in April 1962 with the purpose of supplying electricity and gas to consumers with all of Tunisia as its territory. Accordingly, the activities of STEG as an electric power enterprise range from construction, maintenance and operation of power generation facilities, transmitting, transforming and distributing facilities to supply electric power to customers. On the other hand, as a gas enterprise, STEG is responsible for production of city gas and supply of natural gas to industrial consumers. The production scales of city gas and natural gas are as shown in Table 3-1, and it is expected that the proportion of the gas enterprise will be greatly increased from 1981 when production of natural gas offshore of Gabes Bay is commenced.

Table 3-1 Gas Demand in 1975

	Consumption (10^6 m^3)	Remarks
City gas	20.2	4,500 kcal/m^3
Natural gas		
Cap Bon	2.3	11,000 kcal/m^3
El Borma	208.2 1/	11,000 kcal/m^3
Total	230.7	

Note 1/: Approximately 90% of the natural gas produced in El Borma was consumed as a fuel of generation.

The number of gas customers in 1975 was 27,000, small in comparison with the 416,000 customers for electricity.

The organization of STEG, as shown in Fig. 3-1, is that of an Administration Council at the top which serves as a deliberative body on activities management and development plnas. The Council is comprised of seven members, two of whom are from outside STEG. The headquarters of STEG, General Direction, has nine departments and bureaus under the President, and under these there are local offices dividing all of Tunisia into 13 service areas.

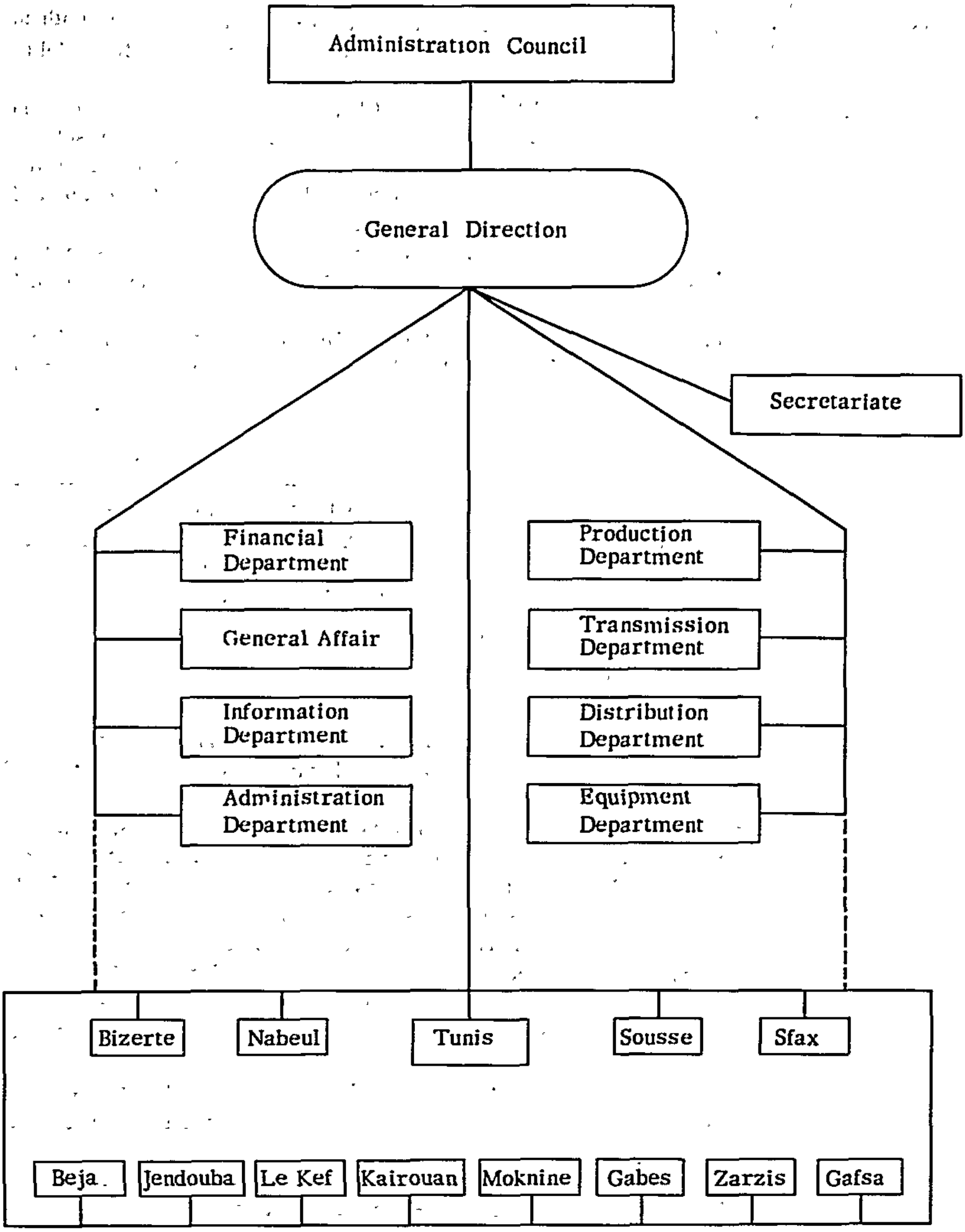
Maintenance and operation of electric power facilities are administered from the departments and bureaus directly under General Direction, and the maintenance and operation structures of power stations and substations are based on 3 shifts. At the El Borma natural gas and petroleum extraction site south of Gabes, there are 85 STEG employees and 250 Sté Tuniso-Italienne de Raffinage (STIR) employees working.

The total number of employees of STEG, including the 85 mentioned above is 4,100, the breakdown of which is 451 administrative personnel, 2,189 general personnel and 1,460 field personnel.

3.1.3 Present State of STEG and Five-Year Plan (1977—1981)

Since STEG was founded in April 1962, it invested a total of 290 million Dinars for power generation, transmission, substation and distribution facilities, as a result of which the number of customers has been tripled from the time of establishment of STEG, while the electrification rate has reached a national average of 45%. The installed power generation capacity as of the end of 1976 was a total of 380.0 MW (thermal power generation facilities 360.0 MW, hydro 20.0 MW), the transmission line facilities were 741 km of 150-kV and 442 km of 90-kV lines, and 15 substations of 90 kV or higher with total installed capacity of 685 MVA.

Fig. 3-1. STEC's Organization Chart



With the exception of the southern desert area of Tunisia, the electric power load areas are covered by the above transmission and substation facilities, and when the 338-km, 225-kV transmission line of Bouchemma-Oueslatia-Nassen to be completed in July 1977 and the 317-km, 225-kV line of Tajerouine-Oueslatia-Sousse-Nassen to be completed during 1978 are both in commission, the load area would be covered in grid-form and the electric power supply reliability will be greatly improved.

The power-generation recorded in 1976 was 1,350 GWh (excluding station service power) and energy sales amounted to 1,146 GWh. Of the energy sales, the electric energy sold to low-voltage customers of 400 volts and under made up a proportion of 35% of the whole. Of the low-voltage electric energy sales, 63% was for general residential use, 12% was for commercial use, and the remaining 25% was for irrigation pumps and other uses.

The number of low-voltage customers in 1976 was 454,000 and the energy consumption per customer was 881 kWh/year, whereas the consumption of high-voltage customers was 324 thousand kWh/year.

STEG has scheduled investments totalling 212 million Dinars for electric power facilities during the period of the Fifth Five-Year Plan (1977–1981). The brakdown of the investment amount is as indicated below.

Unit: 10^6 Dinars

Power Generation Facilities	Transmission & Sub-station Facilities	Distribution Facilities	Other	Total
78.5 (182.6)	32.7 (76.0)	80.5 (187.2)	20.7 (48.2)	212.0 (484.0)

Note: Figures in ( ) are US$$10^6$
Source: STEG 5-Year Plan

As funds for the above, STEG has scheduled 79.0 million Dinars in foreign loans, 46.0 million Dinars to be procured domestically and 87.0 million Dinars of its own funds, a total of 212.0 million Dinars.

Of the investment amount of 78.5 million Dinars for power generation facilities, 60 million Dinars are construction funds for Sousse Thermal Power Station (300 MW), while 25.5 million Dinars out of the 32.7 million Dinars for transmission and substation facilities are for 225-kV transmission lines between Nassen and M'Nihla, Sousse and Nassen, and Sousse and Ouestlatia, 150-kV transmission lines between M'Nihla and Tunis Nord, and Sousse and M'Saken, and a 90-kV transmission line between Sidi Salem and Oued Zarga. Of the 80.5 million Dinars to be invested for distribution line facilities, approximately 30.0 million Dinars will be for construction of 5,300 km of 30-kV distribution lines, a total of 99.6 kVA of distribution transformers, and 3,300 km of 400-V low-voltage distribution lines for rural electrification.

Beside the above investments for electric power facilities, 20.7 million Dinars have been allocated for purchasing of load dispatching facilities, data processing apparatus, vehicles, and materials.

STEG revised its electricity rates in April 1975, and to implement the electric power facilities expansion plan scheduled in the Fifth Five-Year Plan and to maintain a fair return of 10% at the rate base, it is scheduled for raises averaging 20% in 1977 and 8% in 1979 to be made. This shows that the fuel cost of the gas turbine plants of a total of 154 MW to be started up in 1977 will be higher when compared with the fuel costs of existing thermla power stations, and the average fuel cost of 3.4 millmes/kWh in 1976 will be roughly doubled to 6.7 millimes/kWh in 1978, and compared with the Fourth Four-Year Plan, the Fifth Five-Year Plan will show a doubling of the investment, so that securing of STEG's own funds will be a reason for increasing rates.

The outline of the current electricity rate schedules decided in 1975 is as described below.

(1) Low-Voltage Tariff (Applied to 400 V and under)

Farm work:	17 millimes/kWh (supply cut at lighting time)
	7 millimes/kWh (midnight hourband)
Water heater:	12 millimes/kWh (supply cut at lighting time)
Residential:	45 millimes/kWh (1st step rate)
	35 millimes/kWh (2nd step rate)
Electric motor:	40 millimes/kWh (1st step rate)
	28 millimes/kWh (2nd step rate)

(2) Medium-Voltage Tariff (30 kV or 10 kV receiving)

a) Hourband rate:	15.0 Dinars/month (subscription charge)
kW rate:	1.5 Dinars/month (demand charge)
Meter rate:	11.3 millimes/kWh (daytime)
	18.4 millimes/kWh (lighting time)
	4.1 millimes/kWh (midnight)
b) Stepped rate	
1st step:	20.4 millimes/kWh
2nd step:	15.3 millimes/kWh

(3) High-Voltage Tariff (90 kV and higher)

kW rate:	6.0 Dinars/kW-yr
Meter rate:	11.3 millimes/kWh (daytime)
	18.4 millimes/kWh (lighting time)
	4.1 millimes/kWh (midnight)

The above tariff are applied to customers with receiving facilities of 10 MVA or more.

3.2 PRESENT STATE OF POWER GENERATION, TRANSMISSION AND SUBSTATION FACILITIES

3.2.1 Power Generation Facilities

The total effective installed capacity for power generation of the STEG Electric Power System as of the end of March 1977 was 380.0 MW. The proportions of hydro and thermal are as given below while the breakdown by power station is indicated in Table 3-2.

	Generating End Effective Installed Capacity[1/] (MW)	Proportion (%)
Hydro	20.0	5.3
Thermal		
Steam	183.0	48.1
Gas turbine	165.0	43.4
Diesel	12.0	3.2
Total	380.0	100.0

Note 1/: Excluding station service power.

As can be seen in the table above, the proportions made up by type of power source are hydro 5.3%, steam thermal 48.1%, gas turbine 43.4% and diesel 3.2%, and 94.7% is thermal. The feature of the STEG Electric Power System is that the weight of therml power generation facilities is extremely large with the weight of gas turbine being very large at the same time. Of the gas turbine facilities, 73% are for base load operation using as fuel the abundant and cheap[1/] natural gas obtained as a by-product when extracting petroleum.

(1) Hydroelectric Power Station

The Medjerda River, with its fountainhead in Algeria in the Atlas Mountain Range which runs from west to east in the northern part of North Africa, flows through the northern part of Tunisia from west to east to give the country precious water resources. A fertile agricultural area spreads out along this river, the river supplies potable water to the capital of Tunis, and existing hydroelectric power stations are located on tributaries of the river and are generating electric power.

Sidi Salem Hydroelectric Power Station (36.0 MW) planned for future development by STEG is to be on the mainstream of the Medjerda River, and a multi-purpose dam for irrigation, potable water supply and power generation will be constructed. In this way, the Medjerda River is the only river where it is possible for hydroelectric power stations to be constructed.

Precipitation in the Medjerda River catchment area is 1,000 mm annually at Kasseb, 1,200 mm at Fernana, 400 mm at Nebeur located to the south and 470 mm at Tunis, the capital, and these figures are less than the average annual precipitation of 1,800 mm in Japan.

The existing hydroelectric power stations are located at four sites, the total effective generating-end output being 20.0 MW so that the sizes of the individual power stations are small. Since operation of the reservoirs for securing and supplying potable water and irrigation water is main, operation for the purpose of power generation is restricted.

These reservoirs have storage capacities making possible annual regulation with water impounded during the rainy season of December to around April, and irrigation water and potable water is supplied in the dry season. It may be noted that these dams and reservoirs are under the administration of the Ministère de l'Agriculture.

Note 1/: Said to be about one half (18 Dinars/TEP) compared with the fuel cost of a gas turbine using kerosene.

Table 3-2 Installed Capacity of Generating Facility in March 1977

Classification	Name of Power Plants	Installed Cap. (MW)	Effec. Installed Cap. (MW)	Unit Cap. (MW) x No. of Unit	Major Characteristics	Commencement of Operation	Remarks
Hydro	El Aroussia	4.9		4.9 x 1			
	Nebeur	13.0		6.5 x 2	Vertical Francis	1956	
	Fernana I	9.0		9.0 x 1	Horizontal Francis	1958	Upper stream
	Fernana II	1.2		1.2 x 1	Horizontal Francis	1962	Lower stream
	Kasseb	0.7		0.7 x 1	Horizontal Francis	1969	
	(Sub-total)	28.8	20.0				
Thermal (steam)	La Goulette I	40.0	30.0	17.5 x 1 15.0 x 2 10.0 x 1	Heavy oil	1931	
	La Goulette II	110.0	95.0	27.5 x 4	Heavy oil	1965	Additional 2 unit put into service in 1968
	Ghannouch I	60.0	58.0	30.0 x 2	Natural gas	1972	
	(Sub-total)	210.0	183.0				
Gas turbine	Ghannouch II	59.0	59.0	15.0 x 1 22.0 x 2	Natural gas	1971	Additional 2 unit put into service in 1973
	Tunis-Sud	44.0	44.0	22.0 x 2	Oil gas	1975	
	Bouchemma	62.0	62.0	31.0 x 2	Natural gas	1977	
	(Sub-total)	165.0	165.0				
Diesel		12.0	12.0				Various diesel units
	(Total)	415.8	380.0				

Table 3-3 Annual Energy Production without Station Service Demand in 1976

Unit: 10^6 kWh

Month	Hydro Plants					Steam Thermal Plants					Gas Turbines			Diesel	Total
	El Arou-ssia	Ne-beur	Fer-nana I & II	Kasseb	Sub-total	La Gou-lette I	La Gou-lette II	Ghan-nouch I	Sub-total	Ghan-nouch II	Tunis Sud	Bou-chem-ma	Sub-total		
Jan.	0.6	0.3	0.8	–	1.7	4.1	39.6	394	83.1	27.5	2.9	Under construction	30.4	0.1	115.3
Feb.	0.9	0.1	0.8	0.0	1.8	3.1	37.0	36.4	76.1	30.2	2.3		32.5	0.1	110.5
Mar.	1.3	0.5	0.8	0.0	2.6	0.4	37.2	40.0	77.6	29.0	3.6		32.6	0.1	112.9
Apr.	0.7	0.5	0.8	0.1	2.1	–	36.8	38.5	75.3	24.6	4.7		29.3	0.1	106.8
May	1.3	0.6	1.8	0.2	3.9	–	35.7	38.1	73.8	23.2	2.9		26.1	0.1	103.9
Jun.	0.7	1.2	0.9	0.2	3.0	–	41.7	28.5	70.2	26.8	2.4		29.2	0.1	102.5
July	1.4	5.0	1.0	0.2	7.6	–	44.3	33.2	77.5	26.4	1.0		27.4	0.2	112.7
Aug.	0.7	3.6	1.1	0.2	5.6	–	50.7	34.2	84.9	17.6	4.5		22.1	0.2	112.8
Sep.	0.7	3.3	1.1	0.2	5.3	–	47.0	36.7	83.7	18.7	2.2		20.9	0.2	110.1
Oct.	0.9	1.3	1.1	0.1	3.4	–	47.7	38.9	86.6	19.4	2.1		21.5	0.1	111.6
Nov.	1.3	3.2	2.2	0.2	6.9	7.3	42.4	36.7	86.4	17.9	4.1		22.0	0.1	115.4
Dec.	1.7	2.9	4.2	0.1	8.9	8.2	52.8	36.1	97.1	12.1	6.0		18.1	0.2	124.3
Total	12.2	22.5	16.6	1.5	52.8	23.1	512.9	436.3	972.3	273.4	38.7	–	312.1	1.6	1,338.8
Portion (%)	0.9	1.7	1.2	0.1	3.9	1.7	38.3	32.6	72.6	20.4	2.9		23.3	0.1	100.0
Utility factor (%)	28.4	19.8	19.7	24.5	21.4	8.8	56.3	85.9	57.8	54.8	10.5	–	22.4	1.5	39.1

The principal specifications of the reservoirs and power generating facilities are described below.

i) Ben Metir Multi-purpose Dam

This dam was completed in 1958 and is used for potable water supply to the capital city of Tunis (maximum intake 2.0 m^3/sec), irrigation water (maximum intake 6.0 m^3/sec)1/ for the downstream area, and for power generation.

Note 1/: Water used for power generation at the Fernana I (upstream) and II (downstream) power stations is to be first collected at Bou Heurtma Reservoir (storage capacity 117 x10^6 m^3) completed in 1976 and then supplied by an irrigation waterway, and this waterway is presently under construction.

Catchment area:	108 km^2
Av. annual precipitation:	1,200 mm
Av. annual inflow:	1.90 m^3/sec
Reservoir high water level:	EL 440.00 m
Reservoir surface area:	3.50 km^2
Storage capacity:	73.0 x 10^6 m^3
Dam type:	Concrete gravity and rockfill
Dam crest elevation:	EL 441.00 m
Dam crest length:	483.00 m
Headrace tunnel:	3,500 m x 2.8 mϕ
Penstock:	508 m x 2.0 mϕ
Fernana I (upstream)	
Turbine type:	Horizontal Francis turbine
Output:	8,100 kW (at normal head)
Effective head:	152.8 m
Max. discharge:	6.2 m^3/sec.1/
Generator type:	Horizontal, 3-phase AC generator
Capacity:	9,500 kVA
Generator voltage:	5,500 V
Rated current:	998 A
Main transformer type:	3-phase, water-cooled type
Capacity:	9,500/2,200/12,000 kVA
Voltage:	5.5/10.0/93,000 V
Fernana II (downstream)	
Turbine type:	Horizontal Francis turbine
Output:	1,400 kW
Effective head:	26.6 m
Max. discharge:	6.2 m^3/sec1/
Generator type:	Horizontal, 3-phase AC generator
Capacity:	1,480 kVA
Generator voltage:	1,500 V
Rated current:	670 A
Main transformer type:	3-phase, air-cooled type
Capacity:	1,760 kVA
Voltage:	1.5/10.0 kV

Note 1/: Estimated by Survey Mission

ii) Nebeur Multi-purpose Dam

This dam was constructed for irrigation of the downstream area of the Medjerda River and for power generation, and was completed in 1956.

Catchment area:	1,000 km^2
Av. annual precipitation:	400 mm
Av. annual inflow:	4.75 m^3/sec.
Reservoir high water level:	El 269.00 m
Storage Capacity:	300.0 x 10^6 m^3
Dam type:	Modified arch dam
Dam crest length:	470.0 m
Turbine type:	Vertical Francis turbine
Output:	6,900 kW
Effective head;	53.7 m
Max. discharge:	15.1 m^3/sec.1/
Generator type:	Vertical, 3-phase, AC generator
Capacity:	8,250 kVA x 2
Generator voltage:	5,500 V
Rated current:	867 A
Main transformer type:	3-phase, self-cooled x 2
Capacity:	8,250 kVA
Voltage:	5.5/92 kV

Note 1/ : Estimated by Survey Mission

Nebeur Power Station has been constructed immediately downstream of the dam and there are two turbine-generator units installed as indicated above, but in contrast to the average annual inflow of 4.75 m^3/sec the maximum discharge is 30.2 m^3/sec, and therefore, in normal operation, power is generated only during the daytime and the lighting time peak hours with operation shut down during other hours.

iii) Kasseb Multi-purpose Dam

This dam was completed in 1969 and will be the dam for the lower reservoir in the event Kasseb Pumped Storage Power Station is constructed. At present, it is being used for potable water supply to Tunis (maximum intake 1.20 m^3/sec) and power generation. The size of the power sation is very small at only 660 kW.

Catchment area:	101 km^2
Av. annual precipitation:	1,000 mm
Av. annual inflow:	1.43 m^3/sec.
Reservoir high water level:	EL 291.00 m
Reservoir surface area:	4.37 km^2
Storage capacity:	82.0 x 10^6 m^3
Dam type:	Concrete arch dam

Dam crest length:	245.0 m
Dam height:	58.0 m
Turbine:	Horizontal Francis turbine
Output:	700 kW1/
Generator:	Horizontal, 3-phase AC generator
Output:	825 kVA

Note 1/ : Estimated by Survey Mission

The existing Kasseb Power Station is located 400 m downstream from the dam.

As described above, the weight of hydroelectric power supply capacity in the STEG Electric Power System is small. The energy production of hydroelectric power stations is increased in the dry season as irrigation water is supplied. As shown in Table 3-3, the ratio of hydro in the total energy production of the STEG Electric Power System in 1976 was only 3.9%. Until Kasseb Pumped Storage Power Station is realized, the weight of hydro will not be changed for the greate, in the future also.

(2) Thermal Power Stations

As mentioned previously, thermal power stations make up as much as 94.7% of the power generating facilities in the STEG Electric Power System. As is indicated in Table 3-3, Ghannouch I Power Station which uses natural gas as fuel has a high utilization factor among thermal power generating facilities and is operated throughout the year at a high load factor.

Up to 72.8% of the electric power demand of the STEG Electric Power System is filled by steam thermal power generating facilities.

As for diesel power stations comprising independent systems and chiefly scattered about in the Sfax Branch Office territory in the central part of Tunisia, excepting Sfax and Secours, the maximum installed capacity is 620-kW.

i) Steam Thermal Power Stations

The total installed capacity of steam thermal power stations owned by STEG is 183-MW, the ratio of which in total installed capacity is 48.1%, but the proportion of energy production is 72.9% of total energy production. In effect, this indicates that steam thermal power stations comprise the main force in supply capability.

La Goulette I Power Station started operation in 1931 and was expanded later in 1948, 1950 and 1954, and the total installed capacity (nameplate rating) is 57.5 MW, but being antiquated, boiler outputs have fallen and the present generating capability is an output of 30-MW.

La Goulette II Power Station was constructed accompanying the increase in power demand in the capital city of Tunis with 27.5-MW x 2 units installed in 1965 and 27.5-MW x 2 units in 1968, and is presently the principal power generating facility of Tunisia.

Ghannouch I Power Station is located in the vicinity of Gabes which is showing remarkable development as an industrial area and is the newest steam thermal power station having been completed in 1972. The fuel consumed by this power station is natural gas produced accompanying petroleum recovery at El Borma 300 km south of Gabes and near the border with Algeria. A

10-3/4 inch pipeline has been laid between El Borma and Gabes to transport this natural gas, and 58,000 m^3 per hour are pumped and used mainly as fuel for power generation. The cost of this natural gas is said to be about one half (18 Dinars/TEP) of the international price of natural gas, and therefore, as can be seen in Table 3-3, this power station has the highest utilization factor.

The maintenance and operation of the three steam thermal power stations described above are being performed satisfactorily through utilization of amply stored spare parts and a repair shop and the level of maintenance and operation techniques is high.

ii) Gas Turbine Thermal Power Stations

Gas turbine thermal power stations will play an important role in the STEG Electric Power System as base-load or peak-load supply capability until 1980 when Sousse Thermal Power Station will be completed.

Especially, the gas turbines of Ghannouch II Power Station (59.0 MW) and Bouchemma Thermal Power Station (62.0 MW) provided in the Gabes industrial area generate power with natural gas transported by pipeline from El Borma as fuel similarly to Ghannouch I Power Station.

The utilization factors of these power stations were around 20% in 1976, but it is expected that these utilization factors will continue to rise until 1980 when Sousse Thermal Power Station will be completed.

The gas turbines, 22 MW x 2 units, installed in the compounds of Tunis-Sud Substation are peak-load power supply facilities using kerosene as fuel, while at the same time they have the role of adjusting voltage of the power system as they are capable of condenser operation.

iii) Diesel Power Stations

Diesel power stations are mainly scattered about the central part of Tunisia, and all comprise independent systems, while the station sizes are small ranging between 40 kW and 620 kW. The total installed capacity is as much as 11,970 kW, but the area which had been supplied from Secours Diesel Power Station is now supplied from the STEG Electric Power System, and when Secours is excepted, there is only 1,340 kW in operation.

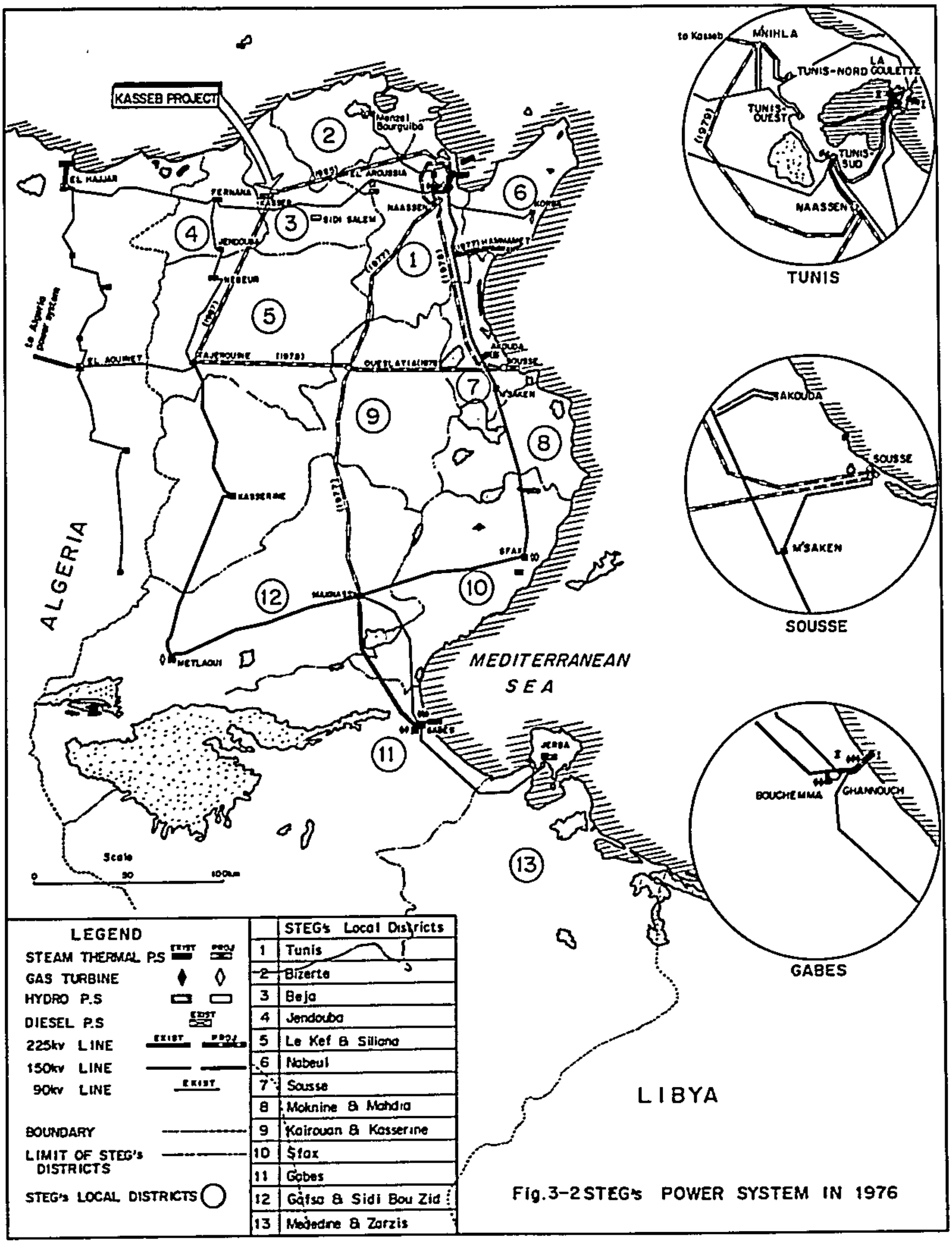
The locations of the power generating stations, substations and the principal transmission lines of the STEG Electric Power System as of the end of 1976 are indicated in Fig. 3-2.

3.2.2 Power Transmission Facilities

The reliability of the power transmission system of STEG will be enormously improved through completion from 1977 to 1979 of 225-kV trunk transmission lines covering all of Tunisia, and through construction of a 225-kV outside loop at the Tunis area.

In effect, through their completion, the power transmission system of STEG will become a strong grid structure, and by loop operation at all times along with improvements in the protective system, it is thought substations which will drop out due to faulting of a section of transmission line will be practically eliminated.

Most of the trunk tranmission lines are single route, single circuit, but since there are few long-distance power supply transmission lines, with the longest section being the 226 km between Oueslatia and Bouchemma which may rather be considered an exception, most of the sections are only a little over 100 km so that the grid meshes are small, and it is thought reliability will be



	STEG's Local Districts
1	Tunis
2	Bizerte
3	Beja
4	Jendouba
5	Le Kef & Siliana
6	Nabeul
7	Sousse
8	Moknine & Mahdia
9	Kairouan & Kasserine
10	Sfax
11	Gabes
12	Gafsa & Sidi Bou Zid
13	Medenine & Zarzis

Fig.3-2 STEG's POWER SYSTEM IN 1976

fairly high if reclosing is done at high speed.

In Japan, when formulating a system plan, considerable emphasis is placed on stability, but it appears that power flow is being stressed at STEG. It is thought the reason for this is that transmission lines are mostly short distance and there are few cases of damage from natural phenomena such as lightning and strong winds, but when the 225-kV system is commissioned it is thought more attention will have to be paid to stability than is necessary for 150-kV system.

This is because compared with the 150-kV tranmission lines there is more electric power carried on 225-kV transmission lines, in addition to which distances between electrical stations will be longer and reactances greater so that more attention must be paid to faults than for 150-kV transmission lines.

As another factor, soiling of insulators which was previously no problem in the past will become a serious matter with high voltage. Especially, in an area where there is little rainfall, washing effect of insulators is small, and when there is a fault, caution will be required as damage to insulators can occur.

The voltages of transmission lines are 225-kV now under construction (partially completed and being operated as 150-kV), 150-kV and 90-kV, and these voltages are stepped down to 30-kV or 10-kV at receiving substations, and power is distributed to large customers without further step-down and to households in general on further step-down to 3 phase, 4 wires system, 380-V at pole transformers. In this case, the voltage to ground is 210-V at the customer end. Further, a change to a 3 phase, 4 wires system is presently under way.

The 225-kV, 150-kV and 90-kV lines are all neutral direct grounded systems with steel towers mostly single-circuit chat types or triangles, while insulators used are made of glass.

It is worthy of special mention that all of the transmission lines do not have ground wires with only ground wires at substation steel structure extended from lead-out steel towers for about 5 tower spans.

The protective system is a distance relay type and a carrier relay system is not adopted.

Only, single phase reclosing is being performed for 150-kV and 90-kV transmission lines, and this is planned for the 225-kV line also.

Since most of the transmission lines are single-route and single-circuit, 3-phase reclosing is not being done. Transmission facilities existing or definitely to be constructed are given in Table 3-4.

The central load dispatching office belongs to the Transmission Department and is located at the head office of STEG. A system panel indicating the trunk systems and many pen recorders are provided at the central office, and commands to the various electrical stations and communications are made by power line carrier systems. The outputs of the various power stations are tlemetered by power line carrier system. There are no microwave facilities and neither are there future plans for them under the present circumstances.

However, STEG is studying introduction in the near future of an automatic load dispatching system using a modern computer.

Automatic regulation of system frequency is not being done at all, and a man on duty watching the frequency meter at La Goulette II Power Station manually regulates the frequency. Frequency regulation by governor-free operation is not being done, but frequencies are good, and on examination of the records of the pen recorders for a short period of time, it was seen that system frequencies were being held within a range of 49.5 to 50.5 Hz. Textile plants which most dislike frequency variation are not using pot motors, but 50-Hz electric motors speeded up mechanically, and it was confirmed that frequencies are within 50 ± 1.0 Hz, the allowable range of frequency variation at the textile plants.

Interconnection with an adjacent country is done with Algeria, and interconnecting lines

Table 3-4 Transmission Lines of STEG as of February 1977

Section	Voltage (kV)	Distance (km)	No. of cct	Con-ductor	Size of conductor (mm^2)	Remarks
Existing transmission line						
Tajerouine - El Aouinet	90	60	1	ACSR	288	
Tajerouine - Nebeur	90	59	1	ACSR	288	
Nebeur - Jendouba	90	21	1	ACSR	288	
Jendouba - Fernana	90	27	1	ACSR	288	
Fernana - El Hajjar	90	93	1	ACSR	288	
Fernana - Tunis-Sud	90	143	1	ACSR	288	
Tunis-Sud - Tunis-Ouest	90	10	1	ACSR	288	
La Goulette - Tunis-Sud	90	16	2	ACSR	288	
La Goulette - Tunis-Ouest	90	27	1	ACSR	288	
Tunis-Ouest - M. Bourguiba	90	58	1	ACSR	181.6	
Tunis-Sud - Korba	90	65	1	ACSR	176	
Naassen - Tunis-Sud	90	8	2	ACSR	420	
Sub-total	–	587	–	–	–	
La Goulette - M'Saken	150	129	1	ACSR	297	
M'saken - Sfax	150	102.5	1	ACSR	297	
Sfax - Maknassy	150	104	1	ACSR	297	
Makuassy - Metlaoui	150	116	1	ACSR	297	
Metlaoui - Kasserine	150	106	1	ACSR	297	
Kasserine - Tajerouine	150	83.5	1	ACSR	297	
Ghannouch - Robbana	150	102	1	ACSR	297	
Maknassy - Ghannouch	150	100	1	ACSR	297	
Maknassy - Ghannouch	225 (150)	93	1	ACSR	411	
Sousse - M'saken	150	14	1	ACSR	411	
Bouchemma - Ghannouch	150	3.5	1	ACSR	265	
Ghannouch - Cimenterie	150	10	1	ACSR	297	
Sub-total	–	870.5	–	–	–	
Total	–	1,457.5	–	–	–	
Under construction & projected						Operation in
Maknassy - Oueslatia	225	140	1	ACSR	411	1977
Oueslatia - Naassen	225	112	1	ACSR	411	1977
Oueslatia - Tajerouine	225	100	1	ACSR	411	1978
Oueslatia - Sousse	225	105	1	ACSR	411	1978
Sousse - Naassen	225	112	1	ACSR	411	1978
Naassen - M'Nihla	225	40	1	ACSR	411	1979
Total		609				

are comp. 'd of two 90-kV transmission line routes (totalling 2 circuits). That is, there is a transmission line between Fernana Power Station and El Hajjar Substation of Algeria in the north and another between Tajerouine Substation and El Aouinet Substation of Algeria in the south, and cross operation is done at normal times cutting at the Fernana Power Station side in the north and at the El Aouinet Substation side in the south.

When there is an emergency requirement for electric power on the Tunisian side, it is possible for power interchange to be done up to a limit of 30 MW by going into parallel at Fernana Power Station without warning to the other side, and any interchange in excess of this limit is done on discussion between the central load dispatching stations of the two countries.

The largest amounts of interchange were recorded in 1973 and 1974, with 11 GWh each in both years.

3.2.3 Substation Facilities

The features of substations of STEG are that gas turbines are installed in the compounds of some of them, in which case they are power generating stations simultaneously with being substations. Examples are Tunis-Sud and Ghannouch substations, while those substations where gas turbines will be installed in the near future are Sfax, Korba and Menzel Bourguiba.

Many of the substations are not monitored at all times, while those under construction are designed for remote supervision and control to be remote-controlled from large substations nearby. For example, Korba is tele-controlled from Tunis-Sud substation, and it is possible for remote control of ON-OFF of the various banks, adjustment of voltage regulators when loaded and opening and closing of circuit breakers. The 225-kV Naassen Substation and Ouestlatia Substation are also designed for tele-control from Tunis-Sud substation.

The main transformers of existing substations are 3-phase equipment, but almost all of the substations have spare transformers. Most of the substations are not equipped with lightning arrestors, and together with the fact that transmission lines are not provided with ground wires, it is seen that there is little lightning damage, and that there is little chance of abnormal voltages being produced as grounding is direct.

Further, instead of lightning arrestors, rod gap horns are provided on bushings of transformers.

Main transformer windings are fully insulated on the neutral sides in spite of direct grounding.

Bus systems are ring buses for 225-kV substations under construction, while double buses are standard for existing 150-kV and 90-kV substations.

Reactive power supply facilities (static power condenser) are 10 MVar at Kasseb, 9.6 MVar each at each at Metlaoui, M'Saken and Menzel Bourguiba substations, and 8.4 MVar each at Tunis-Sud and Tunis-Ouest substations, a total of 55.6 MVar.

Further, there is a shunt reactor of 6 MVar at Metlaoui and it is thought this is used for line charging.

On-load tap changers are in almost all cases equipped with transformers and voltage regulation is performed automatically.

The bank capacities of main transformers of the various substations are indicated in Table 3-5.

Table 3-5 Transforming Facilities of STEG Power System (As of March, 1977)

Substation	Unit No. of transformer	Capacity (MVA)	Primary voltage (kV)	Secondary voltage (kV)	Reactive power supply equipment		
					Capacitor or reactor	Voltage (kV)	Capacity x No. of unit (M Var)
La Goulette	1	50	96	33			
	2	40	96	33			
Tunis-Sud	1	30	90	11			
	2	30	90	11			
	1	20	90	33	Capacitor	30	8.4 x 1
	2	20	90	33			
	3	30	90	33			
Tunis-Ouest	1	15	90	33			
	2	20	90	33			
	1	30	90	11	Capacitor	10	8.4 x 1
	2	30	90	11			
	3	40	90	11			
Menzel Bourguiba	1	30	90	33	Capacitor	30	9.6 x 1
	2	20	90	33			
	3	20	90	33			
Jendouba	1	15	90	33			
	2	10	90	33			
Tajerouine	1	15	90	33			
	2	15	90	33			
Korba	1	15	90	33			
	2	15	90	33			
M'Saken	1	15	150	33	Capacitor	30	9.6 x 1
	2	15	150	33			
	3	25	150	33			
Sfax	1	25	150	33			
	2	25	150	33			
Metlaoui	1	15	150	33	Capacitor	30	9.6 x 1
	2	15	150	33	Reactor	150	6 x 1
Kaserine	1	15	150	33			
	2	15	150	33			
Ghannouch	1	15	150	33	Reactor	150	6 x 2
	2	15	150	33			
Robbana	1	15	150	33			
Maknassy	1	15	150	33	Reactor	150	6 x 1

CHAPTER 4

LOAD FORECAST

CHAPTER 4 LOAD FORECAST

4.1 BASIC CONDITIONS

4.1.1 Data and Information

When new power generation and transmission facilities are to be constructed, enormous funds and a long period of 5 to 10 years are required. In order to utilize limited funds to maximum effect, it is necessary for the future electric power demand to be accurately grasped. In general, economic activities in developing countries are extremely fluid with sharp fluctuations, and since electric power demand is closely related, making a precise forecast is a fairly difficult matter. The Survey Mission made special efforts to gather data to be able to make accurate judgments as much as possible.

In essence, the load forecast was made based on the "Fifth Socio-Economic Development Plan (1977–1981)", the V^{e} Plan, 1977–1981 (Project du Rapport de Synthese) of STEG and the electric power demand forecast data thereof, the economic statistics data obtained from the various government agencies of Tunisia and referring to the United Nations Statistical Yearbook 1975, etc.

The fundamentals in load forecasting are the collection of data such as the above and their comparison studies, and investigations of the actual situations in the related load areas to put the prediction of demand on a footing which is as close as possible to reality. For this purpose, the Survey Mission studied the various load forecast data and other related papers with extreme care, while also making the following field investigations.

(1) Investigation of the actual situations of plant expansion plans, electric power demand predictions and private power generation facilities of the El Fouladh Steelworks, the SACEM (Sté Anoyme de Constructions Electro-Mécaniques) transformer manufacturing plant and the STIR (St]e Tuniso-Italiano de Raffinage) oil refinery located at the northern industrial area of Tunisia.

(2) Investigation of the actual situation of power demand, allowable frequency variations of spindles and looms at the SOGITEX (Sté Générale des Industries Textiles) textiles plant at the city of Sousse at the Mediterranean coast to the east.

(3) Investigation of the actual situations of facilities expansion plans, electric power demand predictions and private power generation facilities of the superphosphate fertilizer plant ICM (Industries Chimiques Maghrebines) and the aluminum fluoride plant ICF (Industrie Chimiques du Fluor) at the Gabes Industrial Area located at the southern Mediterranean coast of Tunisia.

(4) Investigation of the electric power demand of the areas of local offices of STEG located at the provincial municipalities of Beja, Sfax and Kairouan.

(5) Comparison studies of principal areas through observations. Investigation of the actual situation of electrification of entire Tunisia through comparison observations for the principal municipalities and agricultural areas of the country.

(6) Grasping of the electric power demand through investigations of the state of construction

of power generation, transmission, transformation and distribution facilities, and the present state of operation and maintenance of STEG.

4.1.2 Fundamental Conditions for Forecast

(1) Economic Growth

Since the power demand forecast is one of predicting the future for 15 years from now, it can be made based on numerous preconditions. It may be considered that the most basic of these is that the government and economy of Tunisia will develop stably for a long period in the future. In concrete terms, this means that real growth of about 7.5% will be continued as given in the five-year plan of the Tunisian Government from 1977 to 1981. In effect, there is a close correlation between growth of power demand and economic growth rate, and in the case of Tunisia, it is thought that the growth rate of power demand will be lowered 1.4% if the economic growth rate falls by 1%.

(2) Increase in Electrification Rate and Investment in the Power Distribution Sector

The electrification rate of Tunisia as of 1976 was a nationwide average of 45% and it is thought this will reach 60% in 1981 when the Fourth Five-Year Plan will be completed. It is considered that STEG will continue thereafter with active investment in the power distribution sector.

(3) Period of Forecast

The period considered for electric power demand forecast was taken to be 15 years and this covers the year of commissioning estimated for the Kasseb Pumped Storage Power Generation Project and the year 1991 when roughly all of the installed capacity of the Project will be utilized. However, power demand up to the year 2000 has been forecast by a macroscopic method, but there will be no special significance to the figures for the last year.

(4) Service Area

The service area of STEG is all of Tunisia. Although it is possible for the STEG power system to be interconnected with adjacent Algeria by a 90-kV transmission line, it was decided not to consider supply of electric power to that country.

Electric power demand is forecast based on the above fundamentals by a macroscopic method and by an analytical method described in the following, and the appropriateness of the forecast results of the analytical method is crosschecked by the forecast results of the macroscopic method.

4.2 FORECAST BY MACROSCOPIC METHOD

4.2.1 Forecasting Method

It is a well-known fact that the eletric power consumption of a country has a very good correlation with the economic activity of that country.

The economic activity of a country is expressed in a most all-enveloping manner by the index called GNP. Since electric power is used in practically every sector of the national economic activity of production and consumption, it may be considered that there is an extremely good correlation with GNP from a long-range viewpoint.

Macroscopic prediction of electric power demand is a method of estimating the scale of demand for the country as a whole over a long-range period based on the correlation between GNP per person, that is, GNP/capita, and electric power consumption per person, that is kWh/capita, and electric power consumption per person, that is kWh/capita. Such a correlation is governed by the economic scale and individual income level of each country, and therefore, there is a considerable difference according to the country. However, according to the statistical investigations by country prepared by Electric Power Development Co., Ltd., Tokyo, Japan (EPDC) and approved by the International Atomic Energy Agency (IAEA) and the International Bank for Reconstruction and Development (IBRD), there are rough trend curves existing for electric power consumption scales corresponding to a number of income levels. The parmeters necessary for this long-range forecast method are the following:

(a) Average growth rate of GNP/capita at present stage of national economy estimated from past performance.

(b) Present scale of GNP/capita.

(c) Present scale of kWh/capita.

(d) Degree of variation in growth rate corresponding to variation in scale of GNP/capita.

(e) Degree of variation in kWh/capita corresponding to variation in scale of GNP/capita.

The scale of nationwide electric power demand estimated based on these parameters is as described below. The basic economic indices for predicting electric power demand by the macroscopic method are indicated in Table 4-1.

(1) Present GNP/Capita and Average Growth Rate of kWh/Capita during Past 4 Years

As the principal economic indices, population, GNP and countrywide gross power generation from 1973 to 1976, the period of the Third Four-Year Plan, were adopted as reflecting the average growth rate of the economy of Tunisia at the present stage. The average growth rates of GNP/capita and kWh/capita of Tunisia at present obtained from these data and the figures for these in 1976 are the following:

GNP/capita average growth rate:		6.0%
kWh/ captia average growth rate:		8.5%
1976 GNP/capita	:	US$422/capita 1/
1976 kWh/capita	:	233 kWh/capita

Note: 1/ Price in 1968

In the macroscopic forecast, the performance of GNP/capita in 1976 is the starting point of the longrange forecast.

Table 4-1 Basic Economic Index for Demand Forecast

Year	Population (1,000)	GNP at constant price in 1972 (10^6 Dinars)	GNP/capita (Dinars/capita)	Wholesale index (1970:100)	GNP/capita evaluated by constant price in 1968 (Dinars/capita)	GNP/capita evaluated by US$ constant price in 1968 (US$/capita)	Energy consumption in entire country (Gwh)	Energy consumption per capita (Kwh/capita)	
1968				95					
1969				96					
1970				100					
1971				107					
1972	5,200	1,077.6	202.7	109	180.6	347	882	170	Performance (1972–1976)
1973	5,330	1,082.4	203.0		176.9	340	988	185	
1974	5,450	1,181.4	216.8		188.9	363	1,079	198	
1975	5,577	1,286.3	230.6		201.0	386	1,152	207	
1976	5,715	1,443.7	252.6		220.1	422	1,330	233	
1977	5,859	1,525.2	260.3		226.9	435	1,510	258	Prediction by Five-Year Development Plan (1977 ~ 1981)
1978	6,000	1,669.3	278.2		242.5	465	1,820	303	
1979	6,140	1,779.8	289.9		252.7	485	2,100	342	
1980	6,281	1,953.1	311.0		271.0	520	2,450	390	
1981	6,428	2,082.6	324.0		282.4	542	2,800	436	

(1) Economic growth rate in GNP/capita ········ 1972 ~ 1976 (Fourth Plan) 5.1% per year (performance)
1972 ~ 1981 5.1% per year (performance plus Fifth Plan)

(2) Conversion rate from 1968 to 1970 ········· 1US$ = 0.521 Dinars

(2) Correlation between GNP/Capita and Growth Rate

According to statistical investigations, as indicated in Fig. 4-1, there is a rough correlation between scale of GNP/capita and corresponding growth rate, and it is shown that until GNP/capita reaches US$500 to $1,000 the tempo of growth gradually increases, after which it gradually decreases. Such a correlation is not the same for all countries of the world and the growth rates of various countries of the same scale of GNP/capita differ. However, when these are classified according to groups of high, low and medium growth rates, the respective trend curves are as indicated in Fig. 4-1.

Taking the US$422/capita which is the GNP/capita for Tunisia in 1976 and following the trend curve gradually increasing to US$500, US$600, US$700 and so on, the corresponding annual growth rates are as indicated in Table 4-2.

(3) Correlation between GNP/Capita and kWh/Capita

Similarly, according to results of statistical investigations, a rough correlation exists between GNP/capita and kWh/capita. This correlation, as in the case of the relation between GNP/capita and growth rate of the preceding item, is not the same for all countries of the world, but it is possible to classify the correlations into a number of groups.

On drawing a trend-curve plotting GNP/capita and kWh/capita of Tunisia during the past 3 years, it may be confirmed that it is slightly under the average curve for the world.

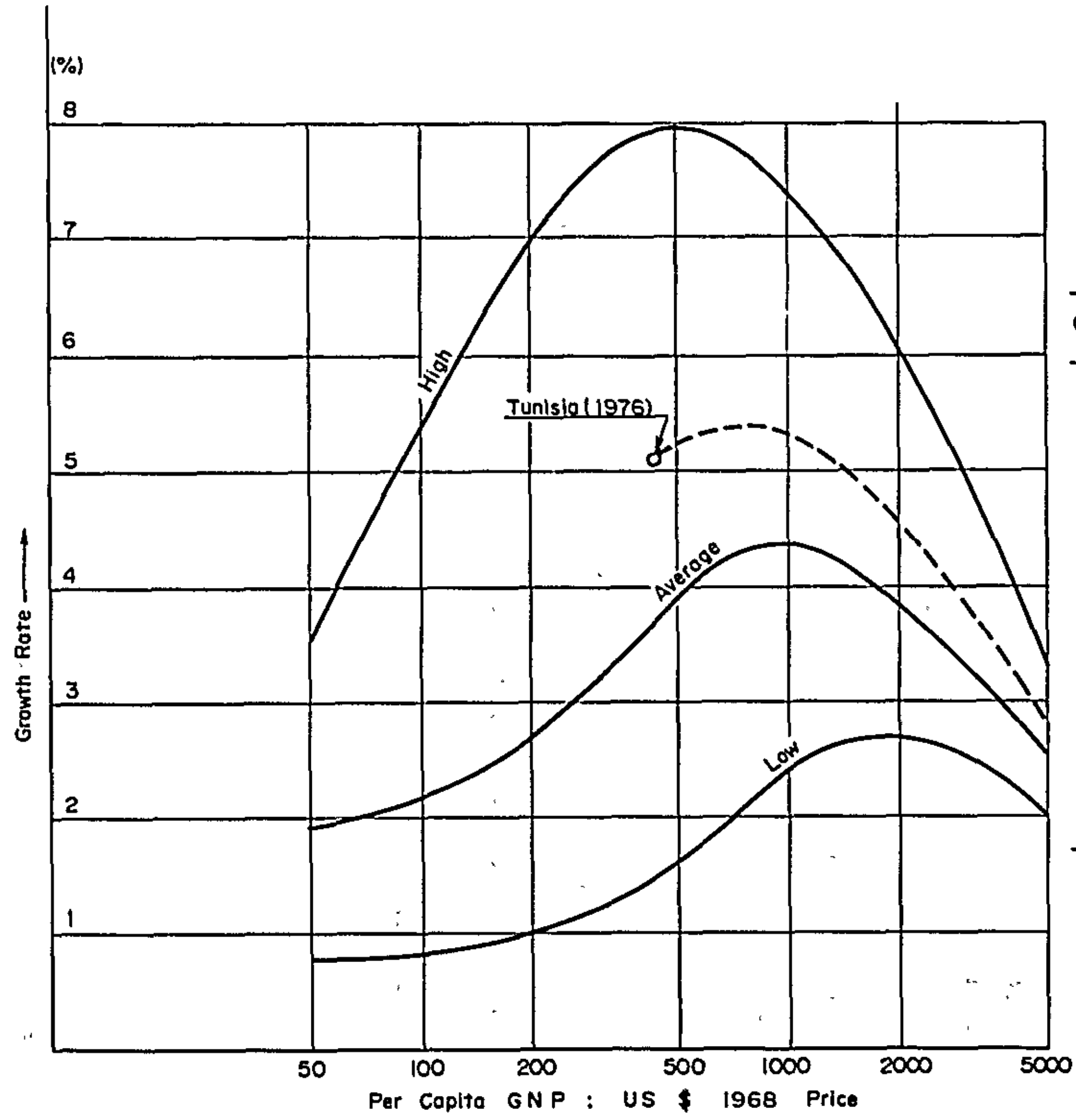
4.2.2 Forecast Results

According to the statistical data of the United Nations of 1975, the population growth rate of Tunisia from 1967 through 1974 was an annual rate of 2.7%, but going by the national census carried out in 1975, the growth rate for the past 10 years (1966 through 1975) was 2.3%, and it is expected that the population growth rate will be gradually lowered in the future. Therefore, in this Report, the future population growth rate, as a condition for long-range prediction, was based on the estimations of the Tunisian Government as indicated below.

Year	Population	Growth Rate
1975	5,577,300)	
		2.36
1980	6,280,900)	
		2.24
1985	7,031,300)	
		2.10
1990	7,812,000)	
		1.79
1995	8,549,000)	
		1.48
2000	9,236,600	

Although a period up to the year 2000 was taken for the long-range forecast, the last year is of no particular significance. For the starting point of the forecast, the average growth rate in GNP/capita as of 1976 was taken to be 5.10%. The nationwide trend in demand by year is as indicated in Table 4-3. Excerpting the energy demands for 1980, 1985, 1990 and 1995 from this table and calculating the average grow th rates in demand for every 5-year period, they are the following:

Fig. 4 - 1 Correlation between Per Capita GNP and its Growth Rate



GNP/Capita	Growth rate	Average growth rate
(US $)	(%)	(%)
435	5,10	
		5,18
500	5,25	
		5,30
600	5,35	
		5,38
700	5,40	
		5,43
800	5,45	
		5,43
900	5,40	
		5,38
1000	5,35	
		5,18
1500	5,00	
		4,80
2000	4,60	

Table 4-2 Energy Demand Forecast by Macroscopic Method

Year	Growth rate in GNP/capita (%)	GNP/capita price in 1968 (US$)	Energy consumption per capita (Kwh/capita)	Predicted population (1,000)	Energy consumption in entire country (Gwh)	Annual increase in energy consumption (%)
1976	5.18	422	233	5,715	1,330	
1977	5.18	444				
1978	5.18	467				14.2
1979	5.18	491				
1980	5.30	517	360	2,261	2,260	
1981	5.30	544				
1982	5.30	573				
1983	5.38	604				12.5
1984	5.38	636				
1985	5.38	670	580	4,078	4,080	
1986	5.43	706				
1987	5.43	745				
1988	5.43	785				11.5
1989	5.43	828				
1990	5.43	873	900	7,031	7,030	
1991	5.38	920				
1992	5.38	970				
1993	5.18	1,022				10.2
1994	5.18	1,075				
1995	5.18	1,131	1,330	11,371	11,370	
1996	5.18	1,189				
1997	5.18	1,250				
1998	5.18	1,316				9.0
1999	5.18	1,384				
2000	5.18	1,455	1,900	17,550	17,550	

Source: Figures on population were given by "Fifth Social Economic Development Plan" 1977 to 1981

Fig. 4 - 2 Correlation between Per Capita GNP and Per Capita Electricity Production

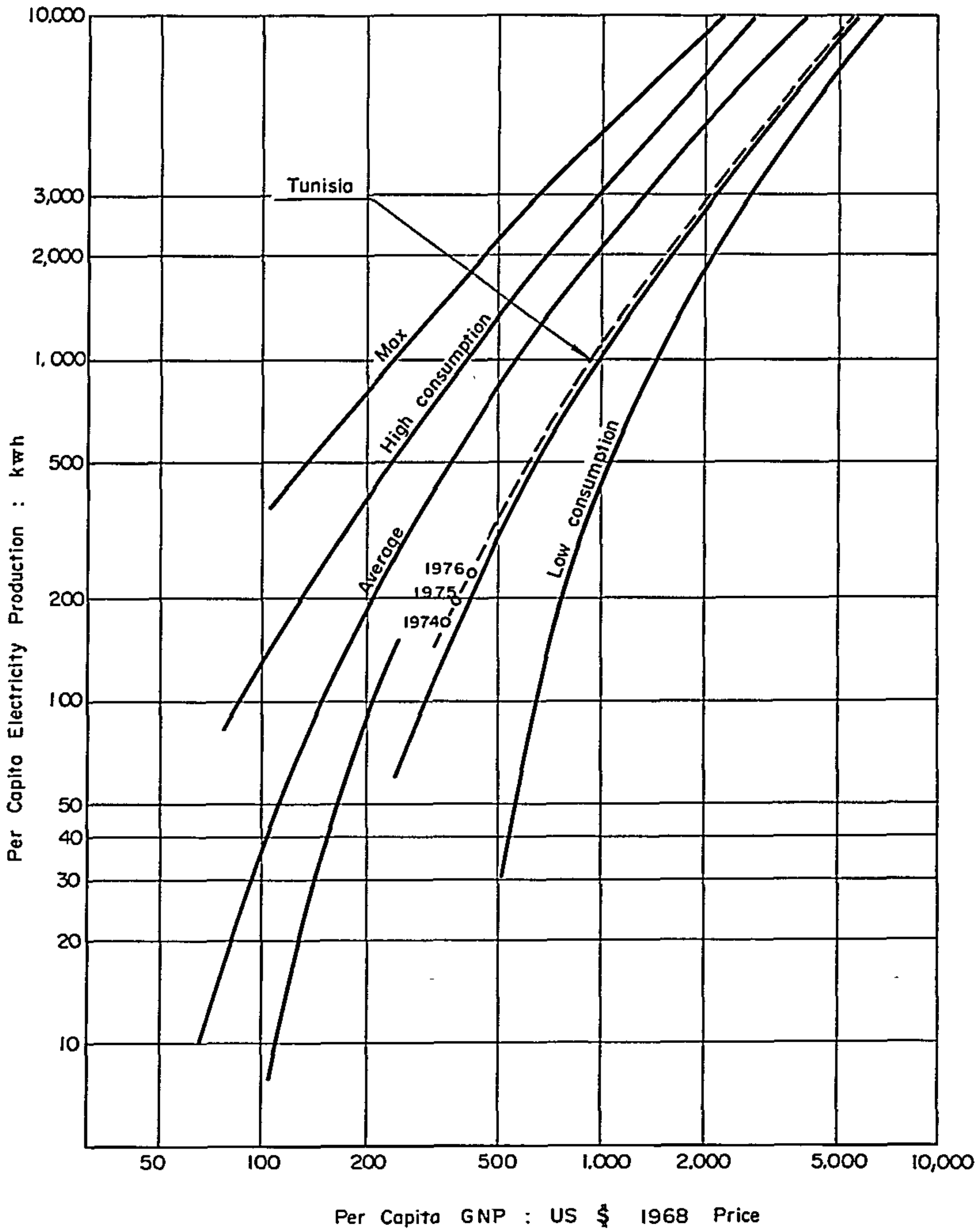


Table 4-3 Power Demand Forecast by Macroscopic Method

Year	Performance and prediction from data of STEG										Prediction by macroscopic method					
	Entire country	STEG High-voltage	STEG Low-voltage	Total	Proportion (D)/(A)	Proportion (B)/(D)	Generating energy in STEG system	Peak power in STEG system	Transmission and distribution loss	Annual load factor	Prediction for entire country	STEG High-voltage	STEG Low-voltage	Total	Generating energy in STEG system	Peak power in STEG system
	(A)	(B)	(C)	(D)	(%)	(%)	(GWh)	(MW)	(%)	(%)					(GWh)	(MW)
1970	692	399	178	577 (2.4)	83	69	677.7	140	15.2	54.5						
71	764	450	195	645 (1.8)	84	70	766.7	162	16.1	54.0						
72	882	516	222	738 (2.3)	84	70	866.7	175	15.2	56.5						
73	988	563	253	821 (2.4)	83	69	960.7	192	14.8	57.1						
74	1,078	616	287	903 (2.5)	84	68	1,096.7	225	17.9	55.6						
75	1,152	669	341	1,010 (3)	87	66	1,203.8	247	16.1	55.5						
76	1,330	746	399	1,145 (2)	86	65	1,339.4	280	14.5	54.5						
77	1,510	849	460	1,309	87	65	1,520	315	13.9	55.1	1,520	849	460	1,309	1,520	315
78	1,820	994	530	1,524	84	65	1,700	355	10.4	54.7	1,730	994	530	1,524	1,700	355
79	2,100	1,147	610	1,757	84	65	1,940	400	9.4	55.4	1,980	1,147	610	1,757	1,940	400
1980	2,450	1,304	690	1,994	81	65	2,230	460	10.6	55.3	2,260	1,304	690	1,994	2,230	460
81	2,800	1,447	780	2,227	80	65	2,510	500	11.3	57.3	2,540	1,447	780	2,227	2,510	500
82	2,120			2,500	80						2,860	1,630	870	2,500	2,790	570
83	3,480			2,800	80				(Average 10.5% 1978 to 1981)	(Average 56%)	3,220	1,820	980	2,800	3,130	640
84	3,810			3,130	82						3,620	2,030	1,100	3,130	3,500	720
85	4,190			3,500	84						4,080	2,280	1,220	3,500	3,910	800
86	4,640			3,950	85						4,550	2,570	1,380	3,950	4,410	900
87											5,070	2,800	1,510	4,310	4,820	990
88											5,660	3,130	1,680	4,810	5,370	1,100
89											6,310	3,480	1,880	5,360	5,990	1,220
1990											7,030	3,890	2,090	5,980	6,680	1,360
91											7,740	4,280	2,300	6,580	7,350	1,500
92											8,520	4,710	2,530	7,240	8,090	1,650
93											9,380	5,180	2,790	7,970	8,910	1,820
94											10,330	5,710	3,070	8,780	9,810	2,000
95											11,370	6,280	3,380	9,660	10,790	2,200
96											12,390	6,840	3,690	10,530	11,770	2,400
97											13,510	7,460	4,020	11,480	12,830	2,620
98											14,720	8,780	4,730	13,510	15,090	3,080
99											16,050	8,870	4,770	13,640	15,240	3,110
2000											17,550	9,700	5,220	14,920	16,670	3,400

Note:
1. High-voltage load demand for 1982 and after was estimated as 65% of total demand.
2. Peak power demand for 1982 and atfer was estimated based on load factor of 56% and transmission and distribution loss of 10.5%.
3. Entire country energy demand of 85% forecast by Macroscopic Method shall be furnished by STEG.

	1975	1980	1985	1990	1995
Energy Demand (GWh)	1,152 1/	2,260	4,080	7,030	11,370
Growth Rate (%)		14.2	12.6	11.7	10.1

Note: 1/ Actual for 1975.

The above long-range prediction is predicated on the economic structure of Tunisia not varying abruptly and development continuing gradually in the future based on the present tempo of growth.

4.3 FORECAST BY ANALYTICAL METHOD

4.3.1 Forecasting Method

Of the electric power demand of Tunisia in 1976, 86% was supplied by STEG. The methods employed by STEG for classifying customers in statistics on electric power demand may be broadly divided into the following two. These are high-voltage customers receiving power from the power system of STEG at high voltage and customers for low-voltage demand.

(1) High-Voltage Customers (30–kV and Over)

	Number of Customers
Extractive industries	70
Iron & Steel industries	16
Chemical industries	108
Construction materials	97
Paper & publishing industries	30
Textile industries	160
Food & tobacco industries	180
Various other industries	186
Pumping	507
Tourism	187
Transport and communication	175
Others	591
Sub-total	2,307

(2) Low-Voltage Customers (400 V and under) 454,000

Note: Number of cutomers as of end of 1976.

According to the performance of supply to customers in 1976, the power consumption of high-voltage customers make up 65% of the electricity sales of STEG, and the power consumption per high-voltage customer in 1976 was 368 times that of alow-voltage customer. As may be seen from the above, grasping the trend of high-voltage customers as exactly as possible will serve to improve the accuracy of the load forecast values in making an electric power demand forecast for Tunisia.

The method of load forecasting by the analytical method is that of investigating the past trends of power demands by type of customer along with investigating increase in power demand accompanying new construction and additions of facilities, and in case of ordinary low-voltage customers, the increase in new customers and increase in power demand of existing customers (for example, through the trend of increased introduction of electrical household appliances) accompanying the expansion of the distribution network are investigated to carry out power demand forecasts according to category of customer, and these are aggregated to forecast the electric power demand for the whole.

The classification of customers in the STEG Electric Power Systym is as described above, that of broad division into the two classes of high-voltage and low-voltage customers, and the load forecast is therefore made based on this classification.

(1) Electric Power Demand of High-Voltage Customers

In carrying out electric power demand forecasting, the previously-mentioned facilities expansion plans of the various customers and the performances from 1972 to 1976 were considered by category in making the forecast for the period up to 1981. For 1982 and after, since data are scarce to make forecasting by category difficult, it was decided to make the forecast based on the performances from 1972 to 1976 and the total of the forecast figures by category for 1977 through 1981.

i) Extractive Industries (70 Customers in 1976)

The greater part of the industrial power demand in this category in the past has been that accompanying extraction of phosphorite and fluorspar. The record for 1972 through 1976 was a comparatively low 4.2% per year in terms of growth rate of electric power demand. However, it is scheduled for ore dressing facilities to be expanded at four mines in 1978 and 1979, while the electric energy consumption of a gas chemical industry to be newly opened at Sfax in 1980 is expected to be 50 GWh in 1980 and 70 GWh in 1981, and it is assumed that the power demand in 1981 will reach 3.4 times the demand in 1976.

Unit: GWh

	Performance					Forecast				
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Power Demand	103	111	109	116	123	134	264	291	357	417
Portion Supplied by STEG	–	(106)	(105)	(111)	(118)	(122)	(147)	(164)	(170)	(175)

However, since there are plans for expansion of private power generation facilities in 1978 and after, the growth rate for power demand to be supplied by STEG is forecast to be 8.2% per year.

ii) Iron and Steel Industries (16 Customers)

The greater part of the industrial demand in this category is the power demand of El Fouladh Steelworks (annual production 180,000 tons, including 160,000 tons steel bar, 20,000 tons steel wire) located at Menzel Bourguiba in the northern part of Tunisia. The growth of electric power demand from 1972 through 1976 was 11.0% per year. The plant expansion plans for El Fouladh Steelworks call for an arc furnace now under construction to go into operation in 1977 which will result in an increase in power demand of approximately 70 MW.

Unit: GWh

	Performance					Forecast				
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Power Demand	58	67	79	81	88	103	111	116	117	117
Portion Supplied by STEG	–	(47)	(59)	(63)	(71)	(83)	(91)	(96)	(97)	(97)

Approximately 80% of the electric power demand will be supplied by STEG. As a result, the growth rate in the power demand supplied by STEG from 1976 to 1981 is forecast to be 6.4% per year.

iii) Chemical Industries (108 Customers)

The representative customers in this category are phosphate fertilizer plants, SIAPE (Sté Industrielle d'Acide Phosphrique et d'Engrais) and NPK (Engrais Sat) located at Sfax, and phosphoric acid manufacturing plants ICM_1 and ICM_2 (Industries Chimiques Maghrebines) located at Gabes. Many of the power consumers in this field have private power generating facilities and 84% of the demand is supplied by the private generating facilities. It is scheduled for production of ammonium phosphate to be commenced in 1979 as the first-stage project of SEPA (Sté des Engrais Phosphates et Azôtés) and synthetic ammonium as the second-stage project.

Unit: GWh

	Performance					Forecast				
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Power Demand	114	127	144	115	165	174	186	213	283	356
Portion Supplied by STEG	–	(12)	(21)	(25)	(26)	(33)	(45)	(52)	(72)	(75)

The power demand in this category will be supplied to a large extent by private generating facilities in the future also, but the growth in power demand supplied by STEG from 1976 through 1981 is forecast to be 23.6% per year.

iv) Construction Materials (97 Customers)

The representative power demand in this category is that of the cement industry. The cement plant at Gabes which will start operation in 1977 will have an annual production of 660,000 tons, while existing cement plants are also planed to be expanded. The growth in electric power demand from 1972 through 1976 was 6.8% per year and is forecast to increase greatly to 23.6% per year from 1976 through 1981. This increase in power demand is due to the rapid expansion in the cement industry of Tunisia and the brick industry for bricks used in structures.

Gabes Cement Plant (New)	600,000 t/year 1977–1979
Bizerte Cement Plant (Add.)	900,000 t/year 1978–1980
Ouest Cement Plant (New)	1,000,000 t/year 1980

Unit: GWh

	Performance					Forecast				
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Power Demand	83	86	90	97	108	133	172	227	273	311
Portion Supplied by STEG	(83)	(86)	(90)	(97)	(108)	(133)	(172)	(227)	(273)	(311)

Note: All of the electric power demand will be supplied by STEG in the future also.

v) Paper and Publishing Industries (30 Customers)

Typical consumers in this category are the two companies of SNTC (Sté Nationale Tunisienne de Cellulose) and SOTUALFA representing the pulp industry and the power demands of these two companies amounted to 44 GWh in 1974 making up 90% of the total demand.

Unit: GWh

	Performance					Forecast				
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Power Demand	56	61	58	57	55	61	61	62	64	65

Portion Supplied by STEG	-	(50)	(49)	(47)	(50)	(51)	(51)	(52)	(54)	(55)

The power demand from 1972 through 1976 has decreased gradually after a peak in 1973, but this is a temporary phenomenon and it is thought there will be a gradual increase. However, since there are no new plans in this field, it is forecast that the growth in electric power demand from 1976 through 1981 to be supplied by STEG will be 1.9% per year.

vi) Textile Industries (160 Customers)

The representative consumers in this category are the SOGETISS (Sté Génerale de Tissus Eponge) and SOGITEX (Stè General des Industries Textiles) textile plants located at Bou Hjar and Monastir. Only SOGITEX has plans for new or additional facilities from 1977 or after, and compared with its growth rate from 1972 through 1976 of 5.0% per year, the growth from 1976 through 1981 is forecast to be 9.8% per year. The proportion of power supply by private power generation facilities was 8% as of 1976.

Unit: GWh

	Performance					Forecast				
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Power Demand	41	42	47	50	50	54	60	66	73	80
Portion Supplied by STEG	-	(39)	(43)	(46)	(46)	(50)	(56)	(62)	(69)	(76)

It is forecast that the growth rate of power demand to be supplied by STEG from 1976 through 1981 will be 10.6% per year.

vii) Food and Tobacco Industries (180 Customers)

The electric power demand in this field is showing a constant growth every year, and it is thought this basic pace will not change in the future. As future projects, a tobacco plant is planned for Kairouan in 1979 and a sugar refinery in 1983.

Unit: GWh

	Performance					Forecast				
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Power Demand	53	58	62	69	73	77	84	91	99	107
Portion Supplied by STEG	–	(51)	(54)	(60)	(65)	(69)	(76)	(83)	(91)	(99)

The proportion of power supply made up by private power generation in 1976 was 10%.

However, there are no new or additional private power generating facilities planned to correspond with increase in power demand. The growth rate in the power demand to be supplied by STEG from 1976 through 1981 is forecast to be 8.8% per year.

viii) Various Other Industries (186 Customers)

The electric power demand in this field is that of various industries not included in the abovementioned categories, and customers are increasing yearly. A growth rate in power demand of 17.1% per year was indicated from 1972 through 1976.

Unit: GWh

	Performance					Forecast				
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Power Demand	28	34	39	42	53	65	77	94	114	138
Portion Supplied by STEG	–	(27)	(32)	(36)	(47)	(59)	(71)	(88)	(108)	(132)

It is thought there will be a rapid increase in the number of industrial consumers not included in the abovementioned categories with progress in industrialization in Tunisia. In making the forecast for 1976 through 1981, the average growth rate of 21.9% was adopted taking into consideration of the average growth rate of 17.1% for 1972 through 1976 and the average growth rate of 26.2% from 1975 through 1976.

ix) Pumps (507 Customers)

The electric power demand in this category consists mainly of that of large-capacity water pumps for irrigation which receive power directly from high voltage. The growth rate ftom 1972 through 1976 was 14.4% per year. Future pump demands planned are those of the Bou Hertma Irrigation Project where it is expected there will be power demands for pumps of 8.0 MW at the end of 1977 and another 8.0 MW in 1978.

Unit: GWh

	Performance					Forecast				
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Power Demand	24	28	33	35	41	49	61	72	84	96
Portion Supplied by STEG	–	(28)	(33)	(35)	(41)	(49)	(61)	(72)	(84)	(96)

It is expected that pump power demands will continue to grow greatly in the future, and the growth in power demand from 1976 through 1981 will be 18.5% per year.

x) Tourism (187 Customers)

It is expected that tourism which contributes a large proportion of the foreign currency earnings of Tunisia will continue to develop greatly in the future. According to the Fifth Socio-Economic Development Plan (1977–1981), it is forecast that annual utilization of hotel rooms will be approximately 1,000,000 day-rooms. It is thought that the performance in 1975 was in excess of 800,000 day-rooms.

Unit: GWh

	Performance					Forecast				
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Power Demand	39	44	44	57	60	65	71	78	86	95
Portion Supplied by STEG	–	(44)	(44)	(57)	(60)	(65)	(71)	(78)	(86)	(95)

The growth rate in electric power demand from 1972 through 1976 was 15.2% per year, and is forecast to be 9.6% per year for 1976 through 1981.

xi) Transport and Communication (175 Customers)

The power demand in this field is mainly that of the electric railroad connecting Tunis and Carthage. As future projects, it is forecast there will be 10 GWh in 1980 and 20 GWh in 1981 for a light-gage electric railway in the city of Tunis.

Unit: GWh

	Performance					Forecast				
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Power Demand	24	31	31	31	35	40	46	52	64	82
Portion Supplied by STEG	–	(31)	(31)	(31)	(35)	(40)	(46)	(52)	(64)	(82)

The growth rate in electric power demand from 1972 through 1976 was 9.9% per year, and is forecast to be 18.6% per year from 1976 through 1981.

xii) Others (571 Customers)

The power demand in this category consists of buildings, public enterprises, commercial, banking and insurance establishments, and service businesses. The growth rate in electric power demand from 1972 through 1976 was 17.8% per year, and is forecast to be 14.3% per year from 1976 through 1981.

Unit: GWh

	Performance					Forecast				
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Power Demand	41	47	55	61	79	95	107	121	136	154
Portion Supplied by STEG	–	(47)	(55)	(61)	(79)	(95)	(107)	(121)	(136)	(154)

The power demand forecasts by category of the high-voltage consumers above are indicated in Table 4-4.

(2) Load Forecast for Low-Voltage Customers

In making load forecasts for low-voltage customers, a target for 1990 was set considering the power consumption per customer according to the performances in advanced countries, and then the number of customers and the energy consumption per customer of every year to reach the target were determined, and the products of these were taken to be the annual power demands.

In effect, as shown in Table 4-5, these figures for Tunisia in 1990 were estimated based on the electric lighting consumption per person in a household and GNP/capita.

Table 4–5 Lighting Demands of Principal Advanced Nations

Country	Persons per Household	Lighting Consumption per Capita (kWh/year)	GNP/Capita
U.S.A.	3.3 (1960)	2,186 (1970)	4,289 (1970)
U.K.	2.9 (1966)	1,448 (1970)	2,014 (1970)
W. Germany	2.9 (1961)	810 (1970)	2,752 (1970)
France	3.1 (1962)	612 (1970)	2,477 (1970)
Japan	3.7 (1970)	499 (1970)	1,636 (1970)
Tunisia	4.5 (1990)	300 (1990)	873 (1990)

Note: The lighting consumptions per capita of the U.S.A., U.K. and West Germany include those for agricultural purposes. France is for low voltages. The figures in parentheses indicate year.
Sources: Overseas Electric Industries Statistics, Japan and United Nations Statistics, 1975.

According to the national census of 1975, the number of persons per household was 5.5. It is thought that the number of people per household in Tunisia in the future will be rapidly lowered, but with 4.5 persons in 1990, the lighting consumption, 300 kWh, per capita, if the GNP per capita were to reach US$870, may be considered to be reasonable.

Table 4-4 Load Forecast for STEG's Power System

Item	Year	Actual				Forecast															Increase (%)		
		–4	–3	–2	–1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
		1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	'73–'76	'76–'81	'81–'91
1. Energy consumption																							
i) High and middle voltage																							
Extracting industries	(GWh)	106	105	111	118	122	147	164	170	175											4.2	8.2	
Iron & steel industries	(GWh)	47	59	63	71	83	91	96	97	97											14.8	6.4	
Chemical industries	(GWh)	12	21	25	26	33	45	52	72	75											29.4	23.6	
Construction materials	(GWh)	86	90	97	108	133	172	227	273	311											7.9	23.6	
Paper & edition industries	(GWh)	50	49	47	50	51	51	52	54	55											0	1.9	
Textile industries	(GWh)	39	43	46	46	50	56	62	69	76											5.7	10.6	
Food industries	(GWh)	51	54	60	65	69	76	83	91	99											8.4	8.8	
Various industries	(GWh)	27	32	36	47	59	71	88	108	132											20.3	21.9	
Pumps	(GWh)	28	33	35	41	49	61	72	84	96											13.6	18.5	
Turism	(GWh)	44	44	57	60	65	71	78	86	95											10.9	9.6	
Transport & communication	(GWh)	31	31	31	35	40	46	52	64	82											4.1	18.6	
Others	(GWh)	47	55	61	79	95	107	121	136	154											18.9	14.3	
Sub-total	(GWh)	568	616	669	746	849	994	1,147	1,304	1,447	1,640	1,850	2,080	2,340	2,620	2,930	3,290	3,660	4,080	4,530	9.5	14.2	12.0
ii) Low voltage																							
Number of customer	(10^3)	352	383	416	454	503	558	619	687	758	792	853	929	1,009	1,101	1,163	1,236	1,338	1,448	1,514	8.8	10.8	7.2
Consumption per customer	(kWh)	719	749	820	881	915	950	985	1,004	1,029	1,060	1,090	1,120	1,160	1,190	1,230	1,270	1,300	1,350	1,390	7.0	3.2	3.0
Energy consumption	(GWh)	253	287	341	400	460	530	610	690	780	840	930	1,040	1,170	1,310	1,430	1,570	1,740	1,940	2,090	16.5	14.3	10.4
iii) Total energy consumption	(GWh)	821	903	1,010	1,146	1,309	1,524	1,757	1,994	2,227	2,480	2,780	3,120	3,510	3,930	4,360	4,860	5,400	6,020	6,620	11.8	14.2	11.5
2. Transmission & distribution energy loss	(%)	14.6	17.7	15.9	15.1	13.9	10.4	9.4	10.6	11.3	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	–	–	–
3. Generating energy without station service	(GWh)	961	1,097	1,201	1,350	1,520	1,100	1,940	2,230	2,510	2,790	3,120	3,510	3,940	4,420	4,900	5,460	6,070	6,760	7,440	12.0	13.2	11.5
4. Maximum peak demand without station service	(MW)	192	225	247	280	315	350	390	445	490	550	615	690	775	870	965	1,075	1,195	1,330	1,465	13.4	11.8	11.5
5. Annual load factor	(%)	57.1	55.6	55.5	55.0	55.1	55.4	56.8	57.2	58.5	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	–	–	–

4.3.2 Forecast Results

As described above, the electrical power demand according to the analytical method was forecast separated into high-voltage demand and low-voltage demand. For high-voltage demand the year up to which forecasts can be made according to category is 1981, and for 1982 and after, the annual average figure of the growth of 9.5% from 1973 through 1976 and the growth rate of 14.2% per year from 1976 through 1981 was taken, rounding this out to 12.0%. As a result, the growth rate in high-voltage power demand from 1976 through 1991 is forecast to be 12.8% per year.

The growth rate in low-voltage power demand from 1976 through 1991 is lower compared with that of high-voltage demand and is forecast to be 11.6% per year.

The maximum peak demand and energy generation of the entire STEG Power System at power station end (excluding station loads) indicated for the years 1976, 1980, 1985 and 1990 are the following:

	1976	1980	1985	1990	Growth Rate (%)
Max. peak demand (MW)	280	445	775	1,330	11.0
Energy generation (GWh)	1,350	2,230	3,940	6,760	11.3
Annual load factor (%)	55.0	57.2	58.0	58.0	–

The results of the load forecast according to the analytical method are given in Table 4-4.

4.4 COMPARISON BETWEEN FORECAST RESULTS OF MACROSCOPIC AND ANALYTICAL METHODS

The forecast by the macroscopic method was made in the sense of a cross-check on the power demand forecast by the analytical method, and if the future demand forecast by the analytical method is close to the results of forecast by the macroscopic method, it will be permissible to conclude that the forecast by the analytical method is reasonable.

Excerpting the forecast results according to the macroscopic and analytical methods from Tables 4-3 and 4.4, they will be as indicated below for the years 1976, 1980, 1985 and 1990.

		Actual	Forecast		
		1976	1980	1985	1990
A)	Macroscopic Method				
	Max. peak demand (MW)	280	460	800	1,360
	Energy generation (GWh)	1,350	2,230	3,910	6,680
B)	Analytical Method				
	Max. peak demand (MW)	280	445	775	1,330
	Energy generation (GWh)	1,350	2,230	3,940	6,760
A/B					
	Max. peak demand (%)	100	103	103	102
	Energy generation (%)	100	100	99	99

In effect, the forecast results of the analytical method are extremely close to the forecast results of the macroscopic method, and if the economy of Tunisia develops favorably according to plans, it may be concluded that a growth in power demand of about 11% annually can be expected up to around 1990.

4.5 POWER DEMAND BY SUBSTATION

The power demand forecast results described above are power demands at power station ends (excluding power station consumption) in the STEG Power System. For the power system analysis to be described in Chapter 8, it is necessary to forecast the power demand by substation in the STEG Power System. For this purpose, the high-voltage and medium-voltage power demands of the 13 local service areas of STEG were forecast, while the low-voltage power demands were forecast from the 1976 electrification rate and the distribution line expansion plans of the 13 local service areas scheduled in STEG's five-year plan.

The power demands at customer ends according to each of the 13 service areas as of 1981 are indicated in Table 4-6, while the power demands by substation in the years 1981, 1985, 1986 and 1988 are given in Table 4-7.

Table 4-6 Demand at the End of Customers in 1981

	STEG's local districts	Energy demand (10^6 GWh)			Max demand		2/ Additional transformers
		High-voltage	Low-voltage	Total	(MW)	L.F (%)	(kVA)
1	Tunis & Tunis-Sud	429	297	726	127	65.3	9.8
2	Bizerte	220	41	261	43	69.3	6.5
3	Beja	14	16	30	5	68.5	5.4
4	Jendouba	42	12	54	25	71.2	11.5
5	Le Kef & Siliana	86	16	102			4.1
6	Nabeul	59	60	119	30	45.3	19.5
7	Sousse	96	69	165	67	44.3	0.4
8	Mahdia & Monastir	45	50	95			2.1
9	Kairouan & Kasserine	73	50	123	65	53.4	6.3
10	Sfax	83	98	181			6.3
11	Gabes	131	27	158	73	51.0	6.6
12	Gafsa & Sidi Bou Zid	145	23	168			14.6
13	Medenine	24	21	45	9	57.1	6.5
	Total	1,447 1/	780 1/	2,227	444	57.3	99.6

Note: 1/ Refer to Table 4-4

2/ Additional transformers for distribution lines to be installed from 1977 to 1981.

Table 4-7 Maximum Demand at Substations

Unit (MW)

		1981	1985	1986	1988
1	Tunis & Tunis-Sud	144	228	256	308
	La Goulette	(18)	(28)	(33)	(41)
	Tunis-Sud S.S	(46)	(73)	(80)	(94)
	Tunis-Nord S.S	(39)	(62)	(70)	(86)
	Tunis-Ouest S.S	(41)	(65)	(73)	(87)
2	Bizerte				
	Menzel Bourguiba S.S	45	72	78	92
3	Beja				
	Zarga S.S	4	7	8	10
4	Jendouba				
	Jendouba S.S	13	20	22	26
5	Le Kef & Siliana				
	Tajerouine S.S	14	22	23	26
6	Nebeul	30	48	53	65
	Korba S.S	(16)	(25)	(27)	(33)
	Hammamet S.S	(14)	(23)	(26)	(32)
7,8	Sousse, Mahdia & Monastir	77	124	145	194
	M'Saken S.S	(41)	(66)	(77)	(104)
	Akouda S.S	(36)	(58)	(68)	(90)
9	Kairouan & Kasserine	16	25	29	33
	Oueslatia S.S	(6)	(9)	(10)	(11)
	Kasserine S.S	(10)	(16)	(19)	(22)
10	Sfax				
	Sfax S.S	49	79	93	124
11	Gabes				
	Ghannouch S.S	28	44	47	54
12	Gafsa & Sidi Bou Zid	45	72	80	97
	Metalaoui S.S	(38)	(61)	(68)	(83)
	Maknassy S.S	(7)	(11)	(12)	(14)
13	Mededine				
	Robbana S.S	9	14	15	18
	Total	474	755	849	1,047
	Generating End 1/	490	775	870	1,075

Note 1/ Refer to Table 4-4.

CHAPTER 5

POWER DEVELOPMENT PLAN
AND KASSEB PUMPED STORAGE POWER PROJECT

CHAPTER 5
POWER DEVELOPMENT PLAN AND KASSEB PUMPED STORAGE POWER PROJECT

5.1 FUNDAMENTAL CONCEPT OF DEVELOPMENT PLAN

5.1.1 Fundamental Concept

Since a power generation facility once constructed must serve its role of supplying electric power in an electric power system for a long time, the economics of electric power development is evaluated to make the overall cost of the electric power system a minimum over a long term while securing stability of electric power demand and supply. The minimum overall cost of the electric power system in this case is selected by determining the demand and supply balance considering the economical operation of existing and new facilities, carrying out cost calculations for each, and making comparisons. However, for the STEG Electric Power System, it will suffice to make comparison studies of power supply sources for incremental demand of 1983 and after for the reasons described below. The following items were given consideration as means of proceeding with concrete studies:

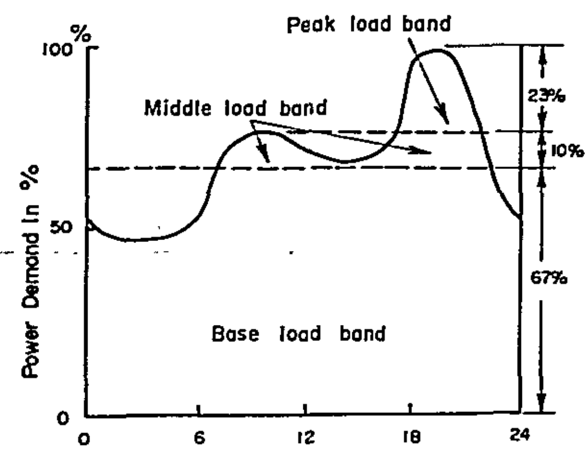
(1) Grasping General Trend of Electric Power Development over Future Years

There are 490.0 MW scheduled for development under the electric power development plan of the STEG Electric Power System from 1977 to 1982, and except for Sidi Salem Hydroelectric Power Station (36.0 MW) scheduled for start-up in November 1982, bidding has been completed for all projects as have been ordering procedures. Therefore, the electric power development program up to the end of 1982 is already definite.

Consequently, the responsibility of the Mission was to formulate an electric power development scheme for 1983 and after, in accordance with load characteristics (form of electric power demand, etc.) while considering the existing power generating facilities and the supply capabilities to be developed from 1977 to 1982.

Making up a model of the STEG Electric Power System, it may be considered dividing into the three portions indicated below.

Fig 5-1 Division of Load Band



The features of the load bands indicated in Fig. 5-1 and the general characteristics required of supply capabilities to suit these bands are as indicated below.

The rivers and streams of Tunisia where hydroelectric power development is possible are the Medjerda River and its tributaries. There are five power stations already constructed on these streams in addition to which Sidi Salem Power Station (36.0 MW) and Kasseb Pumped Storage Power Station (350 MW) are planned.

Table 5-1. General Characteristics of Supply Capabilities to Suit Various Load Bands

Load Band	General Characteristics of Supply Capability: Characteristics from Economic Viewpoint	General Characteristics of Supply Capability: Characteristics from Operation Viewpoint	Applicable Power Plant Type	Installed Capacity at the End of 1982 (MW)	(%)
Peak	Utilization factor is extremely low and influence on power generating cost of fixed costs is large and that of variable costs is small. Consequently, pumped storage hydro, or thermal of lower construction cost per kW even if efficiency is low will be suitable.	Starting and stopping is easy and load-following capability is to be superior.	(1) Reservoir-type & regulating pond-type hydro	36.0	(4.3)
			(2) Pumped storage hydro	0	(0)
			(3) Gas turbine	198.0	(23.5)
Middle	Annual utilization factor is under around 50% and is between peak and base loads. Consequently, the characteristics required are also of intermediate nature. For example, compared with base thermal, a thermal of low construction cost per kW even if efficiency is slightly low will correspond to this category.	Daily mid-night stopping must also be possible.	(1) Regulating pond-type hydro	20.0	(2.4)
			(2) Middle thermal	125.0	(14.8)
			(3) Natural gas-fueled gas turbine	106.0	(12.6)
Base	Annual utilization factor is high at 80 to 90% and influence of variable costs on economics is large. Consequently, a thermal of high efficiency even if construction cost per kW is high to some extent is suitable.	No especially severe restrictions in general	(1) Run-of-river-type hydro	0	(0)
			(2) High-efficiency thermal	300.0	(35.5)
			(3) Natural gas-fueled steam thermal	58.0	(6.9)
			Total	843.0	(100%)

According to the data obtained by the Mission in field investigations, there will be no hydroelectric power development projects after the Kasseb Pumped Storage Power Project under the present circumstances. Therefore, thermal power generating facilities will make up a considerable portion of the supply capability of the STEG Electric Power System in the future.

As indicated in Table 5-1, it may be noted that the installed supply capability in 1982 is that of the supply capacity of base thermal being small as seen from the form (load curve) of electric power demand. Accordingly, the first supply capability to be commissioned in 1983 or after should be a base thermal plant (150 MW unit).

Middle thermal plants will possess adequate supply capability as of 1982, but it can be seen that it will be necessary for new supply capability to be introduced as peaking power to correspond with the growth in electric power demand from 1983 and after.

(2) Tempo of Electric Power Development and Unit Capacity of Thermal Power Plant from 1983

It is estimated that the growth in annual electric power demand from 1983 will be 65 MW as of 1983, and 135 MW as of 1990. In effect, when the growth in electric power demand is considered, it may be seen that it will be necessary for facilities of about 150 MW at intervals of around 1.5 years at the beginning and at intervals of around 1 year at the latter half. Since two thermal power units of 150 MW will be commissioned in the STEG Electric Power System in 1980, it will be advisable to consider thermal units of at least 150 MW for new installation from 1983 and after. From point of view of the scale of the STEG Electric Power System, it will be around 1990 when the next step of adopting 250-MW units will become possible.

Meanwhile, as a hydroelectric power plan, there will be the Kasseb Pumped Storage Power Project, which is planned for coping with the peak demand that will become prominent with growth in electric power demand.

5.1.2 Combinations of Development Plans

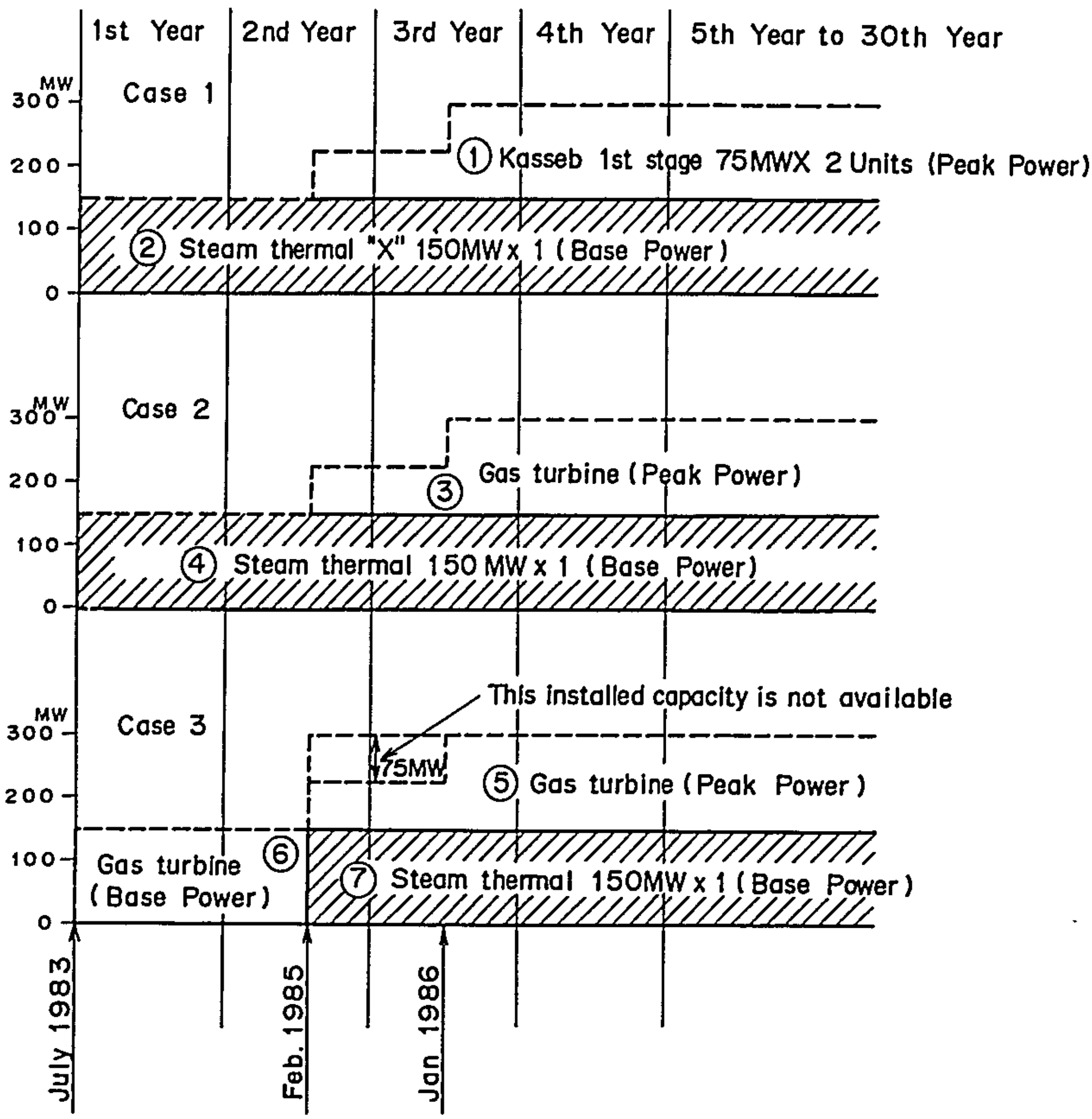
The development plan for 1983 and after will consist of examining the order of development of the abovementioned 150-MW unit having base load supply capabilities and gas turbines or the Kasseb Pumped Storage Power Project as an alternative to gas turbines. Regarding the Kasseb Pumped Storage Power Project, a comparison is made with gas turbine power generating facilities, and the economy of the former is clarified. Meanwhile, base load supply capability will be required in accordance with the growth of power demand, and as will be shown in Item 5.2.2 of this chapter, steam thermal is more economical than gas turbine thermal.

However, as supply capability for 1983, it is conceivable to first build a gas turbine thermal which is of lower construction cost, operate this as a base thermal until 1985, and divert this gas turbine thermal to peak supply capability after the 150 MW unit steam thermal is constructed in 1985, and this proposal is also considered. In effect, there will be the three alternatives listed below and shown in Fig. 5-2 as methods of developing supply capability from 1983 to 1985 which will be the essential concept of the development plan.

- Case 1: Construct a steam thermal (150 MW x 1 unit) in 1983 and start up Kasseb Pumped Storage Power Project (First Stage) in 1985.
- Case 2: Construct a steam thermal (150 MW x 1 unit) in 1983, construct a gas turbine (75 MW) in 1985 and further construct a gas turbine (75 MW) in 1986.
- Case 3: Construct a gas turbine (150 MW) in 1983 and operate for base load until 1985 and construct a steam thermal (150 MW x 1 unit) in 1985.
  Switch the gas turbine to peak-load power operation from 1985.

However, regarding Case 1 and Case 2 in Fig. 5-2, as economic comparison is made of

Fig.5-2 Combination of Power Plants



Note : Operating conditions of gas turbine ⑥ will be varied to ⑤ from February 1985

Kasseb ① and gas turbine ③ in Chapter 7 and the superiority of Kasseb, that is, Case 1 is verified, it will suffice here to compare Case 2 and Case 3. This is done in Item 5.2.2 of this chapter and Case 2 is found to be superior. Consequently, it is thought 150 MW units steam thermal will be suitable as the supply capability to be commissioned in 1983.

5.1.3 Preconditions for Formulation of Development Scheme

(1) Reserve Supply Capacity and Service Level

Service level will be improved depending on the quantity of the reserve capacity (less probability of shortage in supply capability). However, this means that the proportion of power generating facilities lying idle will be large and will be a factor to raise the generating cost of the power system as a whole. The criterion for reserve capacity of STEG is set at 20% of maximum power demand or the sum of the largest-capacity unit and the capacities of two gas turbines (30 MW and 22 MW), whichever is the larger.

This reserve ratio may be said to be considerably higher than the 7 to 10% (not including, however, the supply capability during scheduled outages for periodic inspection of thermal stations) in the electric power industry of Japan.

As a reference, the probability of incapable supply power was calculated taking into consideration shut down capacity due to forced or scheduled outage of thermal power generating facilities which is corresponding to more generator capacity than reserve capacity (202 MW) and based on the following conditions.

– Year for examination:	End of 1983
– Total supply capability:	903MW (except for hydro power plants)
	150MW x 3 units
	30MW x 8 units
	22MW x 9 units
– Outage factors:	5% per unit applying all different units in size

In determining the outage factor of different type of thermal power plants, outage factor of 5% for 150 MW unit steam thermal was adopted without consideration of scheduled outage for maintenance of the equipment and machinery and, fault outage factor of 2% and repair outage factor of 3% were considered for the rest of thermal power plants equivalent to 33 MW units and 22 MW units.

The probability of supply shortage depending on the principal combinations of outage generators is shown below.

Principal combination of outage generators	Probability of outage
Case 1: 150MW x 2 units + The rest of thermal units	0.007125
Case 2: 150MW x 1 unit + 30MW x 2 units	0.004390
Case 3: 150MW x 1 unit + 30MW x 1 unit + 22MW x 2 units	0.002377
Case 4: 150MW x 1 unit + 30MW x 2 units + 22MW x 1 unit	0.002080
Case 5: 150MW x 1 unit + 22MW x 3 units	0.000693
Total	0.016665

It was found that the probability of supply shortage to be influenced to the customers would be 0.018443[1/] or 6.7 days per year that supply can not be made. Regarding STEG's criterion for the reserve capacity, it was considered that the abovementioned value adopted by

Note[1/]: This figure indicates probability of outage accumulated by all combination of outage generators.

STEG would be larger than the Mission dimly imagined. However, it is clear that the probability of supply shortage of 6.7 days per year is not desirable from point of view of the reliability of power supply to the customers and the reserve capacity of 202 MW of the STEG power system is not necessary excessive.

However, when it is considered that increasing the reserve capacity further will increase power generation cost, it may be concluded that the present reserve capacity criterion of STEG is an avoidable.

(2) Handling of Idle and Retired Power Generating Facilities

The oldest existing generating facility in the STEG Electric Power System is La Goulette I Steam Power Station which was commissioned in 1931. The existing hydro electric power stations (5 stations) are all comparatively new having been built after World War II. The years in which the existing power generating facilities started operation are given in Table 3-2.

In establishing the electric power development program for the STEG Electric Power System it is necessary to consider retirement of existing generating facilities from the power system due to antiquation. In this sense, the Mission as a result of discussions with STEG considered that the thermal power generating facilities indicated in Table 5-2 would be taken out. As for the years in which retiring will be done, the service lives based on operating conditions of gas turbines were considered, while for steam thermal, those which would be retired are all of small scale and it was assumed they would be retired one by one from 1983 when operation of three 150-MW steam thermal units will become possible. As a result, gas turbines will be retired on operation in full for 11 years after installation. Steam turbines would be retired in their 22nd years after installation.

Table 5-2 Thermal power plants to be retired

Power Plants	No. of Units	Effective installed Cap.(MW)	Year of commissioning	Year of retirements	Period of operation
Ghannouch II	1	15.0	1971	May 1981	11 years (Gas)
La Goulette I	4	30.0	1931~1954	July 1983	24 years (Steam)
Ghannouch	1	22.0	1973	July 1983	11 years (Gas)
Ghannouch	1	22.0	1973	July 1983	11 years (Gas)
La Goulette II	1	47.0	1965	Nov. 1986	22 years (Steam)
"	1				
"	1	47.5	1968	June 1989	22 years (Steam)
"	1				
Total	11	184.0	–	–	–

(3) Handling of Construction Costs of Transmission Lines and Substations in Economic Comparisons

In general, in examining combinations of individual hydro and thermal projects, it is necessary to carry out analyses of facilities from power plants to transmission lines up to primary substations. In effect, in case of combination with the Kasseb Pumped Storage Power Project, it was decided that evaluations would be made including the construction costs of transmission lines to M'Nihla Substation and Tajerouine Substation. As for steam thermal and gas turbine stations, these are all close to load areas and transmission lines for connection with the electric power system are not considered, but substation facilities for interconnection with 225-kV transmission lines are taken into account.

(4) Evaluation of Instant Adaptability of Kasseb Pumped Storage Power Station

Compared with a thermal station, a hydro station is superior in conforming instantly with variations in load, and therefore, it can adequately be used as spinning reserve or hot reserve during faults. Therefore, it is desirable for the capabilities peculiar to hydro power plants to be given full consideration in evaluation, but since this is difficult to evaluate in terms of money it is not included in the economic evaluation.

5.2 OPTIMUM ELECTRIC POWER DEVELOPMENT SCHEME

As described above, the pattern of the development scheme will become limited when the general feature of future electric power development, the tempo of development and capacities of steam thermal units, combinations of development plans, reserve capacity and service level, and conditions regarding idle and retired facilities are taken into consideration.

5.2.1 Optimum Electric Power Development Scheme and Transitions in Proportions of Supply Capability Composition

In conclusive terms, the optimum electric power development scheme will be as given below.

Jul. 1983: Steam thermal "X", 150-MW unit (Base power)
Feb. 1985: Kasseb Hydro, 75 MW x 1 unit (peak power)
Jan. 1986: Kasseb Hydro, 75 MW x 1 unit (peak power)
Nov. 1986: Steam thermal "Y", 150-MW unit (base power)
Nov. 1987: Kasseb Hydro, 100 MW x 1 unit (peak power)
Oct. 1988: Kasseb Hydro, 100 MW x 1 unit (peak power)
Jun. 1989: Steam thermal "Z", 150-MW unit (base power)

Regarding unit capacities of Kasseb Pumped Storage Power Station, as described in Item 6.2.3, 75-MW units are to be adopted for the First Stage Project and 100-MW units for the Second Stage Project.

The optimum development scheme to cope with incremental power demand from 1982 is shown in Fig. 5-3. As indicated in this figure, it may be seen that 150-MW steam thermal as base supply capability will be commissioned alternately with Kasseb Hydro.

As for the construction sites of the steam thermal stations "X" and "Y", as described in detail in Chapter 8, instead of additions at Sousse Thermal Power Station presently under construction, it will be desirable from the aspects of power flow and system stability for power station sites to be obtained in the vicinity of Tunis which is the main load center.

The proportions of supply capabilities of peak, middle and base load bands from 1983 and after are indicated in Table 5-3. In effect, from view point of the form of electric power demand (load curve), although in the proportions by type of generation facilities the proportion of base power supply capability is slightly small and that of peak power supply capability is slightly large, it may be said that these proportions are more or less reasonable.

Fig. 5- 3 Incremental Demand and Additional Installed Capacity

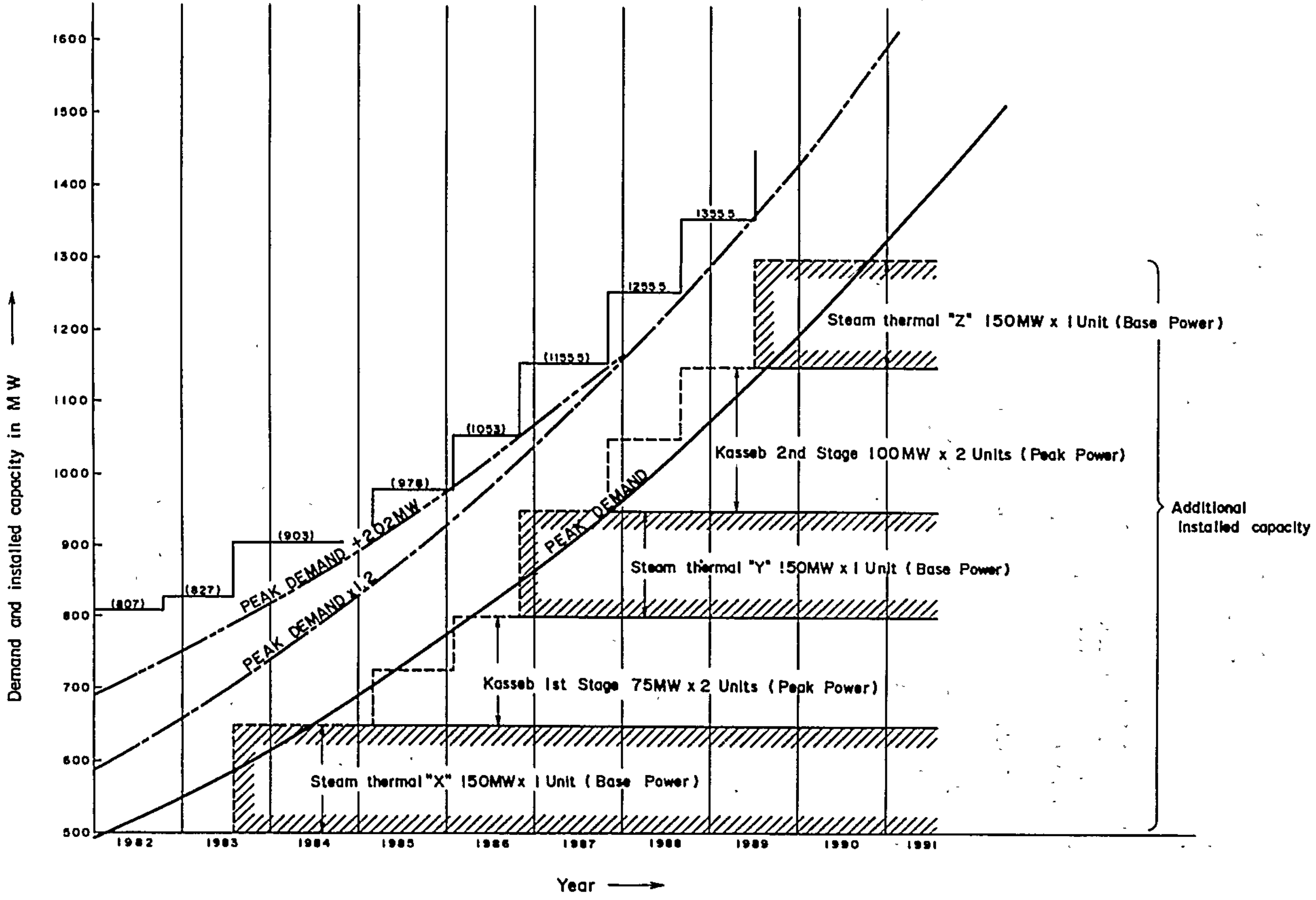


Table 5-3 Proportion of Supply Capability devided into Type of Power Plants

Load band	Applicable power plant type	1983 MW (%)	1984 MW (%)	1985 MW (%)	1986 MW (%)	1987 MW (%)	1988 MW (%)	1989 MW (%)
Peak	Reserver type hydro Regulating type hydro	36.0	36.0	36.0	36.0	36.0	36.0	36.0
	Pumped strage type	–	–	75.0	150.0	250.0	350.0	350.0
	Gasturbine	198.0	198.0	198.0	198.0	198.0	198.0	198.0
	sub-total	234.0 (25.5)	234.0 (25.5)	309.0 (31.1)	384.0 (32.7)	484.0 (38.1)	584.0 (42.6)	584.0 (39.6)
Middle	Regulating pond type	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	Middle thermal	95.0	95.0	95.0	47.5	47.5	47.5	0
	Natural gas-fueled gas turbine	62.0	62.0	62.0	62.0	62.0	62.0	62.0
	sub-total	177.0 (19.3)	177.0 (19.3)	177.0 (17.8)	129.5 (11.1)	129.5 (10.2)	129.5 (9.4)	82.0 (5.6)
Base	Run-of-river type hydro	0	0	0	0	0	0	0
	High efficiency thermal	450.0	450.0	450.0	600.0	600.0	600.0	750.0
	Natural gas-fueled steam thermal	58.0	58.0	58.0	58.0	58.0	58.0	58.0
	sub-total	508.0 (55.2)	508.0 (55.2)	508.0 (51.1)	658.0 (56.2)	658.0 (57.7)	658.0 (48.0)	808.0 (54.8)
	Total	919.0 (100)	919.0 (100)	994.0 (100)	1,171.5 (100)	1,271.5 (100)	1,371.5 (100)	1,474.0 (100)

5.2.2 Considerations in Formulation of Optimum Scheme

(1) Examination of Economics in Selection of Type of Generation Facilities as Base-Load Supply Capability

It is difficult for generation facilities other than steam thermal to be selected as base-load supply capability. However, it was decided to consider gas turbine as an alternative facility to examine the economics of the steam thermal power station.

i) Power Generating Cost of 150-MW Steam Unit

In calculating the power generation cost of the 150-MW unit, the necessary particulars were assumed to be the following:

Characteristics

Installed capacity:	150 MW x 2 units (output excluding station service)
Utilization factor:	75% (excluding station service)
Thermal efficiency (transmitting end):	35.1% (2,453 kcal/kWh)
Energy production (transmitting end):	1,971 GWh
Construction cost:	60,000,000 Dinars (200 Dinars/kW)
Fuel cost (natural gas):	32.5 Dinars/TEP (TEP: 10,500 kcal/kg x 10^3)
Service life:	30 years
Power station employees:	150

Annual Cost

Interest & depreciation:	6,360,000 Dinars (i=10%, f_{CR}=0.106)
Operation & maintenance cost:	16,470,400 Dinars
Maintenance & repair cost: (construction cost x 2.2%)	(1,320,000 Dinars)

Personnel cost:	(190,500 Dinars) (1,270 Dinars x 150 men)
Fuel cost:	(14,959,900 Dinars) (7.59 millime/kWh)
Administrative costs, others:	120,800 Dinars
Total	22,951,200 Dinars
Generating cost per kWh:	11.64 millime/kWh

For the price of natural gas, as described in Item 7.2.3, the average of present international prices of 30 to 35 Dinars/TEP, or 32.5 Dinars/TEP is taken. This natural gas price is also used for calculating the power generating cost of gas turbines which would be alternative power generation facilities.

ii) Power Generation Cost of 22-MW Class Gas Turbine

For comparisons with the 150-MW unit thermal power generation facilities mentioned in i) above, as is described in Item 7.3.1, it is decided to make the evaluations using the construction costs of gas turbine power stations to be built from 1977 through 1978. In this case it is assumed that the output of 300-MW of a steam thermal power station with two 150-MW units and the installed capacity of gas turbine power stations (assumed to be constructed scattered at several locations) are equal. In effect, the outage rates of the two are assumed to be the same, therefore a kW correction factor is not considered.

Characteristics	
Installed capacity:	300 MW
Utilization factor:	75.5%
Thermal efficiency:	26.6% (3,235 kcal/kWh)
Energy production:	1971 GWh
Construction cost:	34,500,000 Dinars (115 Dinars/kW)
Fuel cost (natural gas):	32.5 Dinars/TEP (TEP: 10,500 kcal/kg x 10^3)
Service life:	15 yr
Power station personnel:	130
Annual cost	
Interest & depreciation:	4,519,500 Dinars (i = 10%, f_{CR} = 0.131)
Operation & maintenance cost:	20,650,800 Dinars
Maintenance & repair cost:	(756,000 Dinars) (2.52 Dinars/kW)
Personnel cost:	(165,000 Dinars) (1,270 Dinars x 130)
Fuel cost:	(19,729,700 Dinars) (10.01 millimes/kWh)
Administrative cost, others:	120,800 Dinars
Total	25,291,100 Dinars
Generating cost per kWh:	12.83 millimes/kWh)

As described above, steam thermal is superior to gas turbine as a base supply capability in the comparison of generating costs. Although steam thermal is 73.9% higher in construction cost compared with gas turbine of the same scale, fuel cost is lower as thermal efficiency is. higher, and the higher the utilization factor, the more advantageous will the economics be.

(2) Necessity for Steam Thermal Unit of 150-MW in 1983

The necessity for a steam thermal power station (150-MW unit) has already been described, but this matter will be discussed further in a comprehensive manner from the aspect of demand and supply and the aspect of economy.

i) Necessity from Aspect of Demand and Supply

On examination of the various existing supply capabilities and the corresponding power demand as of 1983, the power demand corresponding to base supply capability is 67% of maximum demand, or 415-MW, and the base supply capability to meet this demand is the 300-MW of Sousse Steam Thermal (150-MW x 2 units) and the 58-MW of Ghannouch Steam Thermal, a total of 358-MW, and the shortage in this type of supply capability is conspicuous. It is conceivable for this shortage in supply capability to be tentatively filled with the 95-MW of La Goulette II which is a middle-load supply capability, but it is undesirable for a middle-load thermal of poor efficiency to be operated for base load, while the shortage of supply in case of forced or scheduled outage of one of the two 150-MW units of Sousse Thermal Power Station will also be a problem, and a new steam supply capability of 150-MW should be considered for 1983.

Further, as is discussed in the preliminary design of the Kasseb Pumped Storage Power Project in Chapter 6, in order to secure pump-up power in the midnight for operating Kasseb Power Station for power generation during peak hours, it will be necessary to have a base supply capability with low power generation fuel cost. A 150-MW steam thermal will be appropriate for this base supply capability, and as is shown in Fig. 6-2, it is clear that three 150-MW steam thermal units will be necessary as base supply capability in 1985 when Kasseb Pumped Storage Power Station will be commissioned.

As described above, a comprehensive study shows that it will be necessary for 150 MW of steam thermal to be newly constructed and added to the electric power system in 1983, and this is considered to be a fundamental factor in the development scheme.

This third 150-MW unit will be called "X" Thermal herein, and to consider the location of construction and period of time required for construction of this 150-MW unit, it will be necessary to locate it in the vicinity of Tunis immediately after the second survey for the Kasseb Pumped Storage Project has been completed, a feasibility report has been submitted, and the conclusions of that feasibility report have become known.

In the event selection of the construction site for "X" Thermal is delayed, it will be possible to make an addition at Sousse Thermal Power Station in the form of a third unit. In this case, operation can be started in July 1983 even if ordering of equipment were to be done in the latter half of 1980.

ii) Necessity from Economic Aspect

The case of first constructing a gas turbine which requires less initial investment and operating it as a base supply capability until a steam thermal comes into operation, and as a peak supply capability thereafter (Case 3) and the case of constructing a steam thermal from the beginning and developing a gas turbine when peaking power becomes necessary (Case 2) as indicated in Fig. 5-2 will be compared below.

The comparison study is made based on the annual costs for a thirty-year period during which equipment renewal costs for gas turbine can be ignored. As for fuel cost when evaluating gas turbine as peak supply capability, the price of 10.20 millimes/kWh given in Item 7.3.3 will be used. The other conditions are those used in calculating generating costs of steam thermal and gas turbine in case of the above-described base supply capability.

Fig.5-4 RATIO OF BASE, MIDDLE & PEAK SUPPLY CAPABILITY

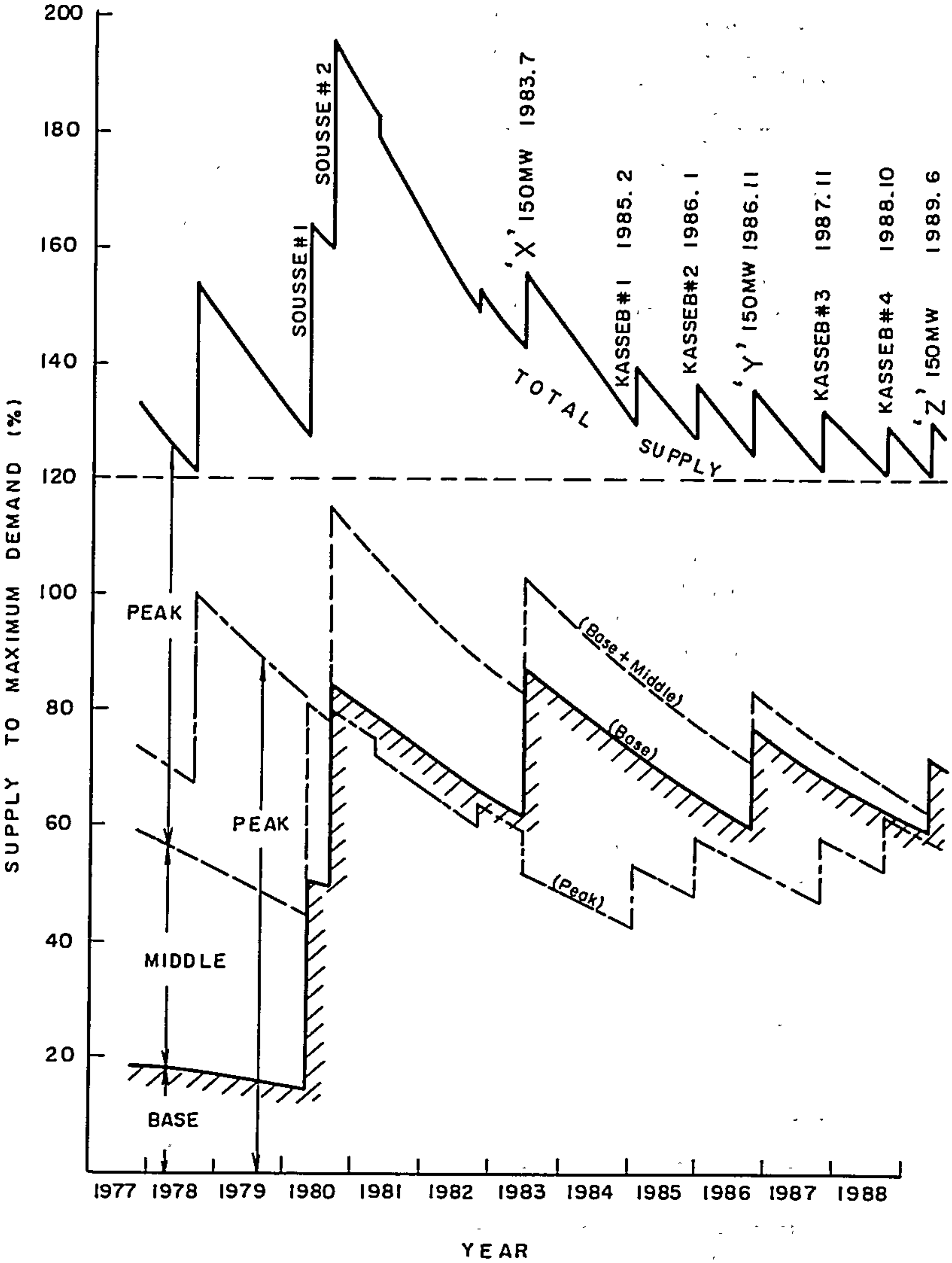
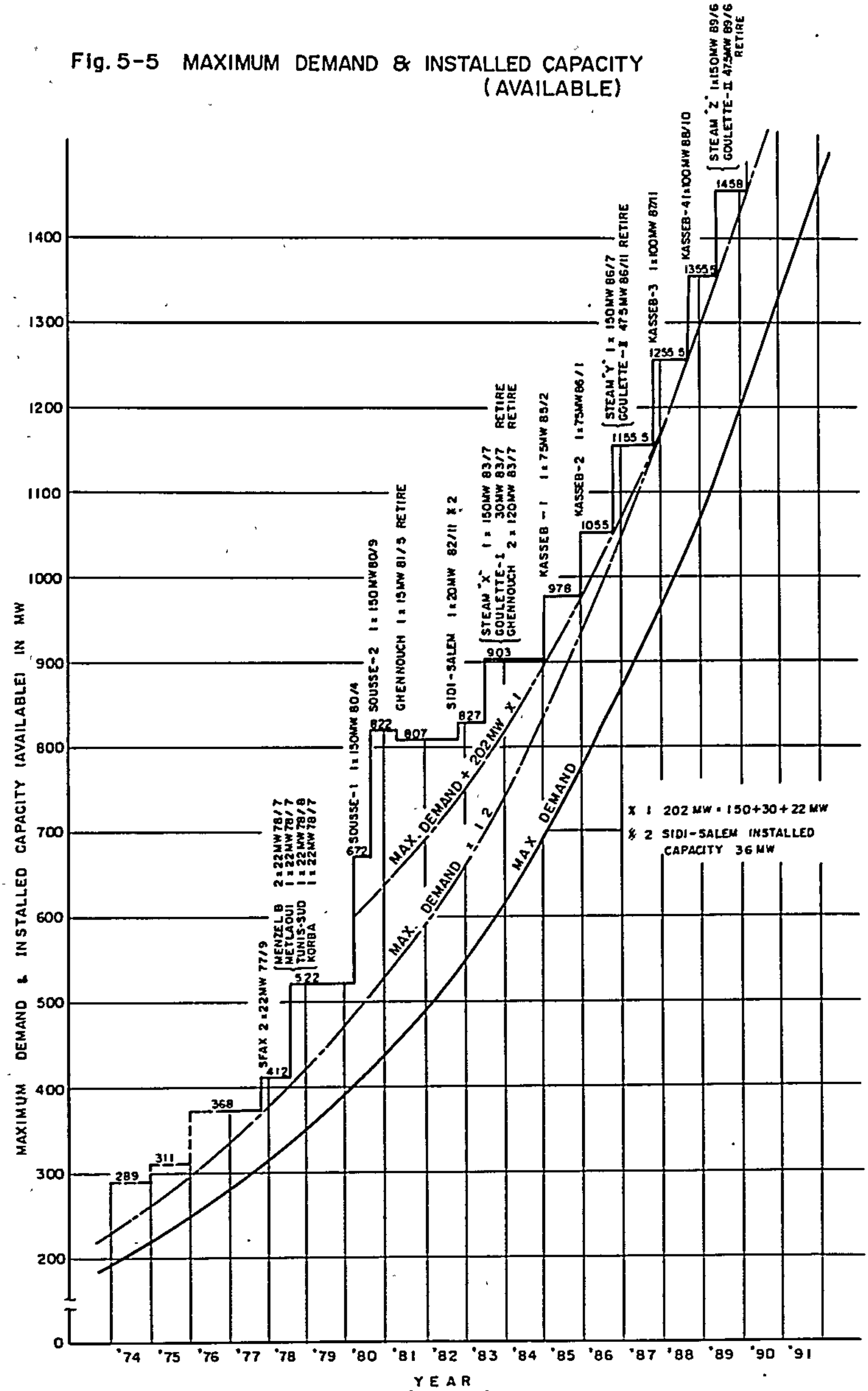


Fig. 5-5 MAXIMUM DEMAND & INSTALLED CAPACITY (AVAILABLE)



As shown in Table 5-4, in the comparison of annual costs for a 30-year period, a benefit of 2,573 x 10^3 Dinars over Case 3 can be expected with Case 2. Consequently, it may be concluded that a 150-MW steam thermal unit should be constructed as the base supply capability to be added in July 1983.

5.3 POWER DEMAND AND SUPPLY BALANCE

In studying the power demand and supply balance it is necessary to make examinations dividing into short-term supply plans and long-term supply plans. Generally, with short-term plans, supply plans over 2-year to 3-year periods are examined with emphasis on electric energy. On the other hand, in the case of long-term plans of 5 years to more than 10 years, it is normal for examinations to be made stressing kW. Since the power demand and supply balance of the STEG Electric Power System considered by the Mission is for a power supply plan for a 7-year period from 1983 through 1989, the evaluation is made emphasizing kW.

In order to examine the power demand and supply situation, there is a necessity to clarify the degree of balance between demand and supply capability. Power supply facilities are accompanied by the risk of faults at all times, while in the case of hydro generating capacity will vary due to high or low of river runoff or restrictions placed on operation, and further, there can be errors in predictions of demand. Consequently, it will be close to impossible to maintain balance of demand and supply merely by possessing power generating facilities matching the maximum demand forecast and it will be necessary to have reserve capacity.

The feature of the STEG Electric Power System, as mentioned previously, is that the effective installed capacity of hydroelectric power stations based on river runoff will be 56 MW in 1982 and only 6.6% of total power generating capacity. Therefore, the influence on the STEG Electric Power System of variation in hydro supply capability due to changes in river runoff may be neglected.

Consequently, in expressing the degree of balance in power demand and supply, it was considered that the supply capability of hydro would be constant, and that the judgment would be made based on whether the reserve capacity described in Item 5.1.3 which is the difference between demand and supply capability is secured in the required capacity. The reserve capacity by year from 1977 through 1989 taking into account newly constructed thermal power generating facilities, the Kasseb Pumped Storage Power Project and retired facilities will be as shown in Table 5-5 and Fig. 5-4.

Table 5-5 Reserved Capacity of STEG Power System

	1977	1979	1981 1/	1983	1985	1987	1989
Installed capacity (MW)	412.0	522.0	807.0	903.0	978.0	1,255.0	1,458.0
Max. demand (MW)	315.0	390.0	490.0	615.0	775.0	965.0	1,195.0
Reserved capacity(MW)	97.0	132.0	317.0	288.0	203.0	290.0	263.0
Reserve ratio (%)	30.8	33.8	64.7	46.8	26.2	30.1	22.0

Note 1/ : 150 MW x 2 steam units will be put into service in 1980.

The ratios of the previously-described peak, middle and base supply capabilities and the ratio of the total installed capacity to maximum demand are also indicated in Fig. 5-4. As shown

Table 5-4. Comparison of Annual Cost between Case 2 and Case 3

Unit: 10^3 Dinars

Year	Present factor (i=10%)	Case 2 Gas turbine Fixed cost	Case 2 Gas turbine Variable cost	Case 2 Gas turbine Sub-total	Case 2 Steam turbine Fixed cost	Case 2 Steam turbine Variable cost	Case 2 Steam turbine Sub-total	Case 2 Total	Case 2 Present value	Case 3 Gas turbine Fixed cost	Case 3 Gas turbine Variable cost	Case 3 Gas turbine Sub-total	Case 3 Steam turbine Fixed cost	Case 3 Steam turbine Variable cost	Case 3 Steam turbine Sub-total	Case 3 Total	Case 3 Present value
1	0.909	–	–	–	3,996	7,480	11,476	11,476	10,431	2,781	9,865	12,646	–	–	–	12,646	11,495
2	0.826	579	329	908	3,996	7,480	11,476	12,384	10,229	2,781	6,084	8,865	1,665	3,117	4,782	13,647	11,272
3	0.751	2,085	1,185	3,270	↑	↑	↑	14,746	11,074	2,781	1,185	3,966	3,996	7,480	11,476	15,442	11,597
4	0.683	2,781	1,580	4,361				15,837	10,817	2,781	1,580	4,361	3,996	7,480	11,476	15,837	10,817
5	0.620	2,781	1,580	4,361				15,837	9,819	2,781	1,580	4,361	↑	↑	↑	15,837	9,819
6	0.564	↑	1,580	↑				↑	8,932	2,781	1,580	↑				↑	8,932
7	0.513		1,580						8,124	2,781	1,580						8,124
8	0.466		1,580						7,380	2,781	1,580						7,380
9	0.424		1,580						6,715	2,781	1,580						6,715
10	0.385		1,580	ditto				ditto	6,097	2,781	1,580	ditto				ditto	6,097
11	0.350	ditto	1,580						5,543	2,781	1,580						5,543
12	0.318		1,580						5,036	2,781	1,580						5,036
13	0.289		1,580						4,577	2,781	1,580	↓				↓	4,577
14	0.263		1,580						4,165	2,781	1,580	4,361				15,837	4,165
15	0.239	↓	1,580	↓				↓	3,785	2,781	1,580	4,361				15,837	3,785
16	0.217	2,781	↑	4,361				15,837	3,436	2,642	↑	4,222				15,698	3,406
17	0.197	2,781		4,361	ditto	ditto	ditto	15,837	3,120	2,642		4,222	ditto	ditto	ditto	15,698	3,093
18	0.179	2,642		4,222				15,698	2,810	↑		↑				↑	2,810
19	0.163	2,642		4,222				15,698	2,559								2,559
20	0.148	↑		↑				↑	2,323								3,323
21	0.135								2,119								2,119
22	0.122		ditto						1,915		ditto						1,915
23	0.111								1,742								1,742
24	0.101								1,585								1,585
25	0.092	ditto		ditto				ditto	1,444	ditto		ditto				ditto	1,444
26	0.083								1,303								1,303
27	0.076								1,193								1,193
28	0.069	↓	↓	↓	↓	↓	↓	↓	1,083	↓	↓	↓	↓	↓	↓	↓	1,083
29	0.063	2,642	1,580	4,222	3,996	7,480	11,476	15,698	989	2,642	1,580	4,222	3,996	7,480	11,476	15,698	989
30	0.057	2,642	1,580	4,222	3,996	7,480	11,476	15,698	895	2,642	1,580	4,222	3,996	7,480	11,476	15,698	895
Total	–	75,944	44,174	120,118	119,880	224,400	344,280	464,398	141,240	81,345	59,794	141,139	113,553	212,557	326,110	467,249	143,813

Steam turbine (Base load)

Fixed cost = $\frac{(6,360 + 1,320 + 190.5 + 120.8) \times 10^3}{2}$

= $3,996 \times 10^3$ Dinars

Variable cost = $\frac{14,959.9 \times 10^3}{2} = 7,480 \times 10^3$ Dinars

Gas turbine (Base load)

Fixed cost = $\frac{(4,519.5 + 756 + 165.1 + 120.8) \times 10^3}{2}$

= $2,781 \times 10^3$ Dinars

Variable cost = $\frac{19,729.7 \times 10^3}{2} = 9,865 \times 10^3$ Dinars

Gas turbine (Peak load)

Fixed cost = same as base load

Variable cost

75 MW $\times$ $3.3^H \times 365^{days} \times 6/7$

$\times$ 10.2 millimes/kWh = 790×10^3 Dinars

150 MW $\times$ $3.3^H \times 365^{days} \times 6/7$

$\times$ 10.2 millimes/kWh = $1,580 \times 10^3$ Dinars in Fig. 5-4, a 150-MW unit of Sousse Steam Thermal Power Station will be commissioned as a base power supply capability in 1980, after which base thermal will be added in 150-MW units with 60% as the lower limit, and the necessary base supply capability will be roughly secured. Peak supply capability will tend to be slightly excessive up to around 1983, and this is because of seven 22-MW gas turbine units to be introduced in 1978 and will be a transient phenomenon until Sousse Steam Thermal Power Station is completed.

The ratio of total installed capacity to maximum demand is such that the reserve capacity requirement of 20% of maximum demand is greatly exceeded until around 1982, but this will converage to a roughly appropriate ratio from 1983.

As described above, it is seen that the demand and supply balance will be maintained from 1983 while securing the necessary reserve capacity. The relations between installed capacity and maximum demand in 1977 and after are indicated in Fig. 5-5.

5.4 MODERNIZATION OF ELECTRIC POWER SYSTEM CONTROL AND OPERATION SYSTEM

An electric power system is a complex, organic entity comprised of electric power facilities distributed over a wide area. Consequently, it is necessary to collect information from every part of the electric power system, issue commands based on the information and in keeping with a

(1) Exclusive telephone channels for load dispatching
(2) Remote metering equipment (telemeter)
(3) Remote display equipment (supervision)

(Present)

↓

(1) Exclusive telephone channels for load dispatching
(2) Remote metering equipment (telemeter)
(3) Remote display equipment (supervision)
(4) Economic load dispatching equipment
(5) Automatic frequency controller

(Near Future)
Adoption of analog computer and single-purpose automatic control equipment

↓

(1) Exclusive telephone channels for load dispatching
(2) Remote metering equipment (telemeter)
(3) Remote control equipment
(4) Comprehensive automatic load dispatching equipment

(Future)
Adoption of digital computer and comprehensive automatic control equipment

single way of thinking and purpose, and carry out controls so each part of the organic entity will work in a manner that harmony will be achieved as a whole. In the case of the STEG Electric Power System, in 1981 when the Fifth Five-Year Plan will be completed, a 225-kV transmission line system will cover the entire country in grid form, the largest unit capacity will be 150-MW, and the total installed power generating capacity will reach 807-MW. When an electric power system is expanded in this way and becomes complex, various load dispatching facilities including telecommunications facilities for transmitting information will be required in order to control and operate the system in a harmonious manner.

Particularly, in order to supply customers with good quality electricity, in effect, to maintain the normal frequency and voltage, it will not suffice merely to measure electrical quantities of the principal power stations and substations, and to monitor ON-OFF conditions of important circuit breakers in the system as is presently being done at STEG, and automatic control equipment such as automatic frequency controllers (AFC) and automatic voltage controllers (AVC) capable of continuous regulation will be necessary. Further, in case of adjusting generating power to maintain the normal frequency, it will become necessary to introduce an economic load dispatching equipment to equalize incremental fuel costs of generation facilities and data loggers for arranging records of operation results. In consideration of the present load dispatching facilities of STEG and the future of the electric power system, it will be necessary for efforts to be made for modernization of load dispatching facilities as indicated below.

The telecommunications system for information transmission in operation of an electric power system must be a highly reliable one for rapid recovery from system faulting or for amply coping with abrupt changes in the condition of the system, and in structuring circuits, those types which are respectively suitable from among ultrahigh frequency radio, power line carrier and telecommunication line systems should be adopted between the central load dispatching station and thermal power stations, hydro power stations and substations.

CHAPTER 6

RESULTS OF PRELIMINARY STUDIES OF KASSEB PUMPED STORAGE PROJECT

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CHAPTER 6

RESULTS OF PRELIMINARY STUDIES OF KASSEB PUMPED STORAGE PROJECT

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RESULTS OF PRELIMINARY STUDIES OF KASSEB PUMPED STORAGE PROJECT

6.1 PAST STUDIES AND REPORTS

The studies on Kasseb Pumped Storage Project has been carried out by STEG for some time. In 1974, a boring geological survey was made by the MECASOL Ingénieur-Conseil and in November of the same year a report entitled "Kasseb-Digue du Bassin Supérieur – Etude d'avant-métré" was submitted to STEG.

Later, in 1974, a contract for preliminary design of Kasseb Pumped Storage Power Station was concluded by STEG with TECSULT International Ltd. of Canada and an interim report and a final report was submitted in the following year, 1975.

The general condition of the Kasseb Project Area and the outlines of the past studies are as described below.

6.1.1 General Condition of Project Area

The projected site of Kasseb Pumped Storage Power Station is in a mountainous area located approximately 100 km west of Tunis and the Oued Kasseb which forms the canyon of this area runs down collecting the water of two oueds, El Brick and M'Zag. The existing Kasseb Dam (arch dam) is located a proximately 400 m downstream from the junctions of these two tributaries and the reservoir is operated between water levels at elevations between 268.50 and 288.50 m for supply of city water and for power generation.

This existing reservoir is surrounded by Mt. Bou Sattar to the north, Mt. El Fahama to the east, Mt. Khour to the south and Mt. Kef El Krenigua to the west, and this reservoir will be the lower reservoir for Kasseb Pumped Storage Power Station.

The upper reservoir for the Project will be created by building a dam at a cross-wise canyon between Mt. Bou Sattar and Mt. El Fahama. The vegetation in this area is abundant and there are numerous cultivated fields. Further, as the Oued Kasseb catchment area is located in the Mediterranean Region, the climate is sub-tropical in the summer while winters are temperate.

6.1.2 Outline of Past Study

(1) Scale of Output

The past study by TECSULT International was carried out for a peaking power station to be operated 7 hours daily with the "Five-Year Power Generation Forecast for 1975–1979" of STEG made in March 1975 as a basis, the preliminary design being made in two versions with the scale of the power station of 150 MW (daily energy production 700 MWh) not considering future expansion in one, and the power station to be developed in stages up to an ultimate 320 MW (daily energy production 1,500 MWh) in the other.

(2) Type of Power Station

The designs are for reversible Francis type turbines with both intake and outlet of tulip-type, while the powerhouse is designed in two forms, an underground type and a vertical shaft type. In both the 150-MW and 320-MW proposals, the location of the powerhouse in the case of the underground type is approximately 300 m inside from the outlet, and in the case of the vertical shaft type approximately 150 m inside from the outlet. In both cases, it has been considered that a surge tank is not necessary.

(3) Operation Plan for Upper Reservoir

Since inflow to the upper reservoir is extremely small, this is ignored and the output and energy production is determined based only on the pump-up from the lower reservoir. The capacity of the upper reservoir was calculated based on a 1/5,000-scale topographical map provided by STEG and the preliminary survey report of MECASOL Ingénieur-conseil, in which case the available drawdown was made 21 m between EL 409 and 430 m considering that with drawdown between 400 and 409 m the capacity would be reduced while marly sedimentation would be increased, and also considering that there is a saddle in the canyon for the upper reservoir at EL 430 m.

(4) Operation Plan for Lower Reservoir

The catchment areas of the two oueds of El Brick and M'Zag, the main tributaries of the oued Kasseb, total 101 km^2, and the discharge conditions of the oued Kasseb are featured by floods caused by heavy rains from September to April of the following year, and by a dry season from May through August. It is recorded that the average annual runoff of the oued Kasseb from 1943 through 1961 was 1.66 m^3/sec and the total annual discharge 52.3 million m^3, with past maximum runoff 175 m^3/sec (affected also by Ben Metir Reservoir and Bou Atma Reservoir).

The operation of the reservoir in a normal condition would be between EL 268.50 and 288.50 m as stated at the beginning, but the water level will rise to a maximum of 292.50 m in the flood season.

The pump-up of water per day is planned at 2,000,000 m^3 (drawdown 0.75 m) in case of the 150-MW proposal and 5,000,000 m^3 (drawdown approximately 2.5 m) in case of the 320-MW proposal.

The gross head used in accordance with the above will be a maximum of 160 m and a minimum of 121 m, and the design hea is planned as 139 m.

6.2 PRELIMINARY STUDY OF KASSEB PUMPED STORAGE POWER PROJECT

As is well known, a pumped storage power project pumps up water to a high place and stores it taking advantage of cheap electric power produced during the midnight when loads are light, and uses the water when necessary for power generation. Therefore, the significance of pumped storage power generation lies in the fact that through work consisting of pump-up, electric energy of low value is changed to electric energy of high value. The Kasseb Pumped Storage Power Project proposes to pump up water during the midnight with 150-MW thermal units utilizing cheap and abundant natural gas recovered offshore of Gabes Bay as the power source for power generation during the hourband of maximum peak load at lighting time.

6.2.1 Features of Pumped Storage Power Generation

(1) Character of Pumped Storage Power Generation and Features of Capability

i) A pumped storage power station requires only a few minutes from starting to full operation, while the capacity for output to follow load variation is much better than a thermal power station, and in system operation it can be handled similarly to an ordinary hydro power station, but since it requires power for pump-up, fuel cost will be involved as in the case of a thermal station. The thermal efficiency of pumped storage power generation in such a case computed with Kasseb as the example will be as follows:

Kasseb pumped storage power generation thermal efficiency = Incremental thermal efficiency of 150-MW units for pump-up x Overall efficiency of pump-up = 35.7% x 69% = 24.6%

In effect, the thermal efficiency of the Kasseb Pumped Storage Power Project can be considered to be equivalent to that of a low-efficiency thermal of 24% (roughly equal to the thermal efficiency of gas turbine), but since there is a surplus in midnight power supply capability, it can be an economically advantageous project if the fuel cost were to be cheap.

ii) Operation duration time of a pumped storage power station is restricted by the capacities of its upper and lower reservoirs. It is not advantageous for the capacity of the upper reservoir of Kasseb Pumped Storage Power Station to be made very large because of topographical reasons, but the development scale of the Kasseb Power Station will be determined by the period of time peaking power to be required in the STEG Electric Power System (4 hours) and the capacity of the upper reservoir. The corresponding hourband in which it will be possible to supply electric power for pump-up in the midnight in case of the STEG Electric Power System may be considered as about 6 hours, and this power station may be planned as a daily-regulated pumped storage power station.

iii) Since a pumped storage power station is not restricted by river runoff as ordinary hydro power plant there are high freedom and accuracy in operation. In essence, when pumped storage power generation is not required, pump-up will not be done, and when necessary, by using surplus thermal as power for pump-up, a constant supply capability can be obtained at all times, and the freedom and accuracy in supply capability are far higher than for ordinary hydro power plant.

(2) Power Supply and Features of Pumped Storage Power Generation in Aspect of System Operation

A pumped storage power station, as described above, possesses the characters of both low-efficiency thermal and reservoir-type hydro, but in addition there is the pump-up operation which these do not have, while further, it is a complex supply capability subject to other restrictions. Therefore, in the aspects of power supply and system operation, it has the following roles other than as a peak supply capability.

i) Reserve Capacity

Since a pumped storage power station can be started quickly and the speed of output increase is high, it can be utilized extremely effectively as reserve capacity to maintain demand and supply balance during faults or when sudden changes occur in demand.

ii) Maintenance of Normal Frequency in Load-Following Operation

Kasseb Pumped Storage Power Station will be used as supply capability for following loads during peak hours, and it will be easy to maintain system frequency at the normal value.

iii) Reduction in Times of Starting and Stopping of Gas Turbines and Middle-Load Steam Thermal Stations Frequent starting and stopping of a steam thermal plant will not only be economically disadvantageous, but also there will be adverse effects on equipment, and by using pumped storage which can be easily started and stopped as peak supply capability, it will be possible to reduce the number of times of starting and stopping of thermal plants.

iv) Improvement of Operating Efficiency of Base Steam Thermal Unit

Pump-up in the midnight will increase the load during the midnight and will alleviate restriction of output of the base steam thermal to make possible high-efficiency operation, and improvement in economy can be aimed for.

v) Supply of Reactive Power to Maintain System Voltage

Since the Kasseb Pumped Storage Power Project will be constructed in the area of the Northern Power System which makes up 60% of the total demand in the STEG System and will be comparatively close to the load center, the supply or absorption of reactive power through pumped storage power generation will be highly effective from the aspect of voltage control of the system, and will be economical as well.

6.2.2 Prediction of Annual Operating Condition of Pumped Storage Power Generation

In formulating a pumped storage power plan, it must first be examined what would result in the greatest economy in developing supply capabilities to cope with future power demand, and then determine the position of the pumped storage project in the scheme. In such case it is necessary to predict as accurately as possible what form (load curve) the future power demand will take, what the load allocation for the pumped storage power station will be, whether pump-up power sources can be secured throughout the future, and what will be the energy production and operating conditions not only of the pumped storage power station, but also of other supply capabilities, and thereby predict the annual operating conditions of the pumped storage power station.

In this sense, the Mission held discussions with STEG upon which the operating conditions of the supply capabilities in the STEG Electric Power System from 1985 when Kasseb Pumped Storage Power Station will be completed were predicted, and as described in the power demand forecast of Chapter 4, since the annual load factor of the STEG Electric Power System will not vary from 1981, it was assumed that the load curve estimated for the STEG System as of 1981 would be proportional in accordance with the growth in power demand.

The form (load curve) of electric power demand for 1981 was forecast based on the present power demand, and fundamentally there is no difference. The annual load curve of the STEG Electric Power System shows that the times at which lighting-time peaks start vary depending on the season, but maximum power indicates a trend of gradual increase, and increases or decreases in demand according to season (variation in power demand due to prominent outside air temperature differences such as between winter and summer) cannot be seen. The feature of the load curve of the STEG Electric Power System is that the daytime peak is about 75% of lighting-time peak, and the difference of 25% is peak load centered around lighting time (see Fig. 6-1).

Under such a form of power demand, allocating the load in excess of the daytime peak to the pumped storage power station will make possible high-efficiency operation accompanied by reduction in starting and stopping of thermal power generating facilities (including gas turbines) and improvement of the load factor. Therefore, as indicated in Fig. 6-2-(1), the Mission considered that Kasseb Pumped Storage Power Station would be operated during 4 to 5 hours of the lighting-time peak. As for the form of the power demand for Sundays and holidays, this differs from that of ordinary workdays as shown in Fig. 6-1, and the size of the lighting-time peak load of a holiday is roughly equal to the daytime peak of a workday, while the daytime peak of a holiday is about 60% of the lighting-time peak, and compared with the difference of 25% between lighting-time and daytime peaks of a workday, the difference of 40%[1/] is large. This indicates that it will be possible for Kasseb Pumped Storage Power Station to be operated (pump-up and power generation) on holidays also.

1/ However, in Chapter 7, "Economics of Kasseb Pumped Storage Power Project," since the sizes of the daytime peak of a workday and the lighting-time peak of a holiday are roughly the same, in effect, since the lighting-time peak of a holiday can be supplied by the power generating facilities operated during the daytime of a workday, the evaluation is made assuming Kasseb Pumped Storage Power Station will not operate on holidays (see Fig. 6-1).

Fig. 6-1 Estimated Week-day and Sunday Load Curves in 1981

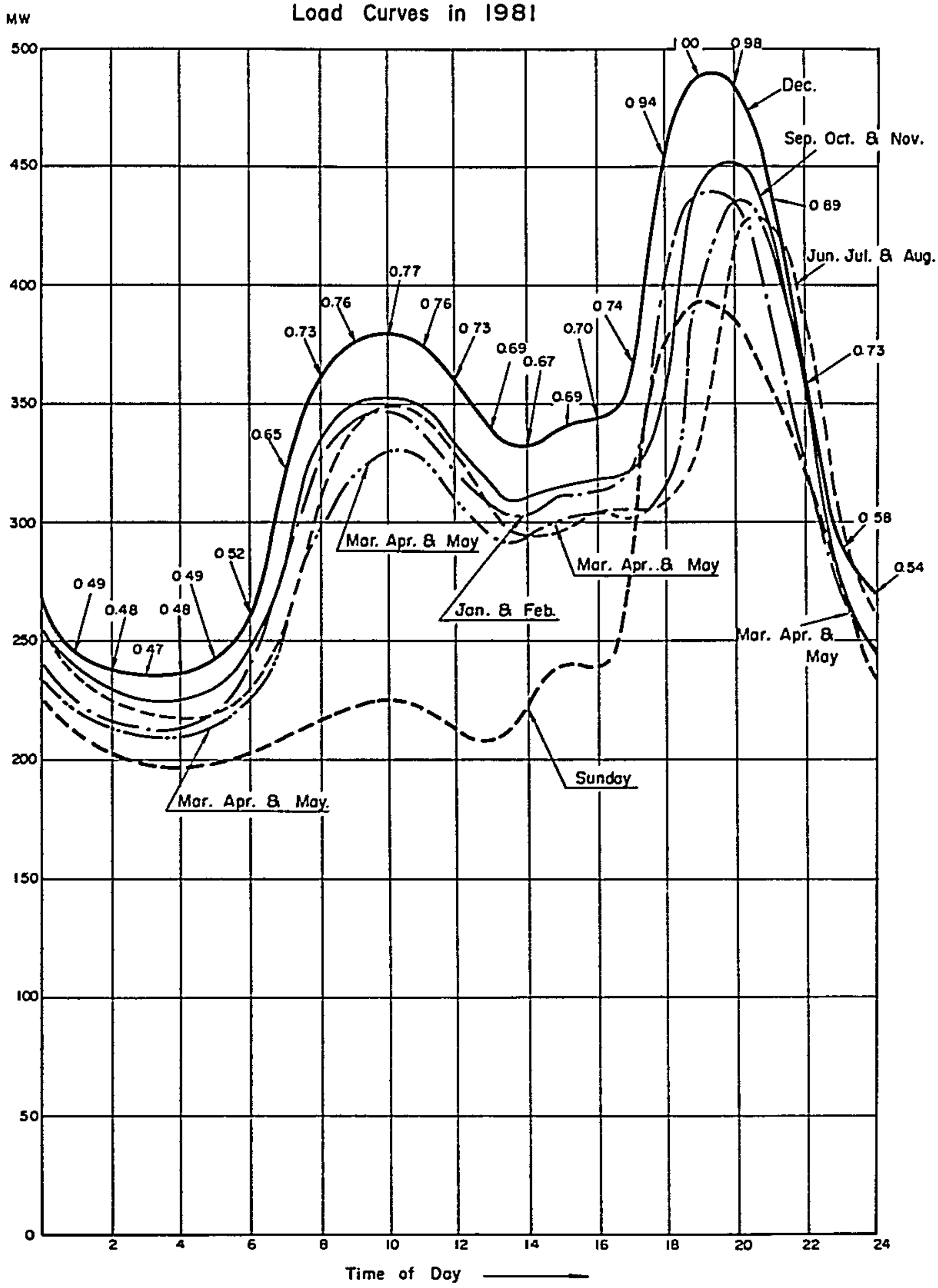


Fig. 6 - 2-(1) Peak Day Load Curve of STEG Power System and Power and Energy to be Provided by Kasseb P.P.

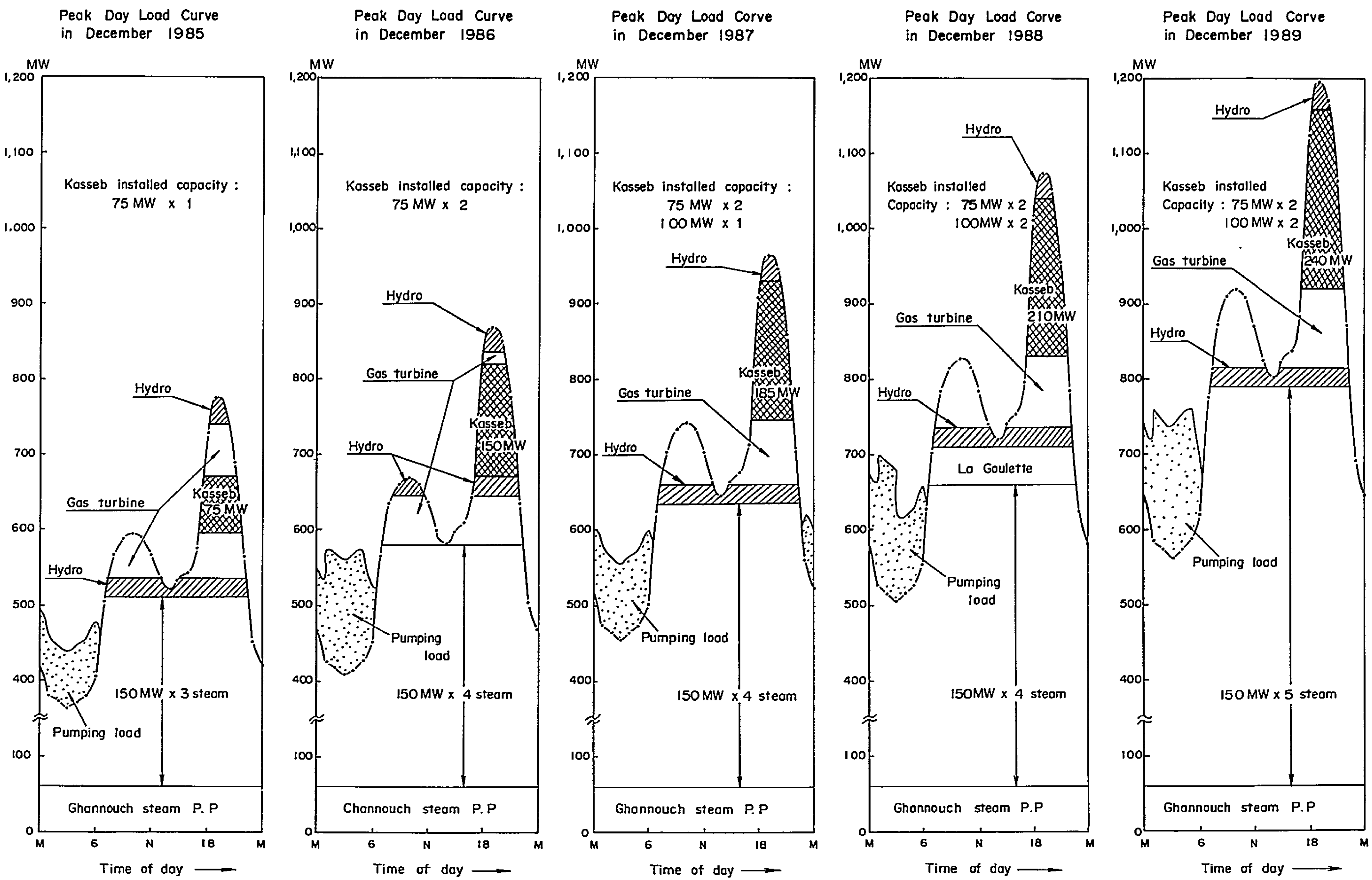
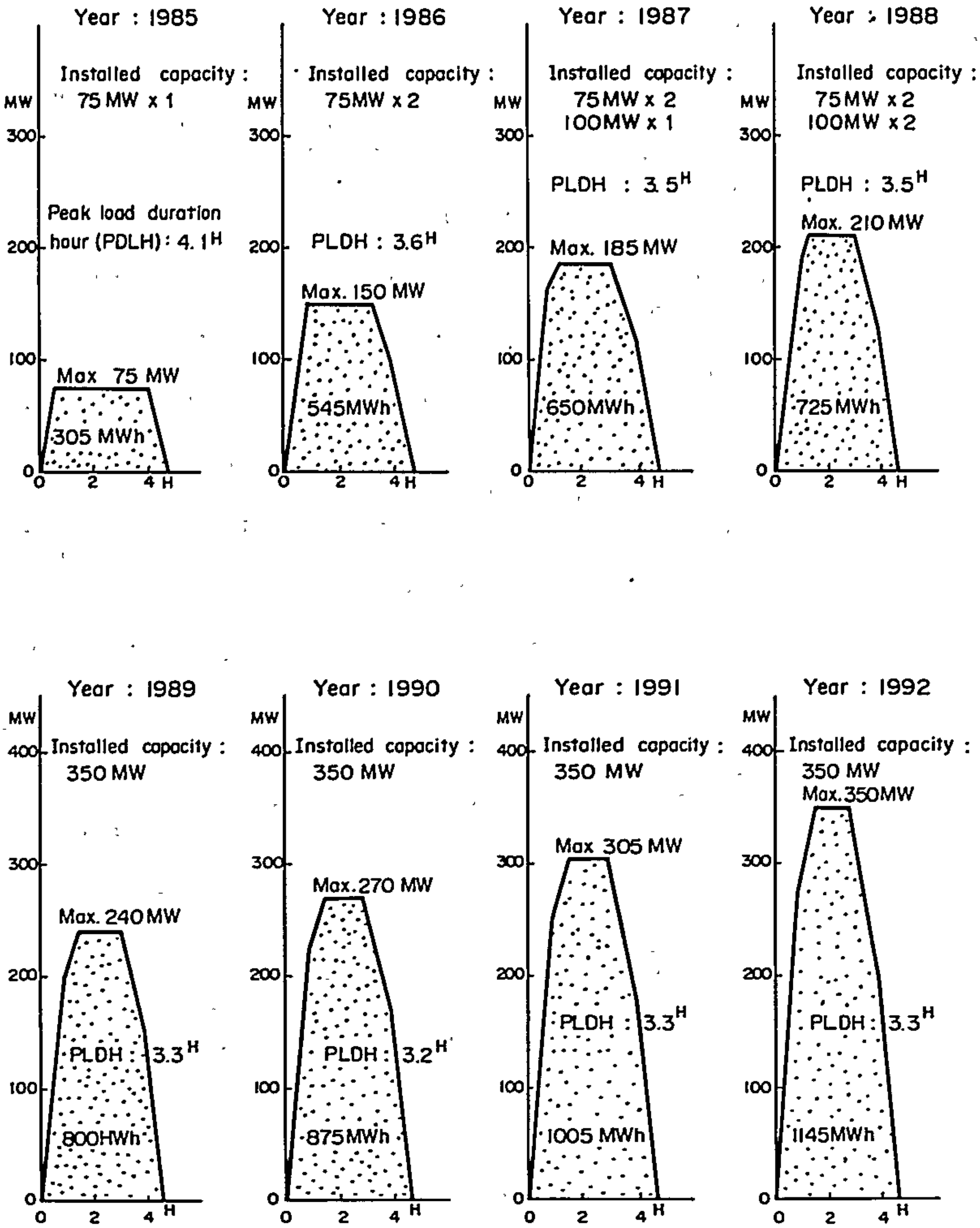


Fig. 6-2-(2) Peaking Power Required by Kasseb Pumped-Storage Station



In effect, Kasseb Pumped Storage Power Station will be a station which will operate 4 to 5 hours during lighting time for peaking power throughout the year in meeting the future power demand of STEG, and this means it will occupy an important place as peaking power. The maximum power and energy production of Kasseb Power Station in each year from 1985 through 1992 are indicated in Fig. 6-2(2).

6.2.3 Determination of Unit Capacities of Generators

The number of main equipment units must be determined based on the greatest advantage taking into consideration transportation limits, manufacturing limits, economy and harmony with the electric power system. In the case of the Kasseb Pumped Storage Power Project, it is thought as a result of reconnaissance of roads and bridges there will be no problem in overland transportation within Tunisia. Therefore, the number of equipment units may be determined from the standpoints of economy and harmony with the electric power system.

Generally speaking, the larger the unit output shows a tendency to economy from point of view of overall economy in equipment and machinery costs and civil works costs. Therefore, it is desirable for the unit output to be as large as possible within limits of reliability in consideration of manufacturing performance records and manufacturing capability. However, in case the power system is small, making the unit capacity too large will result in failure of supply when there is a forced or scheduled outage of a unit. Kasseb Pumped Strage Power Project which differs from conventional type hydro power plant has two principal characteristics provided with both power supply as a hydropower plant and power demand as a water pumped station.

Therefore, the influence of unit output on the electric power system must be examined differentiating between cases of generator operation and pump operation, and the decision must be made from the viewpoint of harmony with the power system.

(1) Determination of Unit Capacity as Pumping Motor

Although it will be more economical the larger the unit capacity, the unit capacity of the first pumping motor to be introduced must be in conformity with the power system capacity of STEG.

i) Motor Input at Start of Pump-up

Since a pumping motor has the characteristic of going into full-load operation quickly after filling its casing of water turbine with water, it is necessary to make an examination taking into consideration STEG's power system constant and incremental output of back-up thermal.

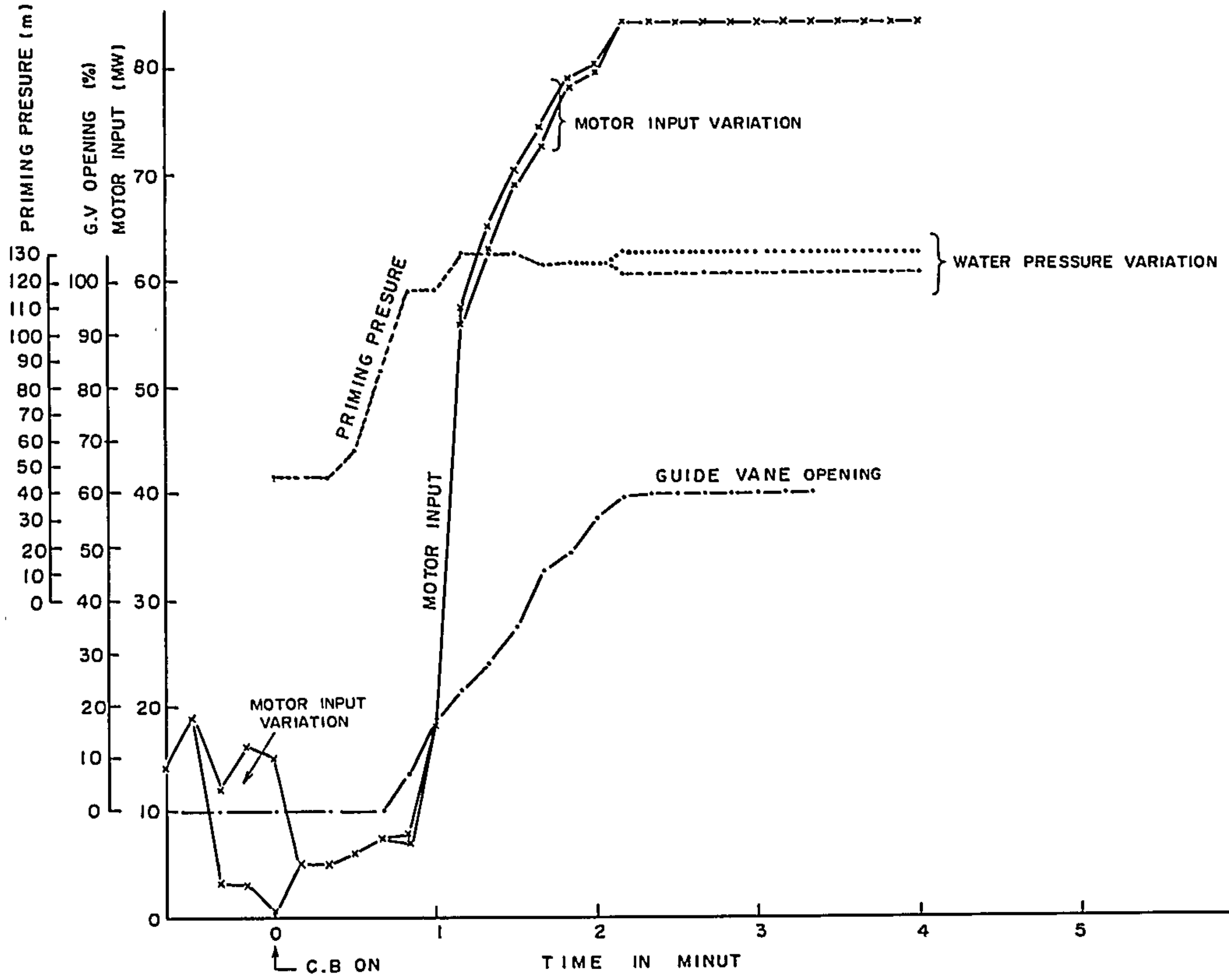
The load characteristics and water pressure variation of a pump-turbine when a generator-motor of a pumped storage power station is introduced into a power system in Japan arė indicated in Fig. 6-3.

According to this, priming pressure is established approximately 40 sec. after closing of the main-circuit breaker, and when the guide vanes begin to open, input is sharply increased linearly to around 60-MW, after which this is slowed slightly until it reaches 100% input of 85-MW. At the steepest point there is an increase in input of 50-MW in 20 sec., and this part causes the greatest disturbance to the power system.

As indicated in Fig 6-3, the pumping motor input rises fairly steeply, but in the case of Japan there are no problems of frequency drop and voltage drop since the power system capacity is large.

Further, until input becomes stabilized, there will be vibrations produced at parts such as pump-turbine guide vanes and these will be caused load variation of the generator motor, and it is desirable for the time to be as short as possibly. However, in the case of

Fig. 6-3 CHARACTERISTCS CURVES OF PUMP-TURBINE



the STEG System, increase of pumping-motor load in a short period of time means that the incremental output speed of corresponding steam thermal plant will not keep in step to result in large frequency variation, and this will not be desirable. Consequently, for the Kasseb Pumped Storage Power Project, necessary measures are to be taken such as adjusting guide vane opening speed to increase generator-motor input to about 1 min.20 sec. while imparting ample mechanical strength against vibration beforehand at the pump-turbine design stage.

(ii) Electric Power Supply at Start of Pump-up

The electric power supply against sudden load increases when the motor pumps up water can be considered to be the following:

a) Rapid load increase of base steam thermal plant
b) Power supply capability from the power system depending on system constant

It is considered that the base thermal steam plants corresponding to sudden increases in the load of the pump will have their outputs raised at a rate of 7% per minute by load limiters. When three 150-MW units and the 58-MW of Ghannouch, a total of 508-MW, are connected to the system, the output increase ΔPg which can be obtained in 1 min. 20 sec. is:

$$\Delta Pg = 508 \times 0.07 \times 1\frac{20}{60} = 47.4 \text{ MW}$$

The electric power lacking (75 MW – 47.4 MW = 27.6 MW) is to be obtained from the supply capability of the electric power system in accordance with the system constant.

In concrete terms, the power system frequency is to be raised beforehand by 0.5 Hz prior to start of pump-up to obtain electric power from the system by the amount of frequency drop of the system produced when the input of the pumping motor suddenly increases, aiming to obtain the pumping motor input through decrease in demand due to lowering of the power system frequency and output discharged by WR^2 of steam thermal plants.

If the power system constant K is put as 8.0%/Hz, the frequency drop Δf corresponding to the abovementioned shortage of 27.6-MW supplied from the power system due to the system constant will be the following:

$$\Delta f = \frac{27.6}{350 \times 8\%} = 0.986 \text{ Hz}$$

iii) Calculations of Frequency Drop by Computer at Operation of Motor for Pump-up of Water

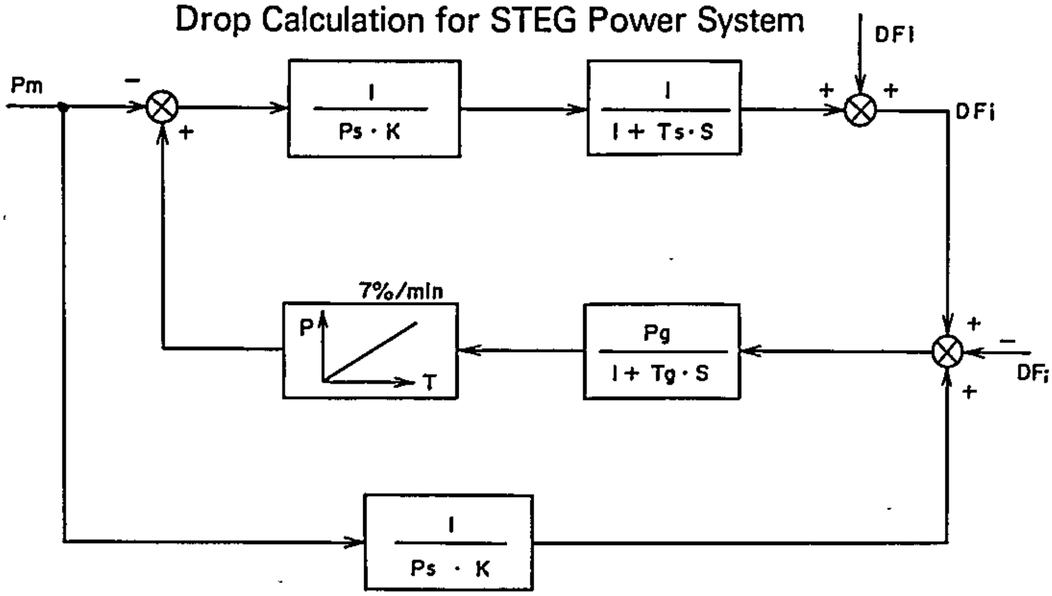
The power system frequency drop was calculated by a digital electronic computer using a simplified the pump-up characteristics by the block diagram of Fig. 6-4. The conditions for the calculations are as indicated below.

a) Pm : motor input considered to be increased linearly in 1 min. 20 sec. from 0 MW to 75-MW (actually not linear, and a curve when coming close to 100% input)
b) Ps : load in the system, 350-MW (midnight, 1985)
c) K : power system constant, to be K = 8.0%
d) Ts : time constant in the power system, taken to be 1.0 sec.
e) Tg : time constant of steam thermal plant taken to be 0.5 sec. with output increase operation to be done manually by operator (operating load limiter). Time constant about 2.0 sec. if to be detected by the speed governor

f) Load-increase speed of steam thermal generator to be 7%/min.

g) Pg : incremental power generating output possible to be 158-MW (350 MW to 508-MW)

Fig. 6- 4 Simplified Blockdiagram for Frequency Drop Calculation for STEG Power System



On carrying out calculations according to the above conditions, the system frequency becomes a minimum 80 sec. later as shown in Fig. 6-5, and after the frequency drops from 50.5 Hz to 49.5 Hz prior to introduction of the pump, there is a gradual recovery along the lines of 7%/min. increase in output of the steam thermal generator, and it will be at around 110 sec. later that the regular 50 Hz is recovered.

Further, since the power system constant K of STEG is unknown, the case of K = 10%/Hz is also included in Fig. 6-5, and the frequency drop will naturally be lower in this case.

iv) Conclusions

In order to carry out pump-up of water for a 75-MW unit in 1985 within the range of the power system frequency variation of ±0.5 Hz, the following conditions will be necessary:

a) 1985 midnight demand: 350-MW or more

b) Power System constant: K=8%/Hz or more

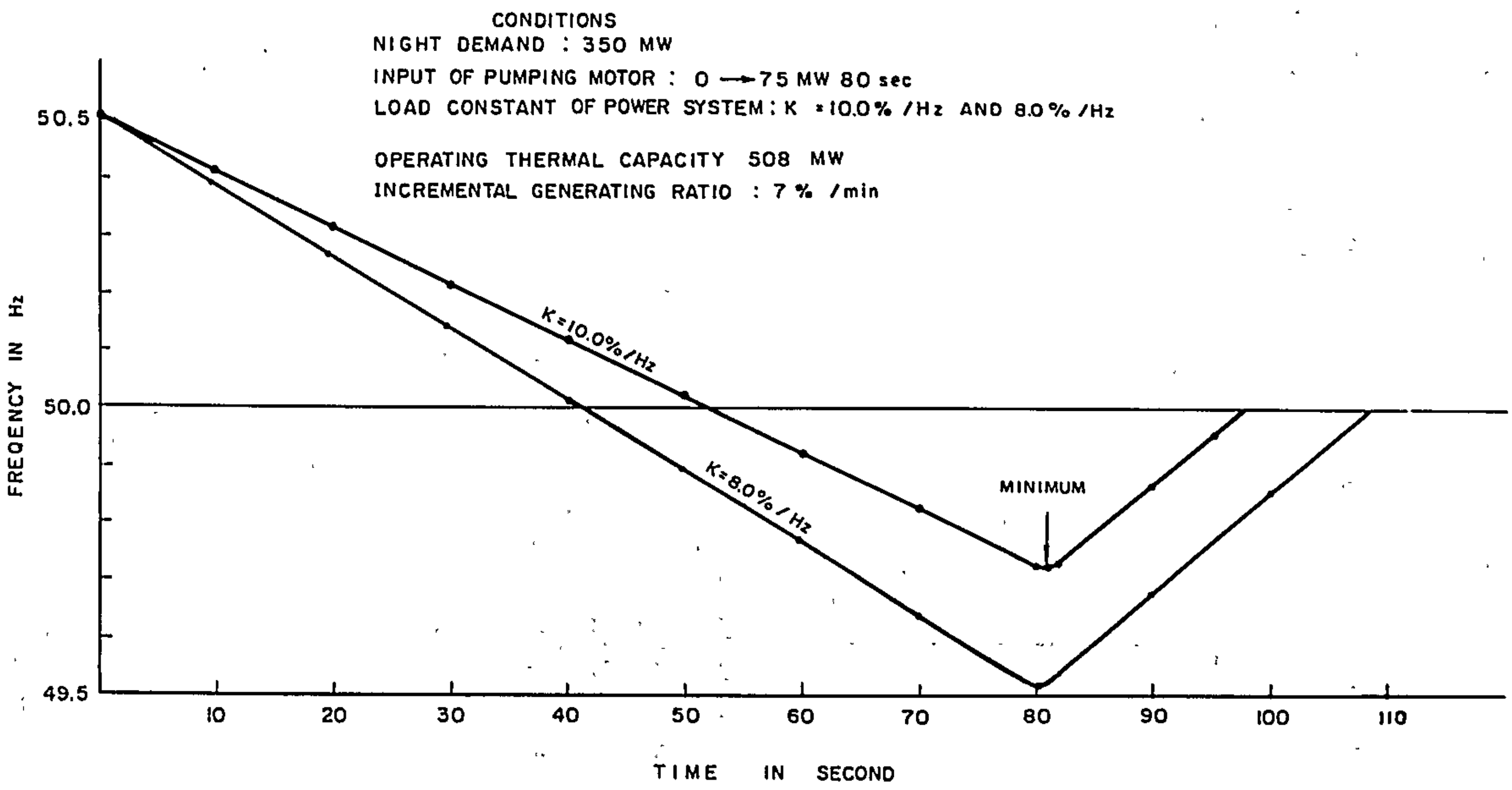
c) Incremental input speed of pump: guide vane opening speed adjusted for incremental input speed of motor to be 0-MW to 75-MW in 1 min. 20 sec.

d) Incremental output speed of 150-MW steam unit: speed of increased load from 50% load to 100% load to be not less than 7%/min.

e) Upper-limit and lower-limit frequencies for continuous operation of 150-MW steam unit: 50.0 Hz ± 0.5 Hz

By selecting a unit of 75-MW capacity beforehand as of 1985, the influence of frequency drop and voltage drop on the power system due to sudden increases in loads of pumping motors in accordance with expansion of the power system will be made small.

Fig. 6-5 FREQUENCY VARIATION AT STARTING OF PUMPING-MOTOR



(2) Unit Capacity as Generator

The harmony with the electric power system in case of generators is in other words a problem of how unit capacity is to be determined to maintain in terms of probability supply dependability of power stations as a whole above a certain standard value considering ratio of faults per generator and number of generators, and the size of the reserve capacity of the power system.

The probability that there will be forced outage of x out of n generator units is given by the binomial distribution $\binom{n}{x} q^x p^{n-x}$ where the supply capability per unit is $p=1-q$.

The rate of faulting[1/] of generators of a hydroelectric power station (q = number of days of forced outage/number of days of operation + number of days of forced outage) is normally said to be 0.01 to 0.03. In the case of the Kasseb Pumped Storage Power Project, electrical equipment will all be imported from foreign countries and it is conceivable that comparatively long periods of time will be required for restoration when faults occur, and it was decided to examine unit capacity adopting q = 0.03.

i) Variation in Number of Generators n and Supply Reliability of Power Stations as a Whole

As is shown in Fig. 6-6, the supply reliability of power stations as a whole will be improved with the greater the number of generators.

Generally, the supply reliability of an electric power system as seen from the standpoint of power consumers, in effect, the probability of a power failure, may be said to be permissible if it is about 1 day in 10 years. In actuality, it is not an overstatement to say that electric power enterprises of many countries of the world are constructing, maintaining and operating power generation, transmission, transformation and distribution facilities with this figure as the ultimate goal. In this case, the number of generators n = 2 is far off from the supply reliability of 1 day of power failure in 10 years, and thus is not desirable.

ii) Variation in hot Reserve Capacity of Power System and Supply Reliability of Power Stations as a Whole

When there is ample reserve capacity in a power system, the supply reliability of the power system as a whole is not changed as covering will be done by reserve capacity of STEG's power system even when faulting of a generator occurs at Kasseb Pumped Storage Power Station.

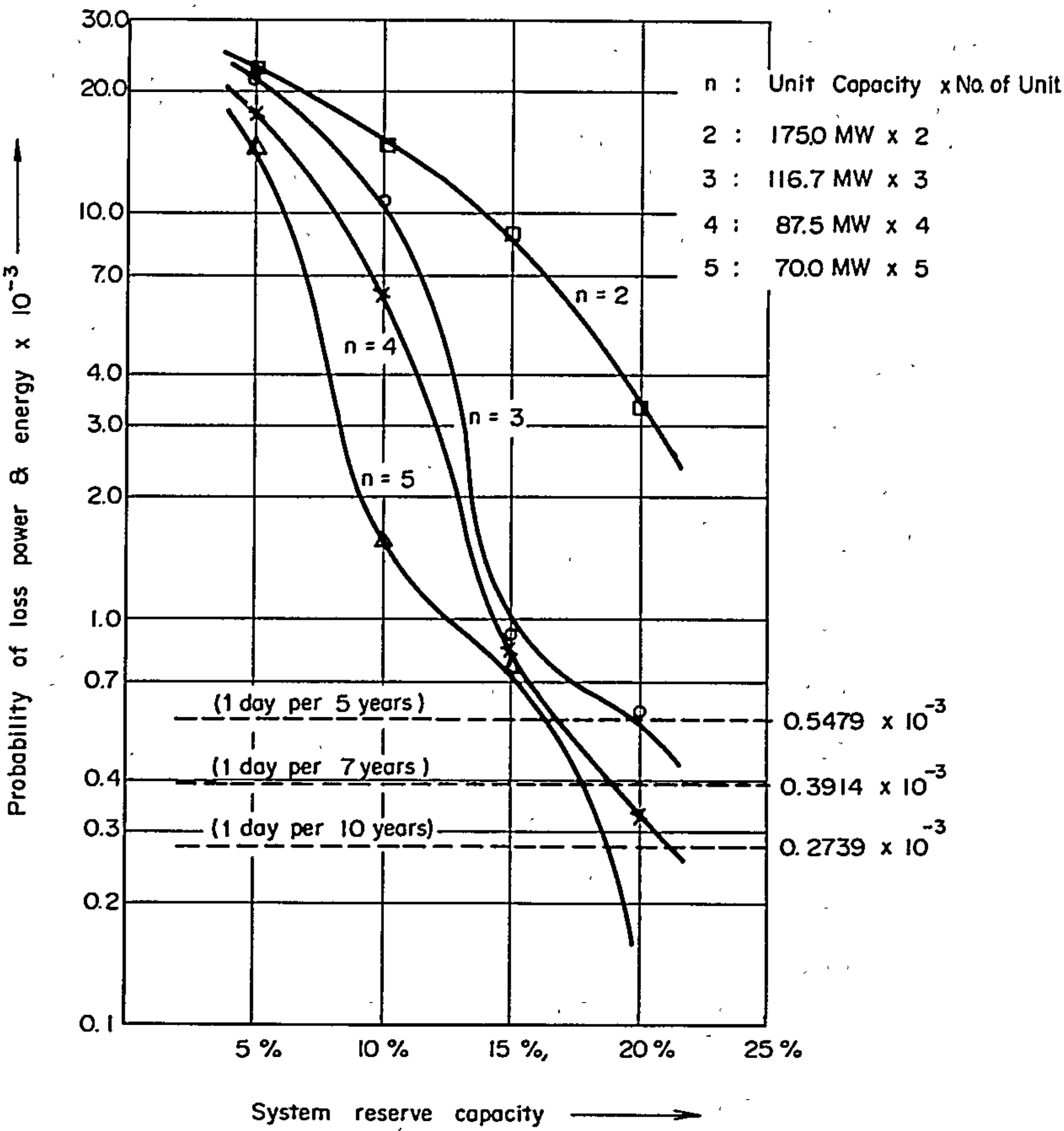
STEG is proceeding with electric power development to be able to annually secure not less than 20% of the maximum demand of the power system, and when considering that the greater part of the power generating facilities in the power system is made up of thermal power generating facilities, the unit capacity of reserve capacity possible to operate for coping with faults should be determined limiting reserve capacity to 20%.

In this sense, when the hot reserve capacity is taken to be 20%, the supply probability of the power stations as a whole will be equal to a power failure probability of 1 day in 5 years in case of number of generators of n = 3, while in case of n = 4, the power failure probability will be close to 1 day in 10 years, and in case of n = 5, the supply reliability will be greatly improved.

From the descriptions given above, it may be concluded that a proposal for 4 units will be optimum when it is considered that the supply probability of Kasseb Pumped Storage Power Station will be roughly equal to the outage probability of 1 day in 10 years. In effect, it may be said that it would be appropriate for four generators of 87.5-MW

Scheduled outage days are included in rate of faulting.

Fig. 6-6 Reliability by Loss of Power & Energy of Kasseb P. P.



output to be installed from the standpoint of power system harmony.

(3) Determination of Unit Capacity of Kasseb Pumped Storage Power Station

When frequency variation of the power system in case of operating as a pumping motor is considered as described, it is required from the viewpoint of harmony with the power system for unit capacity at Kasseb Pumped Storage Power Station to be limited to 75.0-MW. During power generation also, this unit capacity is of a size which will adequately satisfy the requirements of supply dependability of the STEG Electric Power System.

Accordingly, as described under "Optimum Electric Power Development Scheme" in Chapter 5, two 75-MW units are to be installed as a First Stage Project and two 100-MW units as a Second Stage Project.

6.3 OUTLINE OF PRELIMINARY DESIGN

The development site of a pumped storage power station is selected taking into consideration natural conditions such as topography and geology, while the size is determined based on head, reservoir capacities, available drawdown and peak load duration required. The preliminary design for the Kasseb Pumped Storage Power Project described in this chapter is for the purpose of calculating the construction cost required for comparisons with other alternative power development projects in order to meet future power demands.

The various conditions taken into consideration in the preliminary design are as follows:

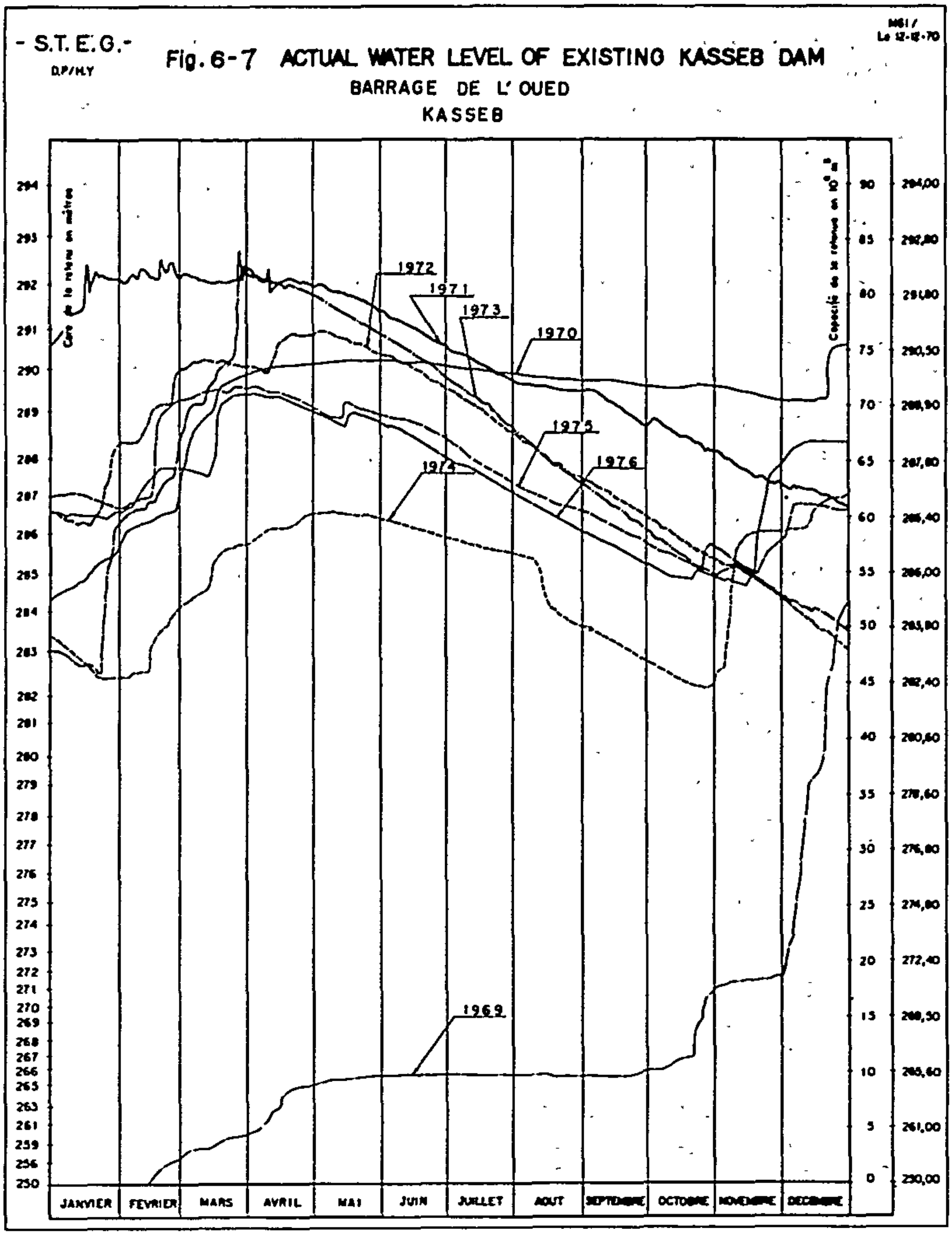
(1) Lower Reservoir Dam (Existing Kasseb Reservoir)

The reservoir to be the lower reservoir for the Kasseb Pumped Storage Power Project was completed in 1969, the dam having been constructed mainly for the purpose of securing a supply of water for the capital city of Tunis. The major particulars are indicated below.

Kasseb Dam	
Catchment area:	101 km^2
Av. annual precipitation:	1,000 mm
Av. annual inflow:	1.43 m^3/sec.
1,000-year probability flood:	1,200 m^3/sec.
Dam type:	Arch dam
Dam height:	58 m
Dam crest length:	245 m
Reservoir storage capacity:	82 x 10^6 m^3
Impoundment area:	4.37 km^2
Existing Kasseb Power Station	
Installed capacity:	660 kW (825 kVA)
Annual available energy production:	3.0 x 10^6 kWh

The available storage water of the lower reservoir will differ according to the scale of Kasseb Pumped Storage Power Station, but in case of power station output of 350-MW, it will be 3.8 million m^3 with fluctuation in reservoir water level being 0.80 m near high water level at around EL 290.00 m and 1.00 m at around EL 280.00 m (see Fig. 6-9).

Whether the powerhouse of the Kasseb Pumped Storage Power Project is to be an underground type, semi-underground type or open type will be decided by the elevation at which low water level of the reservoir is selected. These types will also greatly affect the construction cost of the Project. If the powerhouse is to be an underground type, an access tunnel to the powerhouse will be necessary and bring about an increase in the construction



- S.T.E.G.-
D.P/H.Y
Fig. 6-7 ACTUAL WATER LEVEL OF EXISTING KASSEB DAM
BARRAGE DE L' OUED
KASSEB
1969
1970
1971
1972
1973
1974
1975
1976
JANVIER
FEVRIER
MARS
AVRIL
MAI
JUIN
JUILLET
AOUT
SEPTEMBRE
OCTOBRE
NOVEMBRE
DECEMBRE

Fig. 6 - 8 Water Level of Existing Kasseb Dam (Lower Reservoir for Kasseb Pumped - Storage Station)

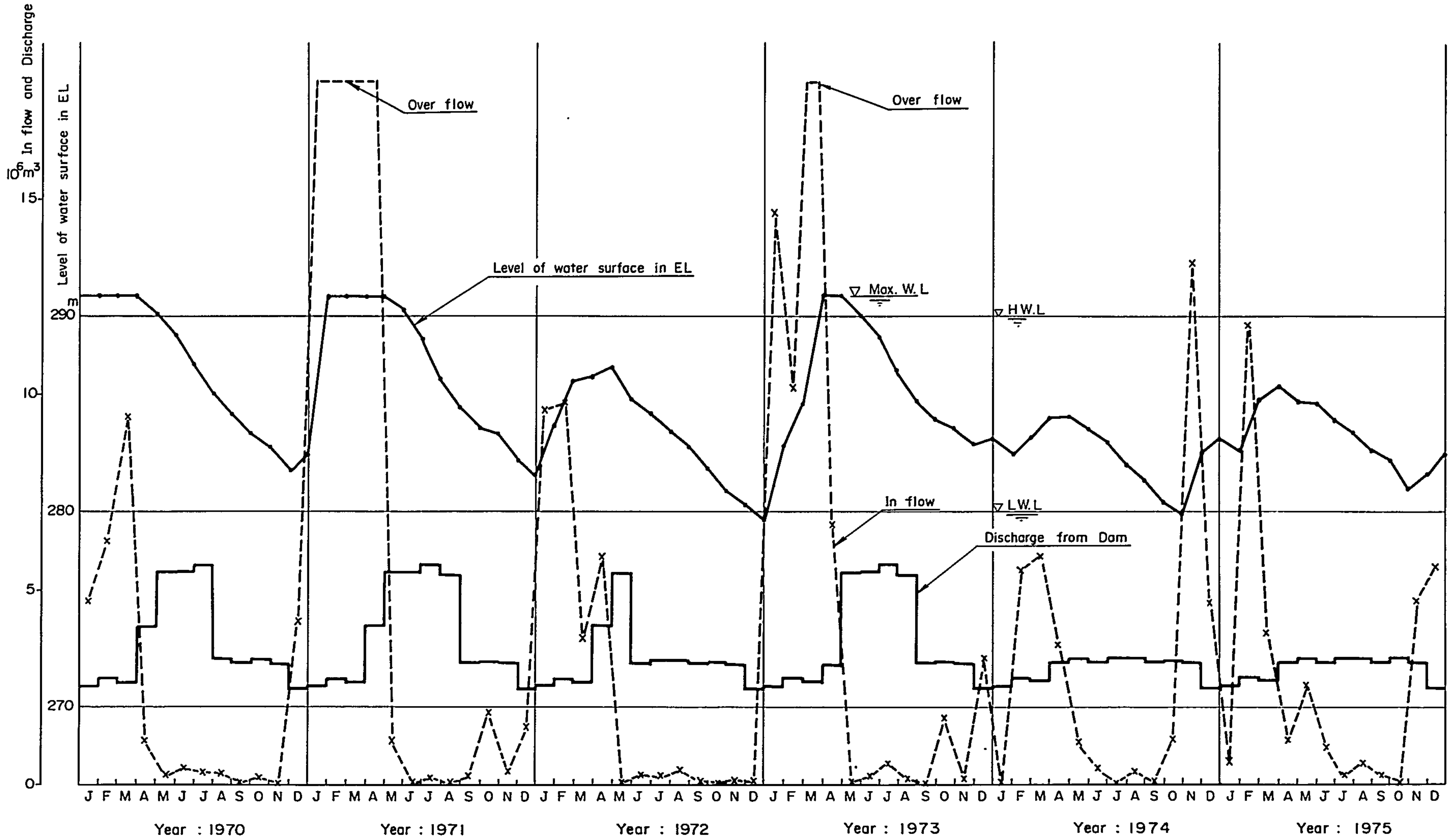
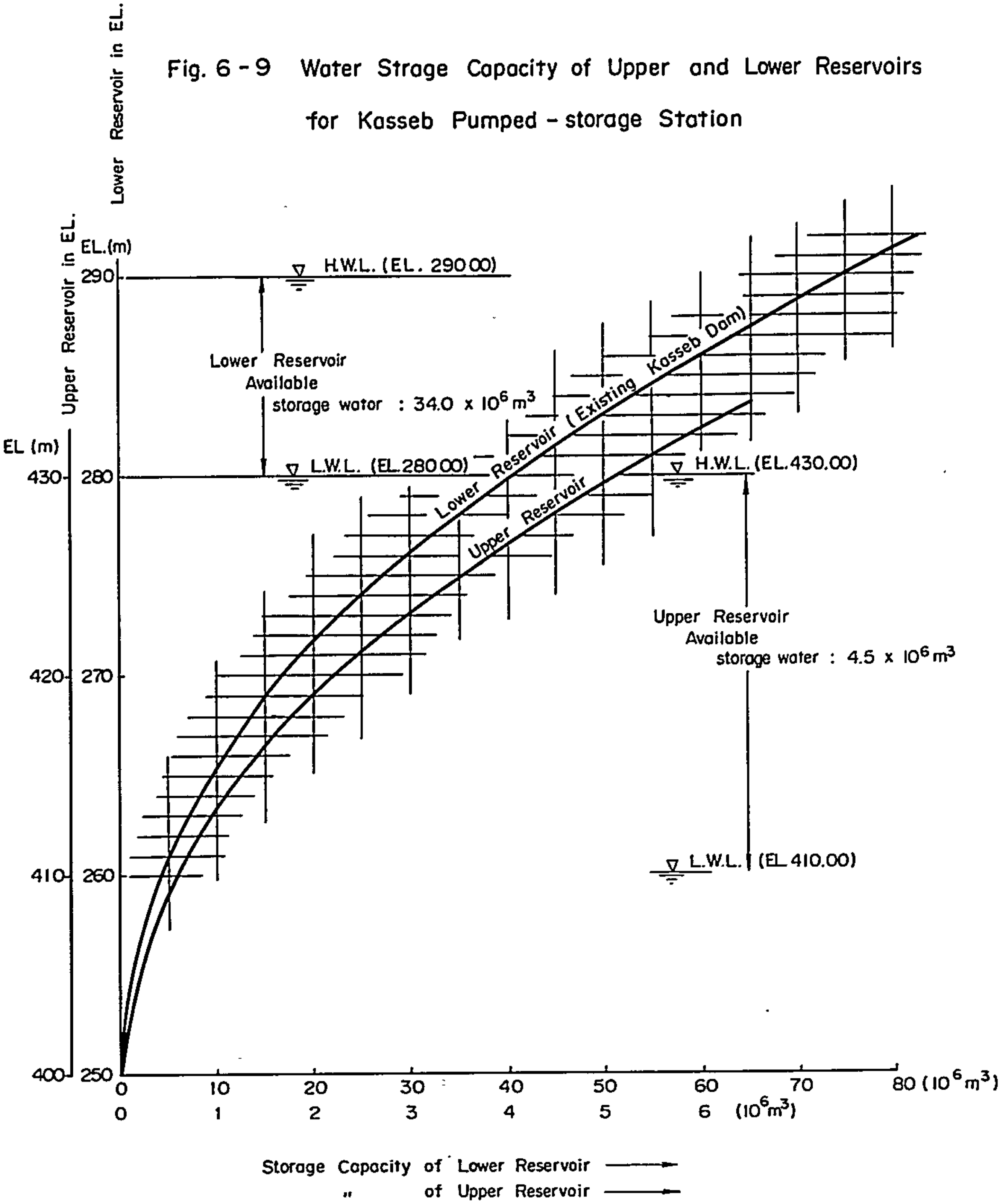


Fig. 6 - 9 Water Strage Capacity of Upper and Lower Reservoirs for Kasseb Pumped - storage Station



cost. In this sense, it will be necessary to carefully decide the low water level taking into consideration the purpose of utilization of the existing Kasseb Dam. The water level curves for the existing Kasseb Reservoir from 1969 to 1976 are shown in Fig. 6-7. As can be seen in this figure, the water level has not dropped below EL 280.00 m since 1969.

Meanwhile, as a result of examination of the water level of the lower reservoir based on runoff data from 1970 to 1975 and assuming the maximum intake recorded in the past for water supply to Tunis is secured and that water for power generation at the existing Kasseb Power Station (600 kW) will be taken from the reservoir when there is large inflow, it is found possible to make the low water level EL 280.00 m as shown in Fig. 6-8. However, considering that the runoff data are only for the 6-year period of 1970 through 1975, more data of the past must be obtained and detailed examinations further made at the time of the feasibility study on the Kasseb Pumped Storage Power Project.

Furthermore, when Sidi Salem Reservoir is completed, it will be possible for intake of an average 1.58 m^3/sec. for city water supply, and by comprehensive operation of Ben Metir Reservoir, Kasseb Reservoir and Sidi Salem Reservoir, it will be even more easier to hold the low water level for the Kasseb Pumped Storage Power Project to EL. 280.00 m.

(2) Upper Reservoir Dam and Maximum Output of Kasseb Pumped Storage Power Station

The upper reservoir dam would be located at the left bank of the existing Kasseb Reservoir and because of topographical conditions the height of the dam will be restricted to 39.00 m and elevation of high water level to 430.00 m. As described in the prediction of the annual operating condition in 1.2 of this chapter, Kasseb Pumped Storage Power Statioon will be required to generate power during lighting-time peaks for 3.3 hours in terms of peak duration time (maximum output 350 MW x hours). The storage capacity required for this is 3.8 x $10^6 m^3$. The water storage at high water level at EL 430.00 m is 5.1 x 10^6 m^3 as shown in Fig. 6-9, and in consideration of changes in the forms of lighting-time peaks and margins to be left as reserve capacity for such times as during faults, the low water level was taken at EL 410.00 m whereby a peak duration time of 4 hours can be secured.

Based on the available water levels of the upper and lower reservoirs described above, the available heads of Kasseb Power Station will be as indicated below. (The elevations with respect to the upper reservoir are based on studies of a 1/5,000-scale topographical and detailed examinations are to be made based on the results of feasibility-level investigations to follow.)

Max. gross head	EL 430.00 – EL 280.00 = 150 m
Min. gross head	EL 410.00 – EL 290.00 = 120 m
Normal gross head	EL 425.00 – EL 290.00 = 135 m

Provided that

	Upper Reservoir	Lower Reservoir
High water level (EL)	430.00	290.00
Low water level (EL)	410.00	280.00

A pumped storage power project differs from a conventional hydroelectric development project in that it is not restricted by river runoff and the scale is determined by the natural topography and the effective storage capacities of reservoirs. In the case of the Kasseb Pumped Storage Power Project the natural inflow to the upper reservoir is negligible and the effective storage capacity is determined by the topographical conditions of the upper reservoir, and therefore, it may be said that the scale is decided by the effective storage capacity. Consequently, the effective storage capacity should be obtained with the height of the dam for the upper reservoir as a parameter, and the scale at which the construction cost per kW is a minimum should be made the optimum scale of Kasseb Pumped Storage Power Station, but considering the present state of geological investigations, that the topographical map is 1/5,000-scale map, and that the inflow data for determining the low water level of the lower reservoir are only for a 6-year period from 1970 through 1975, it is too early to define the optimum scale at this stage of investigation and this should be left to surveys at the next feasibility study level. However, since it is clear from the characteristics of a pumped storage power station that making it as large as possible within the limits of the topographical conditions will result in a more economical power station, the preliminary designs of civil structures and electrical equipment in this chapter were based on a power generation scale of 350-MW, the maximum as seen from the upper reservoir storage capacity.

6.3.1 Civil Structures

(1) Dam

As seen from the results of reconnaissance, the site where the upper reservoir dam is to be constructed is not of a topography to cause concern about leakage and it is thought soluble rocks do not exist in the basement. The dam axis selected by TECSULT appears to be an appropriate one but this must be decided on obtaining the results of geological explorations by test pits and core boring (partially already executed) in the feasibility study to follow. As for the dam type, TECSULT has considered adopting a rockfill dam and since quarrying of rock can be done in the surrounding area of the upper reservoir dam it is thought adopting this type of dam will be reasonable. Under the present circumstances the Mission has no reason to change the preliminary design of TECSULT for the rockfill dam, and therefore, it has been adopted without alteration.

(2) Headrace tunnels

The headrace tunnel (from intakes to powerhouse, and including penstocks) routes have become longer than in the TECSULT proposal (Etude 2A, Variante 1), and this is a result of installing a surge tank and providing an economical design for the pressure tunnels on the dam side of the surge tank. From the surge tank to the powerhouse, the No. 1 headrace tunnel will be 770 m and the No. 2 tunnel 850 m.

(3) Powerhouse

Since the centers of pump-turbines to be installed in the powerhouse were changed from EL 247.50 m in the TECSULT proposal (Etude 2A, Variante 1) to EL 268.00 m, it will be possible to design the powerhouse as a semi-underground type. Consequently, an access tunnel for hauling in equipment in the case of an underground powerhouse will be unnecessary.

(4) Tailrace

Compared with the TECSULT proposal (Etude 2A, Variante 1), it has become possible to shorten the length of the tailrace by approximately 400 m. The reason for this is that the low water level of the existing Kasseb Reservoir which will be the lower reservoir was set at EL 280.00 m.

The particulars of the preliminary design are given below.

Dam

Type:	Rockfill dam
Height:	39 m
High water level:	EL 430.00 m
Low water level:	EL 410.00 m
Available drawdown:	20.00 m
Total storage capacity:	5.1×10^6 m^3

Effective storage capacity:	$4.5 \times 10^6\ m^3$
Headrace tunnels	
Type:	Circular pressure tunnel
Tunnel inner diameter:	5.8 m and 6.70 m
Tunnel length:	900 m and 1,060 m
Surge tank:	Restricted-orifice type with water chamber
Penstocks (including headrace tunnel steel pipe lining):	770 m and 850 m
Powerhouse:	Semi-underground type
Tailrace:	Open channel

6.3.2 Electrical Equipment

(1) Pump-Turbine

The standard effective head of Kasseb Pumped Storage Power Station is 129 m, the maximum head 153 m (estimated figure), the maximum available water during power generating operation 68.8 m^3/sec. with a 75-MW unit and 91.9 m^3/sec. with a 100-MW unit.

The revolution speed of Francis-type pump-turbines, adopting specific speed of pump of around 40 (m^3/sec.m)1/, will be 214 rpm for a 75-MW unit and 188 rpm for a 100-MW unit.

The turbine outputs are 77,400-kW for 75-MW units and 103,400-kW for 100-MW units, and the maximum pump inputs (estimated) are 83,000 kW and 111,000 kW, respectively.

The heights of installation of pump-turbines, as a result of studies of necessary suction heights at maximum and minimum heads are to be −11 m from low water level of the lower reservoir for 75-MW units and −12 m for 100-MW units. Butterfly valves will be adopted for inlet valves.

(2) Generator-Motor

The method of starting a pump will be that of adopting a semi-umbrella type generator-motor providing a wound rotor type induction motor on top of the upper guide bearing, and starting the pump with this motor. The output of the motor is to be 6,000-kW for a 75-MW unit and 8,000-kW for a 100-MW unit.

The capacities of generator-motors will be 84,700-kVA and 113,300-kVA with leading power factor 0.98 for necessary outputs at minimum head and voltage improvement. The voltage is to be the same 13.2-kV for generators and motors.

(3) Switchyard

The switchyard is to be provided adjacent to the powerhouse. The required area is 196 m x 116 m. Singlecircuit transmission lines will be led out to M'Nihla and Tajerouine at voltage of 225-kV. The main transformers and starting transformers to be installed at this switchyard are to be equipped with on-load tap changers to compensate voltage fluctuations during generating operation and pumping operation. The capacities of main transformers are 84,700 kVA and 113,300 kVA, while that of starting transformers is 10,000 kVA.

1/ From 25 to 65 is adopted as pump specific speed n_S (m^3/sec.) of Francis-type pump-turbines of heads from 130 to 150 m.

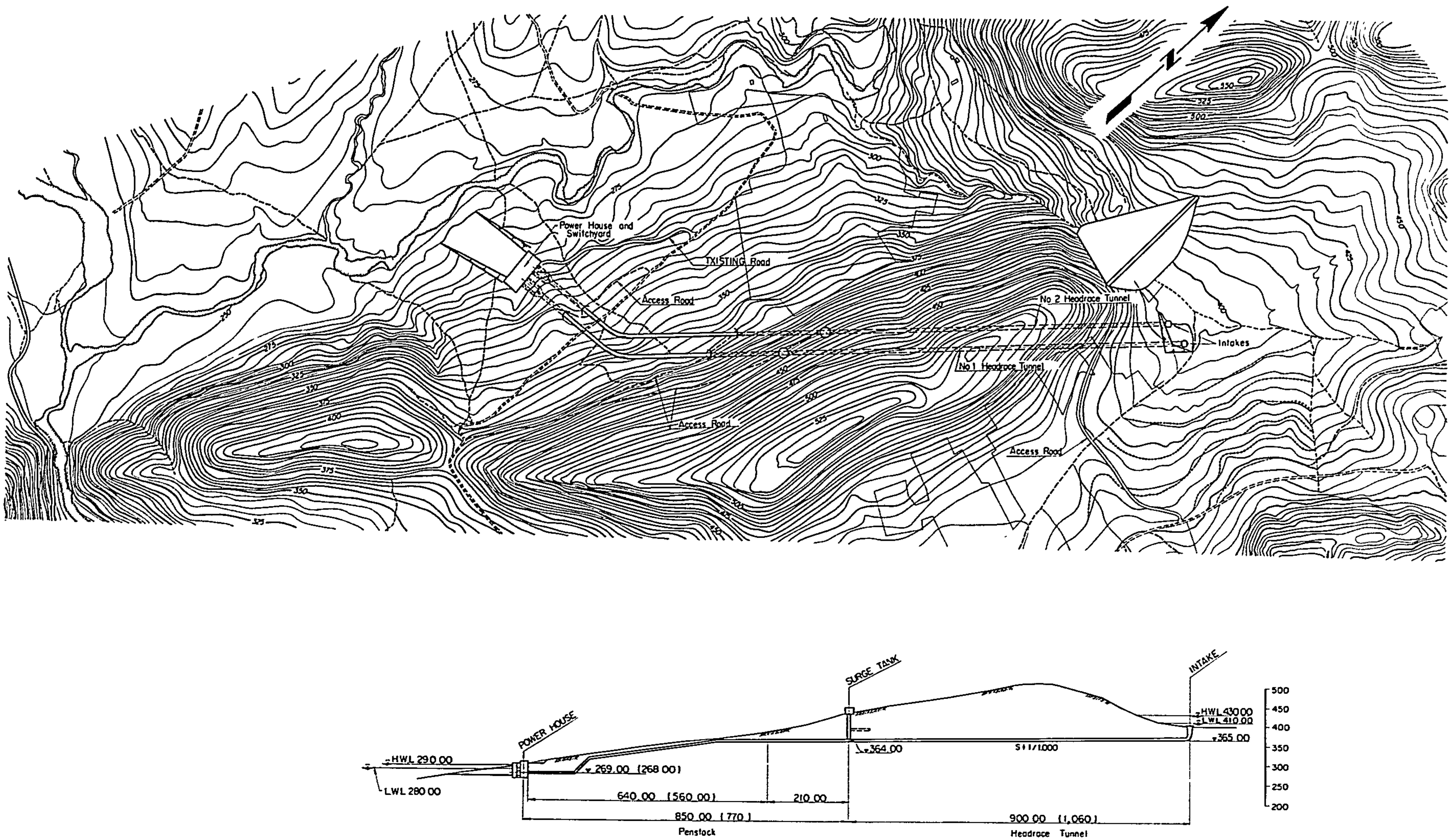


Fig. 6-10

KASSEB PUMPED - STORAGE POWER PLANT

WATER WAY PLAN

75MW x 2 UNITS, 100MW x 2 UNITS

EPDC INTERNATIONAL LTD., TOKYO JAPAN

LOCATION	DATE	DESCRIPTION	BY
REVISION			

SHEET NO. OF

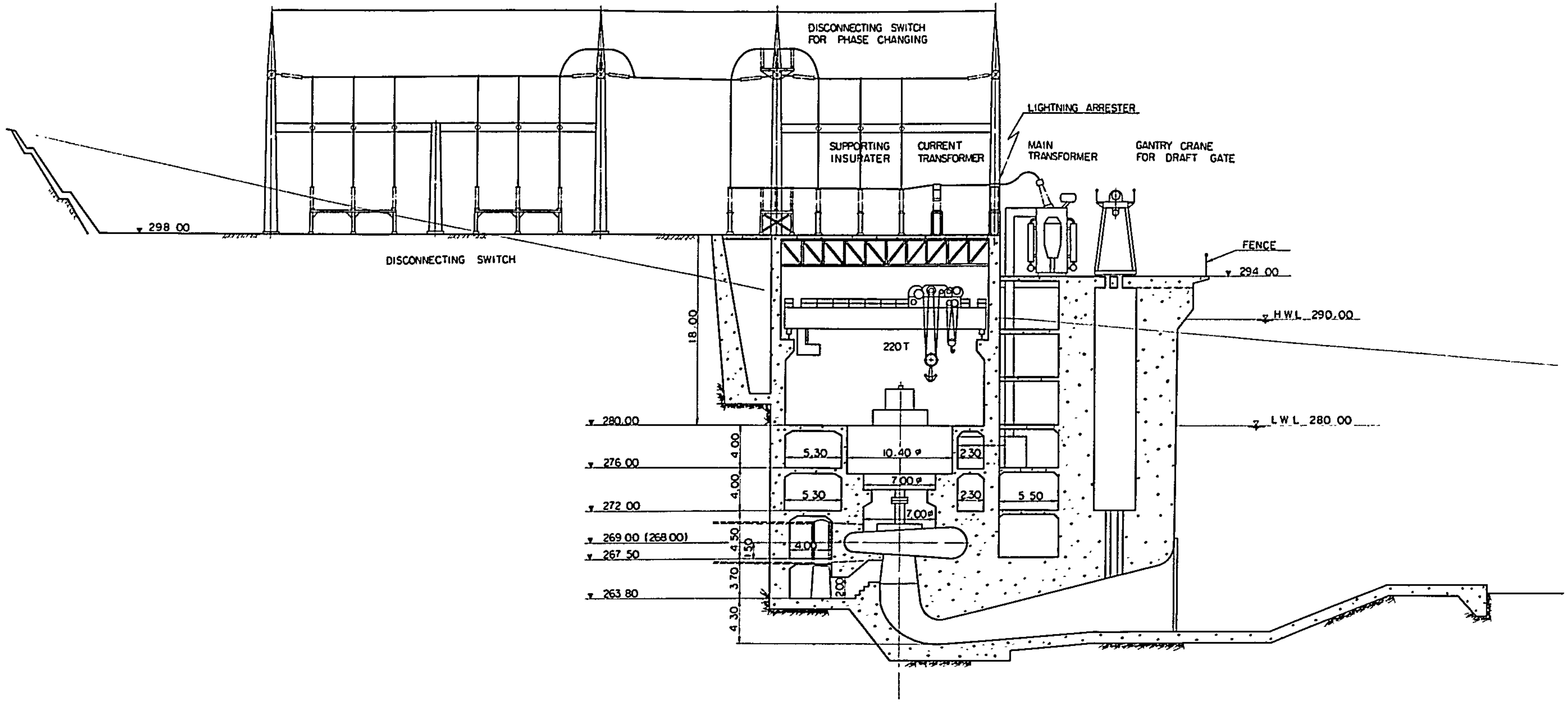


Fig. 6-11

KASSEB PUMPED-STORAGE POWER PLANT

POWER HOUSE SECTION

(SECTION OF 75MW UNIT)

EPDC INTERNATIONAL LTD., TOKYO, JAPAN

LOCATION	DATE	DESCRIPTION	BY
REVISION			

SHEET NO. OF

EL. 263.80

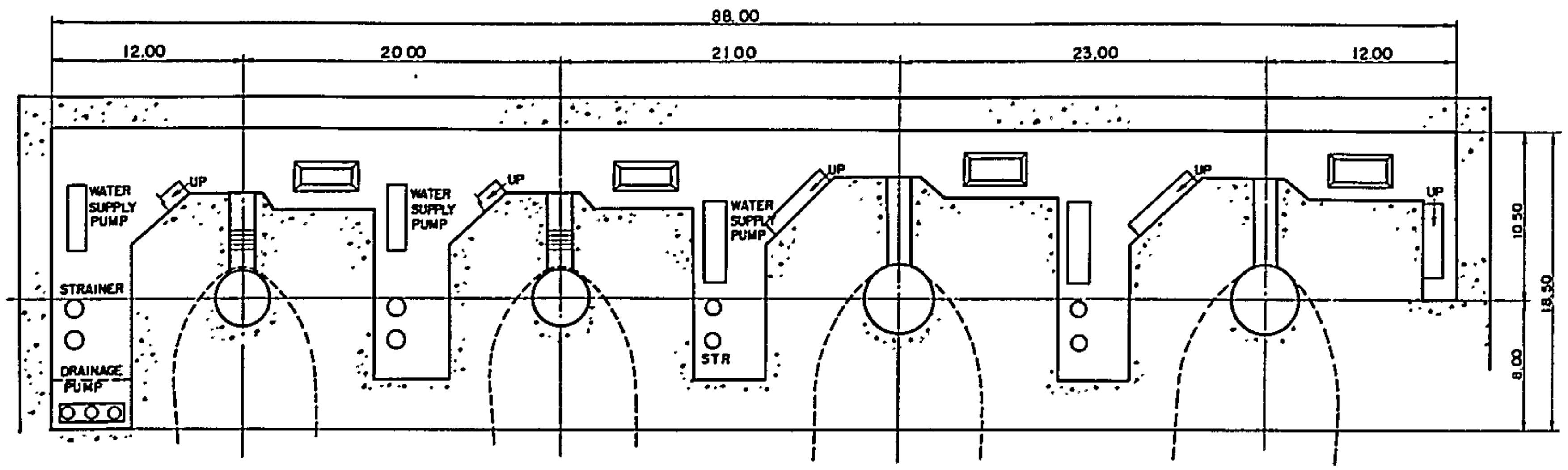


Fig. 6-12

KASSEB PUMPED-STORAGE POWER PLANT

ARRANGEMENT OF EQUIPMENT
EL. 263.80 SECTION

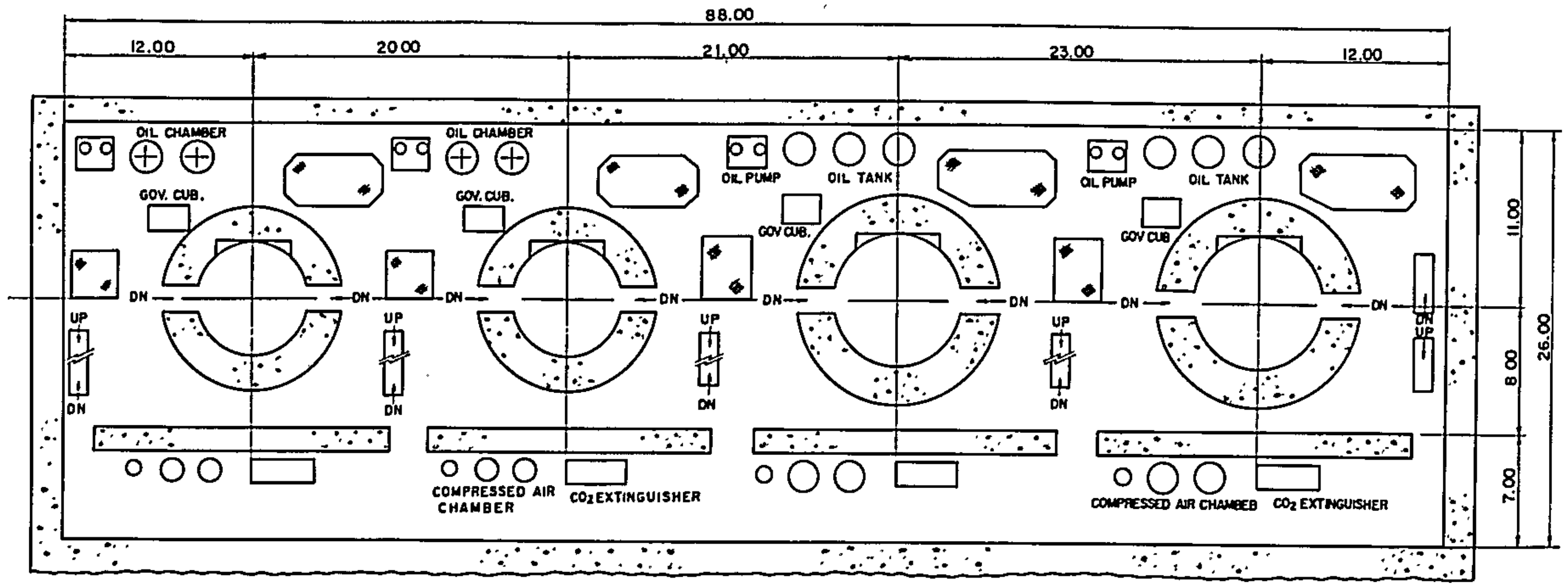
E.P.D.C. INTERNATIONAL LTD
TOKYO, JAPAN

DR: SUBMITTED:
TR: RECOMMENDED:
CK: APPROVED:

LOCATION	DATE	DESCRIPTION	BY
REVISION			

SHEET NO. OF

EL. 272.00



EL. 267.50

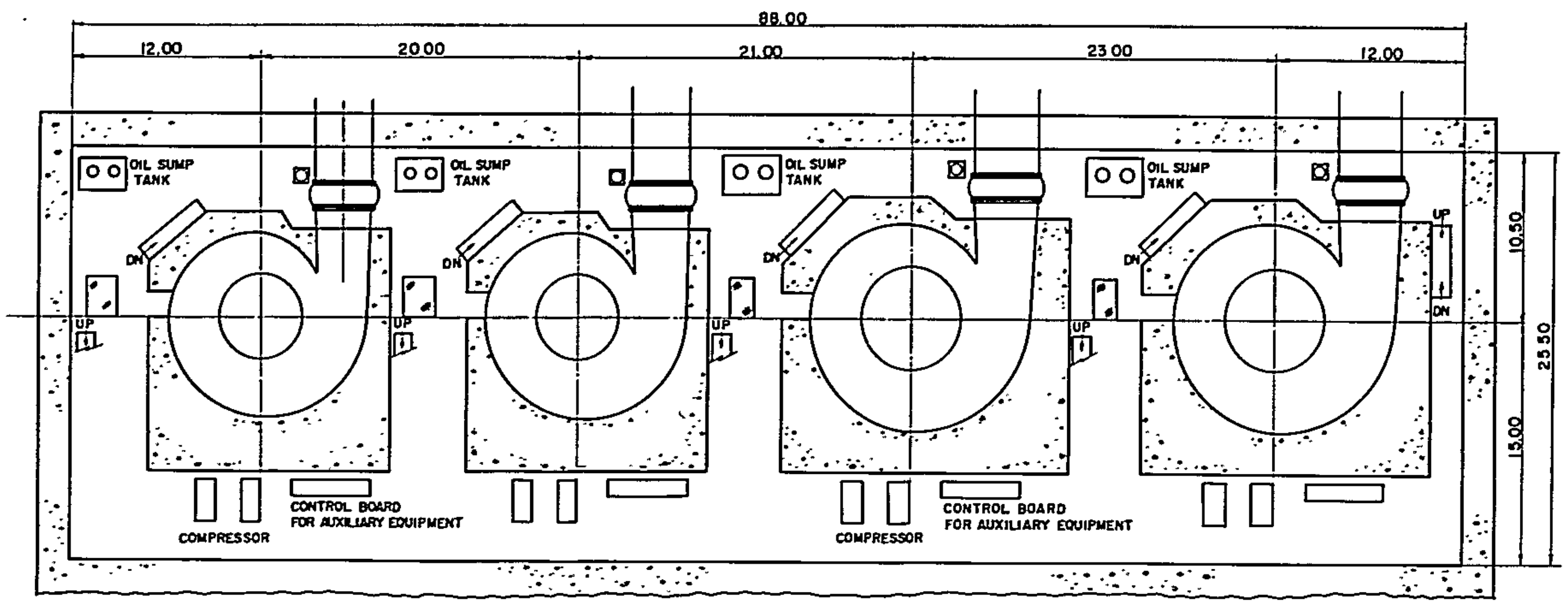


Fig. 6-13

KASSEB PUMPED-STORAGE POWER PLANT

ARRANGEMENT OF EQUIPMENT
EL.272.00 AND EL.267.50 SECTION

E.P.D.C. INTERNATIONAL LTD
TOKYO JAPAN

DR.: SUBMITTED:
TR.: RECOMMENDED.
CK.: APPROVED:

LOCATION	DATE	DESCRIPTION	BY

REVISION

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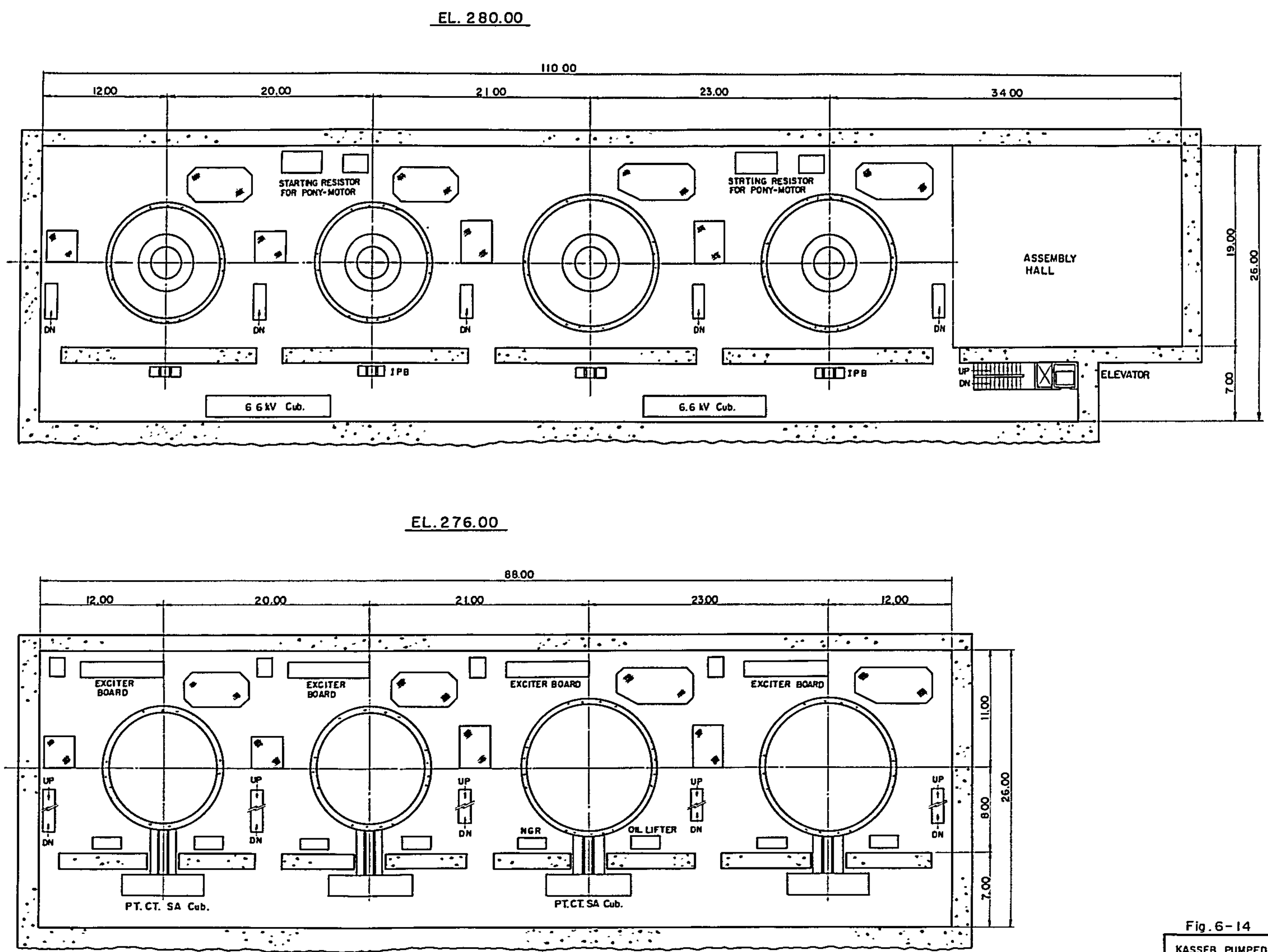

Fig. 6-14

KASSEB PUMPED-STORAGE POWER PLANT

ARRANGEMENT OF EQUIPMENT

EL 280.00 AND EL 276.00 SECTION

E.P.D.C INTERNATIONAL LTD TOKYO, JAPAN

DR: SUBMITTED:
TR: RECOMMENDED.
CK: APPROVED.

LOCATION	DATE	DESCRIPTION	BY

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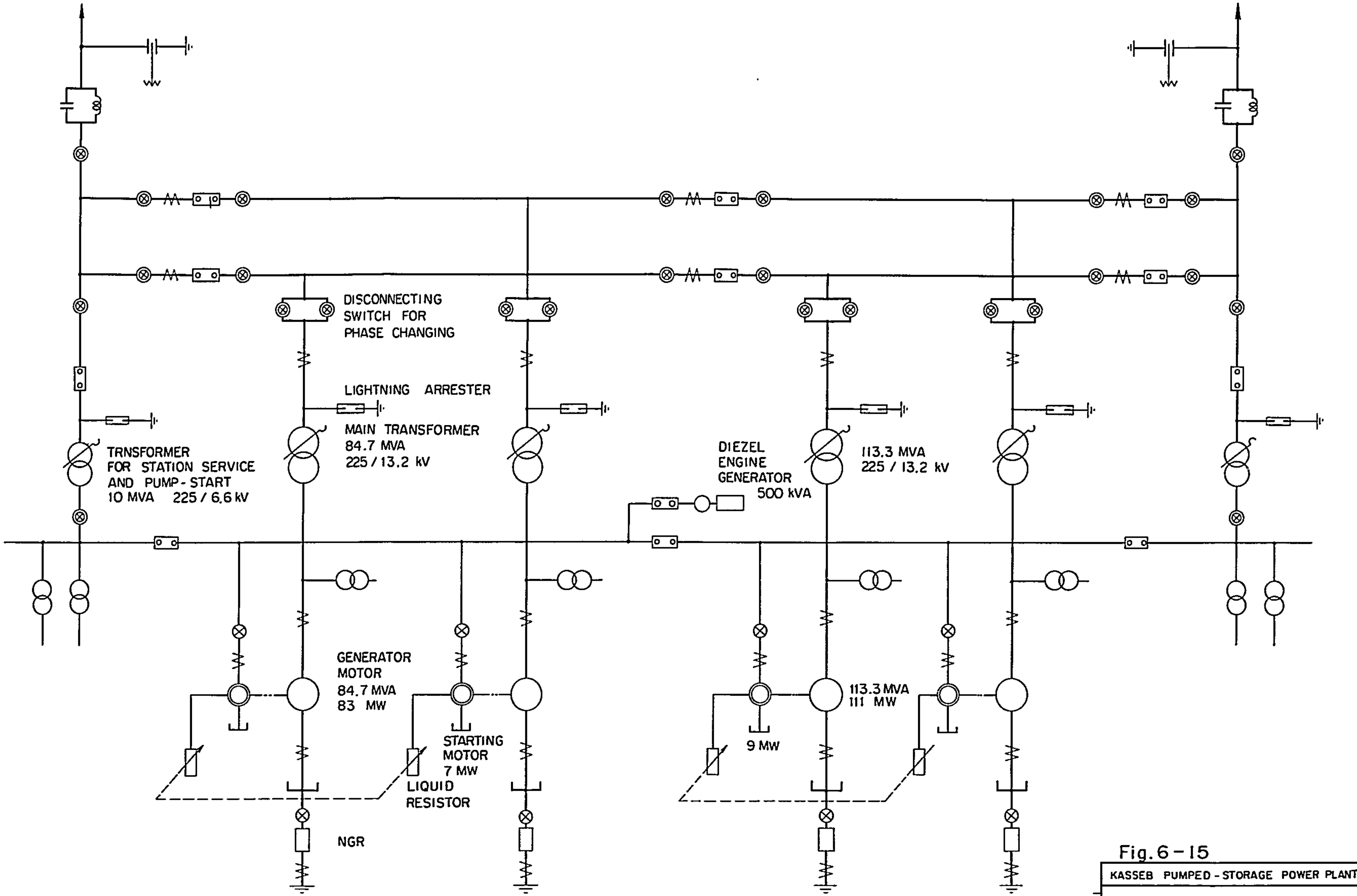


Fig.6-15

KASSEB PUMPED-STORAGE POWER PLANT

SCHEMATIC SINGLE LINE DIAGRAM 350MW

EPDC INTERNATIONAL LTD., TOKYO JAPAN

LOCATION	DATE	DESCRIPTION	BY

REVISION

SHEET NO. OF

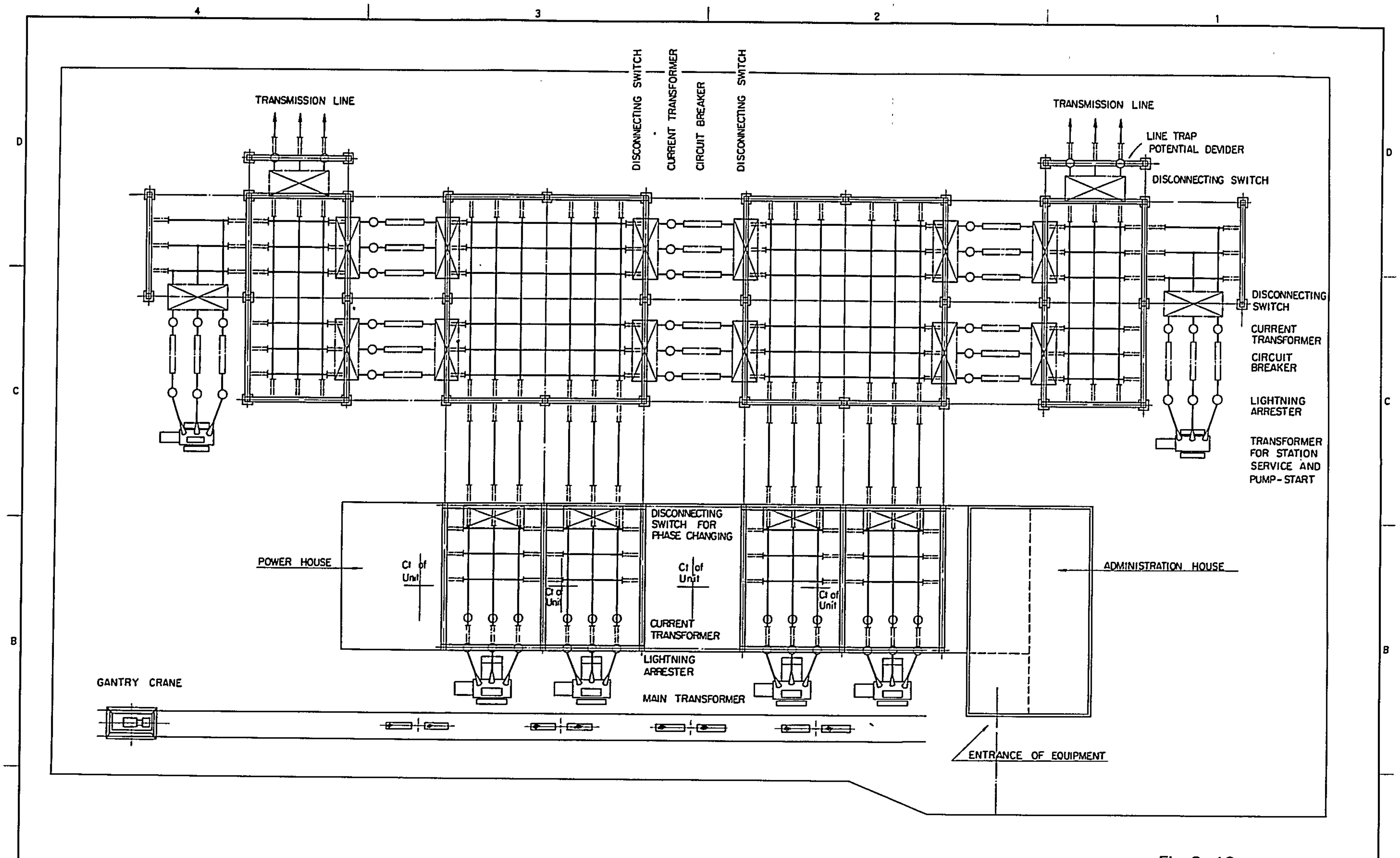


Fig. 6-16

KASSEB PUMPED-STORAGE POWER PLANT

ARRANGEMENT OF
220kV OUTDOOR SWITCHYARD

EPDC INTERNATIONAL LTD., TOKYO JAPAN

D. R.: SUBMITTED:
T. R.: RECOMMENDED:
C. K.: APPROVED.

LOCATION	DATE	DESCRIPTION	BY
REVISION			

SHEET NO. OF

(4) Auxiliary Equipment

Auxiliary equipment for pump-turbines and generator-motors except for starting apparatus will all be unit types. Starting apparatus will be central types, one for every two main equipment units. The total capacity for all appurtenant equipment including auxiliary equipment of Kasseb Pumped Storage Power Station is estimated to be approximately 5,000 kVA.

(5) Single Line Diagram and Control System

The synchronization system of a generator-motor is to be a high-voltage side synchronization system. Accordingly, station service power and starting power will be received from main transformer high-voltage sides. High-voltage buses are to be linked type.

Control of main equipment is to be one-man control and will be done by an operator from the main control room.

Transmission line protection will be by a power line carrier relaying system.

(6) Telecommunications System

The telecommunications system is to be a power line carrier telephone system.

The results of preliminary design of Kasseb Pumped Storage Power Station described above are indicated in Figs. 6-10 through 6-16.

Principal characteristics of electrical equipment for Kasseb Pumped Storage Projects are as follows:

		75MW unit	100MW unit
Pump-turbine	Vertical shaft Francis type, reversible pump-turbine		
Turbine	Output	77,400 kW	103,400 kW
	Net head	129 m	129 m
	Maximum discharge	68.8 m^3/s	91.9 m^3/s
	Velocity of revolution	214 rpm	188 rpm
Pump	Maximum input (assumed value)	83,000 kW	111,000 kW
	Maximum dynamic head	153 m	153 m
	Maximum flow (assumed value)	60 m^3/s	80 m^3/s
	Velocity of revolution	214 rpm	188 rpm
Generator-motor	Three phase synchronous generator-motor, vertical schaft, rotating field, semi-umbrella type		
Generator	Capacity	84,700 kVA	113,300 kVA
	Voltage	13.2 kV	13.2 kV
	Frequency	50 Hz	50 Hz
	Power factor (lag)	0.895	0.895
Motor	Capacity	83,000 kW	111,000 kW
	Voltage	13.2 kV	13.2 kV
	Frequency	50 Hz	50 Hz
	Power factor (lead)	0.98	0.98
Pony-motor	Wound rotor type induction motor		
	Output (assumed value)	6,000 kW	8,000 kW

	Voltage	6.6 kV	6.6 kV
	Velocity of revolution	250 rpm	200 rpm
Transformer	Three-phase outdoor, oil-immersed forced-cooled type with OLT device		
	Capacity	84,700 kVA	113,300 kVA
	Voltage	13.2/225 kV	13.2/225 kV
Starting Transformer	Three-phase outdoor, oil-immersed forced/self cooled type with on-load tap-changer device		
	Capacity	10,000 kVA	10,000 kVA
	Voltage	225/6.6 kV	225/6.6 kV
Outdoor Switchyard	Transmission voltage	225 kV	
	Area	196 x 116 m	
Transmission line	Length	110 km	
	Voltage	225 kV	
	Number of circuits	2 cct	
Telecommunication System	Carrier relaying system		
	Carrier telephone system		

6.4 APPROXIMATE CONSTRUCTION COST AND CONSTRUCTION SCHEDULE

6.4.1 Approximate Construction Cost

(1) Conditions

The construction cost must be estimated considering natural conditions, regional conditions, scale of project and the technological level conceivable at this time of Tunisian contractors, while providing necessary allowance. The detailed investigations of these conditions are to be carried out by the next survey team for feasibility study of the Kasseb Project.

Since investigations regarding the above conditions were not made in the present study, the costs of civil works for Kasseb Pumped Storage Power Station were estimated for 1977 based on the unit prices given in the 1975 study report of the TECSULT International Ltd., which were then multiplied by the subsequent commodity price increase rate. As for the electrical equipment for the powerhouse, switchyard, etc., and transmission lines and sub-stations, the approximate costs were estimated considering the prices of these in Japan and elsewhere as of the present. The commodity price increases since 1975 applied to the present study are the following:

- Civil works — Annual rate 10%
- Mechanical equipment — Annual rate 8% (applied when necessary)

The construction cost will be divided into domestic currency and foreign currency portions, and of these, the former will include wages of domestic labor, salaries of engineers and technicians of STEG required for management of construction, construction materials such as cement, reinforcing steel, lumber, fuel oil, and overland transportation costs of equipment and other articles. Other than these, hydraulic equipment, electrical equipment, power transmission and substation materials and equipment, and engineering fees were considered as foreign currency requirements.

As contingency costs, 10% were included for electrical equipment for both the domestic currency portion including overland transportation and installation work, and for the foreign currency portion, while for the power station civil works the following contingency costs were considered by type of structure:

- Dam 20%
- Intake and headrace tunnel 10%
- Surge tank 10%
- Penstock 15%
- Powerhouse 20%
- Outlet 20%
- Tailrace canal 10%

The engineering fee of the consultant and the administrative cost of STEG were considered to be 10% of construction cost combined, with domestic and foreign currency requirements being 50%, respectively.

Since the interest on funds borrowed are not known at this stage, the interest during construction on domestic and foreign currency will not be included in the construction cost in this chapter.

The exchange rates were considered to be the following:

- US$1.00 = 0.43 Dinar = ¥280
- 1 Dinar = ¥651

(2) Total Construction Cost

Table 6-4-1 shows the civil works construction costs for Kasseb Pumped Storage Power Station calculated based on the unit prices applied in the TECSULT report of 1975. Table 6-4-2 indicates the electrical equipment installation costs of the power station, the transmission line construction cost and the cost of substation lead-in facilities.

Based on the above tables, Table 6-4-3 gives a comparison of the power station construction costs of this Survey Mission's 350-MW proposal and TECSULT's 320-MW proposal in accordance with 1975 unit prices, and the approximate total cost of the 350-MW proposal at 1977 prices (including transmission and substation facilities), the outlines of which are as indicated below.

Unit: 1,000 Dinars

Items	Domestic Currency	Foreign Currency	Total
Kasseb Pumped Storage Power Station			
Civil works	18,464	6,495	24,959
Electrical works	1,844	18,163	20,007
Sub-total	20,308	24,658	44,966
Transmission lines	309	5,236	6,545
Substation lead-in facilities	104	370	474
Total	21,717	30,264	51,985
Kasseb site housing	1,331	–	1,331
Engineering & administrative costs	2,508	2,508	5,016
Total construction cost	25,560	32,772	58,332

(3) Unit Construction Cost of Power Station

A comparison of the unit construction costs per kW of the power station of the 320-MW TECSULT proposal and the Japanese Mission's 350-MW proposal when 1975 unit prices are applied will be the following:

- Japanese proposal (350 MW) 108.5 Dinars/kW
- TECSULT proposal
  (320-MW 2A proposal)
  - Underground type 116.1 Dinars/kW
  - Vertical shaft type 132.4 Dinars/kW

On calculating the above Japanese Mission's proposal at 1977 prices, the unit construction cost will be 128.5 Dinars/kW.

6.4.2 Construction Schedule and Fund Requirement by Year

(1) Construction Schedule

The construction schedule will be governed by the requirements of electric power demand and supply, scale of project, topographical conditions, regional conditions, and further, the technological capabilities of contractors, but in the case of the Kasseb Project, the conditions of access to the site are good, while there are no difficult topographical conditions.

With respect to the technological capabilities of domestic contractors, it is thought their capabilities will be greatly enhanced by the time the Kasseb Project is started because of experience accumulated through the many building projects and large-scale civil works now going on.

From the requirements of electric power demand and supply, it will be necessary for start-up of the No. 1 unit (75-MW) to be in February 1985, that of the No. 2 unit (75-MW) to be in January of the following year, the No. 3 unit (100-MW) to be in November 1987, and the No. 4 unit (100-MW) to be in October 1988, but on the other hand, from the technical and economic viewpoints of the work, it will be better for the No.2 unit to be started a half-year later than the No. 3 unit. Therefore, in this construction schedule, the times of start-up of generators will be set as follows:

- No. 1 Unit (75-MW) Feb. 1985
- No. 2 Unit (75-MW) Aug. 1985
- No. 3 Unit (100-MW) Nov. 1987
- No. 4 Unit (100-MW) May 1988

The respective construction periods for the major structures judging by scale of works are as follows:

- Intakes and headrace tunnel 27 months
- Surge tank 12 months
- Penstocks 21 months
- Powerhouse civil works 27 months
- Outlet and tailrace 12 months
- Generator installation 14 months each
- Transmission lines 18 months/cct

Each generator is to have a 4-month period for test runs after installation and prior to commissioning.

Detailed designs are to be started at the beginning of 1979, and the first orders for equipment are to be placed in the first half of 1981, and start of construction of quarters at the Kasseb site would be in the middle of 1981.

Based on the above, the construction schedule for the entire Kasseb Project will be as indicated in Table 6-4-(5).

(2) Fund Requirements by Year

The following premises will be applied in regard to expenditures for construction by year:

– Civil works	10% advance, payments
– Gates & penstock	according to work performed
On signing contract	10%
On loading aboard ship	60%
On completing installation	20%
On transmitting water	10%
– Electrical equipment	
On signing contract	10%
On loading aboard ship	50%
On commissioning	40%
– Transmission line equipment & materials	
On signing contract	20%
On loading aboard ship	80%

Calculating the fund requirements by year based on the above premises and the construction schedule described previously, the results are as given in Table 6-4-(4). (However, as mentioned before, the interest rate on funds procured is unknown at the present stage, and therefore, interest during construction is not included in the amounts indicated in the table. Accordingly, when formulating the actual funding plan, it will be necessary to include interest during construction in the construction cost indicated above.)

Table 6-4-(1) Summary of Construction Cost of Kasseb Pumped Storage Power Station (Civil Works) (Estimated based on unit prices in 1975)

Item	Description	Unit	Unit Price (Dinars)	Quantity	Total Price (Dinars)
100	Permanent road				
Access Road	Common excavation	m^3	1.07	130,000	139,100
	Asphalt surface treatment	m^2	7.00	9,100	63,700
	Maintenance	Lump Sum			10,000
					212,800
	Temporaly road				
	Common excavation	m^3	1.07	300,000	321,000
	Rock excavation, open	m^3	3.75	30,000	112,500
	Conception of construction	mℓ	15.00	3,000	45,000
					478,500
	Sub-total				691,300
	Excavation				
200	Common excavation	m^3	0.4	16,010	6,400
	Crown-loose ground	m^3	1.0	970	970
Dam	Rock excavation	m^3	2.95	1,600	4,700
	Impervious core fill	m^3	1.28	43,700	55,900
	Filter layer fill	m^3	2.95	41,500	122,400
	Downstream fill	m^3	1.48	164,200	243,000
	Rockfill, upstream	m^3	1.48	125,600	185,900
	Dewatering	Lump Sum			12,000
	Contingecies (20%)				118,730
	Sub-total				750,000
	Excavation				
300	Common excavation	m^3	1.07	30,000	32,100
	Rock excavation, open	m^3	3.75	5,000	18,750
Intake upstream	Rock excavation, shaft	m^3	22.00	13,000	286,000
and Headrace	Concrete in wall	m^3	36.75	500	18,375
Tunnel	Reinforcement	T	300.00	450	135,000
	Concrete in intake	m^3	50.00	4,500	225,000
	Intake screen	T	650.00	90	58,500 1/
	Steel in lining	T	750.00	40	30,000 1/
					803,725

Item	Description of Work	Unit	Unit Price (Dinars)	Quantity	Total Price (Dinars)
	Contingencies (10%)				80,275
	Sub-total				884,000
	Excavation				
	Excavation, open	m^3	1.07	15,000	16,050
	Rock excavation, shaft	m^3	22.00	45,000	990,000
Surge Tank	Concrete in lining	m^3	50.00	12,000	600,000
	Reinforcement	T	300.00	1,000	300,000
	Grouting	m	18.00	7,000	126,000
	Steel in lining	T	1,050.00	100	105,000*
	Contingencies (10%)				213,450
	Sub-total				2,351,000
400	Excavation				
	Excavation, open	m^3	1.07	35,000	37,450
Penstock	Excavation, bifurcation	m^3	8.30	113,000	937,900
	Excavation, tunnel	m^3	10.45	20,000	209,000
	Concrete				
	Horizontal section	m^3	42.00	34,000	1,428,000
	Concrete, tunnel	m^3	39.00	5,000	195,000
	Grouting	m	18.00	37,000	666,000
	Penstock (690m x 2)	T	1,050.00	4,700	4,935,000 1/
	Steel support	T	350.00	1,900	666,000
	Reinforcement	T	280.00	1,200	336,000
	Measuring devices	Lump Sum			10,000 1/
					9,420,350
	Contingencies (15%)				1,413,650
	Sub-total				10,834,000

Item	Description of Work	Unit	Unit Price (Dinars)	Quantity	Total Price (Dinars)
500	Excavation				
	Common excavation	m^3	1.07	40,000	42,800
Powerhouse	Rock excavation, open	m^3	3.75	60,000	225,000
	Rock excavation, tunnel	m^3	8.30	1,000	8,300
	Bolts	m	5.85	5,000	29,250
	Concrete				
	Mass concrete	m^3	20.00	7,000	140,000
	Draft tubes	m^3	40.00	8,000	320,000
	Concrete in wall	m^3	60.00	5,000	300,000
	Concrete in superstructure	m^3	70.00	2,000	140,000
	Reinforcement	T	300.00	600	180,000
					1,385,350
	Contingencies (20%)				277,650
	Sub-total				1,663,000
700	Coffer dam				
	Center core	m^3	5.25	108,000	567,000
Outlet	Impervious surfacing	m^3	2.15	102,000	219,000
	Rock excavation, open	m^3	1.07	5,000	18,750
	Concrete in wall	m^3	36.75	6,000	220,500
					1,025,250
	Mechanical work				
	Draft gate (4.5mx4.5mx2)	T	2,000.00	150	300,000*
	Trash racks	T	650.00	200	130,000*
					430,000
	Measuring devices	Lump Sum			10,000
					1,465,250
	Contingencies (20%)				293,750
	Sub-total				1,759,000
800	Excavation				
	Common excavation	m^3	1.07	210,000	224,700
Tailrace canal	Rock excavation, open	m^3	3.75	50,000	187,500
	Dragaing	m^3	5.35	150,000	802,500

Item	Description of Work	Unit	Unit Price (Dinars)	Quantity	Total Price (Dinars)
	Masonry				
	Masonry,open	m^2	5.25	15,000	78,750
	Masonry, under water	m^2	5.30	7,000	37,100
	Protection, wall	m^2	2.00	10,000	20,000
					1,350,550
	Contingencies (10%)				134,450
	Sub-total				1,485,000
900	Excavation	m^3	1.07	110,000	117,700
	Concrete in foundation	m^3	39.70	7,000	277,900
Switchyard	Building	Lump Sum			15,000
					410,600
	Sub-total				410,600
Total Amount (Civil works)					20,827,900
	– Domestic currency				(15,259,400)
	– Foreign currency				(5,568,500)

Note: Mark 1/ indicates foreign currency portion.

Table 6-4-(2) Summary of Construction Cost of Kasseb Pumped-Storage Power Station
(Electrical Equipment)
(Estimated based on 1977 Prices)

Unit: Dinars

Item	Foreign Currency	Domestic Currency	Total
Hydro Power Plant Equipment			
Pump Turbine	5,241,000	–	5,241,000
Motor Generator	4,650,000	–	4,650,000
Main Transformer	650,000	–	650,000
Starting Transformer Control Switch Board Steel Structure Power Plant Equipment Temporary Facility	4,051,000	–	4,051,000
Cost of Ocean Freight	1,247,300	–	1,247,300
Insurance	73,000	–	73,000
Cost of Inland Transportation	–	276,500	276,500
Erection and Installation Works	599,000	1,399,500	1,998,500
Sub-Total	16,512,000	1,676,000	18,188,000
Contingencies (10%)	1,651,000	168,000	1,819,000
Total Amount	18,163,000	1,844,000	20,007,000
Transmission Lines and Substation Equipment			
Transmission Lines (29,750 Dinars/Km)			
Kasseb – M:Nihla	2,618,000	654,500	3,272,500
Kasseb – Tajerouine	2,618,000	654,500	3,272,500
Sub-Total	5,236,000	1,309,000	6,545,000
Substation Equipment			
M'Nihla Substation	185,000	52,000	237,000
Tajerouine Substation	185,000	52,000	237,000
Sub-Total	370,000	104,000	474,000
Total Amount	5,606,000	1,413,000	7,019,000

Table 6-4-(3) Total Construction Cost of Kasseb Project and Comparison with Estimate made by TECSULT International Ltd.

Unit: 1,000 Dinars

Item	Study 2A (TECSULT) 4 x 80 MW : 1975 Prices		Study made by Japanese Mission (2 x 75 MW, 2 x 100 MW): 1975 Prices			1977 Prices		
	Underground Type	Vertical Shaft Type	Domestic Currency	Foreign Currency	Total	Domestic Currency	Foreign Currency	Total
A. Kasseb Pumped Storage Power Station								
1. Civil Works								
Access roads	970,200	948,300	691,300	–	691,300	836,500	–	836,500
Dam	650,000	650,000	750,000	–	750,000	907,500	–	907,500
Intake and Headrace tunnel	295,000	295,000	795,500	88,500	884,000	962,600	103,200	1,065,800
Surge tank	–	–	2,246,000	105,000	2,351,000	2,717,700	122,500	2,840,200
Penstock	4,925,000	9,240,000	5,889,000	4,945,000	10,834,000	7,125,700	5,767,700	12,893,400
Powerhouse	1,986,000	4,945,800	1,663,000	–	1,663,000	2,012,200	–	2,012,200
Outlet	2,666,600	1,295,000	1,329,000	430,000	1,759,000	1,608,100	501,600	2,109,700
Tailrace canal	3,407,500	3,394,000	1,485,000	–	1,485,000	1,796,900	–	1,796,900
Switchyard	206,100	259,850	410,600	–	410,600	496,800	–	496,800
Access tunnel	969,000	473,000	–	–	–	–	–	–
Sub-total	17,883,100	22,647,450	15,259,400	5,568,500	20,827,900	18,464,000	6,495,000	24,959,000
Contingencies	2,880,000	2,880,000		(Included in the above estimates)			(Included in the above estimates)	
Total (Civil Works)	20,763,100	25,527,450	15,259,400	5,568,500	20,827,900	18,464,000	6,495,000	24,959,000
2. Electrical Equipment								
Powerhouse equipment	12,618,000	13,000,000						
Switchyard equipment	2,152,100	2,209,250						
Sub-total	14,770,100	15,209,250	1,437,000	14,156,000	15,593,000	1,676,000	16,512,000	18,188,000
Contingencies	1,620,000	1,620,000	143,700	1,415,600	1,559,300	168,000	1,651,000	1,819,000
Total (Electrical Work)	16,390,100	16,829,250	1,580,700	15,571,600	17,152,300	1,844,000	18,163,000	20,007,000
Grand total (Power Station)	37,153,200	42,356,700	16,840,100	21,140,100	37,980,200	20,308,000	24,658,000	44,966,000
B. Transmission Lines and Sub-stations								
Transmission lines						1,309,000	5,236,000	6,545,000
Sub-stations						104,000	370,000	474,000
C. Total Direct Construction Cost						21,721,000	30,264,000	51,985,000
D. Kasseb site Housing	1,100,000	1,100,000	1,100,000		1,100,000	1,331,000		1,331,000
E. Engineering Fee and Administration Costs	4,000,000	4,000,000				2,508,000	2,508,000	5,016,000
Total Construction Cost						25,560,000	32,772,000	58,332,000
F. Unit construction cost of Power station (Dinars/KW)	116.1 D/KW	132.4 D/KW		108.5 D/KW			128.5 D/KW	

Table 6-4-(4) Annual Expenditure Schedule

Unit: 1,000 Dinars

Item	Total Construction Cost: Domestic Currency	Total Construction Cost: Foreign Currency	Total Construction Cost: Total	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
A. Kasseb Pumped Storage Power Station													
1. Civil Works													
Access roads	836,500		836,500				836,500						
Dam	907,500		907,500					363,000	544,500				
Intake and Headrace tunnel	962,600	103,200	1,065,800				299,100	543,200	223,500				
Surge tank	2,717,700	122,500	2,840,200					543,600	2,296,600				
Penstock	7,125,700	5,767,700	12,893,400			576,800		7,736,000	4,580,600				
Powerhouse	2,012,200		2,012,200				603,700	1,006,100	402,400				
Outlet	1,608,100	501,600	2,109,700				50,200	1,909,100	150,400				
Tailrace canal	1,796,900		1,796,900					898,500	898,400				
Switchyard	496,800		496,800						496,800				
Sub-total	18,464,000	6,495,000	24,959,000			576,800	1,789,500	12,999,500	9,593,200				
– Domestic Currency			18,464,000				1,729,000	9,176,000	7,559,000				
– Foreign Currency			6,495,000			576,800	60,500	3,823,500	2,034,200				
2. Electrical Equipment Total	1,844,000	18,163,000	20,007,000			762,900		2,023,300	5,028,400	1,642,000	5,588,100	2,801,900	2,160,400
– Domestic Currency			1,844,000					116,300	542,200	116,200	320,800	695,000	53,500
– Foreign Currency			18,163,000			762,900		1,907,000	4,486,200	1,525,800	5,267,300	2,106,900	2,106,900
B. Transmission lines and Sub-stations													
Transmission lines	1,309,000	5,236,000	6,545,000				523,600	2,421,400	327,500	523,600	2,421,400	327,500	
Sub-stations	104,000	370,000	474,000						237,000			239,000	
Sub-total	1,413,000	5,606,000	7,019,000				523,600	2,421,400	564,500	523,600	2,421,400	564,500	
– Domestic Currency			1,413,000					327,000	379,500		327,000	379,500	
– Foreign Currency			5,606,000				523,600	2,094,400	185,000	523,600	2,094,400	185,000	
C. Total Direct Construction Cost													
Total	21,721,000	30,264,000	51,985,000			1,339,700	2,313,100	17,444,200	15,186,100	2,165,600	8,009,500	3,366,400	2,160,400
– Domestic Currency			21,721,000				1,729,000	9,619,300	8,480,700	116,200	647,800	1,074,500	53,500
– Foreign Currency			30,264,000			1,339,700	584,100	7,824,900	6,705,400	2,049,400	7,361,700	2,291,900	2,106,900
D. Kasseb site Housing	1,331,000		1,331,000			731,000	400,000						
E. Engineering Fee and Administration Costs	2,508,000	2,508,000	5,016,000	752,000	83,000	108,000	197,000	1,467,000	1,253,000	171,000	638,000	265,000	82,000
– Domestic Currency			2,508,000		49,000	64,000	116,000	863,000	737,000	100,000	375,000	156,000	48,000
– Foreign Currency			2,508,000	752,000	34,000	44,000	81,000	604,000	516,000	71,000	263,000	109,000	34,000
F. Total Construction Cost Total Amount	25,560,000	32,772,000	58,332,000	752,000	83,000	2,378,700	2,910,100	18,911,200	16,439,100	2,336,600	8,647,500	3,631,400	2,242,400
– Domestic Currency			25,560,000		49,000	995,000	2,245,000	10,482,300	9,217,700	216,200	1,022,800	1,230,500	101,500
– Foreign Currency			32,772,000	752,000	34,000	1,383,700	665,100	8,428,900	7,221,400	2,120,400	7,624,700	2,400,900	2,140,900

Table 6-4-(5) Construction Schedule of Kasseb Pumped Storage Power Project

Item	Works	Quantity	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Detailed Design and Supervision of Works												
Ordering of Materials												
Kasseb site Housing												
Construction works of Power Station												
Access roads												
Dam												
Height of dam: 39 m	Excavation	18,580 m³										
	Embankment	375,000 m³										
Intake and Headrace tunnel												
φ6.70 x 900 m (No. 1 tunnel)	Excavation	156,000 m³										
φ5.80 x 1,060 m (No. 2 tunnel)	Concrete	38,500 m³										
	Gate, etc.	90 ton										
Surge tank												
	Excavation	60,000 m³										
	Concrete	12,000 m³										
Penstock												
φ6.2 x 640 m (No. 1 penstock)	Excavation	55,000 m³										
φ4.5 x 560 m (No. 2 penstock)	Concrete	5,000 m³										
Tunnel 2 x 210 m												
Powerhouse												
2 x 75 MW (First stage)	Excavation	100,000 m³										
2 x 100 MW (Second stage)	Concrete	20,000 m³										
	Installation of	1st unit							▽ February			
	"	2nd Unit							▽ August			
	"	3rd Unit									▽ November	
	"	4th Unit										▽ May
Outlet and Tailrace canal												
	Excavation	415,000 m³										
	Concrete	12,600 m³										
	Gate, etc.	350 ton										
	Masonry	22,000 m³										
Switchyard												
	Excavation	110,000 m³										
	Concrete	7,000 m³										
	Installation of equipment											
Transmission lines and Sub-stations												
Kasseb – M'Nihla	Distance	110 km										
Kasseb – Tajerouine	Distance	110 km										
Sub-stations	Installation of equipment											

Note: ·········· Test and Commissioning

CHAPTER 7

GENERAL OUTLOOK ON ECONOMICS OF KASSEB PUMPED STORAGE PROJECT

CHAPTER 7
GENERAL OUTLOOK ON ECONOMICS OF KASSEB PUMPED STORAGE PROJECT

7.1 BASIC CONSIDERATIONS

7.1.1 General

This long-range electric power development program consists of predicting the power demand for the 10-year period following completion of the "Fifth Economic and Social Development Plan (1977–1981)" presently under way and to formulate an optimum electric power development plan to cope with this demand. The principal objective, however, is to establish a general outlook on whether the Kasseb Pumped Storage Project can emerge as a feasible project in this future power development plan.

With regard to this Kasseb Project, studies requested by STEG have been made up to this time by MECASOL Ingénieur-Conseil and TECSULT International Ltd. In 1975, a final preliminary study report was submitted to STEG by TECSULT International Ltd.

The present mission has now carried out an initial review of the above study report from technical and economic view-points, and has revised the scale of installed capacity and construction cost. However, since this review was not based on detailed field reconnaissances, it may naturally be expected that modifications and réadjustments will need to be made depending on future investigations. The economic analysis in this chapter was made on the basis of the revised construction cost; while a number of parameters required for analysis and evaluation are based on assumed figures so that the precision of analysis cannot necessarily be expected, but it is thought possible for a general outlook on the economics of this pumped storage project to be roughly established.

7.1.2 Method and Objective of Analysis

(1) Comparison with Alternative Project

In general, the economic analysis of a power development project can be made in the form of cost comparisons with an alternative project which provides an "equal service" with the project under consideration. The "equal service" in this case means generating an equal power (kW) and energy (kWh) with those produced by Kasseb Pumped Storage Power Station during peak hours in the Interconnected System, and the optimum alternative project which can provide such service is considered to be gas turbine power stations. Accordingly, the economics of the Kasseb Project are evaluated in the form of cost comparison with an alternative gas turbine project having equal supply capability with Kasseb.

However, it cannot be said sufficient to evaluate the economics merely in the form of comparison of total cost converted to present worth. In essence, a separate consideration must be made taking note of the composition of the funds required for the project.

The most striking features of the Kasseb Project and the alternative gas turbine project from the standpoint of fund requirement are as follows, respectively.

(a) With the Kasseb Project, the proportion of the domestic currency portion (mainly costs of civil works) in the construction cost is very high (43.8%), and therefore, of this domestic currency portion, a fairly large part will take the form of savings by local contractors, suppliers, etc. to act on the national economy, and the savings will produce an enormous indirect effect (consumption benefits) in the future through infinitely repeated reinvestment cycles.

(b) In contrast, with the alternative gas turbine project, the greater part of the required funds will flow out from the country as foreign currency and the proportion of the domestic currency portion is extremely small. Consequently, there will be practically no impact on the national economy to be expected from construction.

In view of the above, the economic analysis in this chapter will be in the traditional form of comparison of the respective total costs (construction cost, operation and maintenance costs, equipment replacement costs) of the Kasseb Project and the alternative gas turbine project converted to present worth as the first step, and computation of the social values of the projects including future indirect effects besides the direct effects as the second step.

(2) Objective of Analysis

As is the case in many other countries, the electric power development program in Tunisia is formulated as a link in the overall economic policy of the country. The objective of the national economic policy is to realize "welfare maximization," not aiming merely for maximization of "economic profitability". Therefore, in economic analysis of an electric power development project, it is thought appropriate for analysis to be made considering the various factors relevant to national welfare besides the direct economic effects of the project.

Normally, the economic policy of a country tacitly includes the following two objectives even when not clearly stated:

(a) Aggregate Consumption Objective

Firstly, it is needless to say that the fundamental objective of national planning is to raise the consumption level of the nation. In the case of the Kasseb Project also, the evaluation must be made ultimately from the viewpoint of the extent of contribution it can make to raising the consumption level of Tunisia as a whole.

(b) Income Redistribution Objective

The second objective of national planning is adjustment of income distribution, in effect, to look forward to the effects of the transfer of income from more favored classes or regions to less favored classes or regions. The project area of Kasseb is located in the comparatively rich northern part of Tunisia, but nevertheless, it is a less-developed area compared with the eastern seashore area centered around Tunis with Gabes at the southern end. Consequently, in the objective of the economic analysis of the Kasseb Project, it will be appropriate to include the effect of income redistribution in the project area.

The economic analysis in this chapter will be made along the lines of the two objectives above.

7.2 TOTAL COSTS OF KASSEB PUMPED STORAGE PROJECT

The total amount of funds to be put into the Kasseb Project consists of the construction costs of dam, power station, transmission lines, and substation facilities, operation and maintenance costs, fuel cost for pump-up, and equipment replacement costs after parts of facilities have lived out their economic service lives.

7.2.1 Construction Costs

(1) Pumped Storage Power Station

As indicated in Table 6-4-3, the total construction cost of Kasseb Pumped Storage Power Station (excluding interest during construction) is estimated to be 44,966,000 Dinars, of which the foreign currency portion is 24,658,000 Dinars (54.8%), while the domestic currency portion is 20,308,000 Dinars (45.2%). The commencement of detailed design for construction is to be 1979 with starts of operation scheduled to be the following:

Feb. 1985	No. 1 Unit	(75-MW)
Aug. 1985	No. 2 Unit	(75-MW)
Nov. 1987	No. 3 Unit	(100-MW)
May 1988	No. 4 Unit	(100-MW)

(2) Transmission Lines and Substations

Transmission lines will be 225 kV, 1-cct lines connecting Kasseb Pumped Storage Power Station and M'Nihila Substation as well as Tajerouine Substation.
The construction cost will be 6,545,000 Dinars for the transmission lines and 474,000 Dinars for substation facilities, a total of 7,019,000 Dinars. Of the construction cost, it is estimated that the proportions of domestic and foreign currency requirements will be 80% for the foreign currency portion and 20% for the domestic currency portion, while commissioning of each single-circuit line is planned as follows:

Kasseb – M'Nihla Substation		Feb. 1985
Kasseb – Tajerouine Substation		Nov. 1987

Although the abovementioned transmission lines are necessary for the Kasseb Project, they should be constructed as optimum power transmission lines from the aspect of increasing the stability of the nationwide system regardless of whether or not Kasseb Power Station will be constructed in the future. Therefore, in the present economic analysis, we considered that it will be reasonable to impute one half of the construction costs of these transmission and substation facilities to the Kasseb Project. Therefore, the allocated costs will be 3,273,000 Dinars for transmission lines and 237,000 Dinars for substation facilities, a total of 3,510,000 Dinars (of which the foreign currency portion is 2,808,000 Dinars and the domestic currency portion 702,000 Dinars).

(3) Engineering Fee and Administration cost

Engineering fee for detailed design and construction supervision, and administration cost of STEG are estimated to be 5% of construction cost, respectively. The breakdown by year of disbursement of the various costs under (1), (2) and (3) above will be as indicated in Table 7-1.

7.2.2 Operation and Maintenance Costs (Excluding Fuel Cost)

Operation and maintenance costs may be broadly divided into personnel expenses and maintenance and repair costs and the ratios of these costs to direct construction costs are more or less the same statistically for all countries. The operation and maintenance costs by facility may be estimated as described below.

(1) Kasseb Pumped Storage Power Station

(a) Personnel Expenses

According to the final report of TECSULT International Ltd., STEG is considering the following organization for operation and maintenance of Kasseb Pumped Storage Power Station:

Chief of Power Station	1
Chief of quarter	1
Chief of block	5
Shift personnel	5
Electrician	1
Mechanic	1
Assistant technician	2
Driver	1
Handyman	1
Total	18

The unit cost of personnel expenses for the power station, as indicated later in 7.3.2(1), is estimated to be approximately 1,650 Dinars/man-year as of 1977, and the annual personnel expenses of Kasseb Pumped Storage Power Station is estimated to be the following:

1,650 Dinars x 18 = 29,700 Dinars

(b) Maintenance and Repair Costs

According to statistics maintenance and repair costs of dam and power station amount to approximately 1% of direct construction cost, of which approximately 80% may be estimated to comprise the cost of imported materials. Therefore, the maintenance and repair costs of Kasseb Pumped Storage Power Station may be estimated to be the following:

44,966,000 Dinars x 0.01 = 449,700 Dinars
(including 359,700 Dinars foreign currency portion and
90,000 Dinars domestic currency portion)

(2) Transmission Lines and Substations

In case of power transmitting and transforming facilities, the personnel expenses are estimated to amount to approximately 0.5% of direct construction costs, maintenance and repair costs to about 2%, and with regard to the latter, about 80% is assumed to be due to importation of materials. Consequently, the operation and maintenance costs of the transmitting and transforming facilities related to the Kasseb Project will be the following:

(a) Personnel Expenses
3,510,000 Dinars x 0.005 = 17,500 Dinars

(b) Maintenance and Repair Costs
3,510,000 Dinars x 0.02 = 70,200 Dinars
(including 56,200 Dinars foreign currency portion, 14,000 Dinars domestic currency portion)

(3) Total Operation and Maintenance Costs by Year

According to the above, the total operation and maintenance costs after completion of Kasseb Project will be the following:

Personnel expenses	47,200 Dinars
Maintenance and repairs costs (domestic currency portion)	104,000 Dinars
Maintenance and repair costs (foreign currency portion)	415,900 Dinars
Total	567,100 Dinars

The breakdown of operation and maintenance costs by year from the time of commissioning of the No. 1 unit of the power station is as given in Table 7-2.

7.2.3 Fuel Cost

(1) Specific Fuel Consumption of Base Steam Power Station

It is estimated that at the initial stage of start-up of the No. 1 unit of Kasseb Pumped Strage Power Station the electric power necessary for pump-up will be supplied from Sousse Steam Power Station or Goulette No.2 Power Station. However, to cope with subsequent increase in demand, it is conceivable that new unit (steam) of 150- to 250-MW will be installed in succession, and several years after start-up, all of the electric power required for pump-up will be supplied from Sousse Steam Power Station. Accordingly, as the specific fuel consumption of the base thermal power station which assumes power generation for pump-up, the 150-MW generators of Sousse Power Station will be applied.

The specific fuel consumption will vary according to the load factor of the generator, but the fuel consumption rate for unit capacity of 150 MW, in case-of load factor of 60%, is 2,486 kcal/kWh (thermal efficiency 34.6%) and in case of load factor of 100%, 2,453 kcal/kWh (thermal efficiency 35.,%). When it is assumed that a generator is operated from at the load factor of 60% to 100% in order to supply electric power for pump-up, the specific fuel consumption caused by this operation will be the following:

$$\frac{(2,453 \times 100) - (2,486 \times 60)}{40} = 2,404 \text{ kcal/kWh}$$

Therefore, thermal efficiency will be 35.7%

(2) Price of Fuel

(a) Fuel Used

Sousse Steam Power Station presently under construction is designed so that both heavy oil No.2 and natural gas can be utilized. . However, in the "Fifth Economic and Social Development Plan", the development of off-shore natural gas which is estimated to have reserves of 50 to 80 billion cubic meters is given as the highest priority project, where it is planned to lay submarine and overland pipelines to supply this natural gas to Gabes – Sousse – Tunis – Bizerte for use as primary energy of thermal power stations at various localities, in addition to which the natural gas resources would be utilized to establish a gas chemical industry in the future. According to the conception of this project at the present stage, start of operation is targeted for 1981 with initial annual production of 1.5 billion cubic meters of gas, increased at the final stage to 3 billion cubic meters annually.

Annual production of 1.5 billion cubic meters of natural gas is enough to enable full operation throughout the year of a total output of approximately 700-MW by base thermal power stations.

Although the development of off-shore natural gas has still unsettled problems regarding funds and other aspects, but there is ample time until the Kasseb Project is to be realized. Therefore, it is assumed in this economic analysis that the fuel to be used for pump-up at Kasseb Power Station will be off-shore natural gas.

(b) Fuel Price

At present, the greater part of natural gas of Tunisia is being produced at El Borma, and the domestic sales price is 18 Dinars/TEP (1 TEP equivalent of 1 ton of heavy oil). Although it is difficult to predict what the production cost will be in case of off-shore natural gas, STEG has estimated that it will be roughly 10 to 20 Dinars/TEP.

Against the above domestic prices, the international prices of natural gas are presently between 30 and 35 Dinars/TEP. This means that if the off-shore natural gas were to be liquefied and exported it would be possible to obtain revenues of 30 to 35 Dinars/TEP. Therefore, the difference with the domestic price of 18 Dinars/TEP represents a sacrifice of an earnings opportunity for the country.

Consequently, in the economic analysis of the Kasseb Project which is a national project, the international price of 30 to 35 Dinars/TEP should be applied as the basis of calculation for both types of power generation, base thermal power station and gas turbine power station.

However, in considering the supply cost of natural gas, on the one hand, the gas pipeline will be designed and constructed to cope with the scale of demand at peak hours of gas consumption, and the more that the gas demand at peak hours increases over the capacity of the pipeline, there will be more additional capital investment required, and the supply cost will become higher. In contrast, the more that gas demand is increased during midnight off-peak hours, the utilization factor of the facilities as a whole will become higher, and the supply cost will become comparatively lower. In this manner, similarly to the case of electric power consumption, the customer responsibility will differ for peak hours and midnight off-peak hours in the case of gas demand, and regarding the natural gas to be used during pump-up for Kasseb Power Station, a price with a suitable adjustment made to the abovementioned international price should be applied.

However, data clearly indicating the marginal costs in gas supply at peak and off-peak hours have not been available. Accordingly, considering that the greater part of the supply cost of both natural gas and electric power is taken up by capital cost (amortization cost), and that daily load curves indicate practically the same shapes, it was decided to proceed with analysis on the assumption that rate of variation of supply costs between peak hours and off-peak hours of natural gas is practically the same as that of electric power.

Thus, in considering the tariff rates of electric power for peak hours, daytime hours and midnight off-peak hours, the price of natural gas for pump-up at Kasseb Power Station (midnight off-peak hours) was estimated in accordance with the following procedure.

(i) According to the actual electricity tariffs of STEG based on marginal cost theory, the meter rates for medium-voltage and high-voltage customers are, per kWh, 11.3 millimes daytime, 18.4 millimes peak hours and 4.1 millimes midnight off-peak hours.

(ii) Unlike electric power, gas can be stored to a certain extent, and therefore, the limits of customer responsibility are not very distinct between peak hours and daytime. Accordingly, one method would be to take the ratio of the average of the peak and daytime tariff rates as a cost reduction ratio of midnight gas supply. In this case, the cost reduction ratio is calculated as follows:

(11.3 millimes + 18.4 millimes) ÷ 2 = 14.9 millimes

4.1 millimes ÷ 14.9 millimes = 0.275

(iii) The above reduction rate is extremely low and the reason for this is that, as is normally the case in the electric power industry, there is a requirement from rate policy to suppress power demand in peak hours as much as possible. To make a bold approximation, the supply cost ratio for peak and off-peak hours will be proportional to their respective demand scales (and consequently, capacities of supply facilities) to a certain extent. Therefore, in this economic analysis, the ratio of the scales of the demands during peak and off-peak hours, that is, 2:1, was considered, and it was decided to assume a reduction rate of 0.5 in the gas supply cost for midnight off-peak hours.

(iv) Although it is difficult for an accurate estimate to be made of the production cost of off-shore natural gas, when 20 Dinars/ton estimated on the higher side at the present stage is applied, the reduction amount for gas supply during off-peak hours will be the following:

20 Dinars/ton × (1 – 0.5) = 10.0 Dinars/ton

(v) Therefore, with the international prices of 30 to 35 Dinars/TEP (average 32.5 Dinars/TEP.) as the basis, the price of gas utilized for pump-up of water at Kasseb Power Station will be the following:

32.5 Dinars/TEP – 10.0 Dinars/TEP = 22.5 Dinars/TEP

(c) Unit Fuel Cost

The calory content of 1 TEP is 10,500 kcal/kg, while the specific fuel consumption is 2,404 kcal/kWh, so that the unit fuel cost for pump-up of water by a base thermal plant will be 5.2 millimes/kWh.

(3) Overall Efficiency of Kasseb Pumped Storage Power Station

Taking into account examples in Japan and elsewhere, the overall efficiency of Kasseb pumped storage Power Station will be assumed as follows:

During Pump-up		During Power Generation	
Transformer	0.995	Tunnel and penstock	0.975
Motor	0.975	Turbine	0.89
Pump	0.89	Generator	0.975
Tunnel and penstock	0.975	Transformer	0.995

Power transmission loss during pump-up, 2%

Based on the above, the overall efficiency will be 69%. As for power transmission loss during power generation, it is assumed to be equal to the loss in case of the alternative gas turbine project so that this item will not be considered for either the Kasseb Project or the alternative gas turbine project.

(4) Fuel Cost for Pump-up

Based on (1), (2) and (3) above, the annual fuel cost required for pump-up of water will be as indicated in Table 7-3.

7.2.4 Equipment Replacement Costs

Amortization periods for equipment, structures, etc., will differ according to country, but with regard to economic service life there are standards which are more or less internationally recognized. For this economic analysis, taking into account the international standards and the standards in Tunisia, the replacement costs of machinery, apparatus, etc., will be calculated based on the following service lives:

– Civil work structures	50 years
– Transmission line	50 years
– Electrical equipment at Power station	30 years
– Substation facilities	30 years

7.3 TOTAL COSTS OF ALTERNATIVE GAS TURBINE PROJECT

The total costs of alternative gas turbine project consist of the construction costs of gas turbine power stations of equal power generation scale as Kasseb and appurtenant substation facilities, operation and maintenance costs, fuel cost and equipment replacement costs.

7.3.1 Construction Costs

(1) Gas Turbine Power Stations

In case of a pumped storage power station, the unavailability rate of the station due to inspections, accidents, etc. is normally about 2%, but since the Kasseb Project is an initial experience in Tunisia, it will be reasonable to take this unavailability rate to be about 3%. Therefore, the annual average output for the installed capacity will be 350-MW x 0.97 = 340-MW.

In contrast, the unavailability rate of gas turbine, according to operation records of 1976, was an average of 10.7% for the two power stations, Tunis Sud and Ghannouch. Therefore, the installed capacity required for gas turbine power stations as an alternative to Kasseb will be the following:

$$350\ \text{MW} \times 97\% \div (1-0.107) = 380\ \text{MW}$$

Next, according to data given by STEG, the construction cost of gas turbine power stations at Sfax, Tunis Sud, Menzel Bourguiba, Korba and Metlaoui with total output of 149.8-MW scheduled to start operation in 1977–1978 is estimated at 13,500,000 Dinars (of which 94% foreign currency portion, 6% domestic currency portion).
However, this amount is the results of competitive bidding at a time when the demand for such gas turbine equipment was small, and the current price is estimated to be approximately 10% higher. In this case, the unit construction cost will be approximately 100 Dinars/kW.

In accordance with the above, and assuming that alternative gas turbine power stations are added matching the tempo of capacity increase at Kasseb Power Station, the installed capacity required for start-up and the construction cost by years will be the following:

Feb.	1985	82-MW	8,200,000 Dinars
Aug.	1985	82-MW	8,200,000 Dinars
Nov.	1987	108-MW	10,800,000 Dinars
May	1988	108-MW	10,800,000 Dinars
	Total	380-MW	38,000,000 Dinars

The construction period is taken to be one year and a half from ordering, and disbursements for equipment and materials are assumed to be 10% at time of ordering, 50% at time of loading aboard ship, and 40% at time of start-up.

(2) Substations

Similarly, according to the Fifth plan of STEG, the construction cost of Tunis Nord Substation (additional equipment of 70-MVA) now under construction work is estimated to be 1.285.000 Dinars, and the unit construction cost is 18.4 Dinars/kVA. However, this unit price was that around 1975–1976, and if it is assumed that the subsequent rate of increase in equipment prices has been an annual 8%, the unit construction cost as of 1977 will be 19.8 Dinars/kVA (of which 80% and 20% are assumed to comprise foreign currency and domestic currency portions, respectively). Meanwhile, in the case of the alternative gas turbine project, it is quite conceivable that some of the sites of these power stations would be selected at idle or closed power staions, in which case existing substation facilities can be used as is, and a fairly large portion of the construction cost can be saved.

Therefore, in this economic analysis, of the total transforming capacity required at power factor of 80%, approximately 60% was taken to be additional capacity newly installed by the alternative gas turbine project, while it is assumed that approximately 2/3 of the construction cost in domestic currency will be saved. If the appurtenant substation facilities are to be constructed in tempo with the beforementioned gas turbine power stations, the total transforming capacity required as well as total costs of facilities and the additionalyxpenditures necessitated by the alternative gas turbine project out of that total costs of facilities will be as indicated below:

Start-up Yr & Mo	Total Transforming Capacity Required	Total costs	Costs necessitated by the Alternative GT
Feb. 1985	102.5 MVA	2,030 Dinars	1,120,000 Dinars
Aug. 1985	102.5 MVA	2,030 Dinars	1,120,000 Dinars
Nov. 1987	135 MVA	2,670 Dinars	1,480,000 Dinars
May 1988	135 MVA	2,670 Dinars	1,480,000 Dinars
Total	475 MVA	9,400,000 Dinars	5,200,000 Dinars

(3) Engineering Fee and Administration Cost

The ratio to construction cost of engineering fee for supervising installation work will be lower than in the case of Kasseb Pumped Storage Power Station, but on the other hand, the ratio of administration cost through mobilization of STEG personnels will be higher. In the present study, it was decided to estimate 3% of direct construction cost as engineering fee and 6% as administration cost.

Based on (1), (2) and (3) above, the total construction costs of the alternative gas turbine project and the annual disbursements will be as shown in Table 7-4.

7.3.2 Operation and Maintenance Costs (Excluding Fuel Cost)

(1) Gas Turbine Power Station

(a) Personnel Expenses

The total amount of salaries paid for 26 operation and maintenance personnel at Ghannouch Gas Turbine Power Station (installed capacity 59-MW) in 1976 was approximately 30,000 Dinars. Therefore, the unit expense was 1,270 Dinars man-yr. However, it is necessary for related expenses such as social insurance, income taxe, etc., to be included, while the rise in the salary level during the past year must also be considered. Assuming that these increase factors are approximately 30%, the unit personnel expense in this present economic analysis was taken to be approximately 1,650 Dinars man-yr.

Next, it is most reasonable to assume from the aspect of supply stability that alternative gas turbine power stations will be constructed by step at 4 different locations with 3 to 4 gas turbines of unit capacity of 20-MW to 30-MW at each station. In this case, since these power stations would generate power during peak hours only, compared with a power station such as Ghannouch Thermal Power Station which supplies base load, the number of personnel required for operation and maintenance would besmaller, and in this economic analysis the number required was taken to be about 15 personnels for each power station, a total of 60 personnels for the 4 stations.

According to the above, the personnel expenses of the power stations are estimated to be the following:

1,650 Dinars x 60 men = 99,000 Dinars.

(b) Maintenance and Repair Costs

Again taking Ghannouch Gas Turbine Power Station as the example, the maintenance and repair costs in 1976 amounted to approximately 110,000 Dinars. Therefore, when the rate of rise in materials and equipment costs of 8% during the past year is considered, the maintenance and repair costs as of 1977 would be 118,800 Dinars, and divided by installed capacity of 59-MW, the unit maintenance and repair cost will be 2.02 Dinars/kW, and it may be seen that this corresponds to exactly 2% of the unit construction cost of 100 Dinars/kW.

From the above, the maintenance and repair costs of the gas turbine power stations after being constructed up to installed capacity of 380-MW are estimated to be the following:

2.02 Dinars x 380,000 = 767,600 Dinars (of which, foreign currency portion 614,100 Dinars, domestic currency portion 153,500 Dinars.)

(2) Substations

As described in 7.2.2 (2), the operation and maintenance costs of substations will be about 0.5% of direct construction cost for personnel expenses and 2% for maintenance and repair costs, of which about 80% of the latter is estimated to be a foreign currency portion.

Therefore, the operation and maintenance costs after all appurtenant substations have been completed are estimated to be as follows:

Personnel expenses	9,400,000 Dinarsx 0.005 = 47,000 Dinars
Maintenance & repair costs	9,400,000 Dinars x 0.02 = 188,000 Dinars

(of which, foreign currency portion 150,400 Dinars, domestic currency portion 37,600 Dinars)

(3) Total Operation and Maintenance Cost by Year

According to the above, the total amount of operation and maintenance costs after the alternative gas turbine project has been completed will be the following:

Personnel expenses	146,000 Dinars
Maintenance & repair costs (domestic currency portion)	191,100 Dinars
Maintenance & repair costs (foreign currency portion)	764,500 Dinars
Total	1,101,600 Dinars

The disbursement of these maintenance and repair costs by year are as given in Table 7-5.

7.3.3 Fuel Cost

(1) Specific Fuel Consumption of Alternative Gas Turbine Power Stations

According to the records for 1976, the specific fuel consumption of Ghannouch Gas Turbine Power Station was 3,206 kcal/kWh at generating end and 3,235 kcal/kWh at the transmitting end. The alternative gas turbines will also be operated at full load similarly to Ghannouch Gas Turbine Power Station after start of parallel running.

However, whereas Ghannouch Gas Turbine Power Station is operated to supply base load, the alternative gas turbines for peak load will be operated in the form of one time of starting and stopping per day, and it will not be appropriate to apply the fuel consumption rate of Ghannouch Gas Turbine Power Station without any adjustment.

In case of gas turbines of unit capacities of 20 to 30-MW, the time required from starting to parallel running is approximately 10 minutes and the fuel consumption rate during this time is approximately 35% of the rate at 100% load factor. Consequently, the specific fuel consumption of a gas turbine operated 3.3 hours daily will be 3,292 kcal/kWh, including starting loss, as shown below.

$$(3{,}235 \text{ kcal/kWh} \times 1/6 \times 0.35 + 3.235 \text{ kcal/kWh} \times 3.3) \div 3.3 = 3{,}292 \text{ kcal/kWh}$$

(2) Fuel Price

Presently, fuels being used in Tunisia for gas turbines are the natural gas of El Borma and imported gas-oil. The price of the latter is about 50 Dinars/ton. Since the reserves at El Borma are comparatively small, it will not be possible to maintian the present production over a long period, but as stated in Item 7.2.3 (2), a development of a huge off-shore natural gas aiming at start of operation in 1981 is being implemented, and it will be appropriate to consider that the fuel to be used at the alternative gas turbine power stations will come from the latter.

The alternative gas turbine power stations would bring about additional consumption of gas during peak hours of gas demand when gas pressure is at its lowest, and therefore, at the same time they determine the marginal development cost of gas supply facilities, they necessitate laying of long branch lines from the main pipeline depending on the locations where they are installed. However, since the additional costs of such branch lines cannot be evaluated at the present stage, they will not be considered in the alternative project.

As for fuel price, the international price of 30 to 35 Dinars/TEP (average 32.5 Dinars/TEP) as described in Item 7.2.3 (2) will be applied.

(3) Unit Fuel Cost

When the fuel consumption rate is 3,292 kcal/kWh and the calorific value of 1 TEP is 10,500 kcal/kg, the unit fuel cost for an alternative gas turbine will be 10.2 millimes/kWh.

The fuel cost by year of the alternative gas turbine project according to the above will be as shown in Table 7-3.

7.3.4 Equipment Replacement Costs

(1) Service Life of Gas Turbine Power Stations

There are various groups of gas turbine manufacturers, such as those of General Electric, Westinghouse, B.B.C., etc., and each group has its own method of calculating equipment service life, but it may be considered that the tempo of mechanical wear will be similar for all groups.

The service life estimated based on a computation formula is for only when running inspections to be made weekly, and service inspections (combustion apparatus systems), minor inspections (turbines) and major inspections (complete overhauls) to be made at given intervals of time will all be ideally performed, and it is surmised that the actual economic service life will be shorter than that estimated based on computation formula.

The computation formula normally applied for service lives of gas turbines is the following:

$$Ze = \underbrace{b_B \cdot Z_B + b_p \cdot Z_p + b_R \cdot Z_R}_{\text{Life depending on hours of operation}} + \underbrace{a_n \cdot N_n + a_f \cdot N_f}_{\text{Life depending on number of starting}}$$

where

Z_e : 80,000 hr
Z_B : base load operation hours (no overload operation)
Z_p : peak load operation hours (approx. 8.5% overload operation)
Z_R : emergency operation hours (approx. 13% overload operation)
N_n : number of starting in normal operation
N_f : number of starting in rapid operation
b_B : constant 1
b_p : constant 5
b_R : constant 12
a_n : 5 hr
a_f : 20 hr

Regarding operating hours, the average for the alternative gas turbine power stations is 3.3 hours, and it is assumed that it will be operated 6 days every week with the exception of Sunday.

After being put into parallel running, the time required to reach full load is 10 minutes in case of normal starting, and 3 minutes in case of rapid starting. The gas turbine power stations as the alternative for Kasseb Pumped Storage Power Station would be comprised of more than ten gas turbines of unit capacity of 20- to 30-MW, and in order to follow load in completely the same manner as Kasseb, it is thought necessary for at least half of the gas turbines to be subject to rapid starting.

Based on the above, the average service life of the alternative gas turbine power stations will be the following:

$$80{,}000\ \text{hr} \div (1 \times 3.3\ \text{hr} \times 365 \times 6/7 + 5\ \text{hr} \times 365 \times 3/7 + 20\ \text{hr} \times 365 \times 3/7) = 16.2\ \text{yr}$$

As described above, the actual service life is usually shorter than that estimated based on calculation formula, and therefore, in this economic evaluation, it will be assumed that the service life of the alternative gas turbines is 15 years (Note 3).

(Note 3) In Japan, gas turbines for peak load belonging to electric power companies are stipulated in corporate tax laws to have service lives of 15 years.

(2) Equipment Replacement Costs

The equipment replacement cost of the alternative gas turbine project will be calculated based on the above gas turbine service life of 15 years and the service life of 30 years of substation facilities indicated in Item 7.2.4.

In this case, as described in 7.3.1 (2), of the appurtenant substation facilities, those to be newly added when the alternative gas turbine project is implemented were asumed to be 60% of the total transforming capacity required. But the equipment replacement costs should be taken into account for all equipments including existing facilities, and it was considered that these existing substation facilities, when the alternative gas turbine project is implemented, will all have been in use for 10 years.

7.4 BENEFIT-COST RATIO AND ECONOMIC INTERNAL RATE OF RETURN

7.4.1 Benefit-Cost Ratio

If the Kasseb Pumped Storage Project were to be realized, the alternative gas turbine project will need not be carried out. In other words, expenditures for the alternative gas turbine project will be unnecessitated by the Kasseb Project and may be considered as benefit due to the Kasseb Project.

Table 7-6 and Table 7-7 indicate the respective yearly expenditures of the Kasseb Project and the alternative gas turbine project according to domestic and foreign currencies, and based on these tables, the total costs at discountrates of 6%, 10% and 12% converted to present worth are as indicated in Table 7-8, while the benefit-cost ratio will be as indicated below.

Discount Rate	Kasseb Project (A) (1000 Dinars)	Alternative GT Project (B) (1000 Dinars)	Benefit-Cost Ratio (B)/(A)
6%	70,621.6	90,840.7	1.29
10%	45,723.0	48,462.9	1.06
12%	38,525.9	37,790.6	0.98

7.4.2 Economic Internal Rate of Return

Based on Table 7-8, the cost curves of the Kasseb and alternative gas turbine projects with discount rates on the abscissa and present worths of total costs on the ordinate will be as indicated in Fig. 7-1, and it is seen that the intersecting point of the two curves is at a discount rate of 11.8%. In effect, this intersecting point shows the profit and loss equilibrium point of the Kasseb Project when compared with the alternative project to indicate the economic internal rate of return, and when the discount rate is 11.8% or under, the Kasseb Project will be economically superior to the alternative gas turbine project.

Since the discount rate of 10% is normally used in economic evaluation of a project in Tunisia, it may be judged that the Kasseb Project is economically superior to the alternative gas turbine project.

Further, at present, the long-term interest rate applied by international finance institutions is generally about 8%, and based on such a rate the Kasseb Project will be approximately 20% (benefit-cost ratio, 1.20) economically superior to the gas turbine project.

7.5 ANALYSIS OF SOCIO-ECONOMIC EFFECT

Although an outlook for the economic superiority of the Kasseb Pumped Storage Project over the alternative gas turbine project has been established in the preceding item, analysis and evaluation of the socio-economic effects of this pumped storage project will be made in accordance with the two objectives cited at the beginning of this chapter.

7.5.1 Aggregate Consumption Objective

(1) First Approximation

(a) Revenues

The socio-economic analysis of the project should be made according to actual cash flow. Therefore, it is necessary to estimate the revenues as return on investment. In the case of the Kasseb Project, the return is the electricity sales income from power supplied by the power station during peak hours, but it will not be appropriate to apply the current tariff rates without adjustment. The reason is that although the actual rate system of STEG established in 1975 is a rational rate system clarifying customer responsibility by hourband based on marginal cost theory, it already has not conformed with actual commodity price rises, and at present is close to being revised.

At international financial institutions, one measure of sound management of an electric power enterprise as a public utility is that the earnings rate is 8% of working assets, but in this study, the total cost of the alternative gas turbine project which is an opportunity cost for the Kasseb Project will be applied as one basis for the proper earnings of the Kasseb Project. The earnings, regulated in such manner, although fictitious, may be considered reasonable seen from the standpoint of socio-economic analysis.

(b) Shadow Pricing of Labor Wages

The prices of commodities, in a fully competitive market, are automatically determined by price mechanisms, but under incomplete competition, the prices of the various commodities do not necessarily reflect actual prices, and there will be necessity for adjustment. In the case of Tunisia, the item thought to require consideration is labor wages. Parenthetically, various construction works are extensively being carried out at present under the "Fifth Social and Economic Development Plan" and the greatest concern of the Government is the creation of opportunity for new additional employment, and seen from the opposite side, this is thought to imply that the society and economy in the whole have not reached a state of full employment as yet. On the other hand, it is conceivable that the labor force for Sidi Salem, and other large-scale infrastructure works being executed under the Fifth Plan may in certain cases become surplus toward the middle of the 1980s when these development works will have come to a pause. In general, when a project is executed under a condition at or close to full employment, the labor force required for the project will need to be pulled out from other sectors, and in such case, the price of labor input in the project is evaluated by the net loss (opportunity cost) of the sector from which the labor force had been taken away.

In the case of the Kasseb project, it is not clear what the proportion will be of a labor force which will not casue any loss to other economic sectors, but in any event, since it may be estimated all of the unskilled laborers and a fairly large proportion of skilled laborers will be made up by idle labor and farmers in the slack season in and around the project area, a portion of the wages paid to these people will represent a "wage premium" added to the real labor price (opportunity cost). In this study, although it is an extremely bold assumption, approximately 20% of the total wages of the labor force mobilized were estimated to be a wage premium to adjust the actually paid wages.

Next, of the domestic currency portion of the Kasseb Project, the proportion taken up by labor wages is roughly the following (see Table 7-9 (1) and Table 7-9 (2)):

Work	Skilled Labor	Unskilled Labor	Total
Civil works of power station	19%	2%	21%
Electrical equipment installation works	42%	–	42%
Transmission line construction works	24%	2%	26%
Substation works	30%	2%	32%

Using the above labor wages ratios, the total costs of the Kasseb Project divided into imported equipment and materials, labor wages, domestically procured materials and others, and converted to present worth is as indicated in Table 7-10. This Table 7-10 shows the appropriate revenues of the Kasseb Project prescribed in Item 7.5.1 (1) and the cash flows of total costs in terms of present worth.

(c) Margins in Costs

The earnings from the Kasseb Project will all go to STEG as electricity sales revenue, while those involved in costs are the following groups:

- Group S STEG (bears construction costs and operation and maintenance costs)
- Group L Laborers (gain labor wages)
- Group P Operation and maintenance personnel (gain salaries)
- Group C Contractors (gain compensation for works)

Of the above groups, regarding the labor wages of Group L (laborers), it has been stated previously that 20% is estimated to be a "wage premium" (σ=–0.20).

Next, regarding the salaries of Group P (operation and maintenance personnel), unlike laborers' wages, they may be considered to comprise an approximate cost reflecting opportunity cost, but when this is further broken down, it may be divided into net living costs and a marginal portion set aside for savings. There is no data to substantiate the ratio of this margin, but it will be assumed to be more or less around 10% (λ = –0.10) of total salaries.

Finally, it is assumed that about the time of execution of the Kasseb Project, domestic contractors will have become adequately experienced and compensation for domestic currency construction work will all go to domestic contractors. In such case, the ratios of the profit margins against construction cost are estimated to be between 15 and 25%, and an average of about 20% (γ=−0.20). It is assumed that the same can be said for suppliers of domestic materials for maintenance.

(2) Second Approximation

(a) Shadow Price of Investment

The gains produced accompanying completion of the project may be expressed as the following:

Gains = Consumption + Savings (reinvestment)

The second approximation in the analysis consists of measuring the social value of investment by a base whereby it will be possible to compare it with the social value of consumption to compute the aggregate social value of the project. (The social value of investment exceeds that of consumption.)

In effect, the actual value of savings in the above equation must be adjusted by the "shadow price of investment." In this case, the "shadow price of investment.' is defined as the present worth of the future aggregate consumption stream produced by a unit investment made at the present point of time. Now, putting the social rate of return on investment in the private sector as q, the marginal rate of reinvestment as s, and social rate of discount as i, the shadow price of investment will be indicated by the following equation:

$$P_{inv} = \frac{(1 - s)q}{i - sq}$$

(Note)

Assuming that 1 unit of marginal investment brings about a cumulative investment amount A_t in yeat t, the return in year t will be the following:

$$qAt$$

This return naturally is divided between consumption and savings (reinvestment). With rate of reinvestment as s, the amount of consumption in year t will be thf wollosing:

$$(1-s)\,qA_t$$

Therefore, the present worth (shadow price of investment) for the entire period of the consumption stream will be the following:

$$P_{inv} = \sum_{t=1}^{\infty} \frac{(1\text{-}s)qAt}{(1+i)t}$$

$$\begin{aligned}
\text{where}\quad A_1 &= 1 \\
A_2 &= A_1 + sqA_1 = (1+sq)A_1 \\
A_3 &= A_2 + sqA_2 = (1+sq)A_2 \\
&= (1+sq)^2 A_1 \\
&= (1+sq)^2
\end{aligned}$$

Therefore,

$$P_{inv} = \sum_{t=1}^{\infty} \frac{(1-s)q(1+sq)^{t-1}}{(1-i)^t}$$

$$= \frac{(1-s)q}{1+sq} \sum_{t=1}^{\infty} \left(\frac{1+sq}{1+i}\right)^t$$

where, since

$$\sum_{t=1}^{\infty} \left(\frac{1+sq}{1+i}\right)^t = \frac{1+sq}{i-sq}$$

therefore

$$P_{inv} = \frac{(1-s)q}{i-sq}$$

(3) Analysis

(a) First Approximation

Item (R) in Table 7-10 represents the expenditures saved for the country as a whole due to implementation of the Kasseb Project, and therefore, may be looked upon as real gains of this Project. In contrast, Items (1) to (4) correspond to resources which would have been utilized (or could have been utilized) by one of the sectors of the national economy if the Kasseb Project has not been implemented. In other words, they comprise "sacrifice of consumption opportunity" caused by the Project. Based on the above, the market value of aggregate consumption benefit for each year, MC, will be given by the following equation:

MC = (R) – (1) – (2) – (3) – (4) .... Eq. (1)

(b) Second Approximation

The second stage of analysis consists of adjusting the price of specific items among the items in Eq. (1) expressed in terms of market prices, and to express the items by real values. With regard to this point, we have assumed the following coefficients:

- Labor wage premium — $\sigma = -0.20$
- Margins in costs
  - Operation and maintenance
    - Personnel — $\lambda = -0.10$
  - Domestic contractor — $\gamma = -0.20$

Based on the above, the social value SC of aggregate consumption benefit will be expressed in the following manner.

Now, if SC^S, SC^L, SC^P and SC^C are the primary consumption benefits respectively of Grups S, L, P and C, Eq. (2) will become the following:

$SC = SC^S + SC^L + SC^P + SC^C$ .... Eq. (3)

The gains of the various groups may be expressed as follows:

$SC^S = (R) - (1) - (2) - (3) - (4)$ .... Eq. (3A)

$SC^L = -\sigma\ [(1 \cdot L) + (4 \cdot L)]$ .... Eq. (3B)

$SC^P = -\lambda(2 \cdot P)$ .... Eq. (3C)

$SC^C = -\gamma\ [(1 \cdot M) + (2 \cdot M) + (4 \cdot M)]$ .... Eq. (3D)

The total of the above 4 equations of (3A), (3B), (3C) and (3D) will be equal to the reply of Eq. (2).

Next, if the propensities to save of the various groups are s^S, s^L, s^P and s^C, respectively, for example, the overall consumption benefit for Group S, C^S, may be expressed as the following:

$$SC = MC - \sigma\ [(1 \cdot L) + (4.\ L)] - \gamma[(1 \cdot M) + (4 \cdot M) + (2 \cdot M)] - \lambda(2 \cdot P)$$

.... Eq. (2)

(c) Final Approximation

The final stage of analysis consists of applying the "shadow price of investment" to adjust the social value of investment to a basis where it may be compared with the social value of consumption, and the aggregated social value of the Kasseb Project may be calculated. Here, in considering the reinvestment amount of the country as a whole, what must be given attention is the difference in the propensity to save among the various classes comprising the society. Therefore, what must be done at the final stage of analysis, is to grasp the gains of the various groups concerned with the Project in terms of the sum of the amounts of primary consumption occurring in the groups, and the secondary (or indirect) consumption triggered in the society as a whole by the parts which remain without being spent (savings). As groups concerned with the Kasseb Project, we have made divisions into the four groups below.

- Group S — STEG
- Group L — Laborers
- Group P — Operation and maintenance personnel
- Group C — Domestic Contractors (and suppliers)

Note: Of the above groups, when it is taken into account that STEG comprising Group S is a government agency and that the construction cost will be enormous, it is conceivable that a part of the construction cost will be borne by the Government, but considering that the marginal propensities to save of the two are practically the same, it will not be significant to separate the two. Consequently, it was assumed that the entire amount of the construction cost would be borne by STEG.

As for the contracted amounts of contractors, they will include labor wages, but since the propensity to save differs between the two, the labor wages were extracted from the contracted amount, and these were apportioned between the two groups.

$$CS = SC^S \cdot s^S \cdot Pinv + SC^S (1 - s^S)$$
$$= SC^S [s^S Pinv + (1 - s^S)]$$

where, $SC^S \cdot s^S$ Pinv is the indirect consumption benefit induced by savings, while $SC^S(1-s^S)$ is a primary (direct) consumption benefit. Similarly, the overall consumption benefit enjoyed by other groups may be expressed as follows:

$$C^L = SC^L [s^L Pinv + (1 - s^L)]$$
$$C^P = SC^P [s^P Pinv + (1 - s^P)]$$
$$C^C = SC^C [s^C Pinv + (1 - s^C)]$$

Therefore, when the ultimate social value of aggregate consumption benefit is C, then

$$C = C^S + C^L + C^P + C^C$$

Therefore, combining with Eq. (3), the following equation is obtained.

$$C = SC + (Pinv - 1) (s^S SC^S + s^L SC^L + s^P SC^P + s^C SC^C)$$

(d) Applicable Parameters

There are a number of parameters included in the above evaluation of aggregate consumption, but it was not possible to obtain accurate data and information on these parameters during the process of our investigations. Accordingly, in the evaluation to follow, the general standard values of these parameters will be applied. Regarding this point, it will be necessary to improve the accuracy of analysis through further detailed studies.

However, it is thought possible in this present study to grasp approximate figures of the socio-economic effects produced through implementation of the Kasseb Project. The parameters applied in this study are as listed below.

(1)	Social rate of discount	i = 6%, 10%, 12%
(2)	Laborer's wage premium	$\sigma = -0.20$
(3)	Operation and maintenance personnel salary margin	$\lambda = -0.10$
(4)	Domestic contractors' margin	$\gamma = -0.20$
(5)	Social rate of returns on private investment	q = 0.20
(6)	Marginal rate of reinvestment out of profits	s= 0.25 (Note)
(7)	Shadow price of investment	Pinv = 15, 3, 2.14
(8)	Marginal propensity to save:	
	(S) STEG	$s^S = 1.0$
	(L) Laborers	$s^L = 0.05$
	(P) Operation & Maintenance personnel	$s^P = 0.25$

(C) Domestic contractors (and suppliers)	$s_C = 0.80$

(Note) The savings rate of all Tunisia against GNP was 25.8% in 1975, 24.8% in 1976.

(e) Evaluation

On computing the social value of consumption benefit to be brought about by the Kasseb Project using the above equations and parameters, they are as indicated in Table 7-11 and Fig. 7-2, and in short are as follows:

Unit: 1,000 Dinars

Item	Social Rate of Discount		
	6%	10%	12%
Surplus consumption benefit at market price	20,219.1	2,739.9	−735.3
Social value of consumption benefit (direct benefit)	23,798.0	5,548.5	1,792.5
Aggregated social value of consumption benefit	338,464.8	14,587.9	2,775.4

In effect, whereas at a discount rate of 10% the direct consumption benefit is 5,548,500 Dinars, the aggregated consumption benefit including the indirect consumption benefit induced is approximately 14,587,900 Dinars and 2.6 times of direct consumption benefit.

In Fig. 7-2, in case of discount rate of 8%, whereas the direct consumption benefit is approximately 13,000,000 Dinars, the aggregated consumption benefit is as much as approximately 5.6 times, 73,000,000 Dinars, to contribute to raising of the nation's consumption level.

7.5.2 Regional Redistribution Objective

The so-called income redistribution which would be the second objective of national economic policy will then be examined.

(1) First Approximation

In Table 7-10, the items relevant to regional income redistribution are as follows:

- Labor wages during construction in Item (1•L) and Item (4•L) will be income for the project area.
- Item (1•A) is the administration cost of STEG during construction, but since the greater part of this administration cost will be personnel expenses of employees engaged in supervision of works and the income will be spent at the project area, it will be income for the project area.
- The salaries of operation and maintenance personnel of Item (2•P) will also be income for the project area.

Of the items above, if one half of the administration cost is assumed to comprise the salary portion, the direct consumption benefit (DR^M) of the project area will be the following:

$$DR^M = (1 \cdot L) + (4 \cdot L) + 1/2\,(1 \cdot A) + (2 \cdot P) \quad \text{....Eq. (5)}$$

Since the objective handled here is concerned with the actual cash flow, it is not necessary to introduce such concepts as opportunity cost of labor wages or shadow price of investment as taken up under the aggregate consumption objective of 7.5.1.

(2) Second Approximation

The second step of the analysis is to adjust the regional consumption benefit of Eq. (5) by a regional income multiplier.

The reason is that when an additional income is brought about in the Kasseb project area through implementation of the Project, a part of it will be respent in the same area. In effect, a series of benefit cycles will be newly produced. For example, spending out of the income from the Kasseb Project will bring about additional income to small businesses and the service sector, and these sectors will further spend part of the additional income for consumption purposes. In this way, infinite cycles of indirect benefits will be triggered within the project area.

Now, taking the ratio between the abovementioned additional income and additional expenditure, that is, the marginal propensity to spend, as r, the indirect benefit (R^I) produced from the direct benefit (R^D) of a certain project will be thf sollowing:

$$\begin{aligned} R^I &= rR^D + r\,(rR^D) + r\,(r^2 R^D) + \ldots.. \\ &= R^D\,(r + r^2 + r^3 + \ldots..) \\ &= R^D\left(\frac{r}{1-r}\right) \end{aligned}$$

Therefore, if the aggregate social value of the regional benefit of a project is put as R^T,

$$\begin{aligned} R^T = R^D + R^I &= R^D\left(1 + \frac{r}{1-r}\right) \\ &= R^D\left(\frac{1}{1-r}\right) \end{aligned}$$

In effect, the ultimate social value of regional consumption benefit is equal to the product of direct benefit of the project multiplied by "regional income multiplier" $\left(\frac{1}{1-r}\right)$.

Therefore, the regional income redistribution effect R^M brought about by the Kasseb Project may be expressed by the equation below.

$$R^M = \frac{DR^M}{1-r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. (6)}$$

Based upon the following assumptions the marginal propensity to consume (r) is calculated to be around 30%:

- Ratio of required materials (accompanied by employment) against labor cost 100%
- Profit ratio of contractors, etc. 20%
- Consumption ratio of wage income in the project area 80%

(3) Evaluation

The regional income redistribution effect brought about by the Kasseb Project calculated using the above equation and coefficients will be as indicated in Table 7-11. In effect,

The above ultimate regional redistributed income, is the infinite stream of consumption benefit based on income converted to present worth, and from these figures it may be expected that the income redistribution effect brought about by the Kasseb Project will be very large.

7.6 CONCLUSIONS

As stated at the beginning of this chapter, it is necessary for further detailed field investigations to be made for the Kasseb Project for final determination of technical characteristics based on which the construction costs must be revised. Also, with regard to various parameters required for socio-economic nalysis, it will be necessary to improve the precisions of analysis applying values amply substantiated in Tunisia.

However, in the present economic analysis made applying construction costs of preliminary study level and parameters of average values in various countries, the benefit-cost ratios at market prices indicate 1.06 at discount rate of 10% and 1.20 at discount rate of 8%, while the economic internal rate of return shows a high figure of 11.8%. Considering the fact that the social rate of discount normally used in Tunisia is 10%, this means that the Kasseb Project, unless a very large increase in construction costs is resulted from investigations made hereafter, may be judged to be a project which is of ample advantage economically.

Further, in the socio-economic analysis considering secondarily induced benefits of the project, the aggregate consumption benefit for the country as a whole remaining after the investment amount has been recovered is calculated to be approximately 14,590,000 Dinars in case of a discount rate of 10% and approximately 73,000,000 Dinars in case of a discount rate of 8%. Such a secondary consumption benefit will be produced from the domestic currency portion of the investment cost of the project going partly to savings through domestic contractors and suppliers giving rise to infinite cycles of reinvestment. Similarly, a marked income redistribution effect will be produced in the project area.

Unit: 1,000 Dinars

Item	Discount Rate		
	6%	10%	12%
Direct income for project area	5,141.8	3,983.3	3,564.7
Aggregated regional income	7,345.2	5,690.4	5,092.4

Such an aggregate consumption benefit and regional redistribution effect can hardly be expected of the alternative gas turbine project where the weight of the foreign currency portion of the fund requirement is overwhelmingly large. In this sense, it may be judged that the socio-economic merit of the Kasseb Project is much higher than that of the alternative gas turbine project.

Table 7-1 Annual Construction Costs of KASSEB Project

Unit: 1,000 Dinars

Item	Total	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
KASSEB Pumped Storage Power Station	44,966			1,339.7	1,789.5	15,022.8	14,621.6	1,642	5,588.1	2,801.9	2,160.4
Foreign Currency	24,658			1,339.7	60.5	5,730.5	6,520.4	1,525.8	5,267.3	2,106.9	2,106.9
Domestic Currency	20,308				1,729	9,292.3	8,101.2	116.2	320.8	695	53.5
Transmission line and Substation	3,510				262.3	1,211.5	281.2	262.3	1,211.5	281.2	
Foreign Currency	2,808				262.3	1,049	92.7	262.3	1,049	92.7	
Domestic Currency	702					162.5	188.5		162.5	188.5	
Supporting facilities at Project site	1,331			931	400						
Foreign Currency											
Domestic Currency	1,331			931	400						
Engineering and Administration costs	5,016	752	83	108	197	1,467	1,253	171	638	265	82
Foreign Currency	2,508	752	34	44	81	604	516	71	263	109	34
Domestic Currency	2,508		49	64	116	863	737	100	375	156	48
Total Investment Costs	54,823	752	83	2,378.7	2,648.8	17,701.3	16,155.8	2,075.3	7,437.6	3,348.1	2,242.4
Foreign Currency	29,974	752	34	1,383.7	403.8	7,383.5	7,129.1	1,859.1	6,579.3	2,308.6	2,140.9
Domestic Currency	24,849		49	995	2,245	10,317.8	9,026.7	216.2	858.3	1,039.5	101.5

Table 7-2 Annual Operation and Maintenance Costs of KASSEB Project

Unit: 1,000 Dinars

Item	1983	1983	1985	1986	1987	1988	1989 –
KASSEB Pumped Storage Power Station			313.3	363.3	372.9	460.2	479.4
Foreign Currency			228.7	268	275.6	344.5	359.7
Domestic Currency			84.6	95.3	97.3	115.7	119.7
Transmission line and Substation							
Foreign Currency			25.8	28.1	32.8	56.2	56.2
Domestic Currency			14.4	15.7	18.3	31.5	31.5
Total O and M Costs			353.5	407.1	424.0	547.9	567.1
Foreign Currency			254.5	296.1	308.4	400.7	415.9
Domestic Currency			99.0	111.0	115.6	147.2	151.2

Table 7-3 Annual Fuel Costs of KASSEB Project and Alternative Gas Turbine Project

Year	Installed Capacity of KASSEB P.S. (MW)	Output and Energy to be supplied during Peaking Hours			Required Annual Energy for Pumping up (MWh)	Unit Fuel Costs (millimes/KWh)		Annual Fuel Costs (1,000 Dinars)	
		Output (MW)	Daily Energy (MWh)	Annual Energy (MWh)		Peak KASSEB	Off-Peak Gas turbine	KASSEB	Alternative Gas turbine
1985	150	75	305	87,470	126,770	5.2	10.2	659.2	892.2
1986	150	150	545	170,510	247,120	5.2	10.2	1,285.0	1,739.2
1987	250	185	650	175,980	255,040	5.2	10.2	1,326.2	1,795.0
1988	350	210	725	226,820	328,720	5.2	10.2	1,709.3	2,313.6
1989	350	240	800	250,290	362,740	5.2	10.2	1,886.2	2,553.0
1990	350	270	875	273,750	396,740	5.2	10.2	2,063.0	2,792.3
1991	350	305	1,005	314,420	455,680	5.2	10.2	2,369.5	3,207.1
1992 – 2037	350	350	1,145	358,220	519,160	5.2	10.2	2,699.6	3,653.8

Table 7-4 Annual Construction Costs of Alternative Gas Turbine Project

Unit: 1,000 Dinars

Item	Total	1983	1984	1985	1986	1987	1988
Gas Turbine Power Stations	38,000	2,050	11,320	3,080	2,660	14,840	4,050
Foreign Currency	35,700	1,540	10,800	3,080	2,030	14,260	4,050
Domestic Currency	2,300	510	520		630	640	
Substations	5,200	200	1,500	540	260	2,000	700
Foreign Currency	4,500	200	1,350	390	260	1,800	500
Domestic Currency	700		150	150		200	200
Engineering and Administration Costs	4,300	220	1,260	380	280	1,660	500
Foreign Currency	1,300	70	390	110	80	500	150
Domestic Currency	3,000	150	870	270	200	1,160	350
Total Investment Costs	47,500	2,470	14,080	4,000	3,200	18,500	5,250
Foreign Currency	41,500	1,810	12,540	3,580	2,370	16,500	4,700
Domestic Currency	6,000	660	1,540	420	830	2,000	550

Table 7-5 Annual Operation and Maintenance Costs of Alternative Gas Turbine Project

Unit: 1,000 Dinars

Item	1983	1984	1985	1986	1987	1988	1989 –
Gas Turbine Power Stations			249.4	373.9	414.6	784.9	866.6
Foreign Currency			177	265	294	556	614.1
Domestic Currency			72.4	108.9	120.6	228.9	252.5
Substations							
Foreign Currency			43	64	71	136	150.4
Domestic Currency			24	36	40	77	84.6
Total O and M Costs			316.4	473.9	525.6	997.9	1,101.6
Foreign Currency			220	329	365	692	764.5
Domestic Currency			96.4	144.9	160.6	305.9	337.1

Table 7-6 Annual Total Expenses of KASSEB Project

Unit: 1,000 Dinars

Item	Total Expenses	1 1979	2 1980	3 1981	4 1982	5 1983	6 1984	7 1985	8 1986	9 1987	10 1988	11 1989	13 1990	13 1991	1992–2037
(1) Construction Costs	54,823	752	83	2,378.7	2,648.8	17,701.3	16,155.8	2,075.3	7,437.6	3,348.1	2,242.4				
(1.F) Foreign Currency	29,974	752	34	1,383.7	403.8	7,383.5	7,129.1	1,859.1	6,579.3	2,308.6	2,140.9				
(1.D) Domestic Currency	24,849		49	995	2,245	10,317.8	9,026.7	216.2	858.3	1,039.5	101.5				
(2) Operatoni and Maintenance Costs	29,520.4							353.5	407.1	424.0	547.9	567.1	567.1	567.1	567.1
(2.F) Foreign Currency	21,638.8							254.5	296.1	308.4	400.7	415.9	415.9	415.9	415.9
(2.D) Domestic Currency	7,881.6							99.0	111.0	115.6	147.2	151.2	151.2	151.2	151.2
(3) Fuel Costs (Domestic)	135,480.0							659.2	1,285.0	1,326.2	1,709.3	1,886.2	2,063.0	2,369.5	2,699.6
(4) Replacement Costs	1 x 20,244			(762.9)		(2,023.3)	(5,146.9)	(1,642)	(5,588.1)	(2,920.4)	(2,160.4)				
(4.F) Foreign Currency	1 x 18,348			(762.9)		(1,907)	(4,578.7)	(1,525.8)	(5,267.3)	(2,199.4)	(2,106.9)				
(4D) Domestic Currency	1 X 1,896					(116.3)	(568.2)	(116.2)	(320.8)	(721.0)	(53.5)				
Total Expenses	240,067.4	752	83	2,378.7	2,910.1	17,701.3	16,155.8	3,088.0	9,129.7	5,098.3	4,499.6	2,453.3	2,630.1	2,936.6	3,266.7
Foreign Currency	69,960.8	752	34	1,383.7	665.1	7,383.5	7,129.1	2,113.6	6,875.4	2,617.0	2,541.6	415.9	415.9	415.9	415.9
Domestic Currency	170,106.6		49	995	2,245	10,317.8	9,026.7	974.4	2,254.3	2,481.3	1,958.0	2,037.4	2,214.2	2,520.7	2,850.8

Note: Figures in parentheses by year indicate the value of annual replacement costs to be required after 30 years from respective initial investment.

Table 7-7 Annual Total Expenses of Alternative Gas Turbine Project

Unit: 1,000 Dinars

Item	Total Expenses	1 1979	2 1980	3 1981	4 1982	5 1983	6 1984	7 1985	8 1986	9 1987	10 1988	11 1989	12 1990	13 1991	1992–2037
(1) Construction Costs	47,500					2,470	14,080	4,000	3,200	18,500	5,250				
(1.F) Foreign Currency	41,500					1,810	12,540	3,580	2,370	16,500	4,700				
(1.D) Domestic Currency	6,000					660	1,540	420	830	2,000	550				
(2) Operation and Maintenance Costs	56,292.2							316.4	473.9	525.6	997.9	1,101.6	1,101.6	1,101.6	1,101.6
(2.F) Foreign Currency	39,066.5							220	329	365	692	764.5	764.5	764.5	764.5
(2.D) Domestic Currency	17,225.7							96.4	144.9	160.6	305.9	337.1	337.1	337.1	337.1
(3) Fuel Costs (Domestic)	183,367.2							892.2	1,739.2	1,795	2,313.6	2,553	2,792.3	3,207.1	3,653.8
(4) Replacement Costs of Gas turbines	3 x 38,000					(2,050)	(11,320)	(3,080)	(2,660)	(14,840)	(4,050)				
(4.F) Foreign Currency	3 x 35,700					(1,540)	(10,800)	(3,080)	(2,030)	(14,200)	(4,050)				
(4.D) Domestic Currency	3 x 2,300					(510)	(520)		(630)	(640)					
(5) Replacement Costs of Sub-stations	1 x 9,400					(200)	(1,500)	(540)	(260)	(2,000)	(700)				
(5.F) Foreign Currency	1 x 7,500					(200)	(1,350)	(390)	(260)	(1,800)	(500)				
(5.D) Domestic Currency	1 x 1,900						(150)	(150)		(200)	(200)				
Total Expenses	410,559.4					2,470	14,080	5,208.6	5,413.1	20,820.6	8,561.5	3,654.6	3,893.9	4,308.7	4,755.4
Foreign Currency	195,166.5					1,810	12,540	3,800	2,699	16,865	5,392	764.5	764.5	764.5	764.5
Domestic Currency	215,392.9					660	1,540	1,408.6	2,714.1	3,955.6	3,169.5	2,890.1	3,129.4	3,544.2	3,990.9

Note: Figures in parentheses by year indicate the values of annual replacement costs to be required after 15 years from respective initial investment for gaz turbines, and 30 years for sub-stations.

Table 7-8 Comparison of Total Present Worth Costs of KASSEB Project and Alternative Gas Turbine Project

Unit: 1,000 Dinars

Item	KASSEB Project			Alternative Gas Turbine Project		
	6%	10%	12%	6%	10%	12%
(1) Construction Costs	38,049.5	31,275.6	28,212.9	30,310.3	22,889.2	19,991.4
Foreign Currency	19,965.7	16,462.4	14,759.9	26,440.7	19,947.3	17,413.3
Domestic Currency	18,083.8	14,813.2	13,453.0	3,869.6	2,941.9	2,578.1
(2) Operation and Maintenance Costs	5,738.8	2,730.6	2,006.4	10,491.1	4,815.8	3,472.9
Foreign Currency	4,201.9	1,997.5	1,467.0	7,280.9	3,342.3	2,410.0
Domestic Currency	1,536.9	733.1	539.4	3,210.2	1,473.5	1,062.9
(3) Fuel Costs (Domestic)	24,649.7	11,182.5	8,037.0	33,362.4	15,137.5	10,882.3
(4) Replacement Costs	2,183.6	534.3	269.6	16,676.9	5,620.4	3,444.0
Foreign Currency	1,983.0	485.9	245.4	15,583.4	5,248.6	3,214.8
Domestic Currency	200.6	48.4	242	1,093.5	371.8	229.2
Total Present Worth Costs	70,621.6	45,723.0	38,525.9	90,840.7	48,462.9	37,790.6

Table 7-9 (1) Labour Wages Ratios in Domestic Currency Portion
(Civil Works)

(1,000 Dinars)

Item	Total	Excavation	Embankment	Concrete Work	Others	Remarks
1. Construction Costs						
(Domestic Currency)						Labour wages ratios:
Access road		572,600				
Dam			734,120			– Skilled labour
Intake and Headrace tunnel		370,540		396,000		(B)/(A) = 19%
Surge tank		1,106,660		660,000		– Unskilled labour
Penstock		1,362,000		1,866,450		(C)/(A) = 2%
Power house		331,320		1,080,000		
Tailrace		22,500	943,200	264,600		– Total 21%
Tailrace canal		1,336,000				
Switchyard		117,700		277,900		
Total (A)	15,259,400	5,219,320	1,686,320	4,544,950	3,808,810	
2. Labour Wages in the Construction Costs						
– Skilled labour						
(%)		(30%)	(27%)	(10%)	(10%)	
(1,000 dinars) (B)	2,856,500	1,565,800	455,300	454,500	380,900	
– Unskilled labour						
(%)		(3%0	(3%)	(2%)		
(1,000 dinars) (C)	298,100	156,600	50,600	90,900		

Table 7-9 (2) Labour Wages Ratios in Domestic Currency Portion
(Electrical Works)

Item	Ratio in the total construction costs (A)	Ratios of Labour Wages in the respective Works (B)	Ratios of Labour Wages in the Total Construction Costs (A) X (B)
1. Installation Works of Electrical Equipment (Power Station)			
Transportation	20%		
Installation	60%	70%	42%
Administration and others	20%		
Total	100%		42%
2. Transmission Works			
Transportation	20%		
Foundation Works (Towers)	40%	30%	12%
Installation	20%	70%	14%
Administration and others	20%		
Total	100%		
3. Substation Works			
Building	60%	30%	18%
Installation	20%	70%	14%
Administration and others	20%		
Total	100%		32%

Table 7-10 Present Worth Cash Flow of KASSEB Project

Unit: 1,000 Dinars

Item	Social Rate of Discount		
	6%	10%	12%
Revenues			
(R) Revenues from Sales of Electricity	90,840.7	48,462.9	37,790.6
Costs	70,621.6	45,723.0	38,525.9
(1) Construction Costs	38,049.5	31,275.6	28,212.9
(1.F) Imported equipment and materials	19,965.7	16,462.4	14,759.9
(1.L) Labour wages	3,663.5	3,005.9	2,732.3
(1.M) Domestic materials	12,646.8	10,376.9	9,432.3
(1.A) Administration	1,773.5	1,430.4	1,288.4
(2) Operation and Maintenance Costs	5,738.8	2,730.6	2,006.4
(2.F) Imported equipment and materials	4,201.9	1,997.5	1,467.0
(2.M) Domestic materials	1,029.7	491.2	361.4
(2.P) Salary of STEG personnel	507.2	241.9	178.0
(3) Fuel Costs (Domestic)	24,649.7	11,182.5	8,037.0
(4) Replacement Costs	2,183.6	534.3	269.6
(4.F) Imported equipment and materials	1,983.0	485.9	245.4
(4.M) Domestic materials	116.3	28.1	14.0
(4.L) Labour wages	84.3	20.3	10.2

Table 7-11 Aggregate Consumption Benefit and Regional Income Redistribution Benefit to be obtained from KASSEB Project

Unit: 1,000 Dinars

Item	Social Rate of Discount		
	6%	10%	12%
Total present worth costs of:			
– KASSEB Project	90,840.7	48,462.9	37,790.6
– Alternative Gas turbine Project	70,621.6	45,723.0	38,525.9
Aggregate Consumption Benefit			
MC Consumption benefit at market prices	20,219.1	2,739.9	△ 735.3
SC^S Consumption benefit to STEG	20,219.1	2,739.9	△ 735.3
SC^L Consumption benefit to labour	749.6	605.2	548.5
SC^P Consumption benefit to personnel	50.7	24.2	17.8
SC^C Consumption benefit to domestic contractors and suppliers	2,758.6	2,179.2	1,961.5
SC Social value of direct consumption benefit	23,798.0	5,548.5	1,792.5
C Social value of aggregate consumption benefit	338,464.8	14,587.9	2,775.4
Regional Redistribution Benefit			
DR^M Direct Income in the projcet area	5,141.8	3,983.3	3,564.7
RM Final income redistribution benefit in the project area	7,345.2	5,690.4	5,092.4

Fig. 7-1 Economic Internal Rate of Return

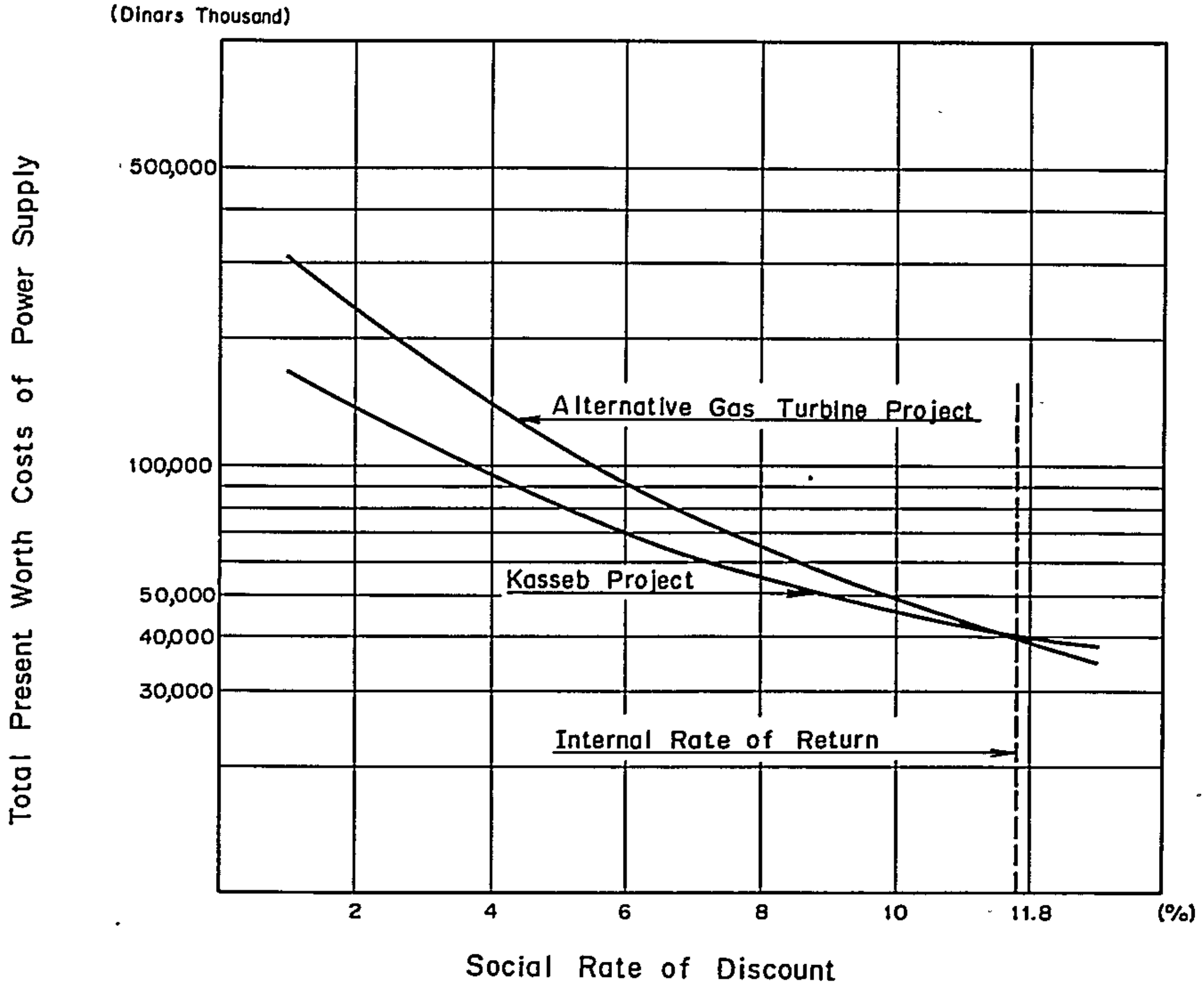
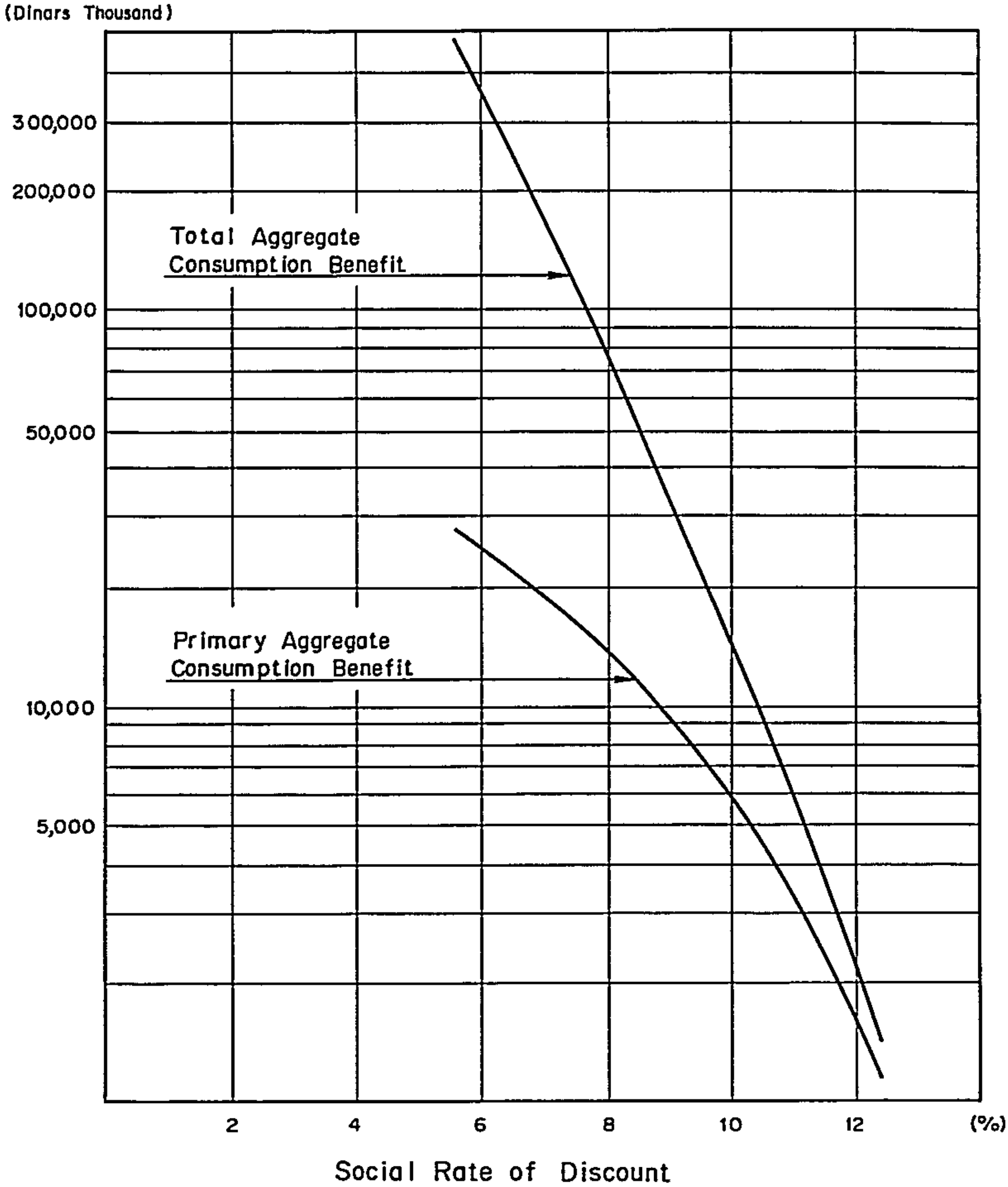


Fig. 7-2 Social Value of Aggregate Consumption Benefit



CHAPTER 8

POWER SYSTEM ANALYSIS

CHAPTER 8 POWER SYSTEM ANALYSIS

8.1 TRANSMISSION METHOD OF POWER GENERATED AT KASSEB POWER STATION

Various parameters are conceivable for the study of the method of power transmission for Kasseb Project, but broadly divided, they can be narrowed down to the three points below.

a) What the transmission voltage should be, and whether to invest in double circuits from the beginning, or to construct a single circuit for the No. 1 and No. 2 units (75 MW x 2) and add another circuit to coincide with commissioning of the No. 3 unit (100 MW)

b) Either a substation in the vicinity of Tunis or Tajerouine Substation is conceivablle as the substation to receive the power generated at Kasseb Project. Whether a single circuuit each leading to the vicinity of Tunis and to Tajerouine Substation (Pattern A) or double circuits to the vicinity of Tunis (Pattern B) would be better as the final form of the power system.

c) There will be four 150-MW steam thermal units required for pump-up power by the 2nd stage Kasseb Project is finally completed, and whether to locate these concentrated at Sousse Thermal Power Station (Pattern 1), or to disperse them (2 units each) at Sousse Thermal Power Station and the Tunis District (Pattern 2).

The problematic points of the above three parameters are touched upon and the results of examination described in Item 8.2.

8.1.1 Transmission Voltage and Number of Circuits

With regard to transmission voltage, 225 kV which is the voltage of the trunk transmission lines of STEG now being constructed and the highest voltage in the STEG System will be adopted. The surge impedance loading of a single conductor of a transmission line of this voltage is $2.5 \times 225^2 = 127$ MW. Therefore, in case of transmission over a distance of approximately 100 km, it will be possible to transmit approximately double the surge impedance loading under the condition of ambient temporation influenced to transmitting capacity and for transmitting the 350 MW of Kasseb Power Station,a 225-kV,two (2) circuits transmission lines will be adequate.

With respect to conductor size, ACSR 410 mm^2 single conductor, the same as that being used in present construction will be suitable. The permissible current of this conductor is approximately 710 A under fairly severe conditions of continuous allowable temerature of 90°C, ambient temperature of 50°C, wind velocity of 0.5 m/sec. heat gain from the sun of 0.1 W/cm^2 and radiation coefficient of 0.9. Converted to capacity (MVA), this corresponds to 276 MVA and it will be possible to transmit the power genrated at the No. 1 to No. 3 units of Kasseb Project with a single circuit.

In examining the number of circuits, in order to restrict initial investment, subcircuit transmission line was adopted under the condition of the second circuit to be commissioned in step with the No. 3 unit of Kasseb Project.

As for chances of transmission lines being tripped by lightning there are extremely few cases to be seen in past records. The I.K.L. map is not published in Tunisia.

8.1.2 Receiving Substations

The substation to receive the power genrated at Kasseb Power station will in the mignight in reverse be the substation transmitting power to Kasseb Power Station for pump-up. Two patterns, A and B, were studied.

– Pattern A consists of intially connecting a single circuit with M'Nihla substation, and connecting an additional single circuit to Tajerouine in time for the commissioning of the No. 3 unit of Kasseb Power Station.

– Pattern B consists of constructing double circuits steel towers with a single circuit strung initially and connecting to M'Nihla with additional stringing done in time for the commissioning of the No. 3 unit of Kasseb Power Station. Since the distances from Kasseb Power Station to M'Nihla Substation and from Kasseb Power Station to Tajerouine Substation are almost the same, if the method of Pattern B of constructing double circuits steel towers is taken, there will be the merit that construction cost will be cheaper than for Pattern A by roughly 30%.

Originally, the Mission had thought of selecting Nassen Substation as the substation for connection to the Tunis District, but a change was made to M'Nihla Substation for the reasons given below.

If connection were to be made to Nassen Substation.

a) The number of 225-kV feeders at Nassen Substation would become 5 circuits and concentration of feeders would be great compared with other 225-kV substations, (Pattern B)

b) If there were to be faulting of the outer loop line between M'Nihla Substation and Nassen Substation before a large-capacity thermal is commissioned in the northern part of Tunis, there will be possibility of power failure at M'Nihla Substation.

and since these would be undesirable from the standpoint of reliability, it was decided the connection should be made to M'Nihla Substation.

8.1.3 Location of 150-MW Steam Units

It would not be desirable to concentrate 150-MW base power steam thermal units at Sousse for the reasons indicated below.

Even if faulting may be infrequent, if there were to be concentration at Sousse Thermal Power Station, outage of that station would mean complete failure of the entire power system of STEG.

Therefore, the 150-MW units should not be concentrated at Sousse District, but a part dispersed to the Tunis District. Through this dispersion, transmission losses would be reduced, there will be less increases required to be made for reactive power supply facilities and supply reliability will be increased.

There are various cases conceivable for dispersion of the 150-MW units. The first two 150-MW units (No. 1 and No. 2 Unit) are already under construction at Sousse Thermal Power Station, and the study thus becomes limited to the pattern of locations for the third and fourth units of 150 MW.

Pattern 1: Install third and fourth units concentrated at Sousse Power Station

Pattern 2: Install third and fourth units in Tunis District

Pattern 2': Install third unit at Sousse Power Station and fourth unit in Tunis District

a) Pattern 2 would be the best for system operation if there were to be a suitable location in the Tunis District other than the old site of La Goulette I. Moreover, as in the case of First Stage Sousse Power Station, since it will be a set of two units, the advance investment will be a minimum.

b) With Pattern 2' there will be 150 MW x 3 units at Sousse Power Station and in semi-peak hourbands a considerable power flow north to Tunis from Sousse Power Station may be expected, with moreover a considerable increase in this during the middle of the night when water is to be pumped up, while there will be a slight increase in advance investment compared with Pattern 2 and thus is undesirable.

The study was narrowed down to Pattern 2 and Pattern 1. The aim of this was to clarify the merits and demerits of the patterns dispersed and concentrated of 150-MW unit. Although there may be other alternatives to the patterns of locating the 150-MW units, they will need further technical examination. The third 150-MW unit of steam is expressed as "X" and the fourth 150 MW unit as "Y" in the study.

8.1.4 Patterns Studied

Combining the above patterns, A and B, and 1 and 2, to make up the basic patterns (A-1, A-2, B-1, B-2), the patterns studied taking into account the influences of increases in demand and supply according to the year as shown in Fig. 8-1 were decided, and the concrete pattern numbers were set for example as "A-5-1-P" which has the following meaning.

– The first character indicates the final pattern of the transmission line.

A: Single circuits to M'Nihla Substation and Tajerouine Substation

B: Two circuits to M'Nihla Substation

– The second numeral indicates the point of time for comissioning of generator units of Kasseb Power Station

5: 1985 (No. 1 unit start-up time)

6: 1986 (No. 2 unit start-up time)

8: 1988 (No. 4 unit start-up time)

A study is not made for 1987 (time of start-up of No. 3 unit), and since this is the time when the second circuit of transmission line between Kasseb Power Station and N'Nihla Substation or Tajerouine Substation will be completed, the situation compared with 1986 will become easy in the aspects of both power flow and voltage regulation. Therefore, a study for 1987 was omitted.

– The third character indicates the pattern number, whether the 150-MW units are concentrated or dispersed.

1: 4 units concentrated at Sousse Power Station

2: 2 units of 150MW each dispersed at Sousse Thermal Power Station and in the Tunis District

– The last character, if P, indicates "peak" and the time when Kasseb Power Station is generating power, and if N, indicates "midnight" when water is being pumped up at Kasseb Power Station.

8.2 RESULTS OF TRANSMISSION METHOD OF POWER GENERATED AT KASSEB POWER STATION

Naturally, depending on difference of power system structure due to mainly trunk transmission lines; the superiorities or inferiorities of power loss, voltage regulation, transient stability will be prominent in accordance with increase in power demand. Within the scope of the period examined, the abovementioned patterns were compared for examination without any modification of 225-kV transmission lines which are constructing and presently planned by STEG. When No. 1 and No. 2 units of Kasseb Power Station are commissioned, the transmission line will be only one circuit, and there is no difference between patterns A and B in 1985 and 1986.

The study for 1988 when the second stage of Kasseb Power Station is completed will have great significance and this will be described.

8.2.1 Receiving Substations

In the comparison of Patterns A and B, Pattern A in which connections of 225-kV transmission line coming from Kasseb Power Station are made to M'Nihla Substation and Tajerouine Substation is more desirable. The reasons are given below.

a) Pattern A Better than Pattern B from Standpoint of System Structure of STEG as a Whole.

With Pattern A, 225kV transmission lines will be connected to M'Nihla Substation and Tajerouine Substation through Kasseb Power Station to form a great outer loop as a part of the entire system, and the power system will become a fairly strong one in grid form. In effect, the Tunis District will be connected with the Sousse District by the following three 225kV lines upon completion of these transmission lines.

- Sousse P.S. – Nassen S.S.
- Sousse P.S. – Ouestlatia S.S. – Nassen S.S.
- Sousse P.S. – Questlatia S.S. – Tajerouine S.S. – Kasseb P.S. – M'Nihla S.S.

Further, Tajerouine Substation which will be the interconnection point with Algeria by 225 kV transmission line in the future is at the end of the system in Pattern B, but with Pattern A, it will be a part of the power system being grid form and reliability will be greatly improved.

b) Improved Reliability for Load Areas between Kasseb Power Station and Tajerouine Substation.

At present, power transmission is being connected by a single circuit of 90-kV, and by interconnection between 225-kV and 90-kV in the vicinity of Kasseb Power Station reliability will be increased and the necessity for additional transmission line of 90 kV will be eliminated.

c) Kasseb Power Station

Receiving of the power generated at Kasseb Power Station during peak hours in case of Pattern B will be strictly limited to the Tunis District, but in case of Pattern A both the Tunis District and the southern district will be covered. With Pattern B, the reliability will be high for Kasseb Power Station to the Tunis District, but when power generated at Kasseb Power Station during outage of a power plants of Sousse Power Station is considered, this would go first to the Tunis District and then to the south, and it is thought there will be less strain with Pattern A.

The same may be said for when pump-up is being done.

d) Transient Stability

As is described in detail in Item 8.4, transient stability will be more stable in case of Pattern A. With Pattern B, when there is failure to reclose a single circuit between Kasseb Power Station and M'Nihla Substation during peak hours, there will be a problem on stability of generators of Kasseb Power Station. However, with Pattern A, for faulting whether both between Kasseb Power Station and Tajerouine Substation and the same section as in case of Pattern B, there will be stability whether succeeding or failing in reclosing.

8.2.2 Location of 150 MW Steam Thermal Units

In this case, the dispersed pattern is clearly better. In essence, when "A-8-1-P" and "A-8-2-P" are compared, transmission loss is less by slightly under 10% for the dispersed type of "A-8-2-P" and the reactive power supply equipment to be added will be approximately 20% less.

The same trend can be seen for B-8-1-P and B-8-2-P,and the dispersed pattern is better.

Regarding transient stability of 150MW thermal unit at faulting of the transmission lines between M'Nihla Substation and Tajerouine Substation through Kasseb Power Station, there is no prominent difference between the dispersed pattern and the concentrated pattern, but it is thought that if the cases of faulting of all other 225-kV transmission lines were to be examined one by one, the dispersed pattern will become more desirable.

8.2.3 Conclusion

As a conclusion, the pattern of A-2 is best (see Fig. 8-1). In effect the pattern is that of leading in a single circuit each to M'Nihla Substation and to Tajerouine Substation whereby two 150-MW steam units each will be located at Sousse Thermal Power Station and in the vicinity of Tunis.

This pattern has the following features compared with other patterns (A-1, B-1, B-2) in 1988.

i) Strengthening of related transmission lines lower than 225 kV will be required at the two sections below.
– There will be a necessity for the 150-kV transmission line between Sousse Thermal Power Station and M'Saken Substation to be increased by two circuits (14 km x 2). It will be necessary for the 90-kV transmission line between M'Nihla Substation and Tunis-Ouest Substation to be strenghened by one circuit (12 km).
Thermal Power Station and M'Saken Substation to be increased by two circuits (14 km x 2).
– It will be necessary for the 90-kV transmission line between M'Nihla Substation and Tunis-Ouest Substation to be strengthened by one circuit (12 km).

ii) Transmission loss is the least of the four patterns at 57.2-MW.

iii) The capacity of the additional reactive power supply equipment (static power condenser) is the smallest of the four patterns at 295-MVar. Furthermore, it is thought shunt reactors will be unnecessary.

iv) The transient stabilities of transmission lines related to Kasseb Power Station are not very much different for A-2 and A-1, but when compared with Pattern B (B-1, B-2), Pattern A is better. However, this does not mean that Pattern B is irretrievably bad. There will be instability only if there is failure to reclose in case of faulting due to 3-phase short-circuiting when operating Kasseb Power Station during peak hours at 350-MW output, whereas the system will be stable when suceeding in reclosing, and even in case of failing in reclosing, when the output of Kasseb Power Station is less, there will be stability.

v) Further, Pattern A will constitute a part of the framework of the future trunk system of STEG, will strengthen the interconnecting point with Algeria, and will also serve to increase the reliability of supply to the load areas between Kasseb Power Station and Tajerouine Substation.

As a result obtained from the above conclusions, the pattern of A-2 will be the most desirable.

8.3 POWER FLOW AND VOLTAGE REGULATION

8.3.1 Power Flow

Power flow calculations were made for peak and midnight hours at the times that the Kasseb Power Station No. 1, 2 and 4 units are started up in 1985, 1986 and 1988. Calculations were not made for 1987 when the No. 3 unit will be commissioned, because this is the time when the second circuit of transmission line from Kasseb Power Station will be completed and the power generated at Kasseb Power Station is smaller than that for 1988 in which the unit of No. 4

Fig. 8－1 Comparison of Various Patterns

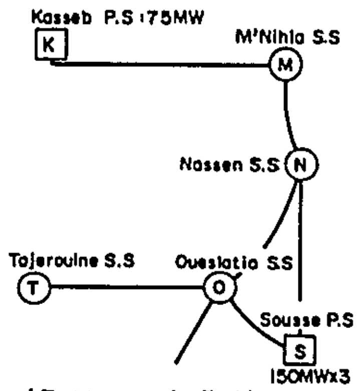
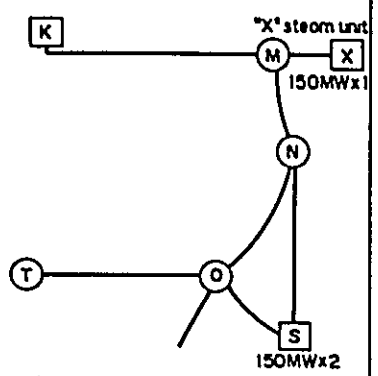
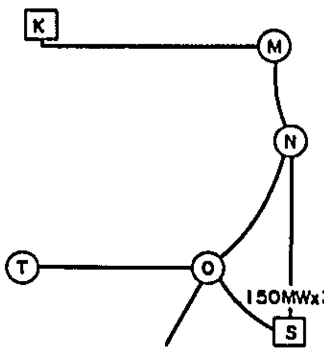
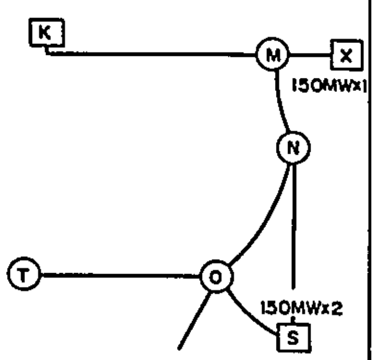
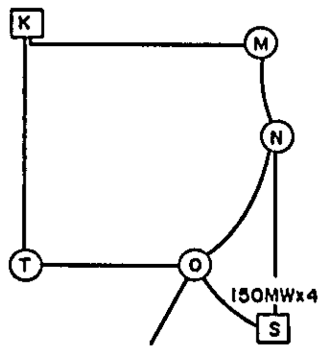
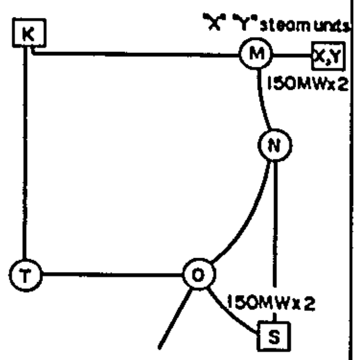
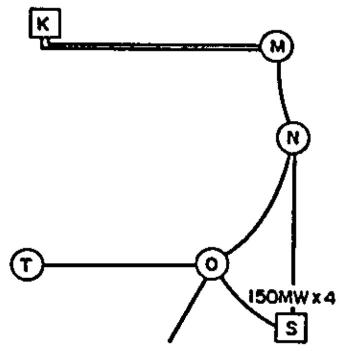
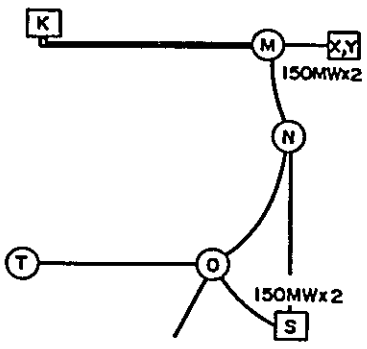
Items examined	A － 1	A － 2	B － 1	B － 2
Power system in 1985	 (Pattern : A-5-1)	 (Pattern : A-5-2)	Same as "A-5-1" (Pattern : B-5-1)	Same as "A-5-2" (Pattern : B-5-2)
Power system in 1986	 (Pattern : A-6-1)	 (Pattern : A-6-2)	Same as "A-6-1" (Pattern : B-6-1)	Same as "A-6-2" (Pattern : B-6-2)
Power system in 1988	 (Pattern : A-8-1)	 (Pattern : A-8-2)	 (Pattern : B-8-1)	 (Pattern : B-8-2)
Transmission line to be added in 1988	1) 150kV, 2cct, 14km Sousse P.S － M'Saken S.S 2) 90kV, 1cct, 12km M'Nihla SS-Tunis Ouest S.S (Total construction cost : 1,120 x 10^3 Dinars)	Same as "A-1"	Same as "A-1"	1) 150kV, 2cct, 14km Sousse P.S-M'Saken S.S 2) 90kV, 1cct, 53km M'Nihla-Menzel Bourguiba 3) 90kV, 1cct, 12km M'Nihla SS-Tunis Ouest S.S (Total construction cost : 2,460 x 10^3 Dinars)
Transmission line loss in 1988	62.3 MW	57.2 MW (Minimum loss)	73.7 MW	80.2 MW
Reactive power supply facilities to be added by 1988	371 MVar	315 MVar	405 MVar	403 MVar
Transient stability in 1988	Stable	Stable	Unstable (at line fault between Kasseb P.S and M'Nihla S.S in case O-C-O)	Critically stable (at line fault between Kasseb P.S and M'Nihla S.S in case O-C-O)
Other characteristics	1) Reinforcement of 225kV power system by forming grid system 2) Reinforcement of interconnection with Algerian power system 3) Improvement of supply reliability in 90kV power system of western district.	Same as A-1		
Comprehensive judgement	Preferable	Best	Not preferable	Not preferable

Table 8-1 Transmission Lines to be Added by The Year of 1988

Section	Year to be put into service	A-1				A-2				B-1				B-2			
		Vol-tage (kv)	Distance (km)	No. of cct to be added	Construc-tion cost (10^3 Dinars)	Vol-tage (kv)	Distance (km)	No. of cct to be added	Construc-tion cost (10^3 Dinars)	Vol-tage (kv)	Distance (km)	No. of cct to be added	Construc-tion cost (10^3 Dinars)	Vol-tage (kv)	Distance (km)	No. of cct to be added	Construc-tion cost (10^3 Dinars)
Sousse~ M'Saken	1985	150	14	1	431.2												
	1986					150	14	1	431.2								
	1988	150	14	1	431.2	150	14	1	431.2	150	14	2	862.4	150	14	2	862.4
M'Nihla~ Menzel Bourguiba	1988													90	53	1	1,303.8
M'Nihla~ Tunis Ouest	1988	90	12	1	295.2	90	12	1	295.2	90	12	1	295.2	90	12	1	295.2
Total construc-tion cost					1,157.6				1,157.6				1.157.6				2,461.4

Note 1) Unit construction cost of transmission lines: 30,800 Dinars/km for 150 kV line
24,600 " for 90 kV line

2) The unit construction cost mentioned above is slightly high considering short distance of the transmission lines to be constructed.

will be commissioned. Therefore, if there were to be no problem with the year of 1988, it was considered that 1987 would be satisfactory also.

In examining power flow and voltage regulation, it was assumed that additional circuits of transmission lines would be constructed when the values below are exceeded.

Transmission line	Conductor size	Permissible current	Power flow
225 kV line	ACSR 410 mm^2	710 A	276 MVA
150 kV line	ACSR 410 mm^2	710 A	184 MVA
150 kV line	ACSR 290 mm^2	580 A	151 MVA
150 kV line	ACSR 180 mm^2	430 A	112 MVA
90 kV line	ACSR 410 mm^2	710 A	111 MVA
90 kV line	ACSR 180 mm^2	430 A	67 MVA

All of the above are for continuous allowable temperature of conductors of 90°C and ambient temperature of 50°C. On looking at power flows for each of the years, those of 225-kV trunk systems have comparatively ample allowances, and only for Case B-8-2-P will there be a slight excess in the power flow to the south between M'Nihla Substation and Nassen Substation.

Regarding the power flow in the same section in case of Pattern B, it is better for the concentrated pattern 1 than the dispersed pattern 2, and there is more power flow with the dispersed pattern.

"B-8-1-P" 57.8 MW – j55.6 MVar (concentrated pattern)

"B-8-2-P" 300 MW – j27.6 MVar (dispersed pattern)

As for the difference between Patterns A and B, they are:

"A-8-2-P" 163.5 MW – j9.6 MVar

"B-8-2-P" 300 MW – j27.6 MVar

and power flow is lighter for Pattern A, because the transmission line between Kasseb Power Station and Tajerouine Substation which is the western-side outer loop line serving as the bypass for the eastern-side trunk line.

There will be no problems for any of the 225 kV trunk lines during the middle of the night.

The sections requiring construction of additional transmission line and their approximate construction costs of 150-kV and 90-kV transmission lines are indicated in Table 8-1. The construction cost of A-1, A-2 and B-1 are 1,157.6 thousand Dinars and B-2 is 2,461.4 thousand Dinars. The transmission-line losses of the respective years are as given in Table 8-2.

Table 8-2 Transmission Line Loss (more than 90 kV lines) in Various Patterns

Unit: MW

Year	A-1	A-2	B-1	B-2
1985 – P	23.3	18.8	–	–
1985 – N	23.2	12.3	–	–
1986 – P	30.0	26.7	–	–
1986 – N	26.2	18.3	–	–
1988 – P	62.3	57.2	73.7	80.2
1988 – N	35.0	18.5	40.1	22.1

As seen in Table 8-2, in 1988 there will be more transmission losses both during peak and midnight hours for the Pattern B rather than Pattern A, and for Pattern 1 rather than Pattern 2. As a conclusion, A-2 is the best, followed by A-1.

8.3.2 Voltage Regulation

Voltage regulation consists of the problem of how to balance the reactive power produced at transmission lines or supplied by generators with the reactive power consumed at transmission lines and transformers and the problem of what transformer taps should be selected at power stations and substations to maintain suitable operating voltage of the power system and proper secondary-side voltages of substations.

(1) Voltage Regulation Plan

Voltage regulation was considered based on the conditions below.

- Target voltages of secondary sides of substations were made uniform 100% voltages (30-kV, 10-kV).
- Generators were considered to be operated at voltages of 95% to 103%. Reactive power supplied by generators was considered to be inside the range of rated power factor, and leading power factor operation in the middle of the night was avoided as much as possible.
- All transformers for power plants were considered to be provided with fixed taps of voltage regulation and also all transformers for substation having on-load tap changers were considered and regulation was done so that all substations would uniformly be in a range of ±10%.
- Reactive power supply equipment installed or planned at substations were considered to be utilized, and when these would be insufficient supply was considered to be made from reactive power supplied by generators, and when still insufficient, new static power condenser or shunt capacitors were considered to be added where necessary.
- Reactive power consumed during pump-up of water at Kasseb Power Station was considered to be generated by the pump-up motors themselves if necessary. In this case, making the power factor too low is undesirable from the standpoint of capacity, and hence price, of the generator-motor, and leading power factor during motor operation was taken to be 98%. Through this, reactive power of approximately 30-MVar can be expected during pump-up with 75-MW x 2 units so that reactive power to be consumed at the transformers of Kasseb Power Station and related transmission lines of Kasseb Power Station can be more than compensated.

(2) Results of Voltage Regulation

The value of reactive power in each year and for each pattern is indicated in Table 8-3 and the reactive power to be required by power stations and substations is indicated in Table 8-4.

Table 8-3 Balance of Reactive Power

Pattern	Demand (consumption)	Lines & Transformers (consumption)	Generators (generation)	Existing & projected R.P. equipment by STEG (generation)	Additional R.P. equipment recommended by JICA (generation)
A-5-1-P	343.25	71.03	330.1	46	38.1
A-5-1-N	181.8	53.57	217.8	18	0
A-5-2-P	343.25	57.02	308.5	46	44.9
A-5-2-N	181.8	−40.65	142.3	0	0
A-6-1-P	379.8	138.8	390.9	55.6	71.8
A-6-1-N	210.4	61.64	232	37.6	0
A-6-2-P	379.8	133.95	408	55.6	49.9
A-6-2-N	210.4	−23.44	145.8	36.4	0
A-8-1-P	473.6	339.17	386.02	55.6	371.1
A-8-1-N	246	68.28	267.8	46	0
A-8-2-P	473.6	318.64	421.2	55.6	315.4
A-8-2-N	246	−23.0	195.9	26.4	0
B-8-1-P	473.6	413.81	426.55	55.6	405.3
B-8-1-N	246	111.48	286.9	46	24.2
B-8-2-P	473.6	455.07	469.4	55.6	403.1
B-8-2-N	246	18.89	237.5	26.4	0

Note R.P. : Reactive Power

From the reactive power balances of Table 8-3 as conclusions, the following may be said:

- The reactive power consumed at transmission lines and transformers is roughly proportional to the square of the value of power flow, and in a comparison between concentrated pattern (Pattern 1) and dispersed pattern (Pattern 2) for 150-MW steam units for each year, the latter requires less reactive power supply equipment. This trend is conspicuous in the middle of the night and in a comparison of "A-8-1-N" and "A-8-2-N", for example, the requirements are 68.3 MVar and −23.0 MVar, the ratios to requirements for peak hours being approximately 20% and −7.2% for a difference of as much as 27%. (The minus sign signifies that transmission lines are capacitive.)
- Additional reactive power supply equipment required are fewer for Pattern A than Pattern B and the difference is

  approximately 10% between "A-8-1-P" and "B-8-1-P"

  approximately 28% between "A-8-2-P" and "B-8-2-P"
- Shunt reactors are unnecessary for the period under study. STEG has planned installation of a shunt reactor of 20-MVar at Ouestlatia Substation, but the necessity for this was not recognized in the present study.
- It was considered that the reactive power consumed during pump-up operation at

Table 8-4 Reactive Power Supply Facilities Required by Electrical Stations

Unit: MVar

Power Station or substation	A-1-P			A-2-P			B-8-1-P	B-8-2-P
	1985	1986	1988	1985	1986	1988	1988	1988
La Goulette P.S	–	–	–	–	–	–	–	–
Tunis-Sud S.S.	8.4	8.4	8.4 (38.2)	8.4	8.4	8.4 (15.1)	8.4 (54.5)	8.4 (82.3)
Tunis-Ouest S.S.	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Tunis-Nord S.S.	–	–	(20.5)	–	–	–	(35.2)	–
Menzel-Bourguiba S.S.	9.6 (38.1)	9.6 (56.3)	9.6 (91)	9.6 (44.9)	9.6 (43.9)	9.6 (79.1)	9.6 (95.4)	9.6 (90.2)
Zarga S.S.	–	–	–	–	–	–	–	–
Jendouba S.S.	–	–	–	–	–	–	–	–
Tajerouine S.S.	–	–	–	–	–	–	–	–
Korba S.S.	–	–	–	–	–	–	–	–
M'saken S.S.	–	9.6	9.6 (96.6)	–	9.6	9.6 (98.9)	9.6 (99.4)	9.6 (120.5)
Sfax S.S.	–	(9.6)	(67.8)	–	–	(63.9)	(50.5)	(49)
Maknassy S.S.	–	–	–	–	–	–	–	–
Metlaoui S.S.	9.6	9.6 (5.9)	9.6 (57.0)	9.6	9.6 (6.0)	9.6 (58.4)	9.6 (70.3)	9.6 (74.5)
Kasserine S.S.	10	10	10	10	10	10	10	10
Ghannouchi P.S.	–	–	–	–	–	–	–	–
Robbana S.S.	–	–	–	–	–	–	–	–
Bouchemma P.S.	–	–	–	–	–	–	–	–
Total	46.0 (38.1)	55.6 (71.8)	55.6 (371.1)	46.0 (44.9)	55.6 (49.9)	55.6 (315.4)	55.6 (405.3)	9.6 (416.5)

Note: Figures in parenthesis indicate the value of reactive power capacity to be added.

Kasseb Power Station would be generated by the motor themselves, but in "A-8-2-N", ample voltage is maintained even at power factor of 100%, and as long as this pattern is adopted it is considered unnecessary for Kasseb Power Station to generate reactive power, but regarding voltage in the future (1988 and after) when 3 units and 4 units are pumping up water simultaneously, further detailed examinations will be necessary.

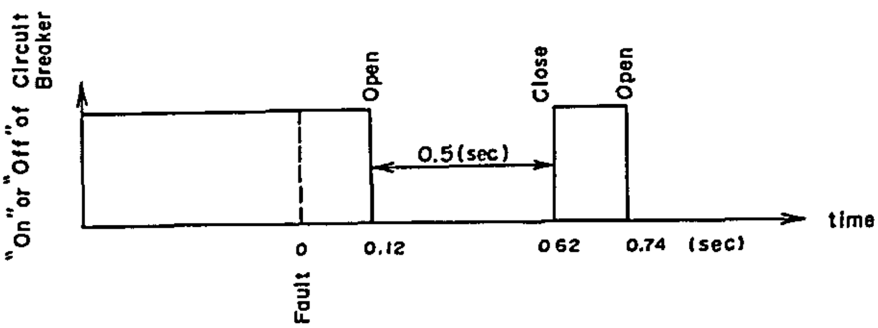
- As a conclusion, the most desirable pattern in voltage regulation is A-2 in which the requirements for additional reactive power supply equipment are least, while the next desirable pattern is A-1.

8.4 TRANSIENT STABILITY

8.4.1 Conditions for Calculation

As calculation conditions, 3-phase line-to-ground fault which is the severest in case of a single-circuit fault was assumed, and examinations were made for cases of success in high-speed 3-phase reclosing (O-C) and failure (O-C-O).

The time sequence is as shown in the diagram below.



The breaking time of circuit breaker is taken at 0.12 sec.including operating time of the protective relays, and 0.5 sec non-voltage interuption time of transmission line, which are standard values for 220-kV transmission line system in Japan.

Transmission line faults which occur most frequently are single-phase line-to-ground faults, and if transient stability is stable with 3-phase line-to-ground fault, it may be considered to be on the more stable with single-phase reclosing (or 3-phase reclosing) in single-phase line-to-ground fault.

Three-phase reclosing at a single-circuit transmission line is possible under the condition that there is a loop circuit in parallel, and this should be done with the purpose of increasing supply reliability also.

Further, examination of transient stability was made only for the year of 1988 when 2nd stage of Kasseb Project will be completed, because the trunk system of STEG which will be adequate without strengthening 225-kV transmission line from 1985 to 1988 and will maintain the same form, and maximum power flow can be assumed in 1988.

8.4.2 Receiving Substations

The results of comparison of Pattern A (one circuit each connected to M'Nihla Substation and Tajerouine Substation) and Pattern B (two circuits connected to M'Nihla Substation) show swing curves to be clearly different. In effect, the result of comparison of "A-8-1-P" and "B-8-1-P" shows step-out at Kasseb Power Station with Pattern B when there is faulting O-C-O between Kasseb Power Station and M'Nihla Substation and there is instability.

However, Pattern B will not be rejected by reason of that in this case Kasseb Power Station will be operating at full capacity (350 MW) and there will be no problem if reclosing is successful and instability only when unsuccessful, and the probability for this to occur is thought to be fairly low. In any event, it was judged that the pattern with the least problems insofar as practicable should be selected and it was decided that Pattern A should be recommended.

Although "B-8-1-P" is instable, "B-8-2-P" (dispersed pattern) is barely stable, and this is considered to be the limit (See Item A-3 Charts No. 3, No. 4)

In any event, Pattern B is inferior compared with Pattern A, in comparison of the stability.

Although the Mission has not made a study in further detail, it will be necessary for more examination to be made of the critical value of Case B-8-1-P (how much the capacity of Kasseb Power Station should be reduced for stability).

When succeeding in reclosing in cases of faults at the same transmission lines, there are stability in both cases as shown below.

	O-C-O	O-C
A-8-1-P	Kasseb : 18.6°	Kasseb : 16.6°
B-8-1-P	Kasseb : Step-out	Kasseb : 35.5°

The above angles indicate the maximum deviations of phase differential angles and there is more stability the smaller the angle. In general, although depending on the length of non-voltage interruption time of transmission line, O-C is more stable than O-C-O.

8.4.3 Difference between Concentrated and Dispersed Patterns of 150 MW Steam Units

There is practically no difference in transient stability between Pattern 1 (concentrated 150 MW steam units) and Pattern 2 (dispersed 150 MW steam units).

When discussing these, it is better to carry out studies separated into Pattern A and Pattern B. However, the differences are extremely small in any event.

With Pattern A, both concentrated and dispersed patterns are almost the same, with the difference that the concentrated pattern has several degrees in phase differential angle with the dispersed pattern. The table below indicates the phase differential angles at Kasseb Power Station (see Item A-2 Charts No. 5 – No.22)

Table 8-5 Phase Differential Angles at Kasseb Power Station (Pattern A)

Time	Fault Line	Reclose	A-1	A-2
Peak	Kasseb ~ M'Nihla	O – C	16.6°	20°
	"	O – C – O	18.6°	20°
	Kasseb ~ Tajerouine	O – C	26.2°	28.3°
	"	O – C – O	26.2°	30.1°
Night	Kasseb ~ M'Nihla	O – C – O	21.0°	22.6°
	Kasseb ~ Tajerouine	O – C –.O	21.7°	24.8°

However, with Pattern B, there is a distinct difference noticeable between the concentrated and dispersed patterns and the dispersed patterns are superior. The table below indicates the phase differential angles at Kasseb Power Station. (see Item A-2 Charts No. 3, No. 4).

Table 8-6 Phase Differential Angles at Kasseb Power Station (Pattern B)

Time	Fault line	Reclose	B-1	B-2
Peak	Kasseb ~ M'Nihla	O – C	35.6°	37.7°
"	"	O – C – O	step-out	54.9°
Night	"	O – C – O	35.4°	32.4°

8.4.4 Stabilities of 150-MW Steam Units Thermal Power Stations

In the preceding Items 8.4.2 and Items 8.4.3, the stability of Kasseb Power Station was mainly considered, but if a transmission line fault were to occur in the vicinity of 150-MW units steam power station in the middle of the night, whether these units will be stable is a matter which is even more important than that of Kasseb Power Station. The result of examination was that of stability as shown in the table below, and there will be no problem (see Item A-2 Charts No. 17 – No. 20).

Table 8-7 Phase Differential Angles at 150MW Units Steam Thermal Power Station
(In case line fault occured in vicinity of the power station at the midnight)

Fault Line	Recole	A-1	A-2	B-1	B-2
Sousse ~ Nassen	O – C – O	Sousse : 19.6°	–	Sousse : 20.4°	–
X, Y ~ M'Nihla	O – C – O	–	X, Y: 22.0°	–	X, Y: 17.7°

Similarly, in cases of transmission line faults near 150-MW units at peak hours, the results are as shown in the table below and there will be no problem (see Item A-2 Charts No. 21, No. 22).

Table 8-8 Phase Differential Angles at 150MW Units Steam Thermal Power Station
(In case line fault occure in vicinity of the power station at the peak time for power demand)

Fault Line	Reclose	A-2	B-2
X, Y ~ M'Nihla	O – C	X, Y: 17.0°	X, Y: 17.8°
X, Y ~ M'Nihla	O – C – O	X, Y: 19.4°	X, Y: 19.0°

8.4.5 Conclusions

The conclusions of the transient stability of STEG power system, according to the comparisons for the year, 1988, are the following:

– Of the Patterns A and B (methods of connecting transmission lines to Kasseb Power

Station), Pattern A (one circuit each to M'Nihla Substation and Tajerouine Substation) is better.

- For Patterns 1 and 2 (150-MW steam thermal units, concentrated or dispersed), there is almost no difference between A-1 and A-2. Of B-1 and B-2, B-2 (dispersed form) is better.
- 150-MW steam units at a transmission line fault in its vicinity will be stable in the middle of the night and at peak hours in case O-C-O.
- As the conclusion of the study on transient stability, it may be said that A-2 is the most desirable.

Typical examples of transient stability calculations are indicated in Table 8-9. For the swing curves, the appended charts should be referred to Item A-2.

[Machine Constants Used for Stability Calculations]

The unit inertia constants and transient reactance xd' used for the motor-generator units of Kasseb Power Station were those of Numappara Power Station which is a representative pumped storage power station in Japan. The principal machine constants are indicated below.

Unit capacity	250 MVA
Power factor	95% (100% during pump-up)
Frequency	50 Hz
Speed	375 rpm
Output	225 MW (250 MW during pump-up)
GD^2	7025 t-m^2
Unit inertia constant	10.8
x_d	126.6%
x_d'	29.2%

For 150-MW thermal units, the following constants were determined.

Unit capacity	179 MVA
Power factor	90%
Frequency	50 Hz
Speed	3000 rpm
Output	161 MW
Unit inertia constant	8[1/]
x_d'	15.0%[1/]

Note[1/] : Standard values of Institute of Electrical Engineers of Japan.

8.5 SHORT-CIRCUITING POWER

The 3-phase short-circuiting powers were calculated based on the conditions below. A map of the short-circuiting power distribution is given in Fig. A-3-19.

Calculation Conditions

- Time: 1988, at completion of 4 units of Kasseb Power Station
- Transmission lines: Two circuits to M'Nihla Substation and one circuit to Tajerouine Substation set so that either Pattern A or B can be taken considering

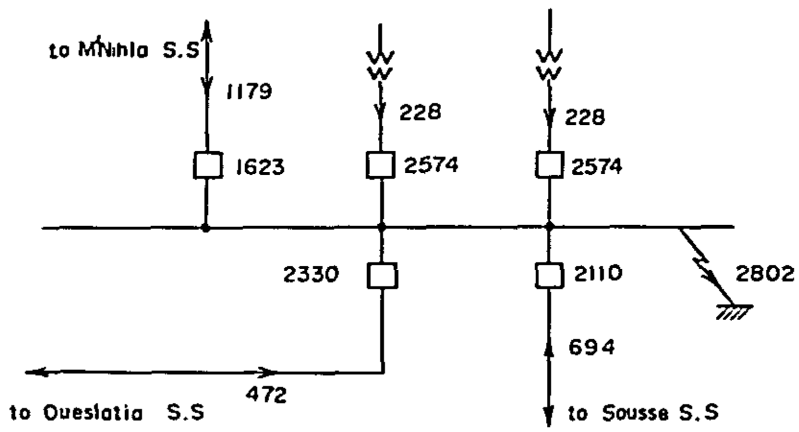
calculation results having some margin of short circuit capacity required

- Locating of 150-MW steam units: In order that it would be permissible to take either the concentrated or dispersed form, 4 units at Sousse Thermal Power Station; and the 2 units X and Y were located at Tunis District simultaneously considering calculation results having some margin of short circuit capacity required.
- Generator reactance: x_d' used .

The results of calculations are given in the order of higher bus short-circuiting power.

Sousse P.S. 225-kV bus:	3763 MVA
M'Nihla S.S. 225-kV bus:	3076 MVA
X, Y P.S. 225-kV bus:	3103 MVA
Naassen S.S. 225-kV bus:	2802 MVA
Kasseb P.S. 225-kV bus:	2540 MVA
Ouestlatia S.S. 225-kV bus:	2086 MVA
Tunis-Sud S.S. 150-kV bus:	2069 MVA
M'Nihla S.S. 150-kV bus:	2008 MVA
Sousse P.S. 150-kV bus:	1999 MVA
Naassen S.S. 150-kV bus:	1853 MVA
M'Saken S.S. 150-kV bus:	1851 MVA

At Nassen Substation, the breaking capacity of a 225-kV circuit breaker being installed was 2,500-MVA, and in case of distribution of short-circuit capacity as indicated below, the short-circuit capacity of the circuit breaker for the transformer is 2,574-MVA and the numerals coincide for calculation result obtained.



Shortcircuit capacity at Naassen Substation.

This means that there is ample allowance in the short-circuit capacity calculated as described previously, and a 2,500-MVA breaking capacity is adequate for Naassen Substation.

With regard to Sousse, if installation up to four 150-MW steam thermal units is considered, the 225-kV circuit breaker will be too small, and it would be desirable for a breaker one rank higher of 3,500-MVA to be installed.

Table 8-9 Results of Transient Stability Study

No. of Swing Chart	Case	Period	Fault				Result			Judg-ment
			Fault Line	Fault Point	Kind of Fault	Reclosing Time (Sec)	Station	Maximum Phase Agnle (Degree)	Time (Sec)	
1, 7	A-8-1-P	Peak	M'Nihla-Kasseb	Kasseb	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb Ghannouch	18.6 15.6	0.4 0.4	Stable
2, 3	B-8-1-P	Peak	M'Nihla-Kasseb	Kasseb	1cct 3LG	0.12-0.62-0.74	Kasseb	Step out		Unstable
4	B-8-2-P	Peak	M'Nihla-Kasseb	Kasseb	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb Sousse-150kV	54.87 37.58	1.1 1.1	Stable
5	A-8-1-P	Peak	M'Nihla-Kasseb	Kasseb	1cct 3LG 0-C	0.12-0.62	Kasseb Sousse	16.6 14.1	0.4 0.9	Stable
6	A-8-2-P	Peak	M'Nihla-Kasseb	Kasseb	1cct 3LG 0-C	0.12-0.62	Kasseb Ghannouch	20 24.7	0.4 0.5	Stable
8	A-8-2-P	Peak	M'Nihla-Kasseb	Kasseb	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb Ghannouch	20 24.7	0.4 0.5	Stable
9	A-8-1-P	Peak	Tajerouine-Kasseb	Kasseb	1cct 3LG 0-C	0.12-0.62	Kasseb La Goulette-II	26.2 22.6	0.5 0.5	Stable
10	A-8-2-P	Peak	Tajerouine-Kasseb	Kasseb	1cct 3LG 0-C	0.12-0.62	Kasseb Sousse-150kV X, Y	28.32 34 25.82	0.5 2.2 0.5	Stable
11	A-8-1-P	Peak	Tajerouine-Kasseb	Kasseb	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb La Goulette-II Sousse-150kV	26.2 22.59 16.3	0.5 0.5 0.5	Stable
12	A-8-2-P	Peak	Tajerouine-Kasseb	Kasseb	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb La Goulitte-II Sousse-150kV X, Y	30.09 28.36 26.07 22.19	0.9 2.0 2.2 0.5	Stable
13	A-8-1-N	Midnight	M'Nihla-Kasseb	M'Nihla	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb	21.04	0.3	Stable
14	A-8-2-N	Midnight	M'Nihla-Kasseb	M'Nihla	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb	22.55	0.3	Stable

No. of Swing Chart	Case	Period	Fault				Result			Judg-ment
			Fault Line	Fault Point	Kin dof Fault	Reclosing Time (Sec)	Station	Maximum Phase Angle (Degree)	Time (Sec)	
15	A-8-1N	Midnight	Tajerouine-Kasseb	Tajerouine	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb	21.74	0.4	Stable
16	A-8-2-N	Midnight	Tajerouine-Kasseb	Tajerouine	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb X, Y	24.77 11.59	0.4 0.5	Stable
17	A-8-1-N	Midnight	Sousse-Naassen	Sousse	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb Sousse-225kV Sousse-150kV	38.82 19.59 13.58	0.4 0.4 0.5	Stable
18	B-8-1-N	Midnight	Sousse-Naassen	Sousse	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb Sousse-225kV	46.66 20.43	0.4 0.4	Stable
19	A-8-2-N	Midnight	M'Nihla-X, Y	X, Y	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb X, Y	24.92 21.95	1.0 0.9	Stable
20	B-8-2-N	Midnight	M'Nihla-X, Y	X, Y	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb X, Y	24.62 17.66	0.3 0.9	Stable
21	A-8-2-P	Peak	M'Nihla-X, Y	X, Y	1cct 3LG 0-C-0	0.12-0.62-0.74	X, Y	19.43	0.9	Stable
22	B-8-2-P	Peak	M'Nihla-X, Y	X, Y	1cct 3LG 0-C-0	0.12-0.62-0.74	X, Y Sousse-150kV Goulette-II	19 12.67 17.13	1.0 1.0 1.0	. Stable
	A-8-2-P	Peak	M'Nihla-X, Y	X, Y	1cct 3LG 0-C	0.12-0.62	X, Y	17.0	0.3	Stable
	B-8-1-P	Peak	M'Nihla-Kasseb	Kasseb	1cct 3LG 0-C 0-C-0	0.12-0.62	Kasseb Sousse-150kV Ghannouch	35.57 23 23	0.5 0.6 0.6	Stable
	B-8-2-P	Peak	M'Nihla-X, Y	X, Y	1cct 3LG 0-C	0.12-0.62	X, Y	17.79	0.3	Stable
	B-8-2-P	Peak	M'Nihla-Kasseb	Kasseb	1cct 3LG 0-C	0.12-0.62	Kasseb Ghannouch	37.74 28	0.5 0.6	Stable
	B-8-1-N	Midnight	M'Nihla-Kasseb	M'Nihla	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb	35.36	0.4	Stable

CHAPTER 9

ITEMS TO BE REQUIRED FOR INVESTIGATIONS HEREAFTER FOR REALIZATION OF KASSEB PUMPED STORAGE POWER PROJECT

No. of Swing Chart	Case	Period	Fault				Result			Judg-ment
			Fault Line	Fault Point	Kin dof Fault	Reclosing Time (Sec)	Station	Maximum Phase Angle (Degree)	Time (Sec)	
15	A-8-1N	Midnight	Tajerouine-Kasseb	Tajerouine	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb	21.74	0.4	Stable
16	A-8-2-N	Midnight	Tajerouine-Kasseb	Tajerouine	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb X, Y	24.77 11.59	0.4 0.5	Stable
17	A-8-1-N	Midnight	Sousse-Naassen	Sousse	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb Sousse-225kV Sousse-150kV	38.82 19.59 13.58	0.4 0.4 0.5	Stable
18	B-8-1-N	Midnight	Sousse-Naassen	Sousse	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb Sousse-225kV	46.66 20.43	0.4 0.4	Stable
19	A-8-2-N	Midnight	M'Nihla-X, Y	X, Y	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb X, Y	24.92 21.95	1.0 0.9	Stable
20	B-8-2-N	Midnight	M'Nihla-X, Y	X, Y	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb X, Y	24.62 17.66	0.3 0.9	Stable
21	A-8-2-P	Peak	M'Nihla-X, Y	X, Y	1cct 3LG 0-C-0	0.12-0.62-0.74	X, Y	19.43	0.9	Stable
22	B-8-2-P	Peak	M'Nihla-X, Y	X, Y	1cct 3LG 0-C-0	0.12-0.62-0.74	X, Y Sousse-150kV Goulette-II	19 12.67 17.13	1.0 1.0 1.0	. Stable
	A-8-2-P	Peak	M'Nihla-X, Y	X, Y	1cct 3LG 0-C	0.12-0.62	X, Y	17.0	0.3	Stable
	B-8-1-P	Peak	M'Nihla-Kasseb	Kasseb	1cct 3LG 0-C 0-C-0	0.12-0.62	Kasseb Sousse-150kV Ghannouch	35.57 23 23	0.5 0.6 0.6	Stable
	B-8-2-P	Peak	M'Nihla-X, Y	X, Y	1cct 3LG 0-C	0.12-0.62	X, Y	17.79	0.3	Stable
	B-8-2-P	Peak	M'Nihla-Kasseb	Kasseb	1cct 3LG 0-C	0.12-0.62	Kasseb Ghannouch	37.74 28	0.5 0.6	Stable
	B-8-1-N	Midnight	M'Nihla-Kasseb	M'Nihla	1cct 3LG 0-C-0	0.12-0.62-0.74	Kasseb	35.36	0.4	Stable

CHAPTER 9

ITEMS TO BE REQUIRED FOR INVESTIGATIONS HEREAFTER FOR REALIZATION OF KASSEB PUMPED STORAGE POWER PROJECT

CHAPTER 9

ITEMS TO BE REQUIRED FOR INVESTIGATIONS HEREAFTER FOR REALIZATION OF KASSEB PUMPED STORAGE POWER PROJECT

The purpose of this long-range electric power plan was to establish an outlook from technical, economic and overall standpoints on whether the Kasseb Pumped Storage Power Generation Project would be feasible in future power generation plans. The result, as described previously, was the conclusion that the Kasseb Project is economically superior compared with gas turbines which would be the alternative power generating facilities. However, the present survey results were not obtained upon detailed field reconnaissances, and moreover, have not been based on a sufficient amount of information. Consequently, the investigations cited below should be carried out to improve the accuracy of the economics of the Kasseb Pumped Storage Power Generation Project and to verify the feasibility by carrying out a financial analysis.

9.1 INVESTIGATIONS TO BE MADE BY STEG PRIOR TO COMMENCING FEASIBILITY STUDY

The feasibility study for the Kasseb Pumped Storage Power Generation Project, must be carried out by the beginning of 1978, but it is desirable for the items below to be investigated by STEG by the end of 1977.

(1) Preparation of 1/2,000-scale topographic maps of the upper reservoir damsite, intake site and power station site (JICA Proposal and TECSULT Proposal Etude 2A, Variante 1). It is acceptable for mapping to be done from existing aerophotographs.
(2) Consolidation of geological data on the upper reservoir dam axis (including studies on necessity for additional boring).
(3) Consolidation of data on inflow to the lower reservoir (existing Kasseb Reservoir).
(4) Consolidation of unit construction cost data.
(5) Examinations and establishment of parameters for socio-economic evaluation.

9.2 INVESTIGATIONS ITEMS REQUIRING SPECIAL ATTENTION IN THE FEASIBILITY STUDY

The investigation items requiring special attention in connection with the results of the present survey are the following:

(1) There will be a great difference produced in the construction cost for the Kasseb Pumped Storage Power Generation Project depending on whether the power-house is constructed a semi-outdoor or underground type. One condition for a semi-outdoor type to be adopted is that it must be possible for the minimum water level of the lower reservoir to be made EL 280.00 m. In effect, the condition is whether it will be possible to operate the lower reservoir throughout the future while securing 1.20 m^3/sec. for portable water supply between high water level at EL 290.00 m and minimum water level at EL 280.00 m. The possibility of this can be examined by analyzing past inflow data.
(2) The fuel for gas turbines which would be the alternative thermal power generation facilities governing the feasibility of the Kasseb Pumped Storage Power Station is offshore natural gas. This natural gas will be used also as fuel for the base thermal

power station of a 150-MW unit in case of receiving power for pump-up at Kasseb Pumped Storage Power Station from the electric power system. Adequate discus sions must be made based on the economic justification method used for fuel in this Report to establish the economic nature of the Kasseb Pumped Storage Power Generation Project in the feasibility study.

(3) Selection of the powerhouse site will affect the length of the headrace tunnel, and therefore influence the civil works construction cost. The results of the preliminary design in this Report, compared with the TECSULT Proposal (Etude 2A), shows the length of waterway structures from intake to end of tailrace to be approximately 450 m longer. The design of the waterway system (headrace tunnel, penstock line and tailrace tunnel) and determination of the powerhouse location must be made in the feasibility study taking the geological conditions into consideration.

APPENDIX

A — I

NATURAL GAS DEVEROPMENT PLAN OFFSHORE OF GABES BAY AND UNIT COST OF NATURAL GAS

A-1

NATURAL GAS DEVELOPMENT PLAN OFFSHORE OF GABES BAY AND UNIT COST OF NATURAL GAS

For realization of the Kasseb Pumped Storage Development Project, it is necessary to know with a certain degree of accuracy the cost of offshore gas which has a close relation with the fuel cost of the 150-MW thermal unit which will be the power source for pump-up. The reason for this is that the economic comparison of Chapter 7 is predicated on the cost of the offshore gas being equal to the natural gas price on the international market. In effect, if the cost of offshore gas were to be higher than the international price, the fuel cost of the 150-MW thermal power station which would be the pump-up power source would decrease the economic benefit of the kasseb Pumped Storage Power Generation Project, while if the fuel cost were to be lower than the international price, the economic benefit would be increased.

The outline of the offshore gas development project given in the Fifth Five-Year Plan (1978–1981) is as indicated below.

a) Construction Cost

Development at site of reserves (Miskar):	88.0×10^6 Dinars
Underwater pipeline construction:	44.0×10^6 Dinars
Processing and gasoline recovery plant at 1 location:	38.0×10^6 Dinars
Overland pipeline construction:	65.0×10^6 Dinars
Total	235.0×10^6 Dinars
	(US$546.5 $\times 10^6$)

b) Offshore Gas Reserves
The reserves of natural gas at Miskar 140 km offshore in Gabes Bay are estimated to be 50 billion to 80 billion m^3.

c) Planned Natural Gas Recovery
With the investment described in a) above, it will be possible for 3 billion m^3 of natural gas to be transported annually. However, the production in the initial year, 1981 is estimated to be 1.5 billion m^3.

d) Purpose of Use of Natural Gas
It will be required for the precious natural gas developed, instead of being used simply as a primary energy source as in the past, to be used for developing a gas chemical industry to revolutionize the Tunisian economy.

The route and diameter of the natural gas pipeline to be laid is indicated in Fig. A-1.

The Tunisian Government has cited offshore gas development as one of the principal projects of the Five-Year Development Plan and at present is actively negotiating with the World Bank for a loan.

The reserves of natural gas as a result of later investigations have been said to be between 80 billion and 150 billion m^3 of which the recoverable quantity is said to be 80 billion m^3. Meanwhile, the total construction cost including the pipeline, the offshore platform in Gabes Bay and petroleum extraction facilities is expected to rise from US$546.5 $\times 10^6$ in the Fifth Five-Year Plan to US$750 $\times 10^6$.

Taking the present situation as described above into consideration, the Survey Mission has calculated the cost of offshore gas based on the conditions below.

(i) Conditions Assumed

a) Total construction cost:	US$750 $\times 10^6$
b) Service life:	20 years (determined generally by

mechanical apparatus on platform)

c) Maintenance, operation and repair cost including administrative costs: 1.23% of total construction cost

d) Capital cost (interest and depreciation)
Interest, case of 7%/annum: US$70.8 x 10^6/year
Interest, case of 10%/annum: US$88.1 x 10^6/year

(ii) Annual Expense

Unit: US$$10^6$

	i = 7%	i = 10%
a) Capital cost	70.8	88.1
b) Maintenance, operation and repair cost	9.2	9.2
Total	80.0	97.3

(iii) Cost of Natural Gas

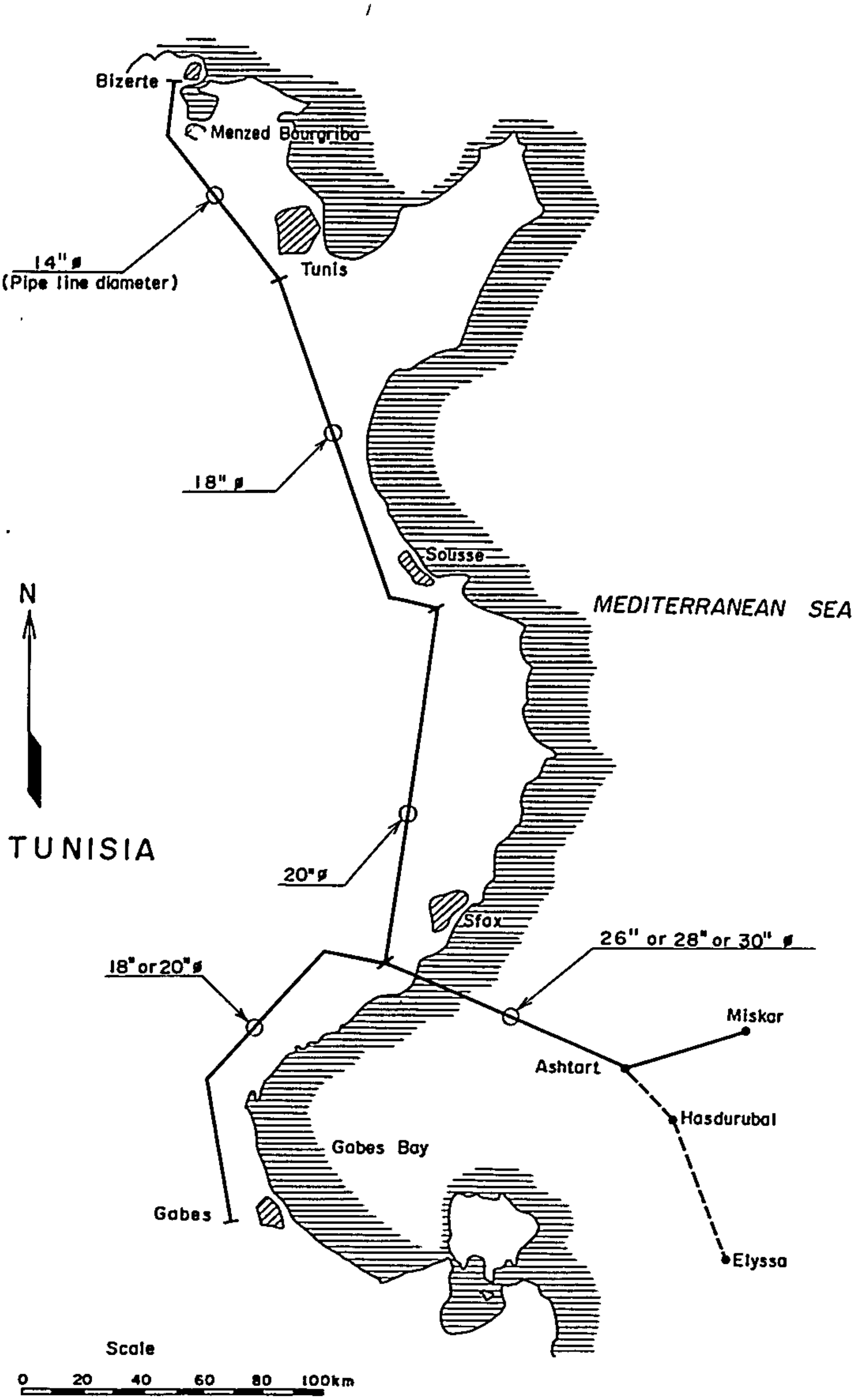
Recovery quantity (10^6 Nm^3)	Case of 1,500	Case of 3,000
Natural gas cost (US$/$10^3$ Nm^3)		
i = 7%	53.3	26.7
i = 10%	64.9	32.4
Ratio with international price of natural gas (%)		
i = 7%	65.5	32.8
i = 10%	79.7	39.8

Note 1/: International price of natural gas, US$75.6.
2/: Approximately 1,000 x 10^6 Nm^3 is consumed in case of operation of 150 MW x 3 units at 100% annual load factor.

The cost of offshore gas to be supplied to Sousse Thermal Power Station is estimated to be between 10 Dinars/$10^3$$Nm^3$ (US$23.3/$10^3$$Nm^3$) and 20 Dinars/$10^3$$Nm^3$ (US$46.4/$10^3$$Nm^3$) in the Five-Year Development Plan for the STEG Electric Power System, and as described above, the cost of natural gas varies depending on the rate of utilization of the natural gas pipeline. In effect, when it is possible to consume 3 billion m^3 of natural gas, the cost will be 13.9 Dinars/$10^3$$Nm^3$ (US$32.4/$10^3$$Nm^3$) in case of annual interest of 10% on borrowings, while in case of 1.5 billion m^3 which is the demand expected for the initial year, the cost will be 27.9 Dinars/$10^3$$Nm^3$ (US$64.9/$10^3$$Nm^3$), and these are respectively 42.9% and 85.8% of the international price of natural gas.

(The calorific value of 10^3 Nm^3 of natural gas is roughly equal to the calorific value of 1 ton of C heavy oil.)

Fig. A-1 Pipe Line for Natural Gas (Off Shore)



A—2

ANALYSIS ITEMS AND ANALYSIS RESULTS OF LOWER RESERVOIR STORAGE WATER USED IN KASSEB PUMPED STORAGE POWER PROJECT

A-2
ANALYSIS ITEMS AND ANALYSIS RESULTS OF LOWER RESERVOIR STORAGE WATER USED IN KASSEB PUMPED STORAGE POWER PROJECT

The water stored at the existing Kasseb Dam is presently being supplied to Tunis as portable water at a maximum rate of 1.20 m^3/sec. In the Kasseb Pumped Storage Power Project this water is to be pumped up to an upper reservoir located at the left bank of the reservoir and dropped to the lower reservoir for power generation. The stored water will be utilized in cycles of pump-up, power generation, pump-up, power generation, but when foreign matter (salts, quartz sand, etc.) is contained in the water, machinery with which the water comes in contact will be subjected to unforeseen damage. The Mission obtained approximately 1 liter of the stored water (from the existing Kasseb Dam for the lower reservoir) at the time of field investigations and brought the sample back to Japan for analysis. The results are as shown in Table A-2-1 below and it was found that special measures in design and manufacture of pump-turbines will be unnecessary.

Table A-2-1 Analysis Results of Lower Reservoir Storage Water

Analysis items	Method of analysis	Quantity required for analysis (mililiter)	Results of analysis	Standard of potable water	
				Regulation in Japan	WHO
Chlorine ion		10	40.0 PPM	<200 PPM	<200 PPM
Cyanogen		200	Not detected	No detection	
Mercury		100	Not detected	No detection	
Cupper		200	Not detected	<1.0 PPM	<1.0 PPM
Iron		200	<0.1 PPM	<0.3 PPM	<0.3 PPM
Fluorine		50	Not detected	<0.8 PPM	
Plumbum		200	Not detected	<0.1 PPM	
Zinc		200	Not detected	<1.0 PPM	<5.0 PPM
Chrome		100	Not detected	Cr^{+6} <0.05PPM	
Arsenic		100	Not detected	<0.05 PPM	
Manganese		200	Not detected	<0.3 PPM	<0.1 PPM
Mineral	EDTA	50	177 PPM		
Calcium	EDTA	50	128 PPM		
Magnesium	EDTA	50	49 PPM		
PH	PH meter	–	7.15		7.0 to 8.5
Conductivity	Conductivity meter	–	390 μ℧/cm		
SS		1,040	8.2 PPM		
COD		50	1.4 PPM		
Cadmium		200	Not detected		

Analysis performed

Place : Isogo Thermal Power Station, EPDC, Japan.

Date : April, 1977.

A—3

RATING AND CHARACTERISTICS
OF ELECTORIC POWER
FACILITIES IN STEG POWER SYSTEM

Appendix A-3-(1)

Rating and Characteristics of Generators and Transformers

Station	Generator						Transformer				
	No. of Unit	Capacity of Unit (MVA)	Out put of Unit (MW)	Power Factor	Xd' Machine Base (%)	M (sec)	Capacity of Transf. (MVA)	Transf. Voltage (KV)	Xt Reactance of Transformer Machine Base (%)	Station Capacity (MW)	
Existing											
La Goulette-II	2	34.375	27.5	0.8	18	8.07	64	99/12.5	10	55	
Ghannouch	2	33.3	30	0.9	20.4	7.2	64	158/12.5	11.2	60	
Tunis-Sud	2	27	21.6	0.8	18.6	19.18	55.38	96.5/5.5	10.74	43.2	
Tunis-Sud	1	27.75	22	0.8	15.6	17.1	29.5	96/11	11.4	22	
Menzer Bourguiba	2	27.75	22	0.8	15.6	17.1	59	96/11	11.4	44	
Bouchemma	2	43.5	34.8	0.8	23.5	12	85	228/11	11	69.6	
Sfax	2	27.75	22	0.8	15.6	17.1	59	158/11	11.8	44	
Korba	1	27.75	22	0.8	15.6	17.1	29.5	96/11	11.4	22	
Metlaoui	1	27.75	22	0.8	15.6	17.1	29.5	158/11	11.8	22	
Side Salem	1	40	36	0.9	37	7	40	90/11	10	36	
Fernana	1	10.9	9.08	0.8	25.1	5.32	12.3	93/5.5	9.26	9.08	
Nebeur	2	8.25	6.6	0.8	37~30	4.84~5.0	16.5	92/5.5	9.7	6.6	
Projected											
Kasseb	2	83.3	75	0.9	29.2	10.8	168	225/16.5	11	150	350
Kasseb	2	111	100	0.9	29.2	10.8	222	225/16.5	11	200	
X, Y	2	179	161	0.9	16	8	400	225/12.5	14	322	
Sousse	1	179	161	0.9	16	8	200	158/12.5	12	161	
Sousse	3	179	161	0.9	16	8	600	225/12.5	14	483	

Characteristics of 225 kV Transmission Line

A-3-(2)

Conductors: ACSR
225 kV, 1000 MVA Base

Line	L (km)	S (mm²)	R (%)	X (%)	Y/2 (%)
Bouchemma - Oueslatia[1]	226	411	39.28	186.13	1.487
Oueslatia - Tajerouine[1]	100	411	17.38	83.36	0.658
Naassen - M'Nihla[1]	40	411	6.95	32.94	0.263
Oueslatia - Naassen[1]	112	411	19.47	93.24	0.737
Naassen - La Goulette[1]	17	2 x 411	1.50	11.75	0.119
La Goulette - M'Nihla[1]	25	2 x 411	2.21	17.28	0.175
Kasseb - Tajerouine[1]	110	411	19.12	90.6	0.724
Kasseb - M'Nihla[1]	110	411	19.12	90.6	0.724
Ghannouch - Sfax[1]	130	411	22.59	107.07	0.856
M'Nihla - M. Bourguiba[1]	53	411	9.21	43.65	0.349
Naassen - M'Nihla[1]	40	2 x 411	3.532	27.64	0.279
Naassen - M'Nihla (par Goulette)[1]	42	2 x 411	3.709	29.02	0.293
Sousse - Oueslatia[1]	105	411	18.25	86.48	0.691
Sousse - Naassen[1]	112	411	19.47	92.24	0.737
Tajerouine - El Aouinet[1]	60	411	10.43	49.42	0.395
X, Y - M'Nihla (1)[2]	20	411	1.766	13.82	0.1397
X, Y - M'Nihla (2)[2]	20	411	1.766	13.82	0.1397

Note 1/: Transmission lines projected by STEG.
2/: Transmission lines estimated by JICA.

Characteristics of 150 kV Transmission Line

A-3-(3)

Conductor: ACSR
150 kV, 1000 MVA Base

Line	L (km)	S (mm²)	R (%)	X (%)	Y/2 (%)
La Goulette - M'saken	129	297	83.59	234.83	0.406
M'saken - Sfax	102.5	297	64.42	186.59	0.323
Sfax - Maknassy	104	297	67.39	189.32	0.328
Maknassy - Metlaoui	116	297	75.17	211.17	0.365
Metlaoui - Kasserine	106	297	68.69	192.96	0.334
Kasserine - Tajerouine	83.5	297	54.11	152.0	0.263
Ghannouch - Robbana	102	297	66.1	185.68	0.321
Maknassy - Ghannouch (1)	100	297	64.8	182.04	0.315
Maknassy - Ghannouch (2)	93	411	36.32	172.14	0.272
M'saken - Akouda[1]	26	297	16.85	47.33	0.0819
Akouda - Hammamet[1]	99	297	64.15	180.22	0.312
La Goulette - Hammamet[1]	83	297	53.78	151.09	0.261
Sfax - Ghannouch[1]	130	411	50.76	240.63	0.380
Naassen - Hammamet[1]	70	297	45.36	127.43	0.221
Sousse - M'saken[1]	14	411	5.47	25.914	0.041
Sousse - Akouda[1]	14	411	5.47	25.914	0.041
Bouchemma - Ghannouch[1]	3.5	265	2.31	6.393	0.011
Ghannouch - Cimenterie de Gabes[1]	10	297	6.48	18.2	0.0315

Note 1/: Transmission lines projected by STEG.

Characteristics of 90 kV Transmission Line

A-3-(4)

Conductor: ACSR
90 kV, 1000 MVA Base

Line	L (km)	S (mm^2)	R (%)	X (%)	Y/2 (%)
Tajerouine - El Aouinet	60	288	109.56	303.54	0.0792
Tajerouine - Nebeur	59	288	107.73	298.48	0.0779
Nebeur - Dendouba	21	288	38.35	106.24	0.0277
Dendouba - Fernana	27	288	49.30	136.59	0.0356
Fernana - El Haddar	93	288	169.82	470.49	0.1228
Fernana - Tunis-Sud	143	288	261.12	723.44	0.1888
Tunis Sud - Tunis-Ouest	10	288	18.26	50.59	0.0132
La Goulette - Tunis Sud (1)	16	288	29.22	80.94	0.0211
La Goulette - Tunis Sud (2)	16	288	29.22	80.94	0.0211
La Goulette - Tunis-Ouest	27	288	49.30	136.59	0.0356
Tunis-Ouest - M. Bourguiba	58	181.6	129.4	286.29	0.0657
Tunis-Sud - Korba	65	176	154	320.8	0.074
Naassen - Tunis-Sud (1)[1/]	8	420	8.64	41.09	0.0084
Naassen - Tunis-Sud (2)[1/]	8	420	8.64	41.09	0.0084
M'Nihla - Tunis-Nord (1)[1/]	7	411	7.525	35.91	0.00735
M'Nihla - Tunis-Nord (2)[1/]	7	411	7.525	35.91	0.00735
La Goulette - Tunis-Nord[1/]	20	288	36.52	101.18	0.0264
Tunis-Nord - Tunis-Ouest[1/]	7	288	12.78	35.41	0.00924
Aroussia - M. Bourguiba[1/]	40	176	94.76	197.44	0.0453
Aroussia - Fernana[1/]	100	288	182.6	505.9	0.132
Aroussia - Tunis-Sud[1/]	43	288	78.52	217.54	0.0568
Sidi Salem - Aroussia[1/]	40	116.2	151.04	197.44	0.0453
Menzel Bourguiba - M'Nihla[1/]	53	181.6	118.24	261.61	0.0601
Naassen - Korba[1/]	58	176	137.40	286.29	0.0657
Sidi Salem - Oued Zarga[1/]	10	288	18.26	50.59	0.0132
Oued Zarga - Aroussia[1/]	40	288	73.04	202.36	0.0528
Oued Zarga - Fernana[1/]	60	288	109.56	303.54	0.0792
M'Nihla - Tunis Ouest[1/]	12	181.6	26.77	59.23	0.0136
M. Bourguiba - Cimenterie de Bizerte[1/]	22	288	40.17	112.3	0.029
Tajerouine - Cimenterie Algero-Tunisienne[1/]	8	288	14.61	40.47	0.01
M. Bourguiba - El Fouladh[1/]	2.5	288	4.57	12.65	0.0033

Note 1/: Transmission lines projected by STEG.

A-3-(5) Rating and Characteristics of 225 kV Transformer for Substation

Station	No. of Unit	Capacity of Trans. (MVA)	Transf. Voltage (KV)	Xt Reactance of Transf. Machine Base (%)	Station Capacity (MVA)	Reactive Power Supply Equipment S.C (Mvar) 10 KV	30 KV	R.C (Mvar)	Reactor (Mvar)
Nassen	2	100	225/90	14	200				
Tajerouine	1	100	225/150	14	100				
Tajerouine	1	50 1/	225/150	14	50				
Oueslatia	2	30	225/30	11	60				20 x 1
M'nihla	2	100	225/90	14	200				
M'nihla	1	100 1/	225/90	14	100				
Sousse	1	100	225/150	14	100				
Sousse	1	100 1/	225/150	14	100				
Bouchemma	1	100	225/150	14	100				20 x 1

Note 1/: Additional transformer.

A-3-(6) Rating and Characteristics of 150 kV Transformer for Substation

Station	No. of Unit	Capacity of Trans. (MVA)	Transf. Voltage (KV)	Xt Reactance of Transf. Machine Base (%)	Station Capacity (MVA)	Reactive Power Supply Equipment S.C (Mvar) 10 KV	30 KV	R.C (Mvar)	Reactor (Mvar)
Hammamet	2	30	150/33	12	60				
Akouda	1	15	150/33	12.15	15				
Akouda	2	30	150/33	12	60				
Akouda	1	25 1/	150/33	11.24	25				
M'Saken	1	25	150/33	11.24	25		9.6x1		
M'Saken	1	25 1/	150/33	11.24	25				
M'Saken	2	40	150/33	12	80				
Sfax	2	25	150/33	11.24	50				
Sfax	1	40	150/33	12	40				
Sfax	1	30 1/	150/33	12	30				
Sfax	1	40 1/	150/33	12	40				
Maknassy	2	15	150/33	12.5 12.6	30				6 x 1
Ghannouch	2	15	150/33	12.07 12.06	30				6 x 2
Ghannouch	1	40 1/	150/33	12	40				
Ciementeri Gabes	1	15	150/33	12	15				
Ciementeri Gabes	1	15 1/	150/33	12	15				
Robbana	2	15	150/33	12.11 11.88	30				
Metlaoui	3	40	150/33	12	120		9.6x1		6 x 1
Kasserine	2	15	150/33	12	30		10x1		
Tajerouine	2	20	150/90	12.2	40				

Note 1/: Additional transformer.

A-3-(7) Rating and Characteristics of 90 kV Transformer for Substation

Station	No. of Unit	Capacity of Trans. (MVA)	Transf. Voltage (KV)	Xt Reactance of Transf. Machine Base (%)	Station Capacity (MVA)	Reactive Power Supply Equipment			
						S.C (Mvar)		R.C	Reactor
						10 KV	30 KV	(Mvar)	(Mvar)
Tunis-Sud	2	20	90/33	12.4 12.6	40		8.4x1	23 x 2 (prod.)	
"	1	30	90/33	11.65	30			6 x 2 (abs.)	
"	2	30	90/11	9.5 9.75	60				
Tunis-Ouest	2	30	90/11	13.1	60	8.4x1			
"	1	40	90/11	13	40				
Tunis-Nord	1	30	90/33	11.6	30				
"	1	40	90/33	11.6	40				
"	1	30	90/11	13	30				
"	1	40	90/11	13	40				
La Goulette	1	40	90/33	9.84	40				
"	1	50	90/33	9.6	50				
Menzel Bourguiba	1	20	90/33	11.6	20		9.6x1		
"	2	40	90/33	11.6	80				
Jendouba	2	15	90/33	10	30				
Oued-Zarga	1	10	90/33	9.7	10				
"	1	15	90/33	10.08	15				
Bizerte	1	20 1/	90/33	9.8	20				
Fouladh	1	20 1/	90/33	9.8	20				
Korba	2	15	90/33	11	30				
"	1	20	90/33	11.55	20				
Tajerouine	2	15	90/33	9.8	30				
Cimenterie Algero Tunisienne	1	20 1/	90/33	10	20				

Note 1/ : Additional transformer.

Fig.A-3-1 Impeadance Map in STEG POWER SYSTEM in 1988

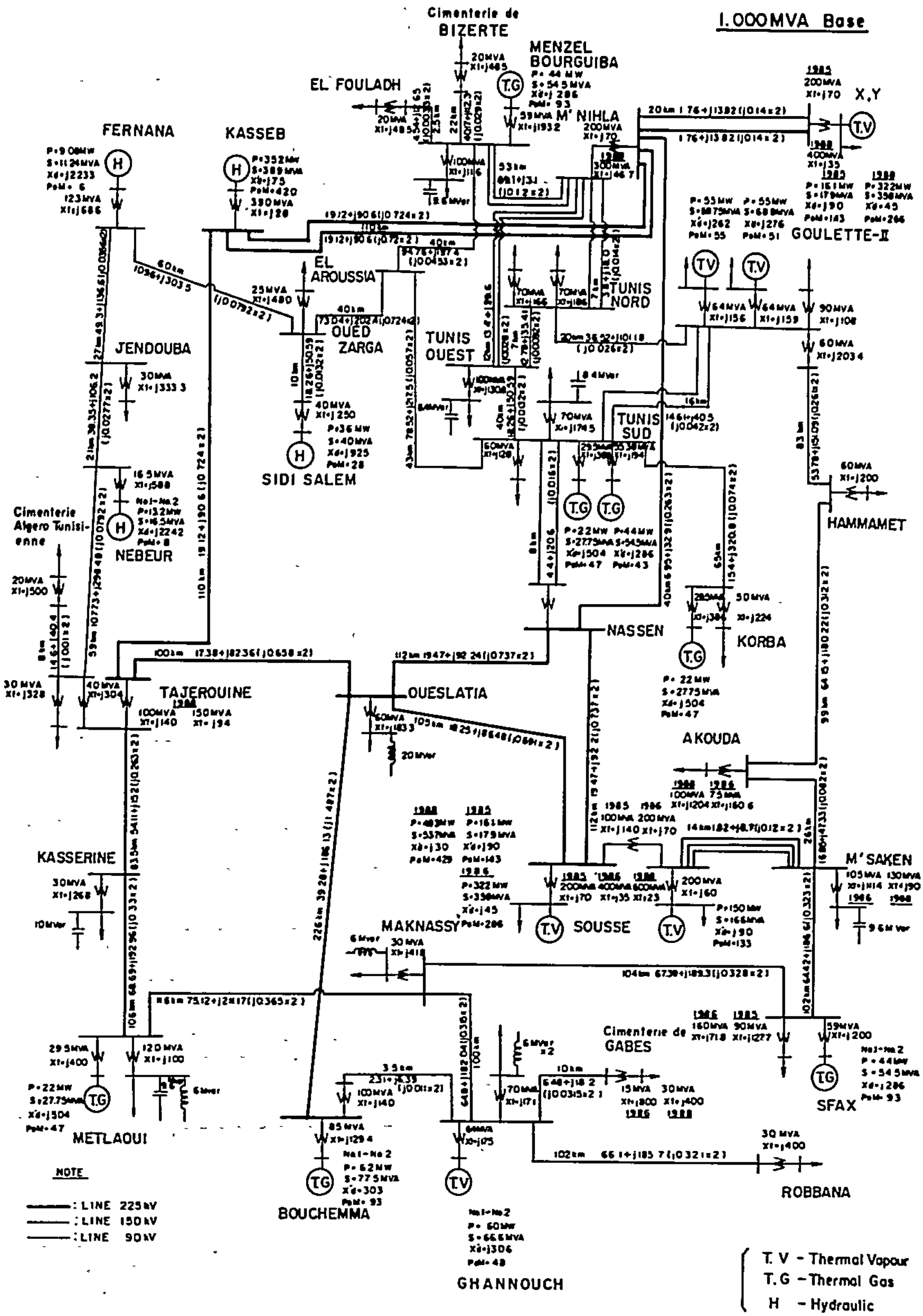
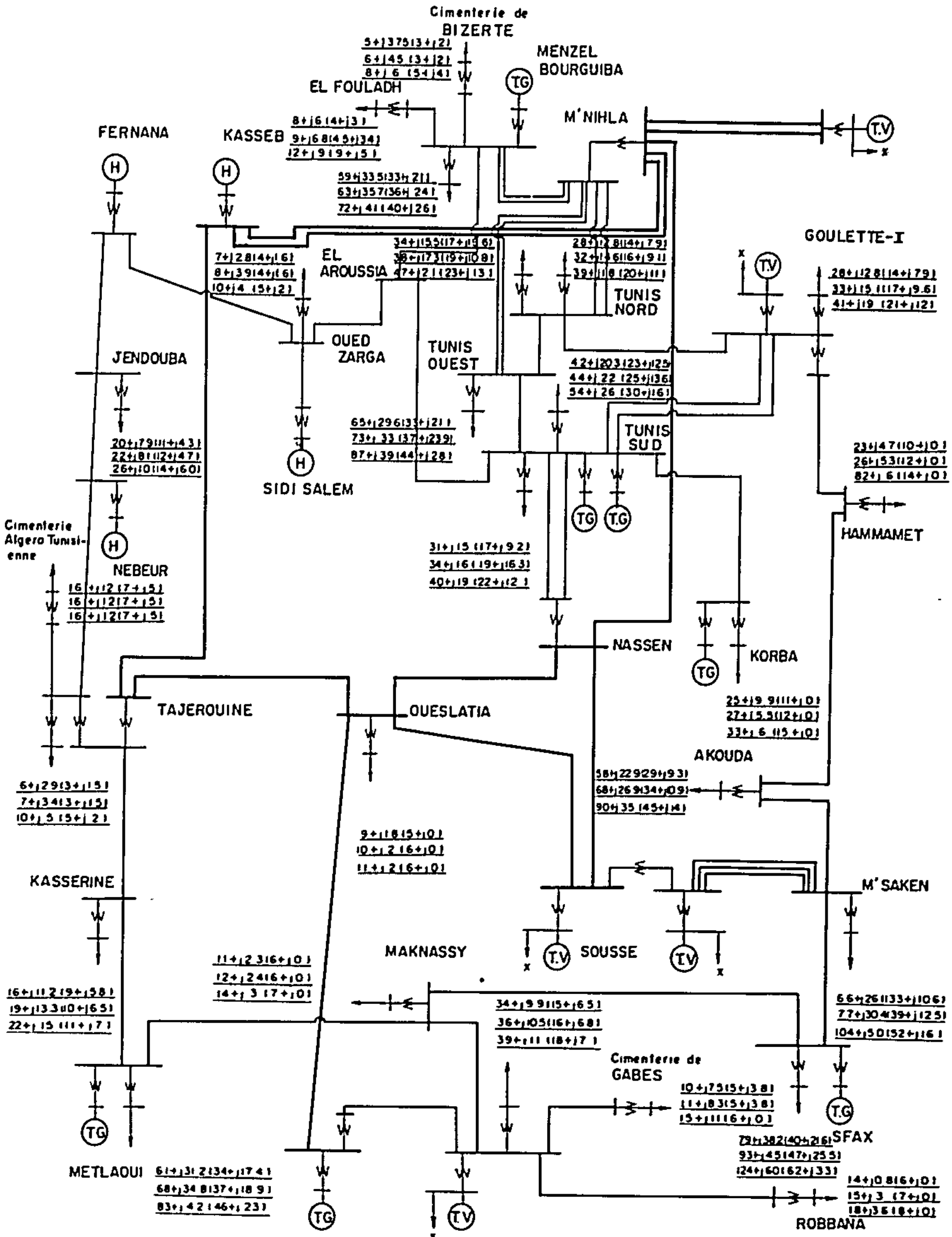


Fig.A-3-2 Load Distribution



NOTE

$P^{MW} + jQ^{MVar}$ This figures show the peak (mid night) load in 1985
" " in 1986
" " in 1988

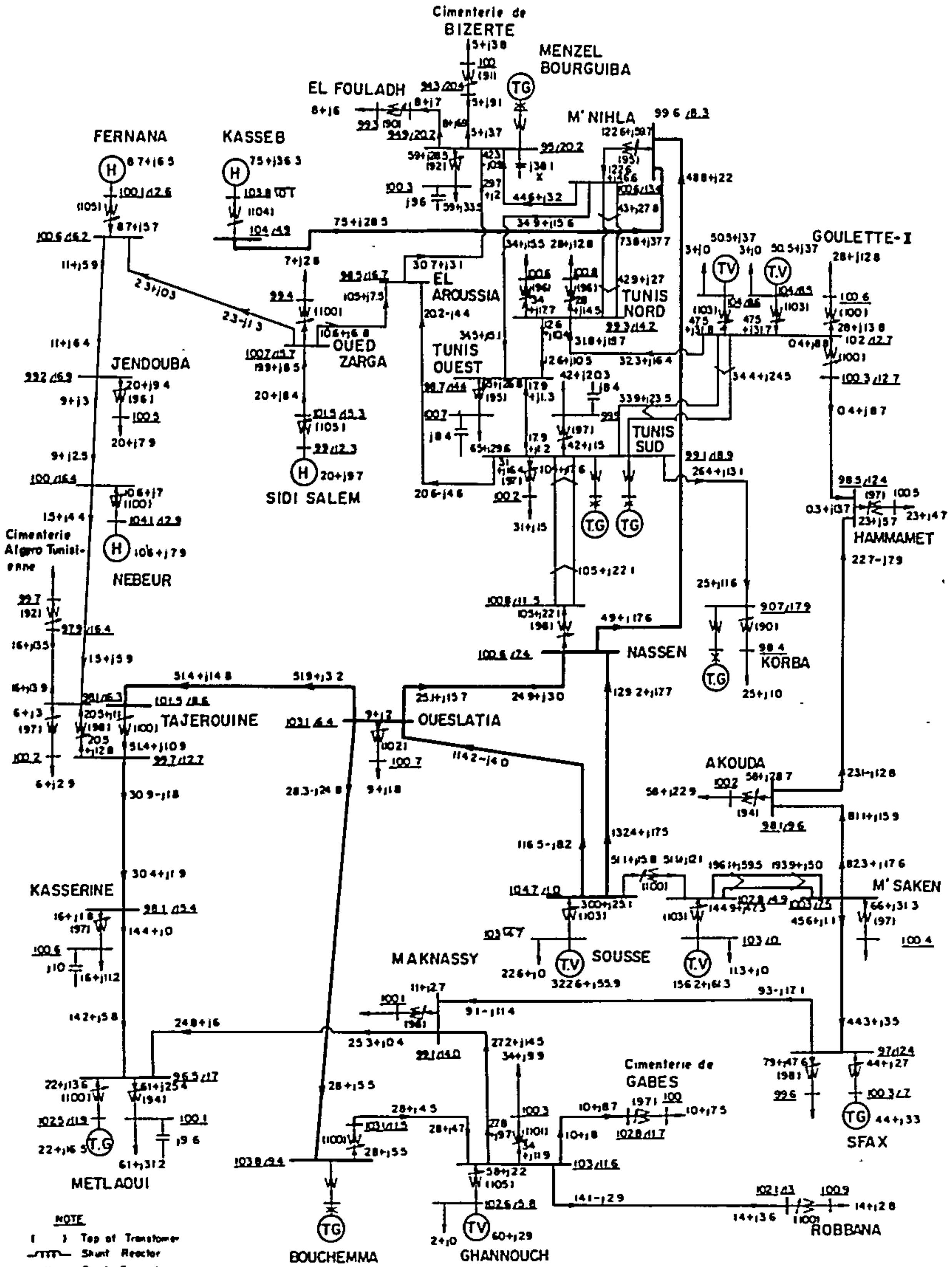
X ------ Auxiliary use

LINE 225 kV
LINE 150 kV
LINE 90 kV

T.V – Thermal Vapour
T.G – Thermal Gas
H – Hydraulic

Case A-5-I-P

Fig.A-3-3 Power Flow and Voltage Regulation at Peak Time in 1985



NOTE

( ) Tap of Transformer

Shunt Reactor

Shunt Capacitor

100.0∠ Bus Voltage (%) and Leading Angle

Bus Voltage (%) and Lagging Angle

Unit : MW and MVar

Line Loss (I²R) = 23.06 MW

Line Loss (I²X) = 71.03 MVar

X : Additional Shunt Capacitor

LINE 225 kV

LINE 150 kV

LINE 90 kV

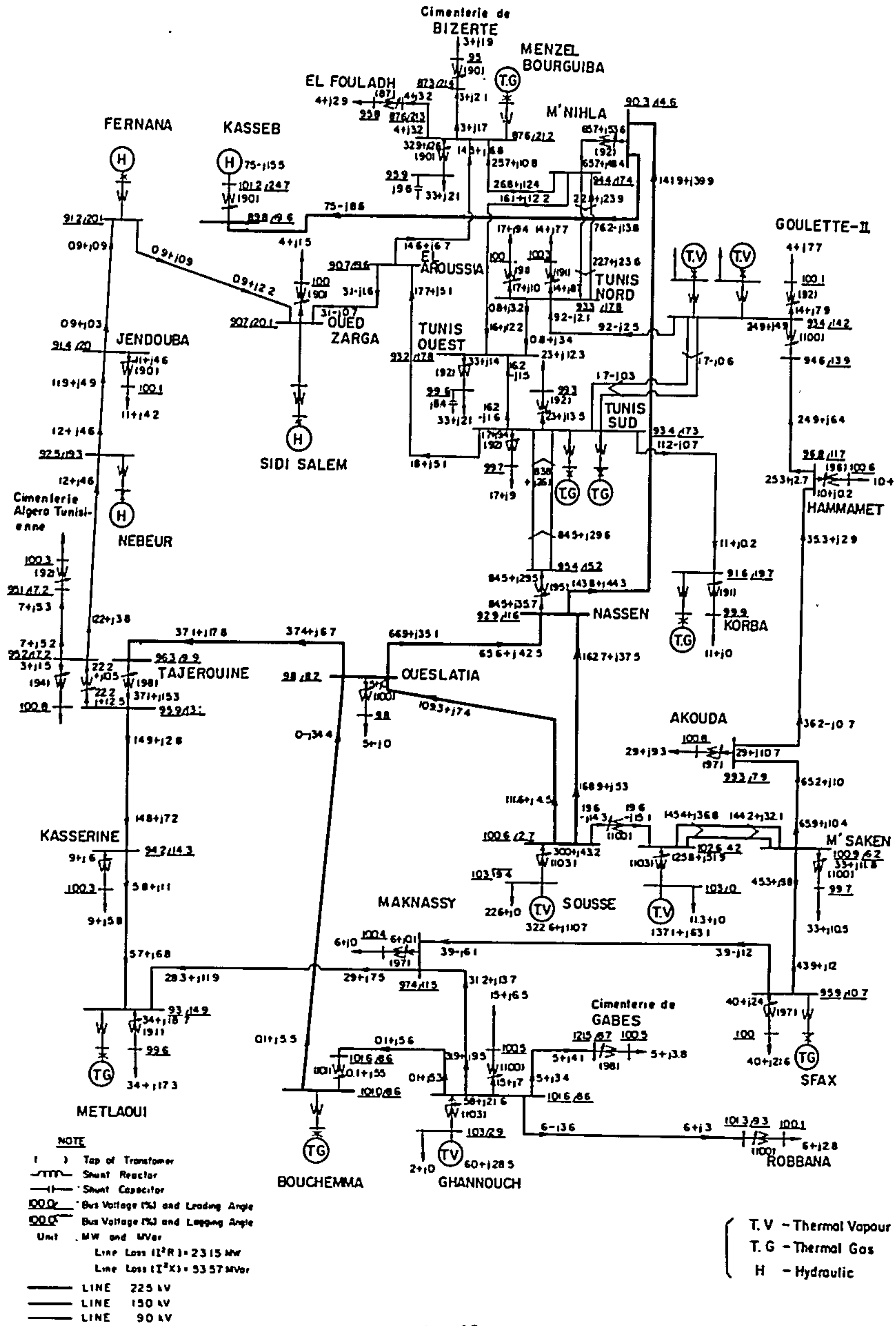
T.V – Thermal Vapour

T.G – Thermal Gas

H – Hydraulic

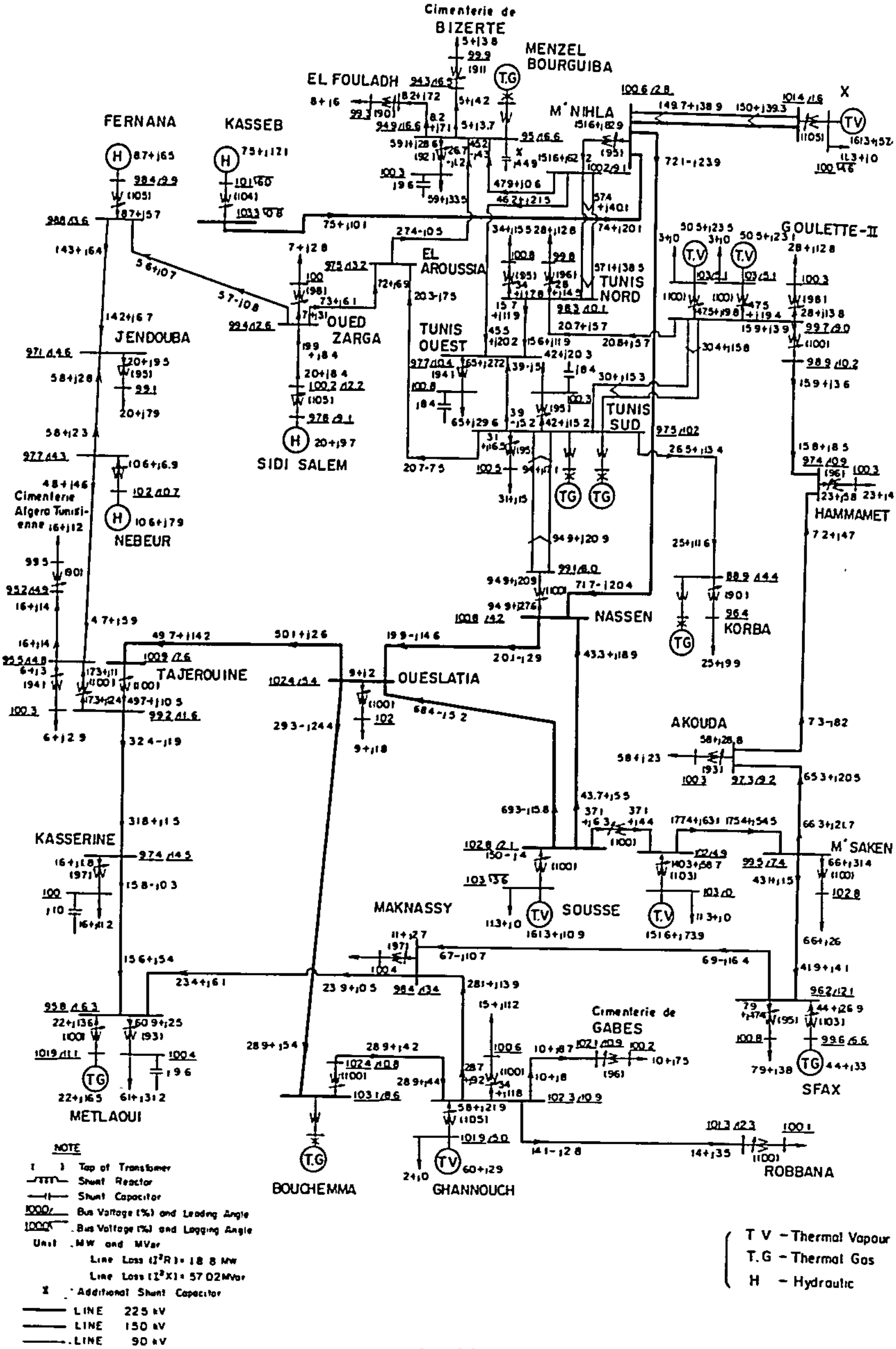
Case A-5-I-N

Fig.A-3-4 Power Flow and Voltage Regulation at Midnight Time in 1985



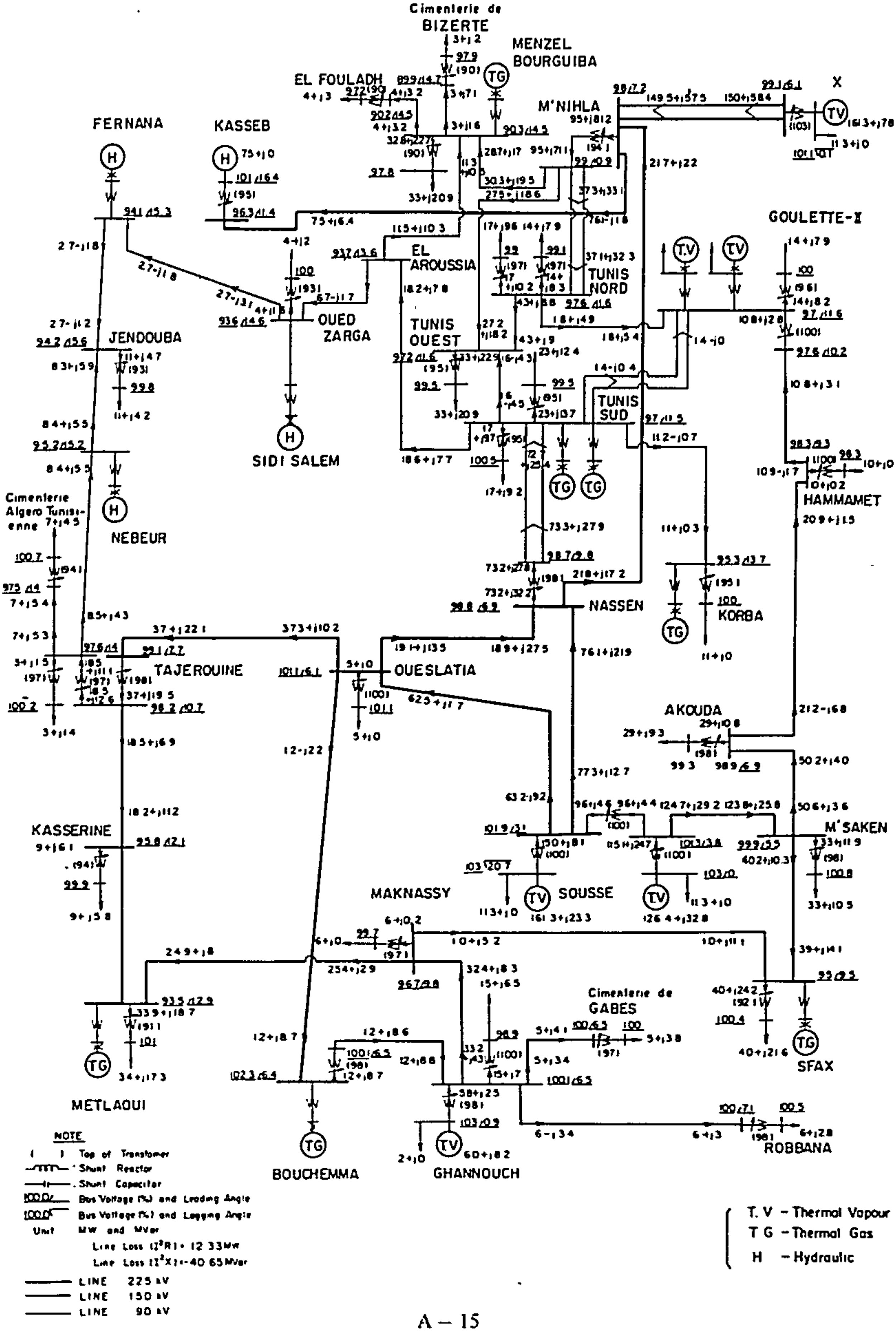
Case A-5-2-P

Fig.A-3-5 Power Flow and Voltage Regulation at Peak Time in 1985



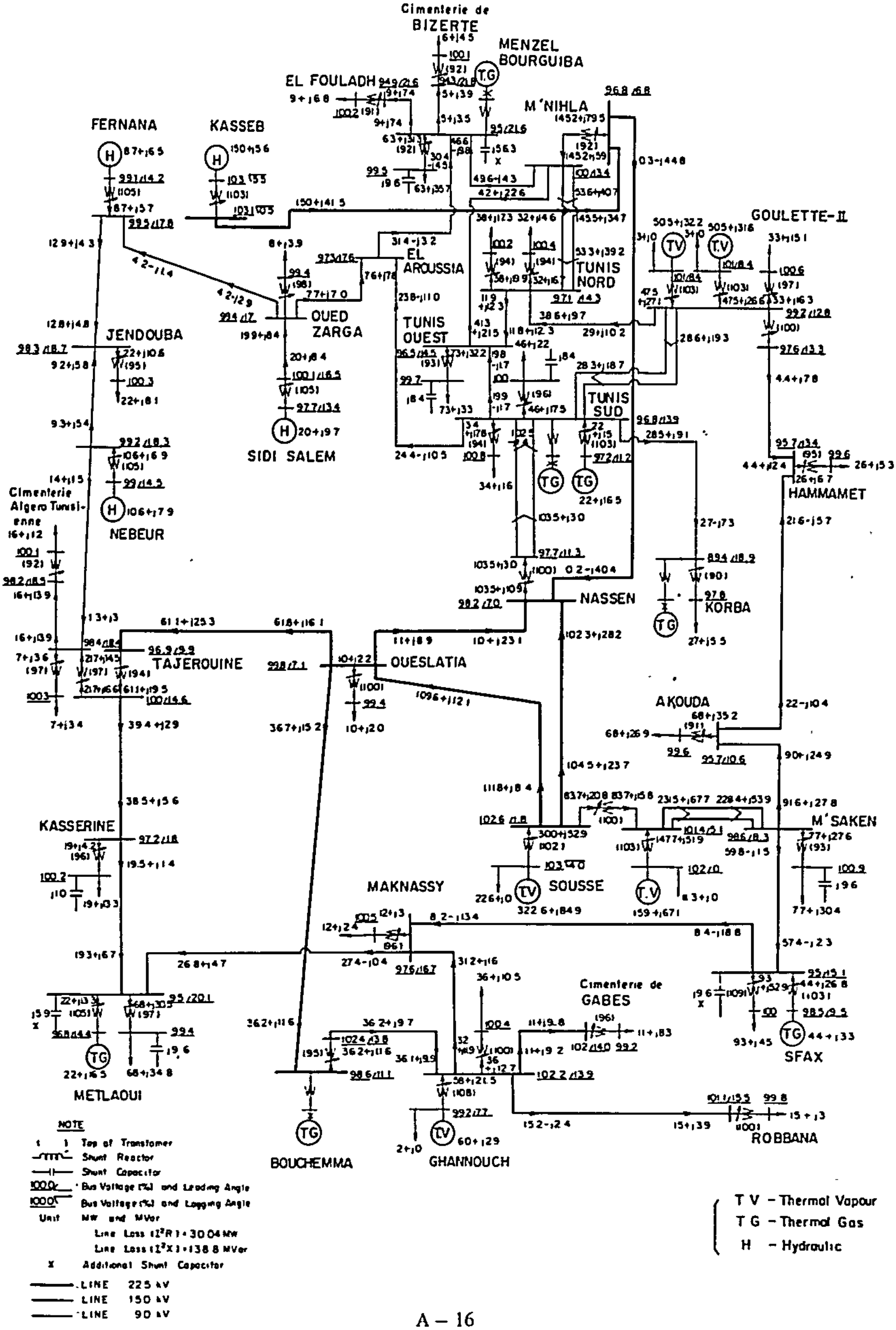
Case A-5-2-N

Fig.A-3-6 Power Flow and Voltage Regulation at Midnight Time in 1985



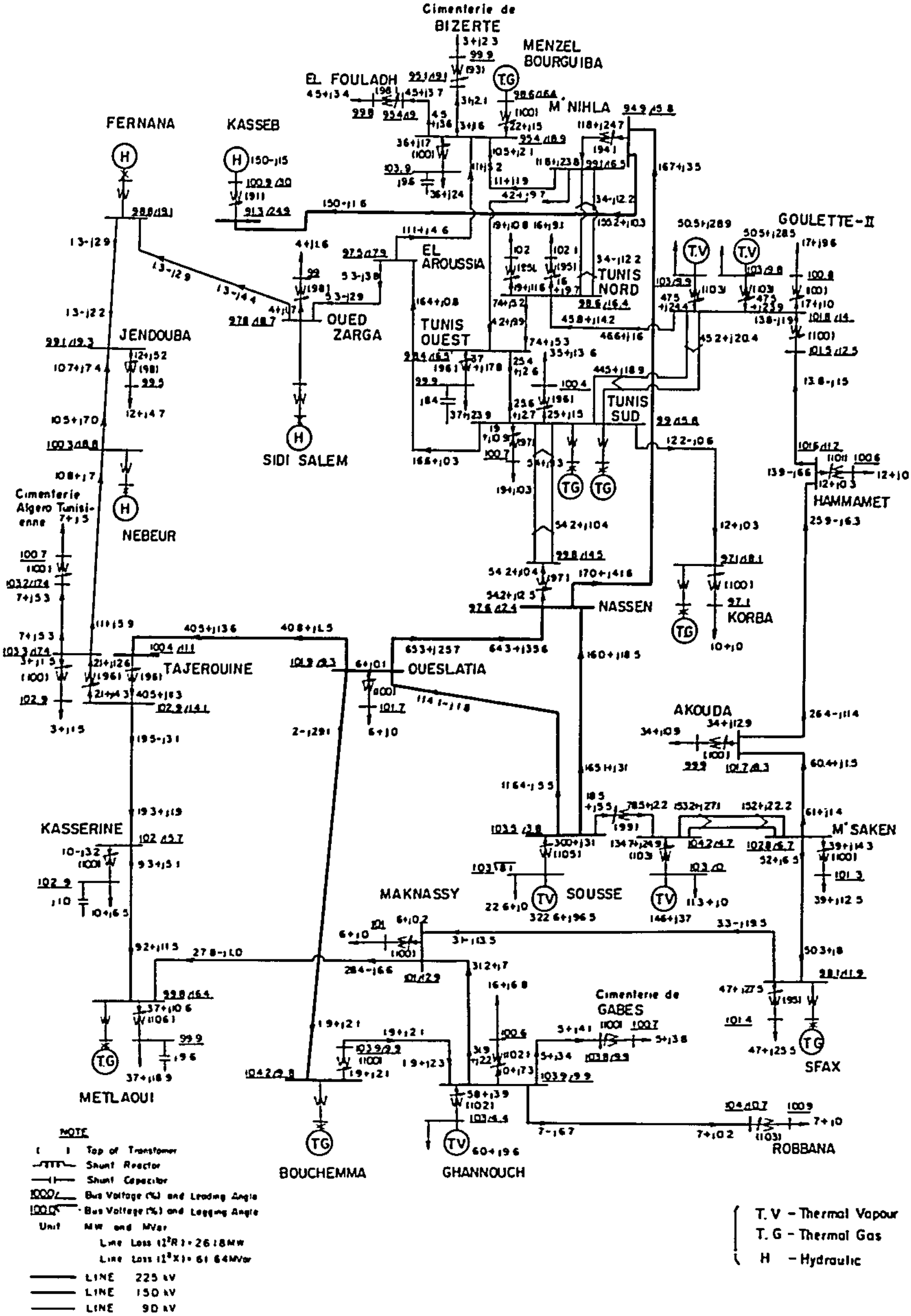
Case A-6-I-P

Fig.A-3-7 Power Flow and Voltage Regulation at Peak Time in 1986



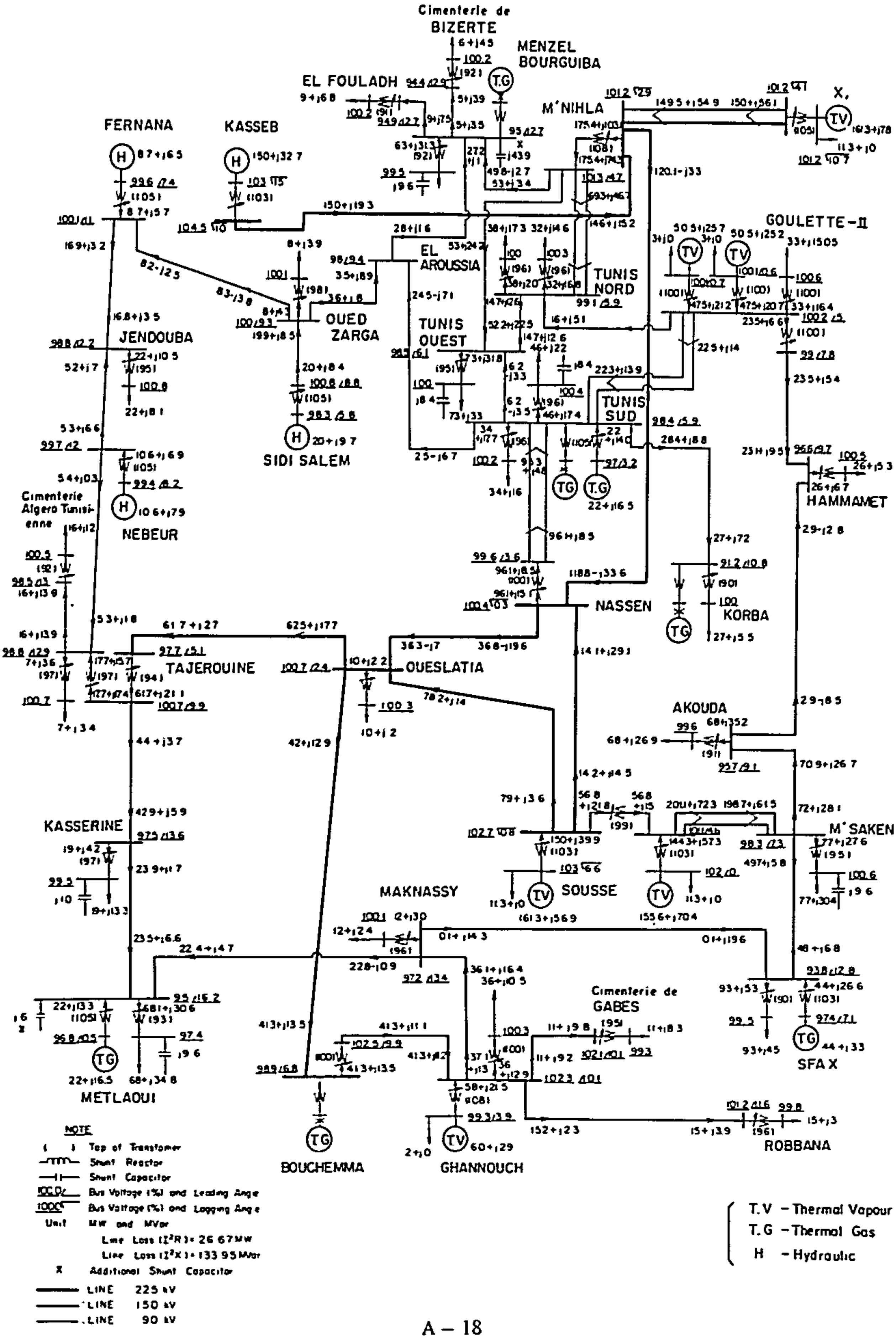
Case A-6-I-N

Fig.A-3-8 Power Flow and Voltage Regulation at Midnight Time in 1986



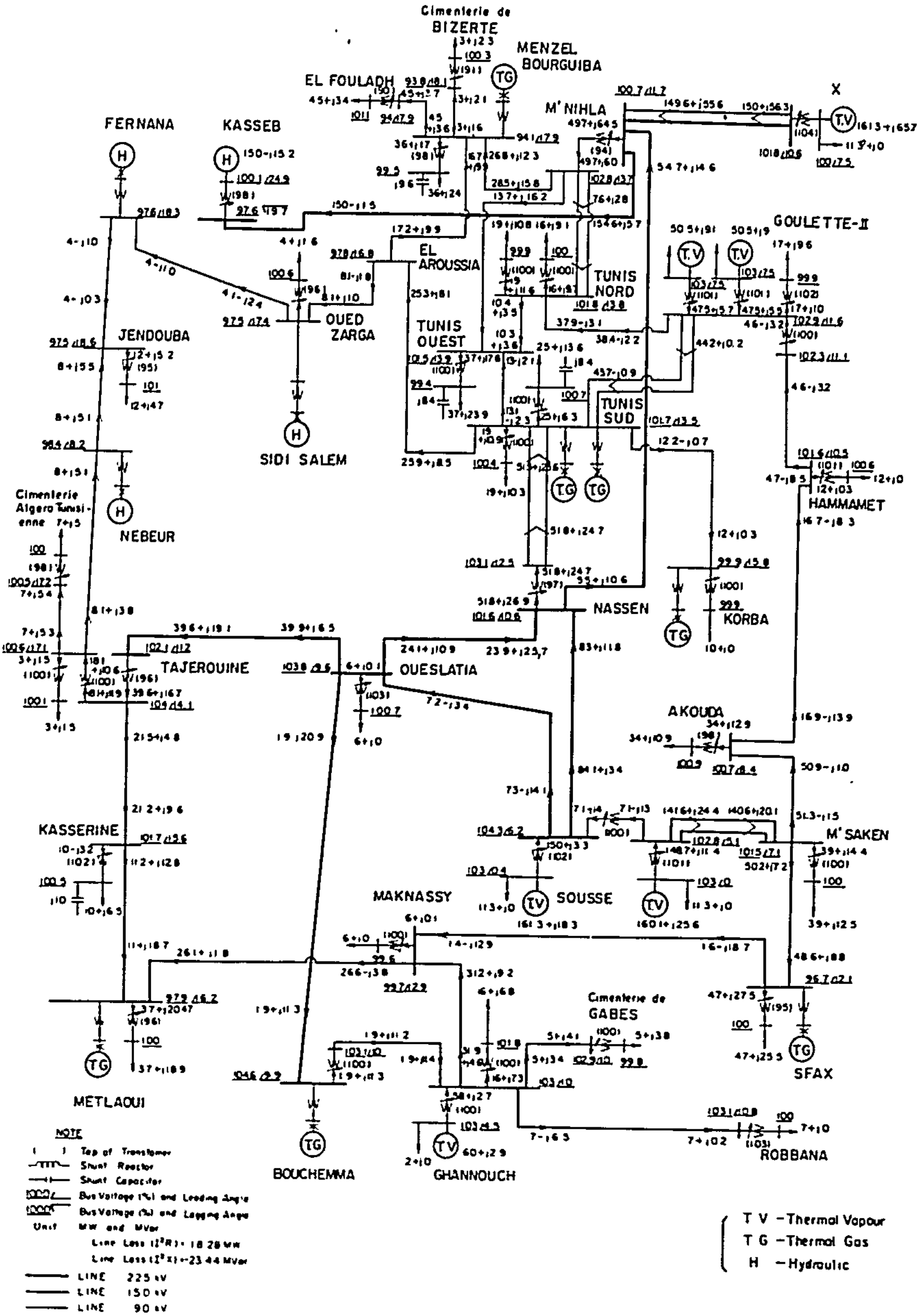
Case A-6-2-P

Fig.A-3-9 Power Flow and Voltage Regulation at Peak Time in 1986



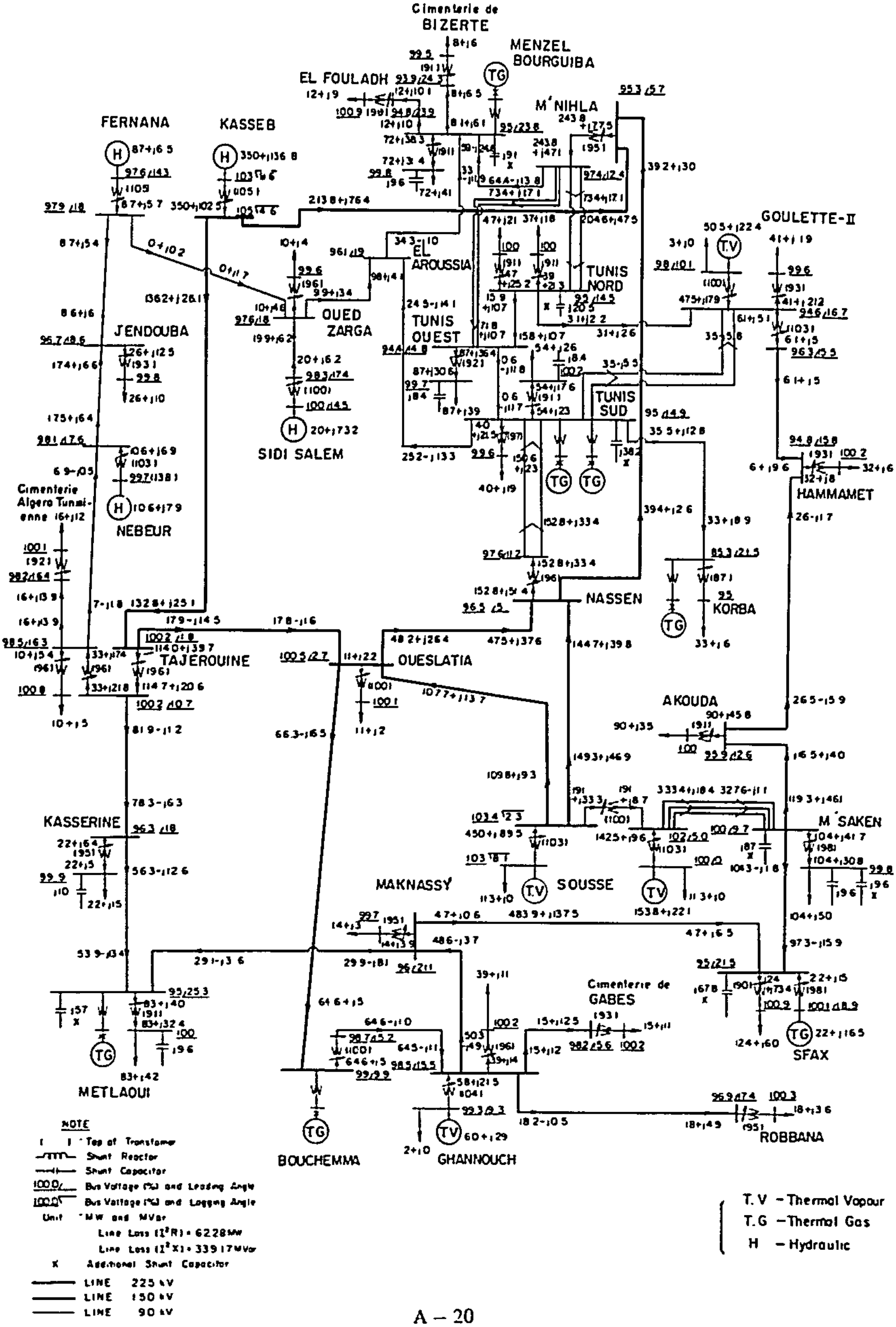
Case A-6-2-N

Fig.A-3-10 Power Flow and Voltage Regulation at Midninght Time in 1986



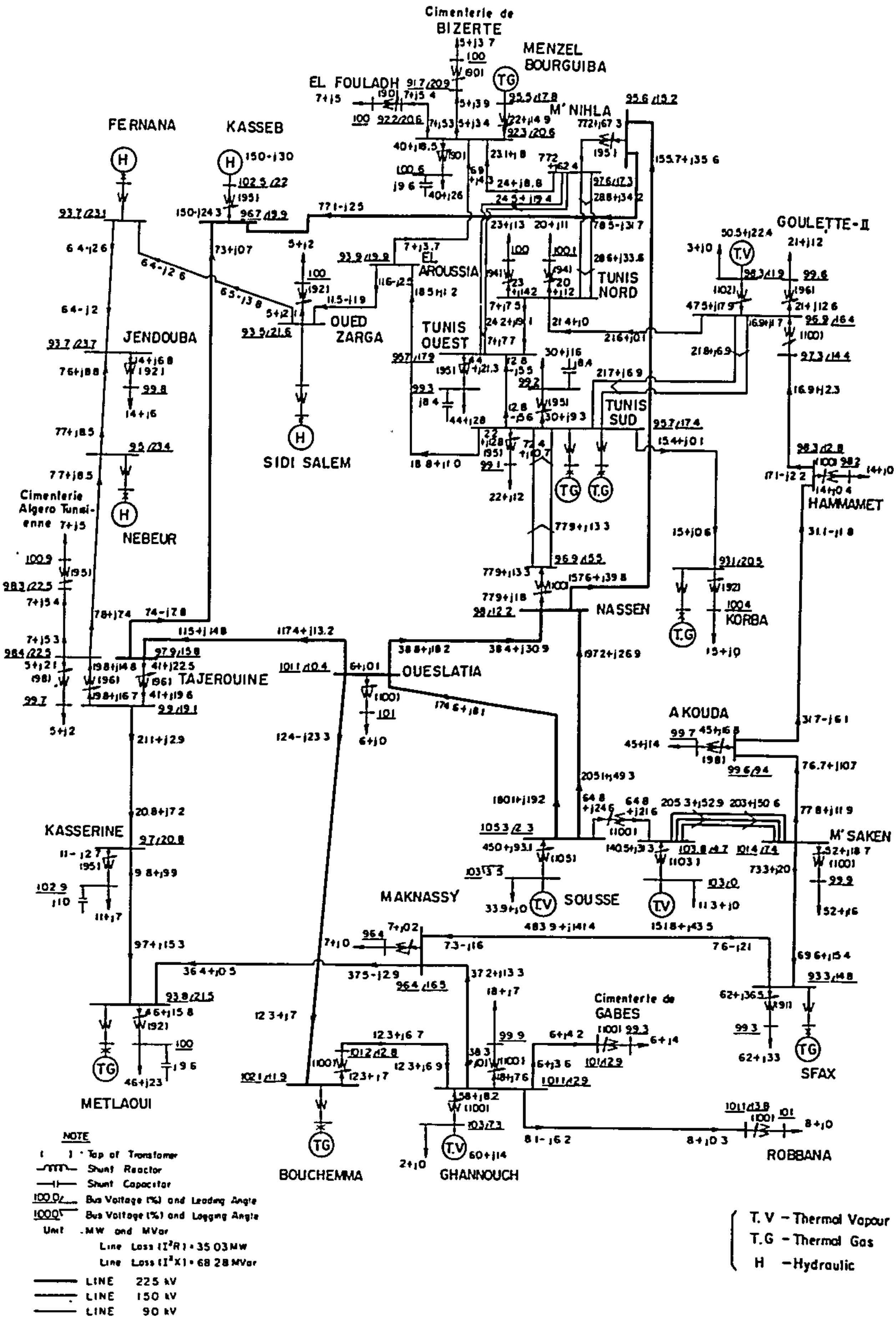
Case A-8-I-P

Fig.A-3-11 Power Flow and Voltage Regulation at Peak Time in 1988



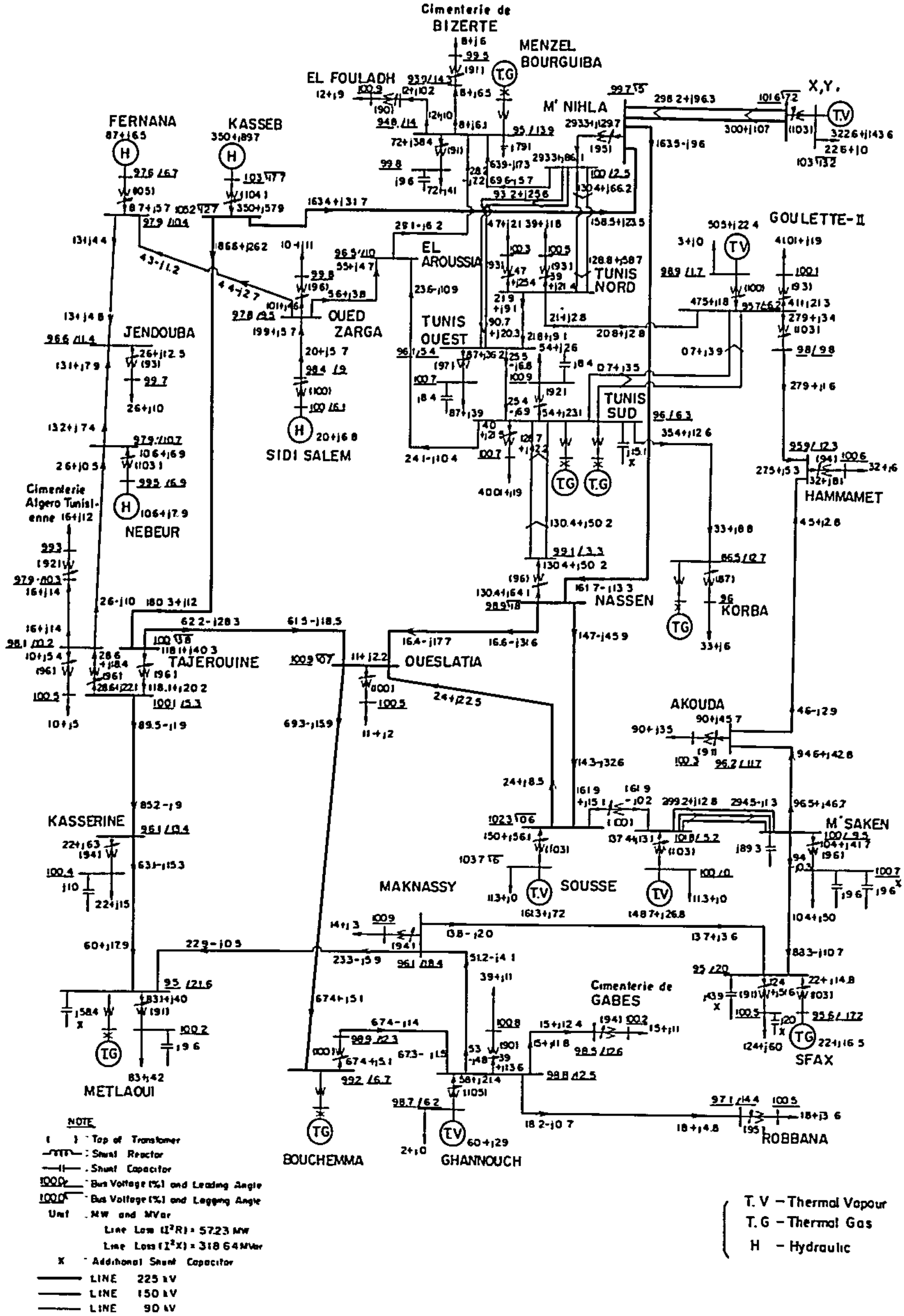
Case A-8-1-N

Fig.A-3-12 Power Flow and Voltage Regulation at Midnight Time in 1988



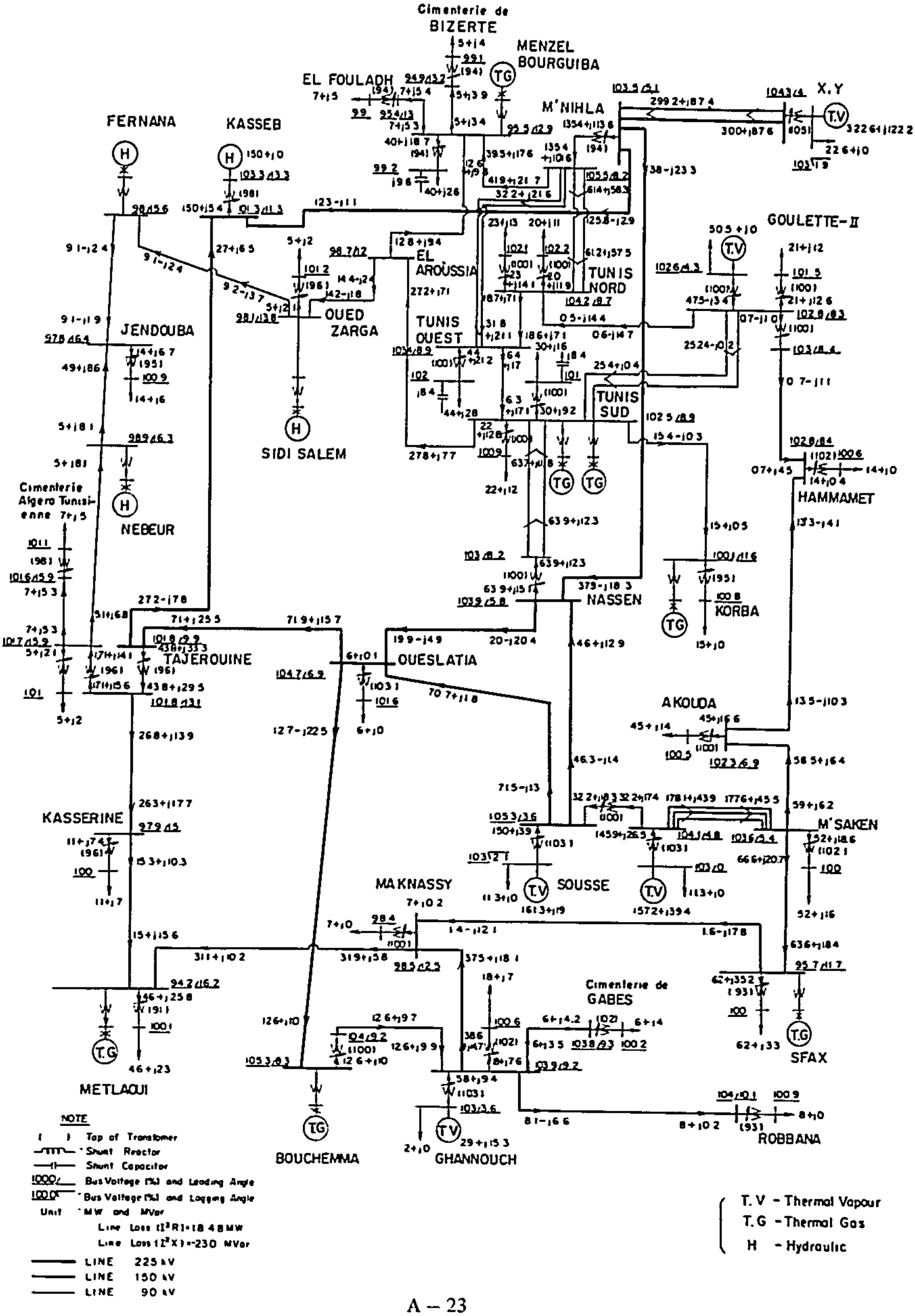
Case A-8-2-P

Fig.A-3-13 Power Flow and Voltage Regulation at Peak Time in 1988



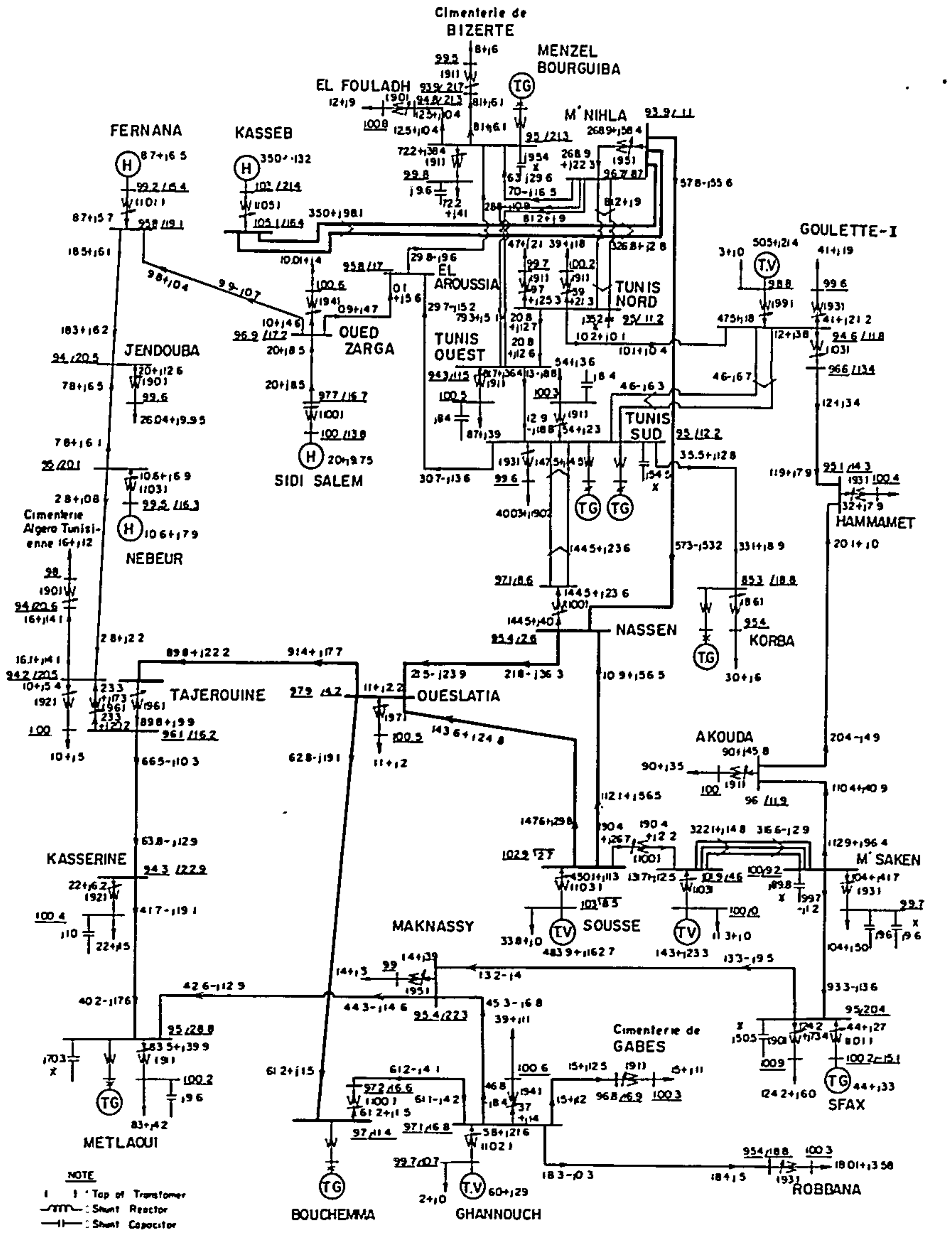
Case A-8-2-N

Fig.A-3-14 Power Flow and Voltage Regulation at Midnight Time in 1988



Case B-8-I-P

Fig.A-3-15 Power Flow and Voltage Regulation at Peak Time in 1988



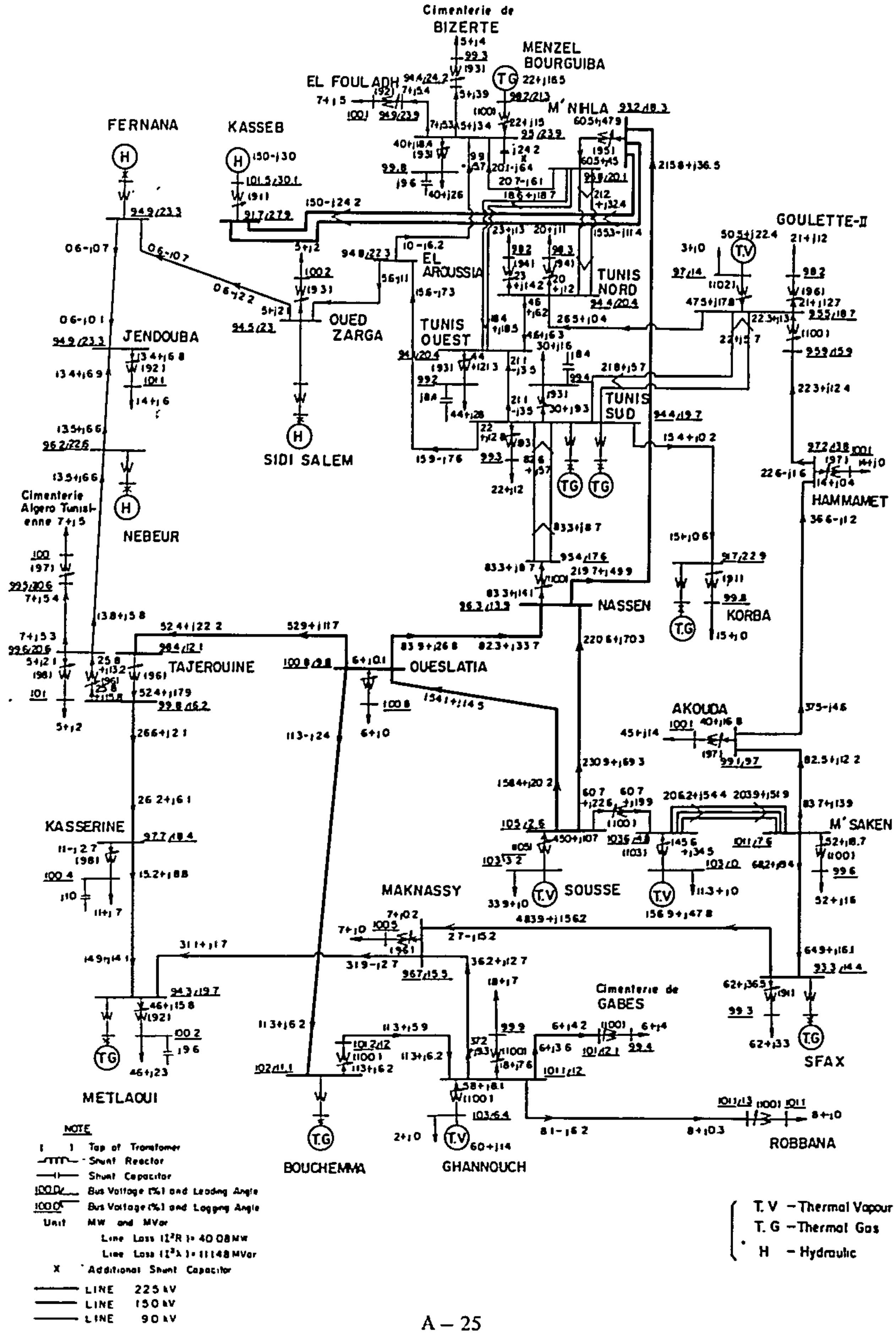
NOTE

Top of Transformer
: Shunt Reactor
: Shunt Capacitor
100.0/ Bus Voltage (%) and Leading Angle
100.0/ Bus Voltage (%) and Lagging Angle
Unit MW and MVar
Line Loss (I^2R) = 73.72 MW
Line Loss (I^2X) = 413.81 MVar
x Additional Shunt Capacitor
LINE 225 kV
LINE 150 kV
LINE 90 kV

T.V - Thermal Vapour
T.G - Thermal Gas
H - Hydraulic

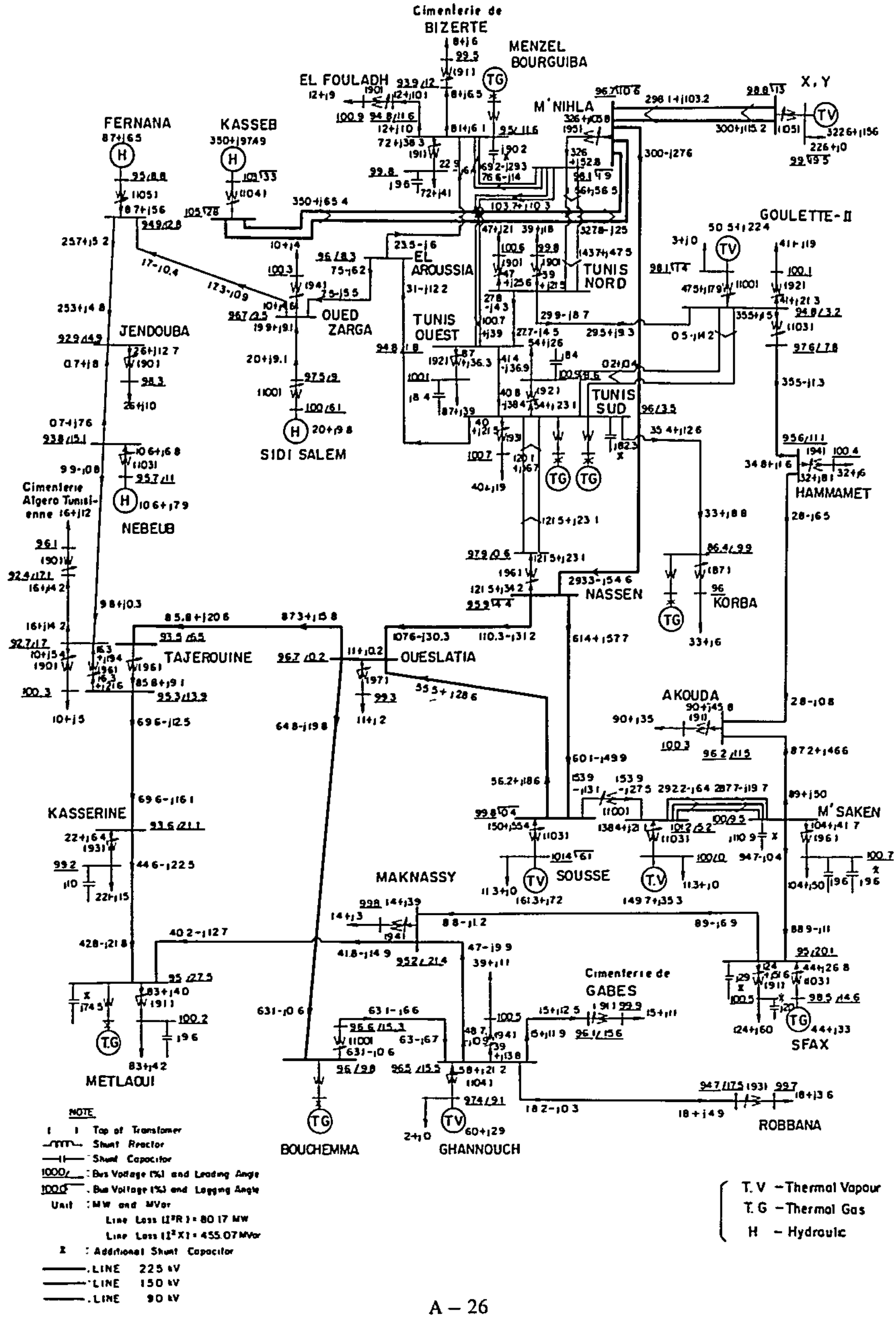
Case B-8-1-N

Fig.A-3-16 Power Flow and Voltage Regulation at Midnight Time in 1988



Case B-8-2-P

Fig.A-3-17 Power Flow and Voltage Regulation at Peak Time in 1988



Case B-8-2-N

Fig.A-3-18 Power Flow and Voltage Regulation at Midnight Time in 1988

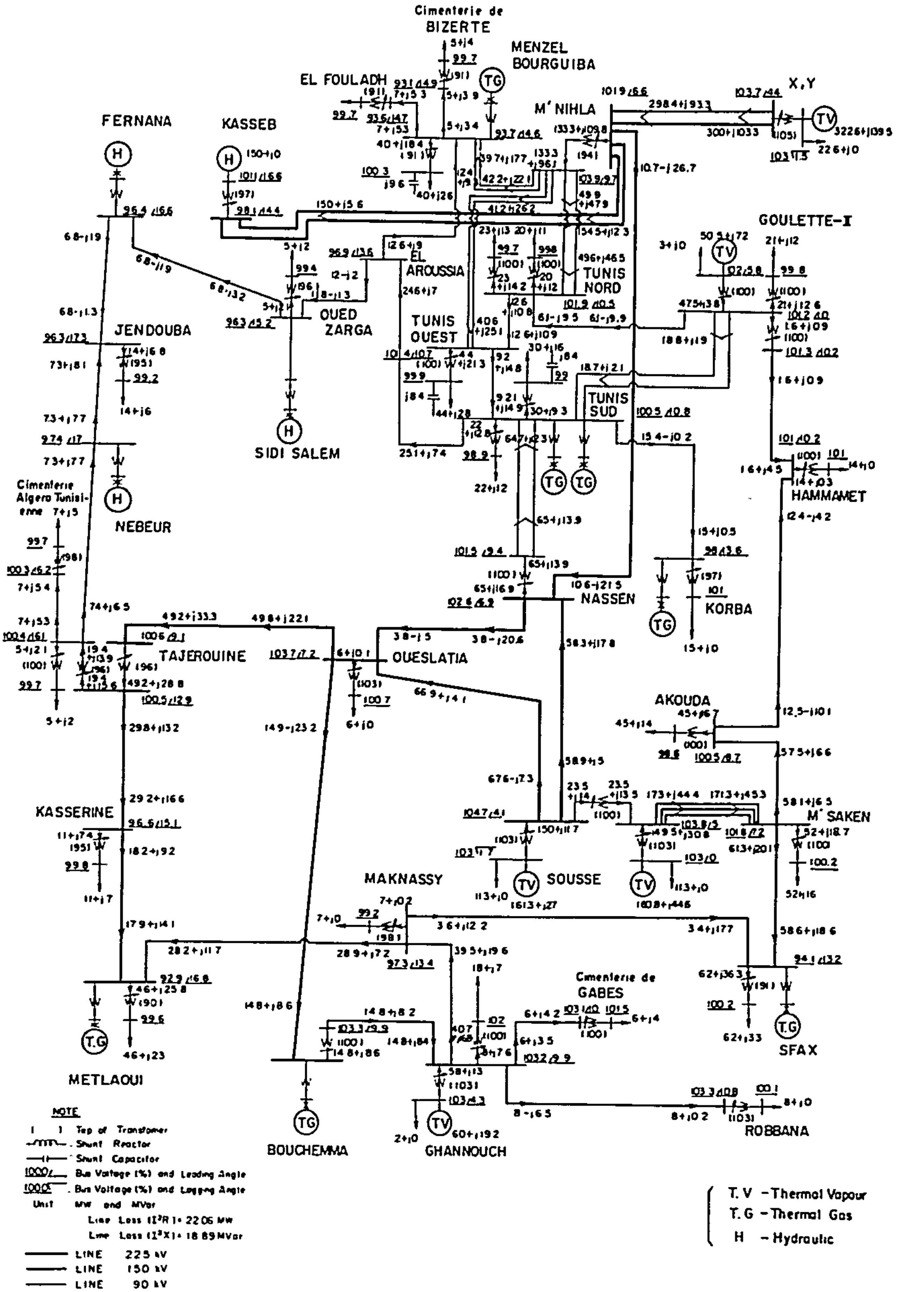


Fig.A-3-19 Fault Capacity in 1988

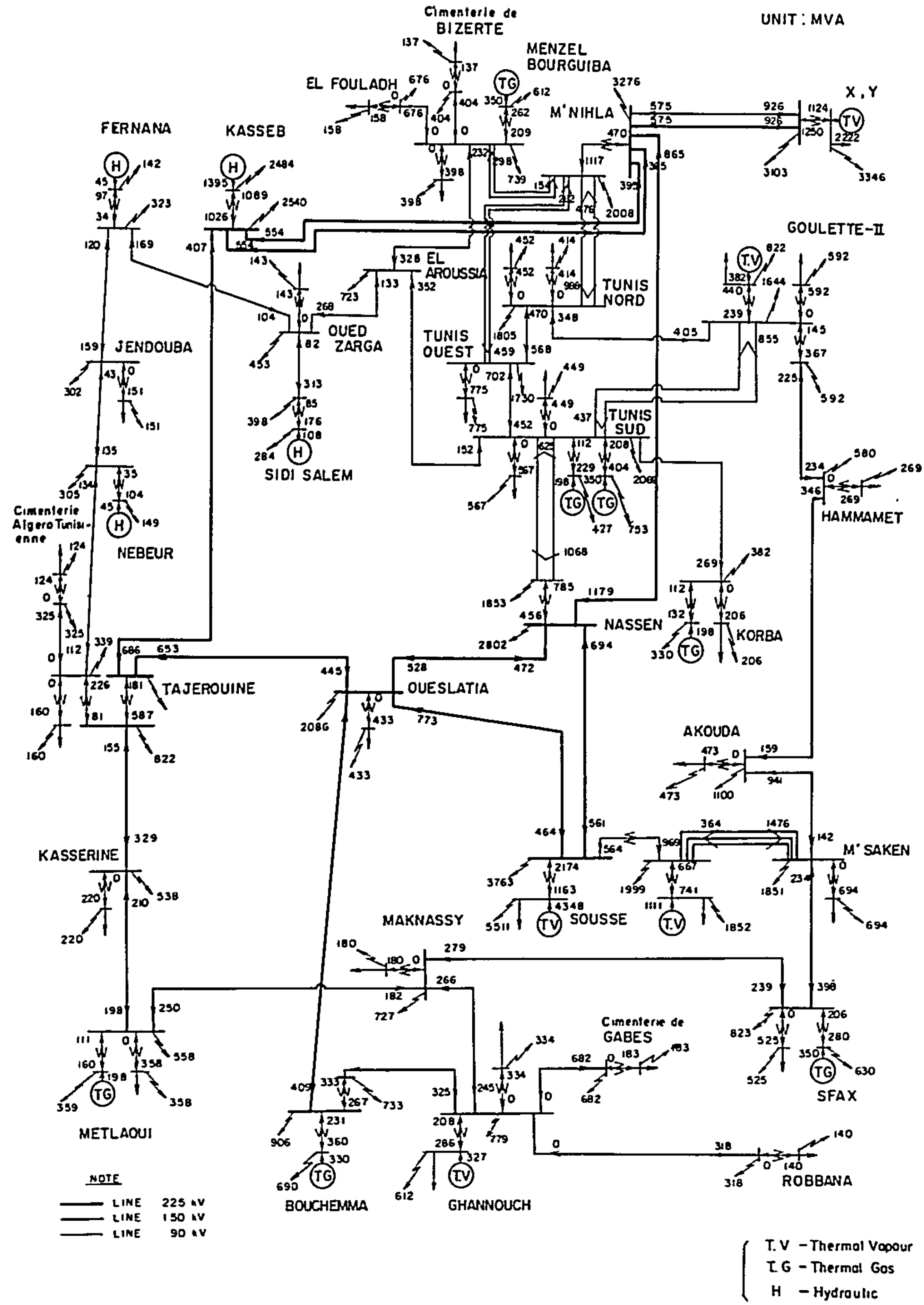


CHART NO.1

Case A-8-1-P KASSEB-M'NIHLA O-C-O

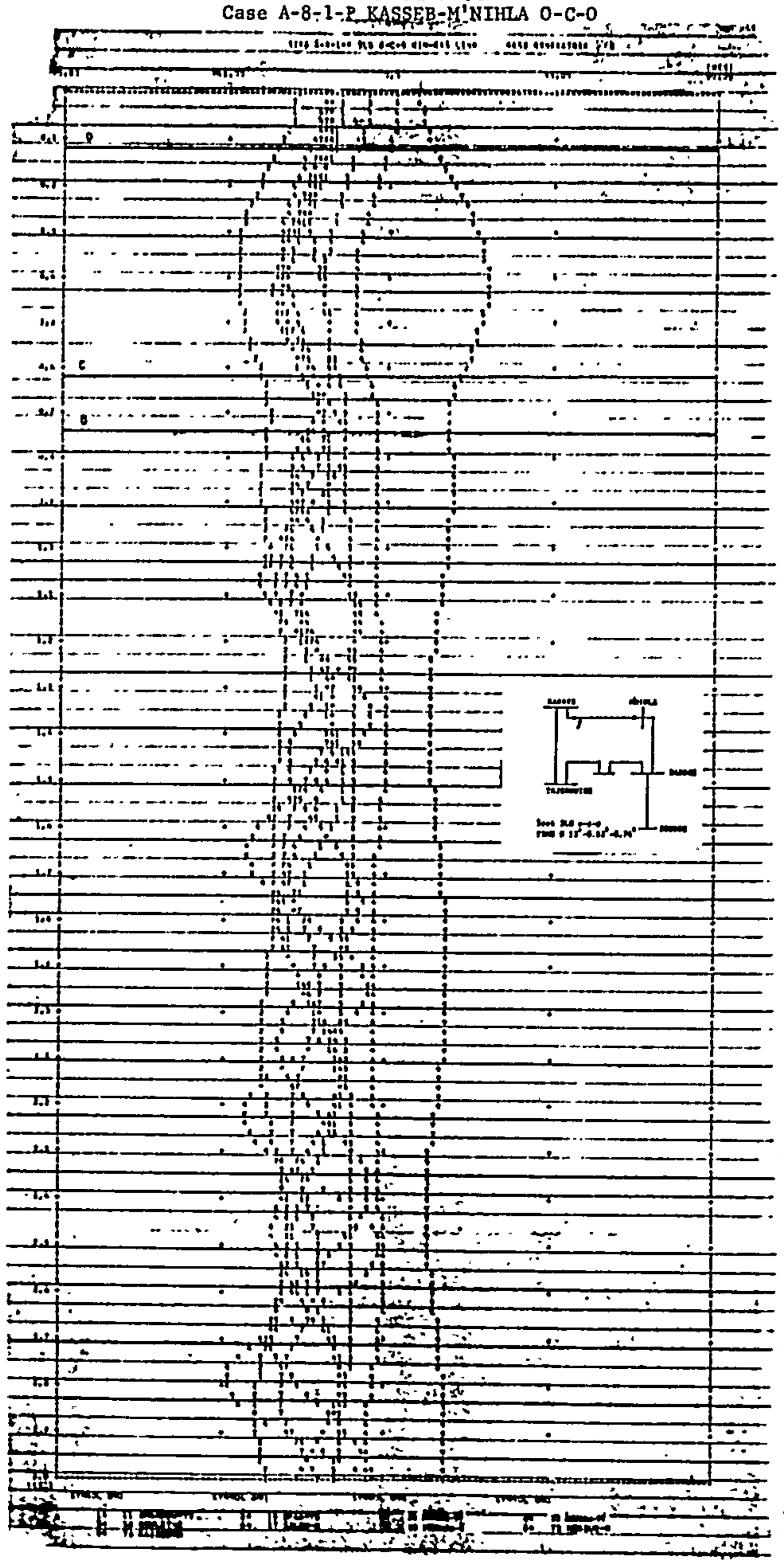


CHART NO.2

Case B-8-1-P KASSEB-M'NIHLA O-C-O

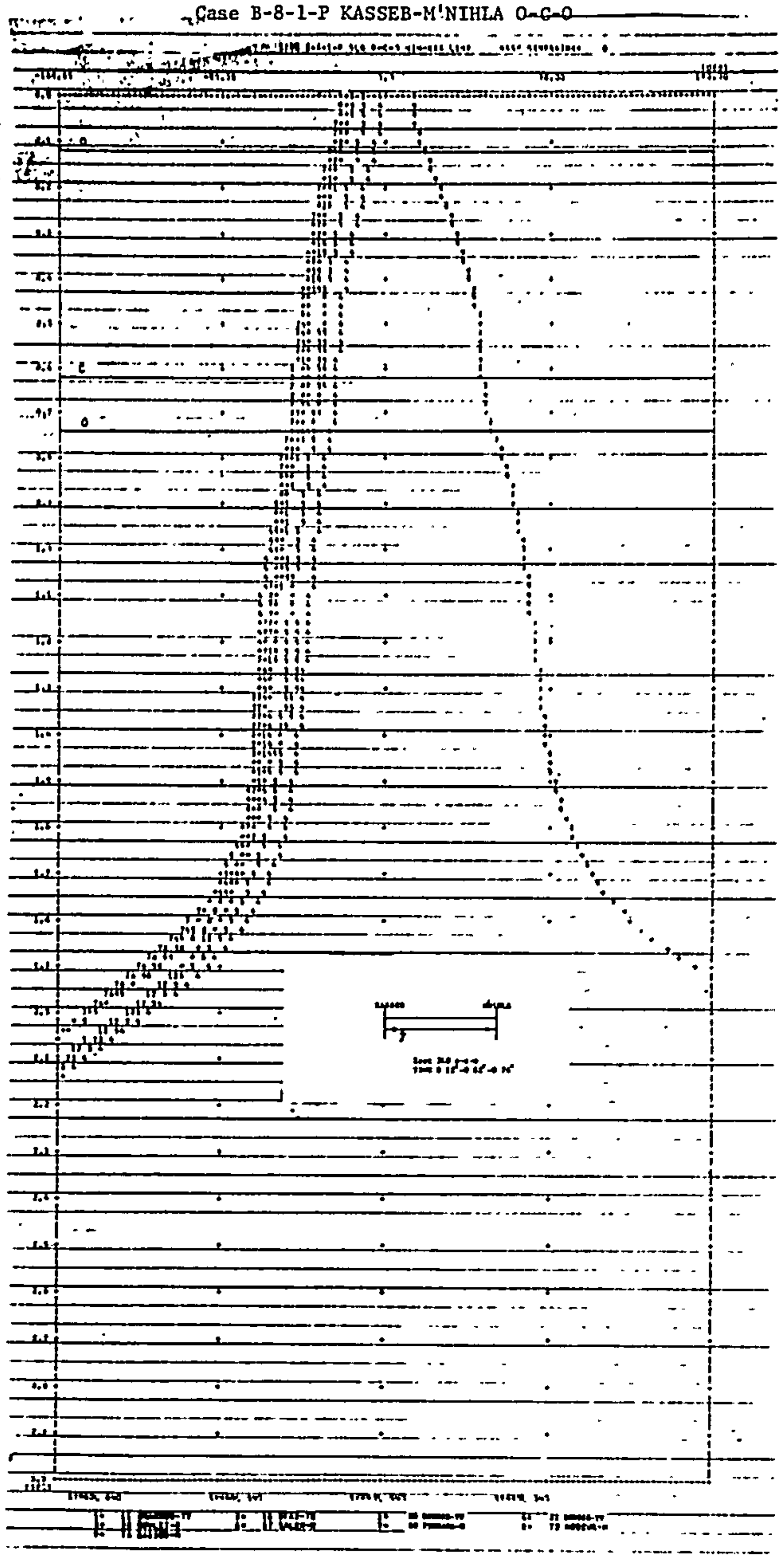
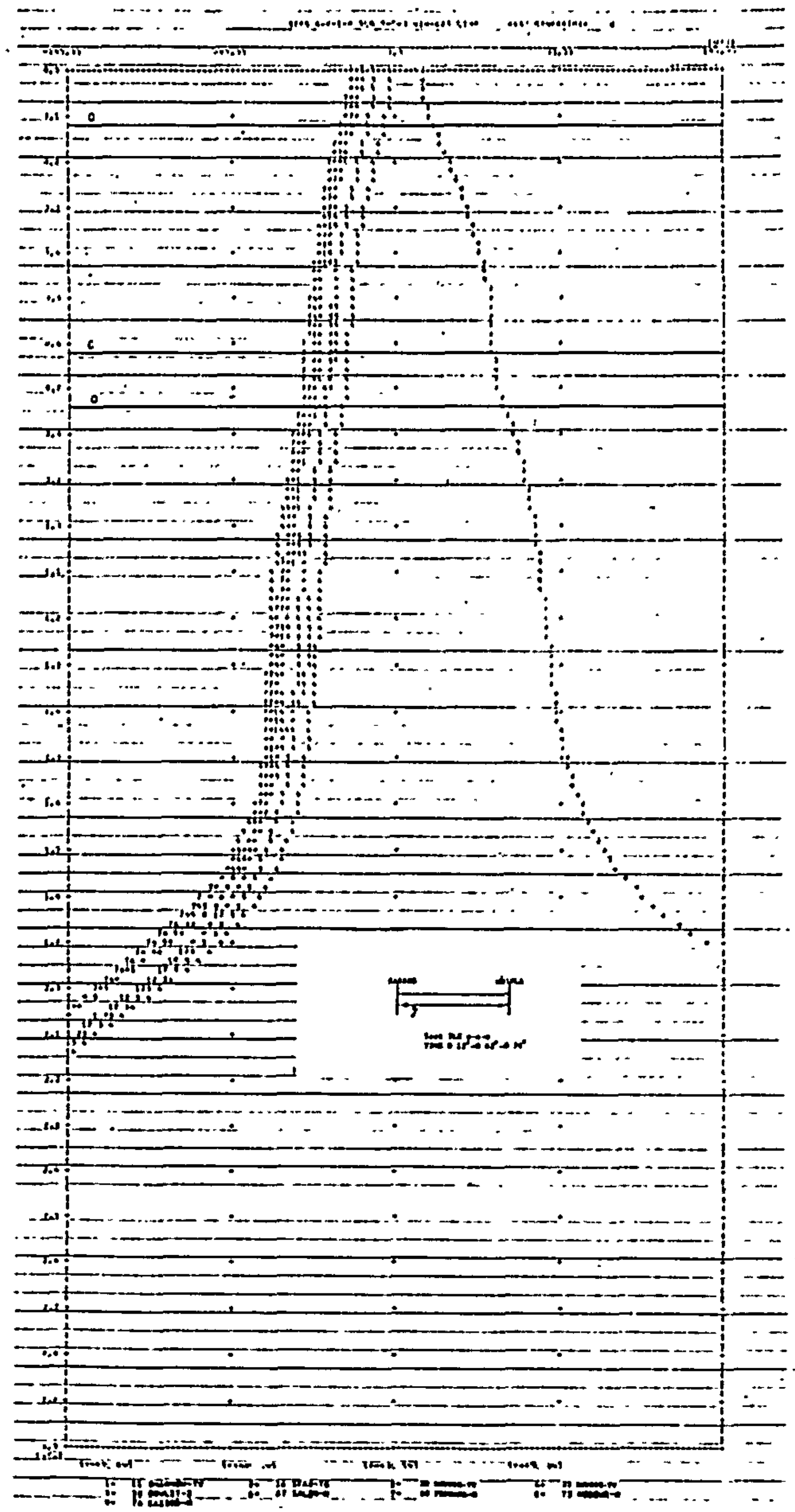


CHART NO.3
Case B-8-1-P KASSEB-M'NIHLA O-C-O



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Case B-8-2-P KASSEB-M'NIHLA O-C-O

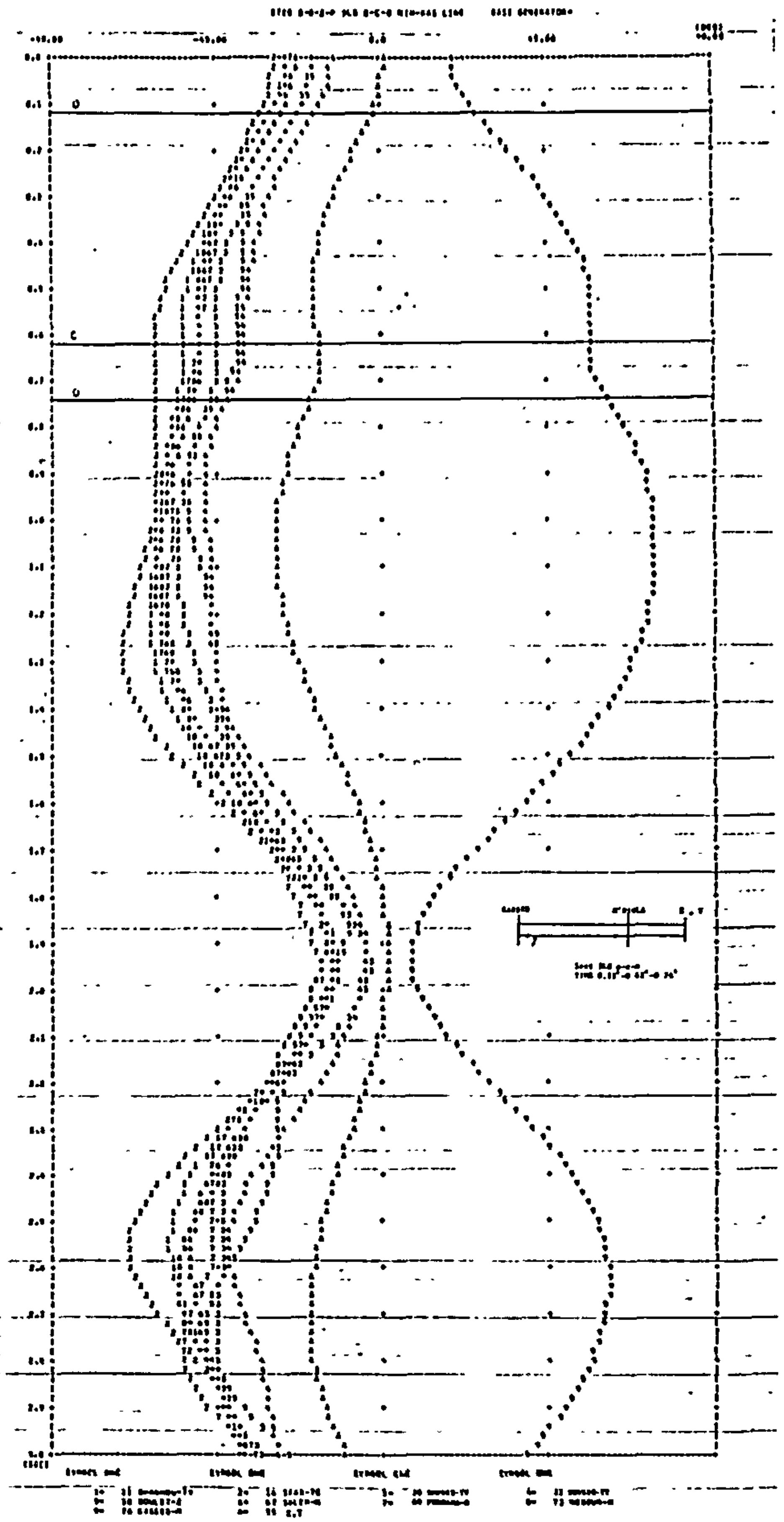
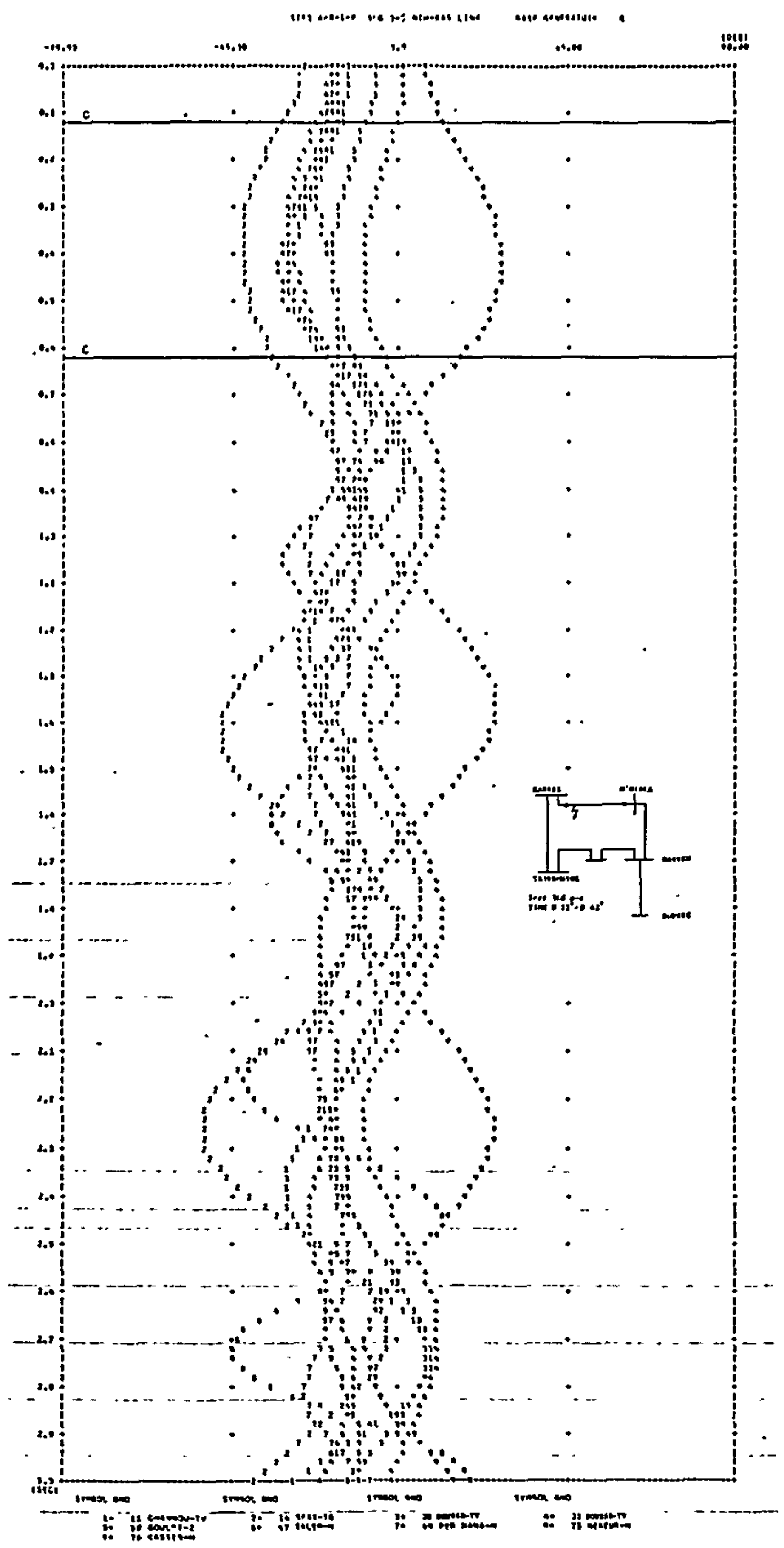


CHART NO.5
Case A-8-1-P KASSEB-M'NIHLA·O-C



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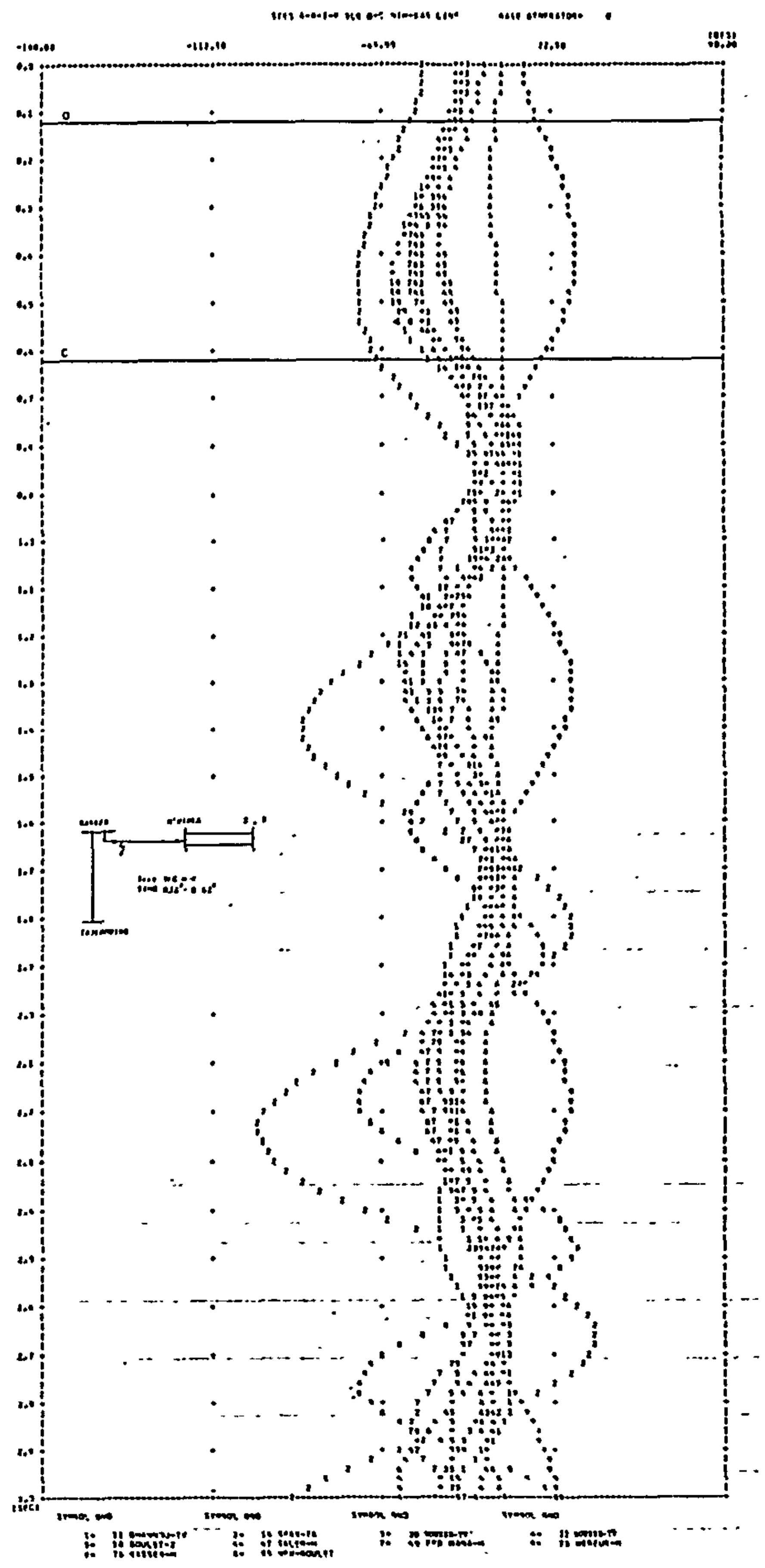

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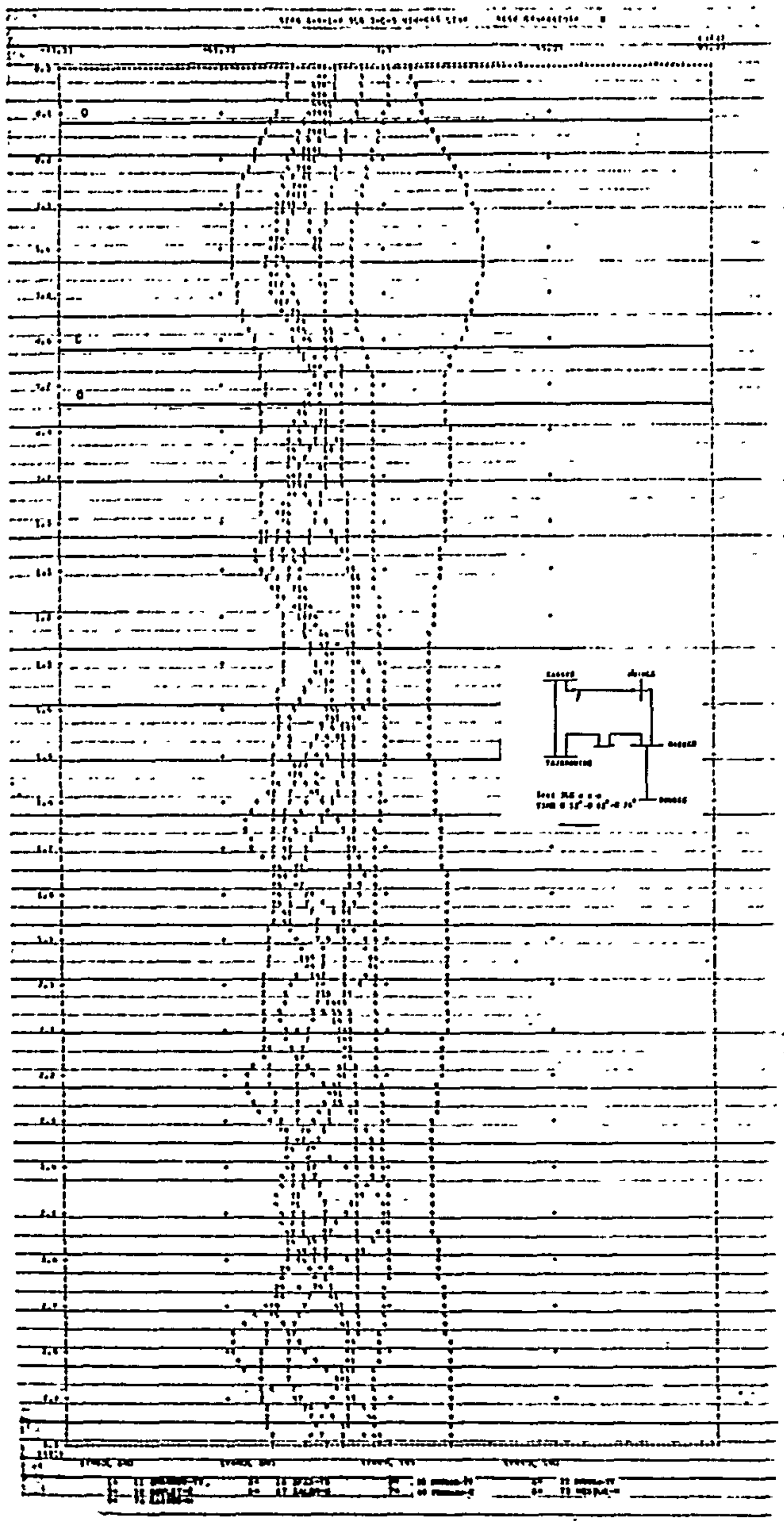

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Case A-8-2-P KASSEB-M'NIHLA O-C-O

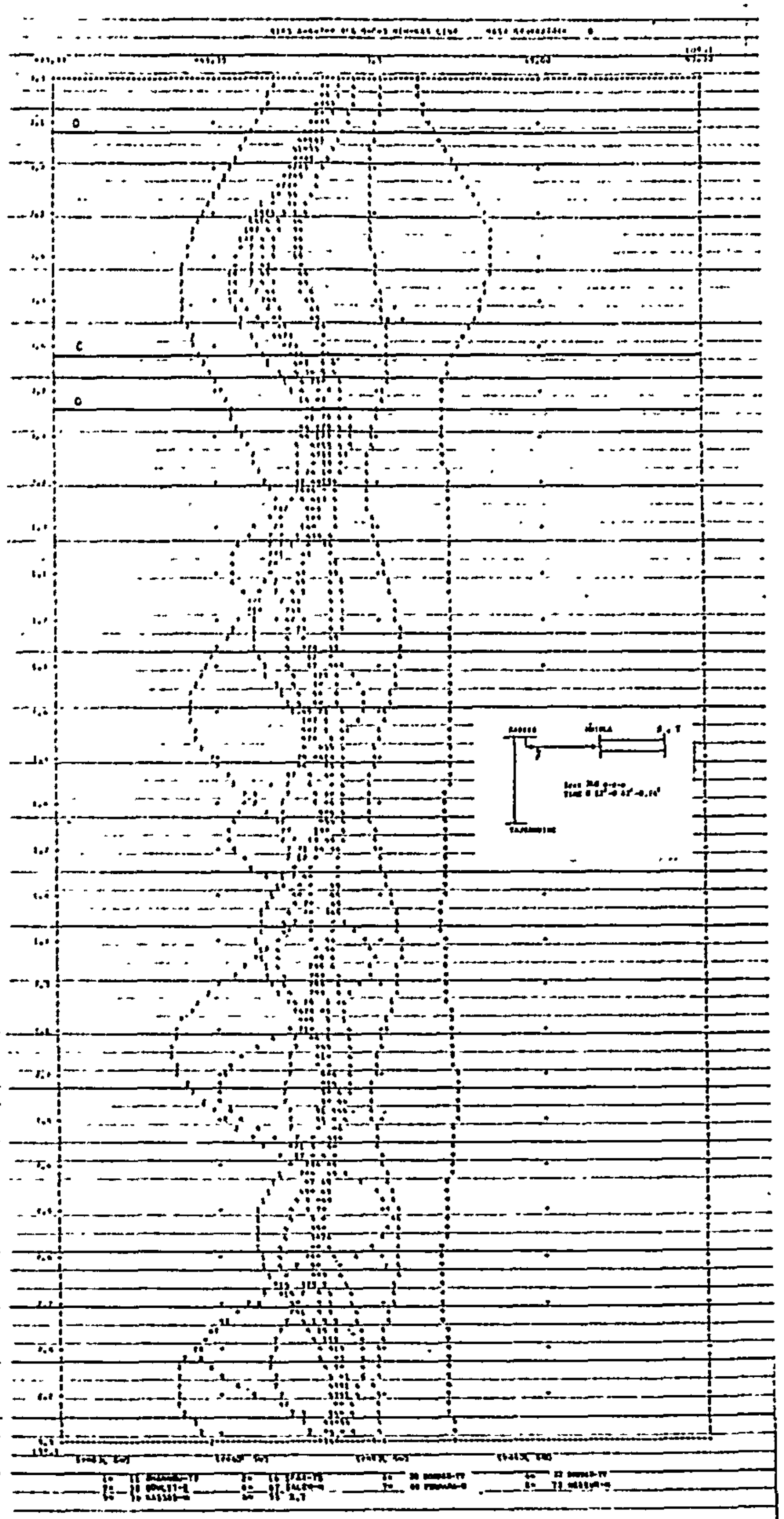
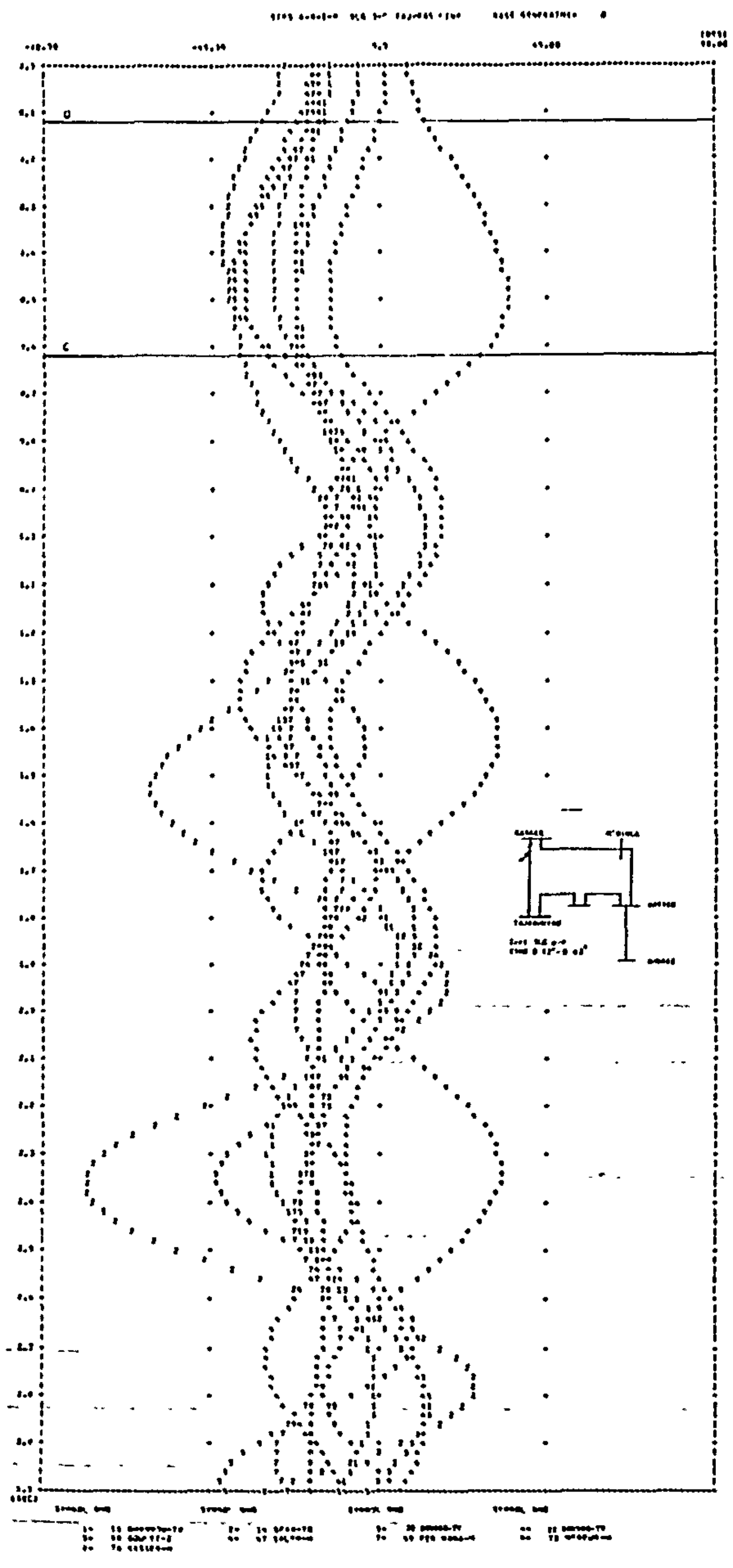


CHART NO.9
Case A-8-1-P KASSEB-TAJEROUINE O-C



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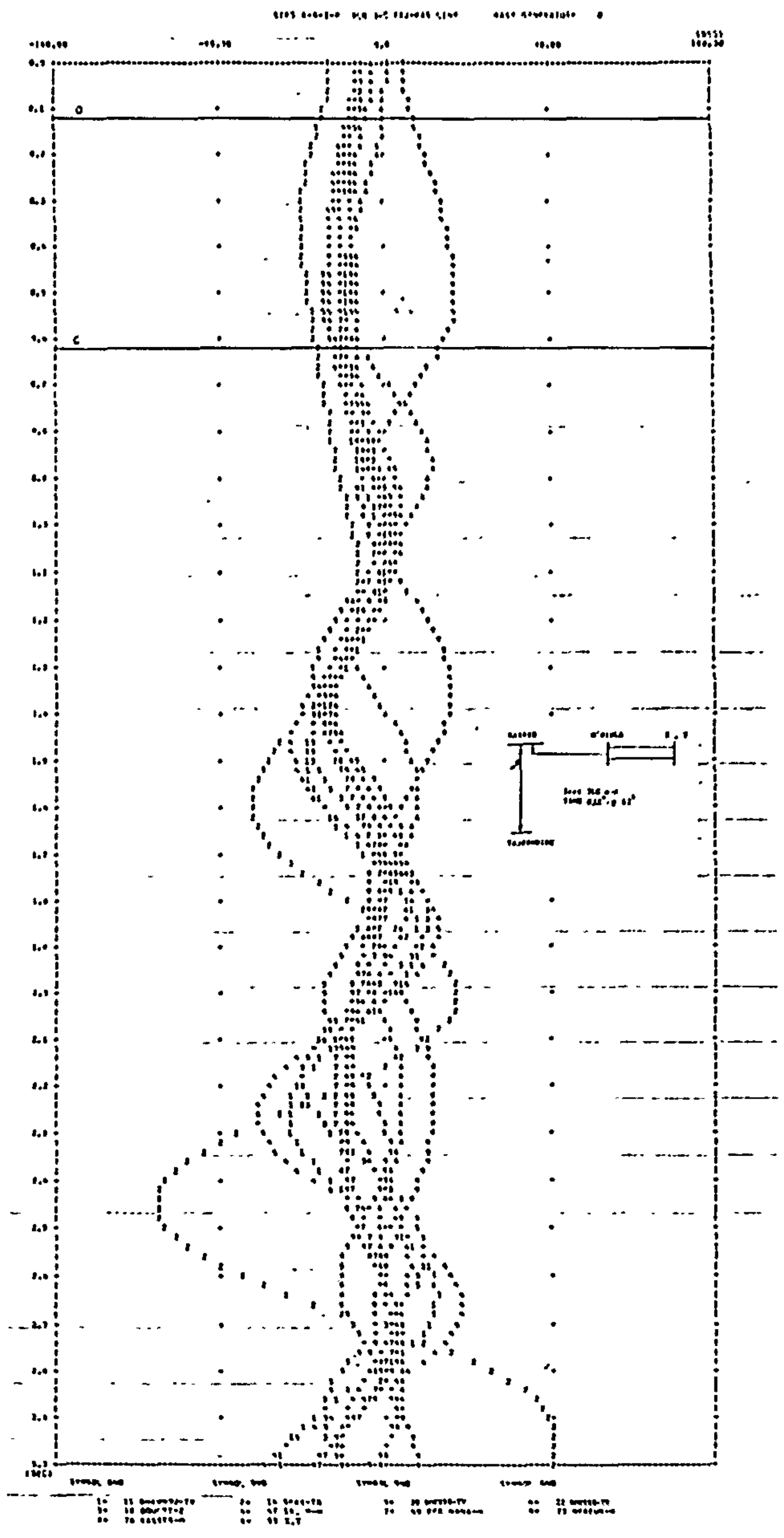

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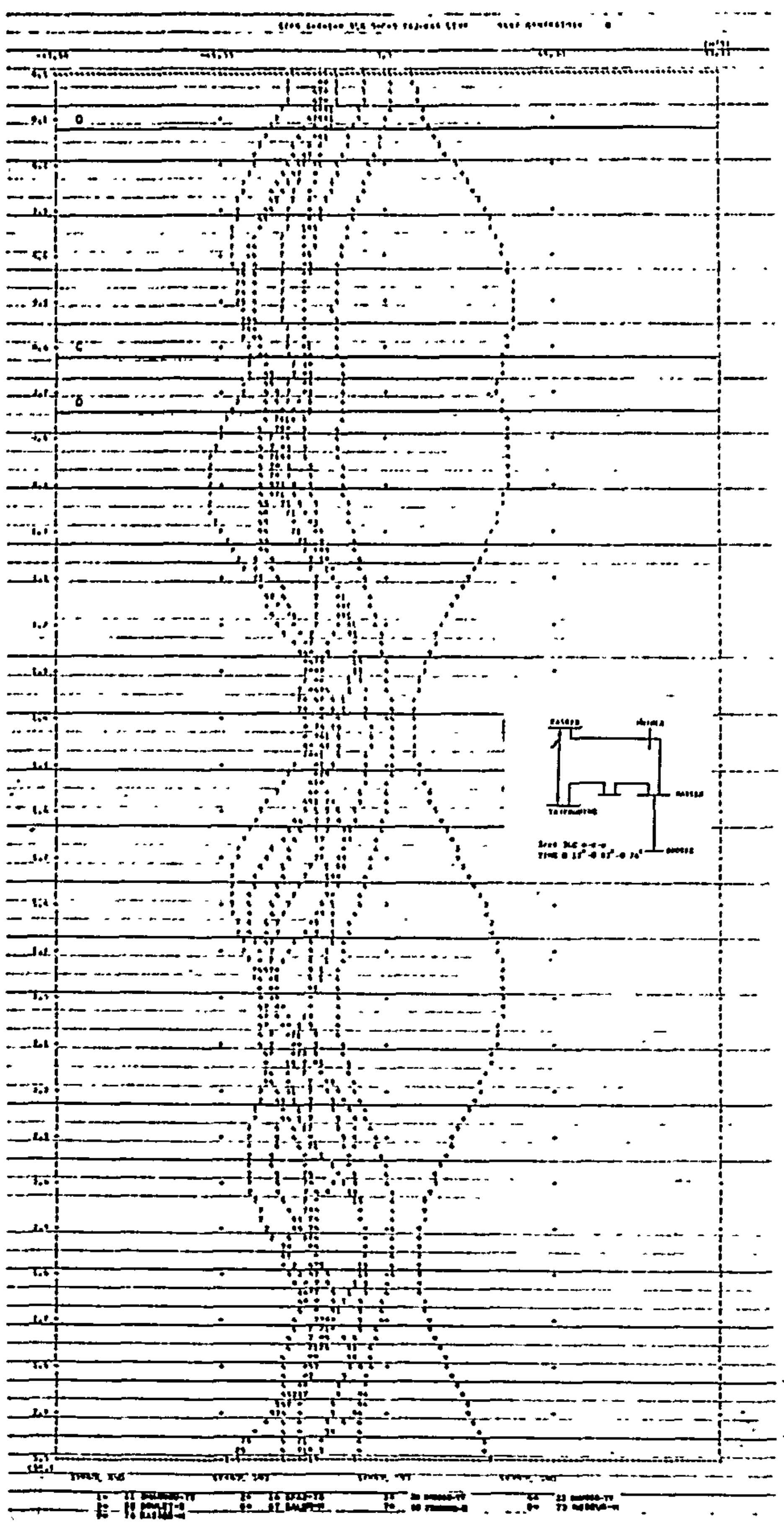

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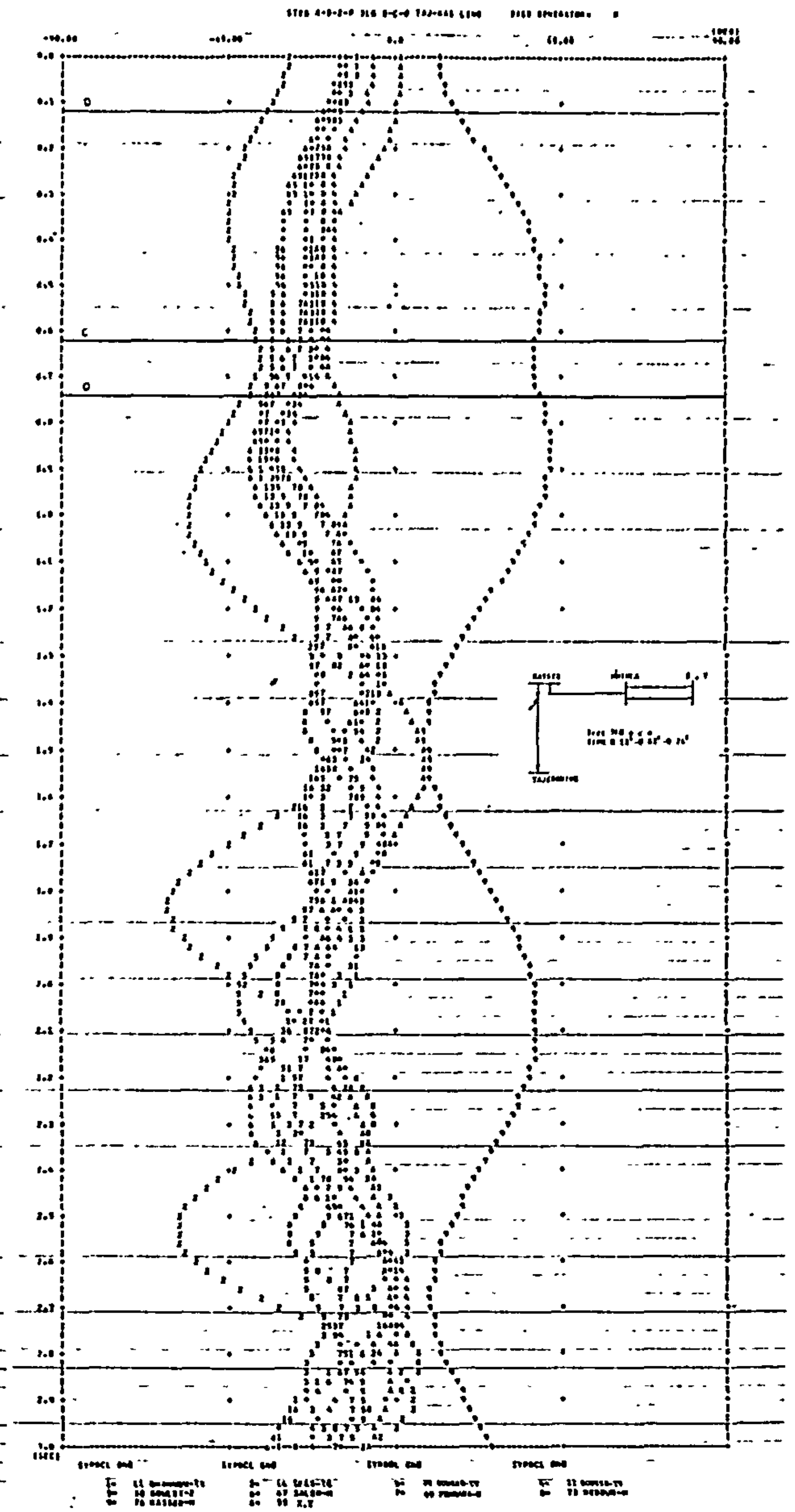

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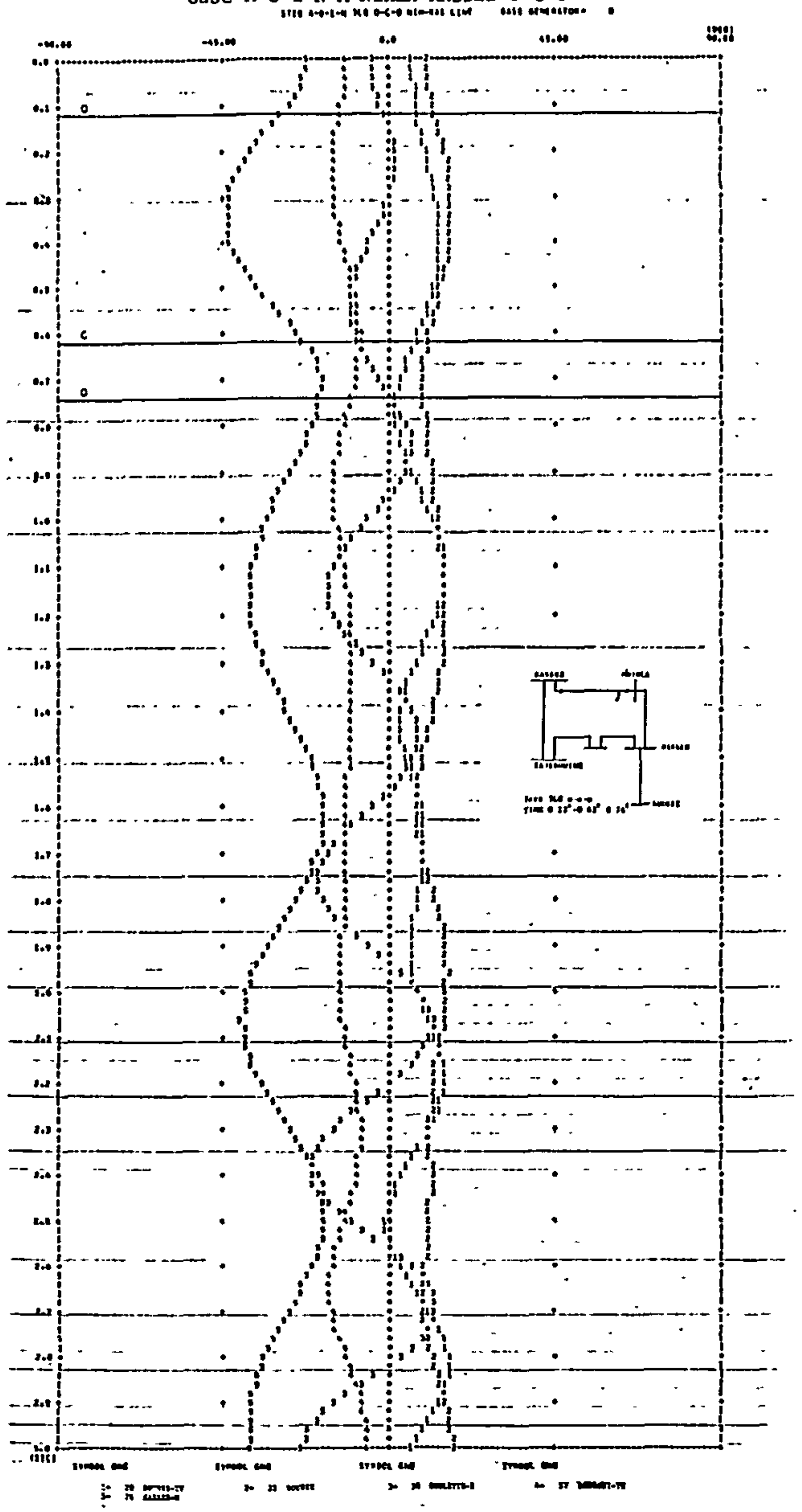

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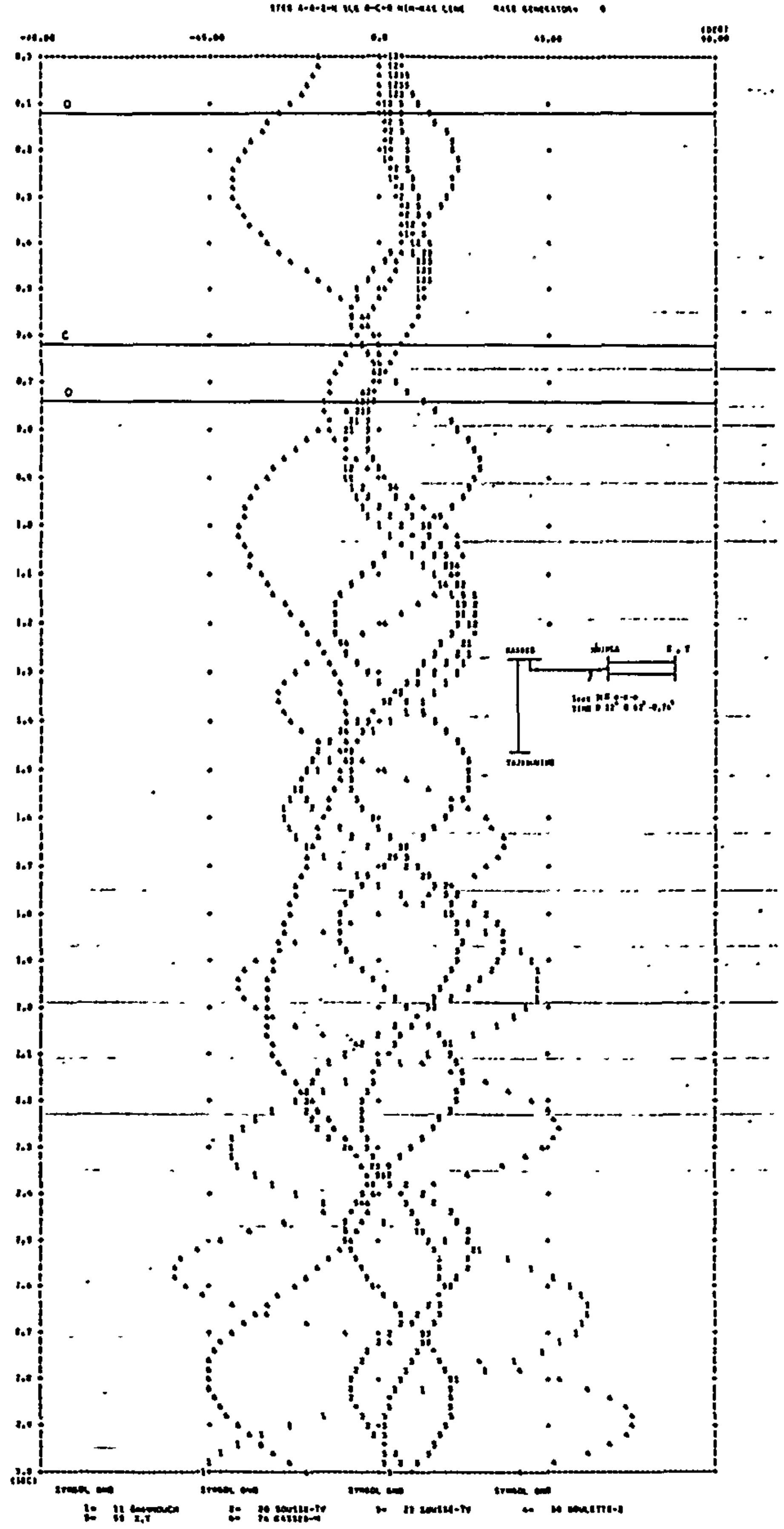

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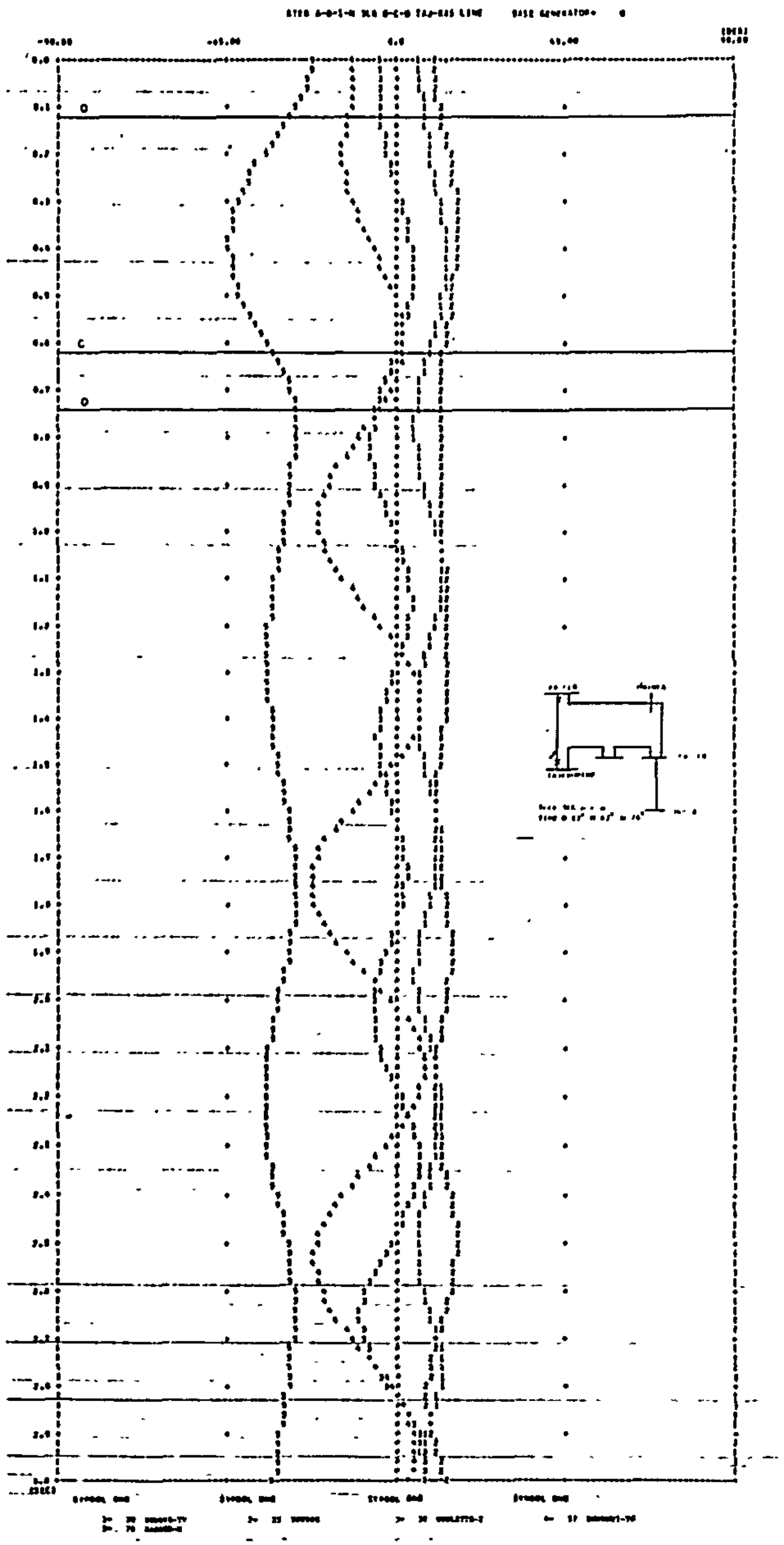

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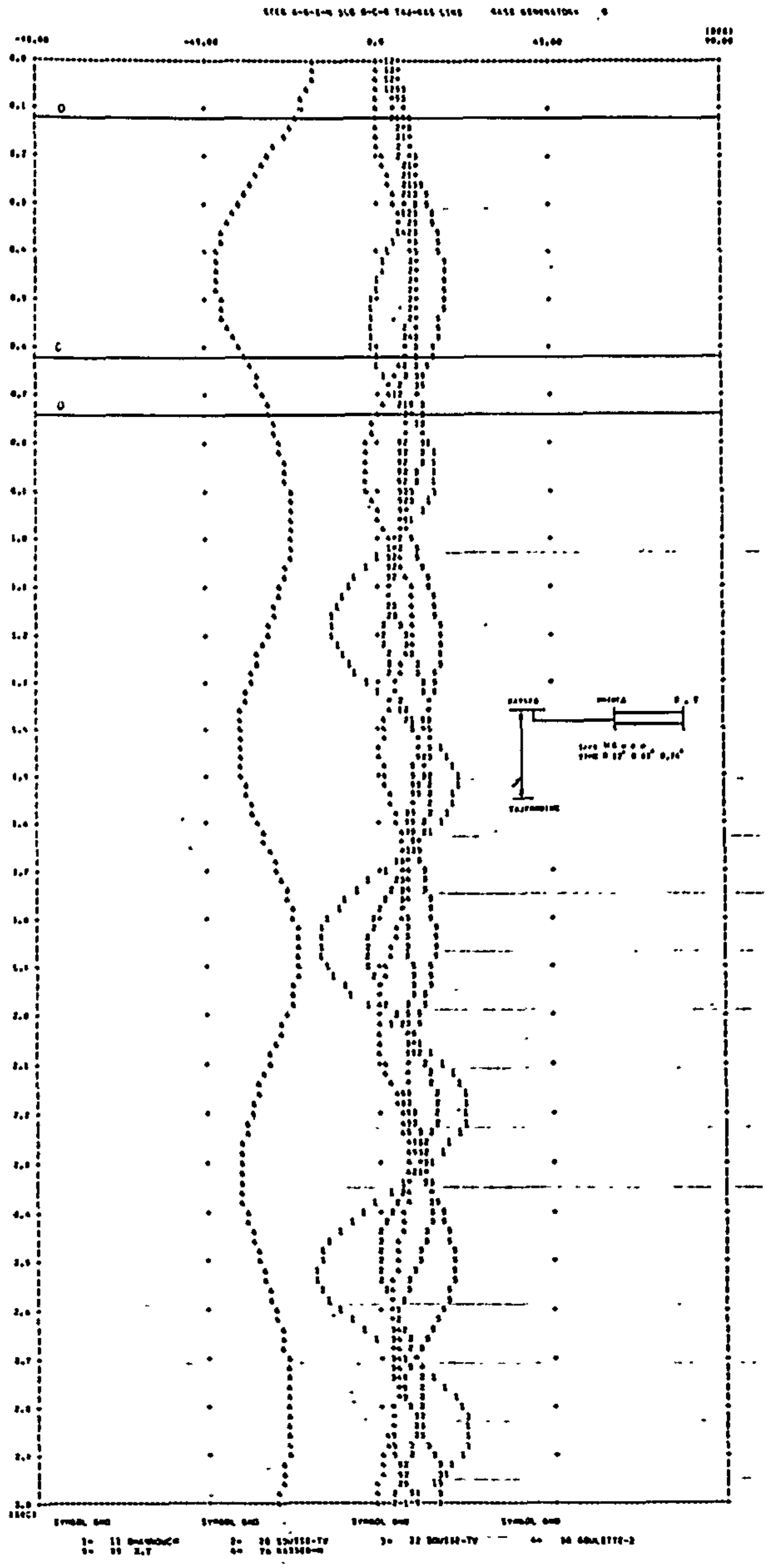

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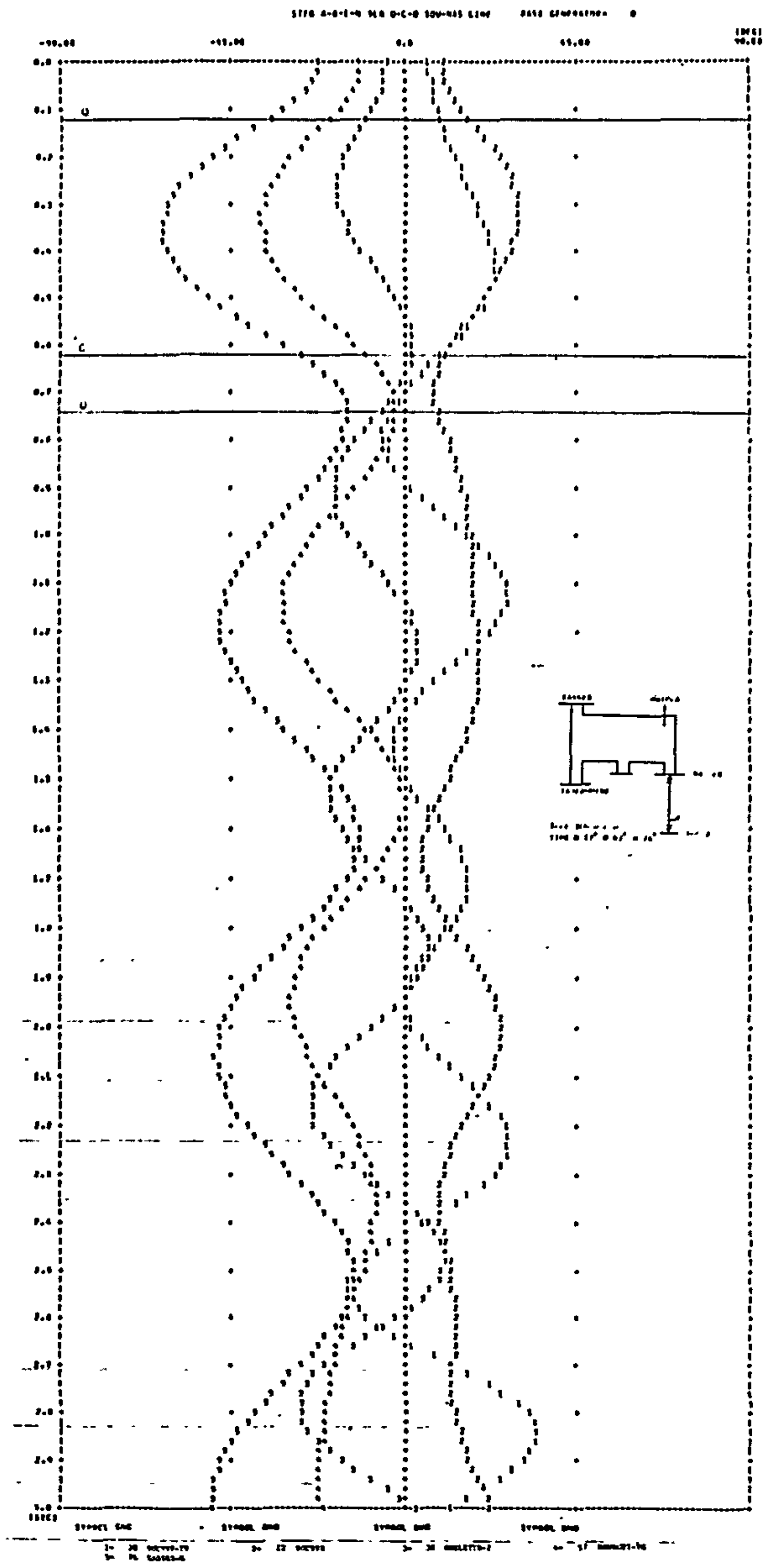

CHART NO.18
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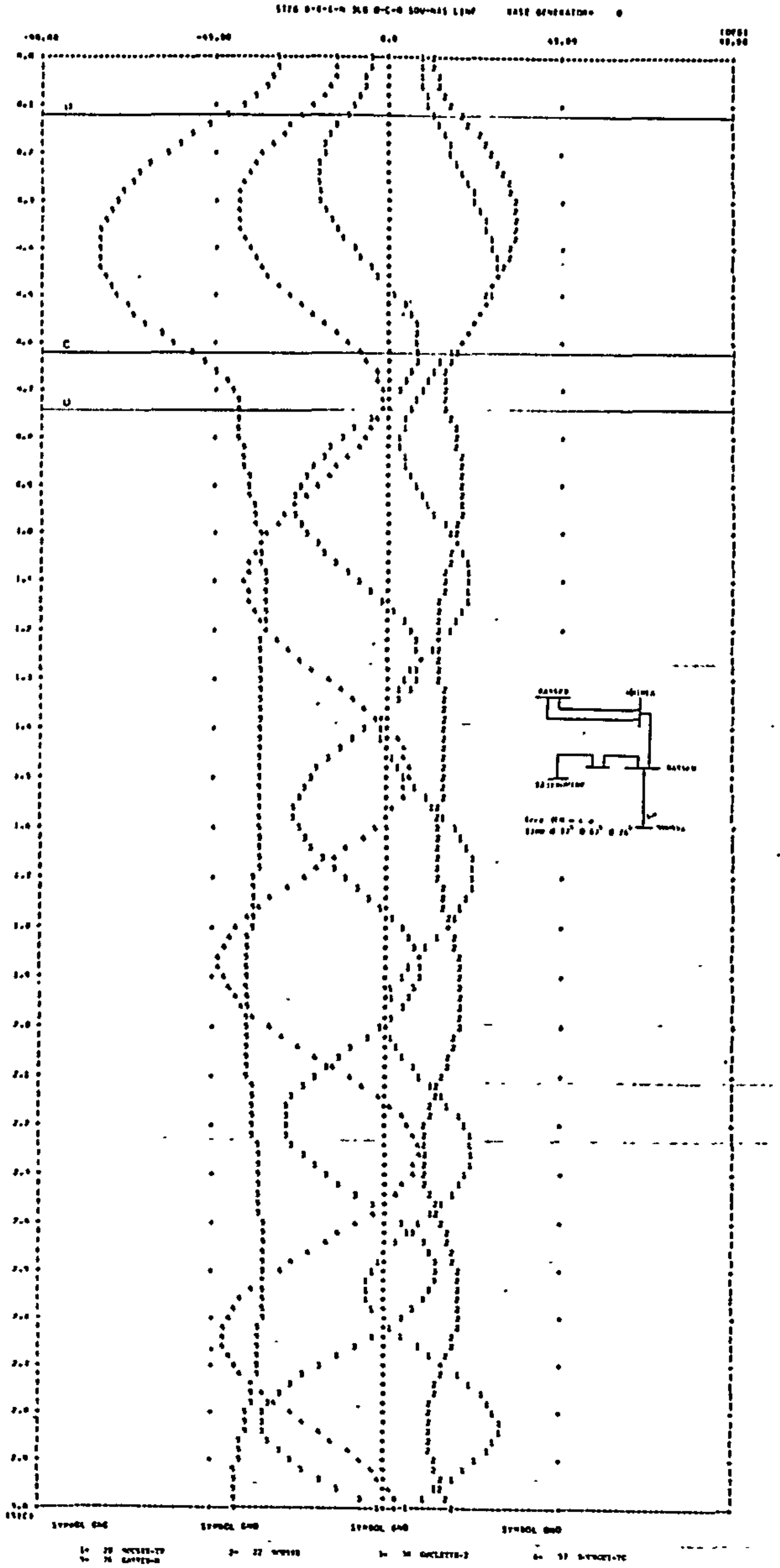

CHART NO.19
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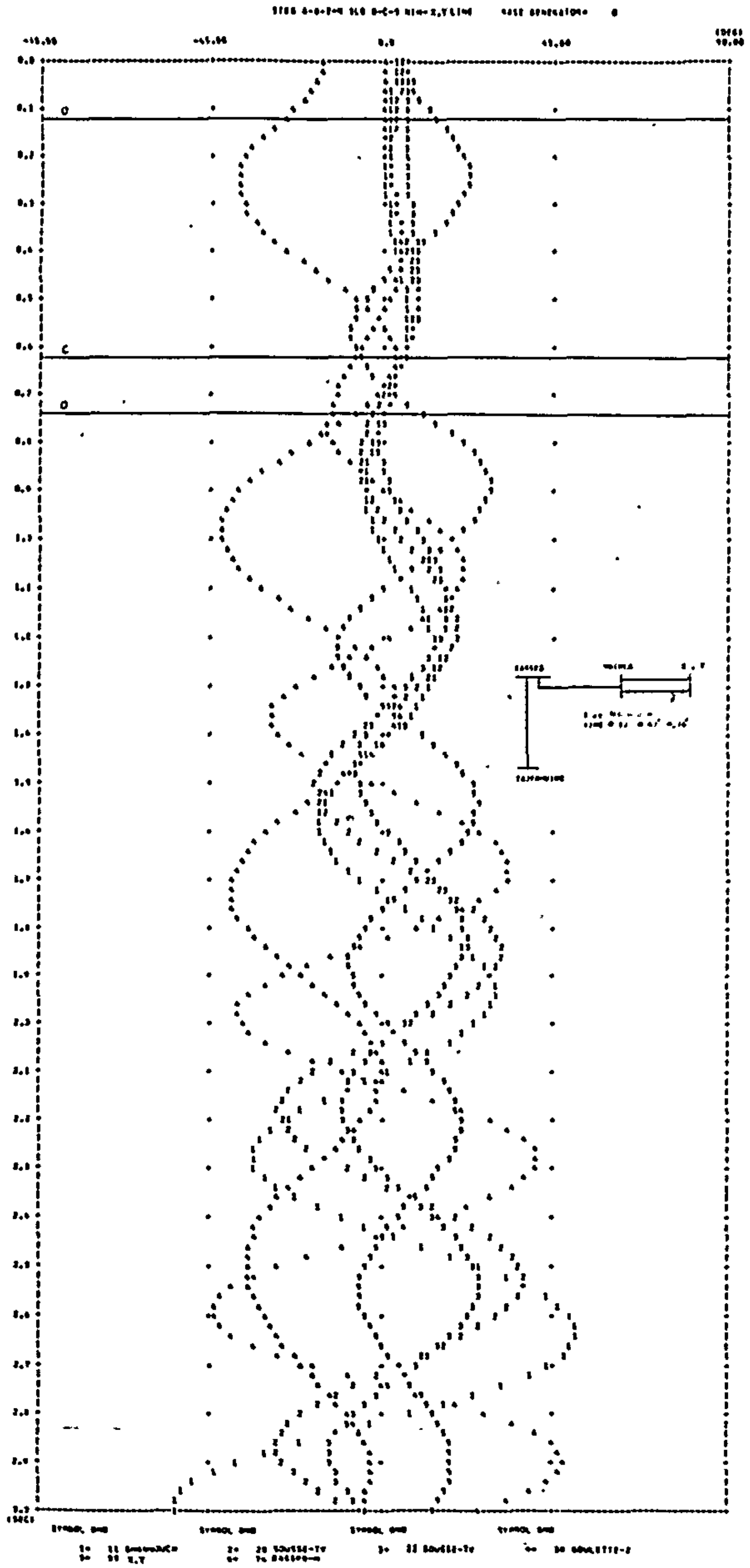

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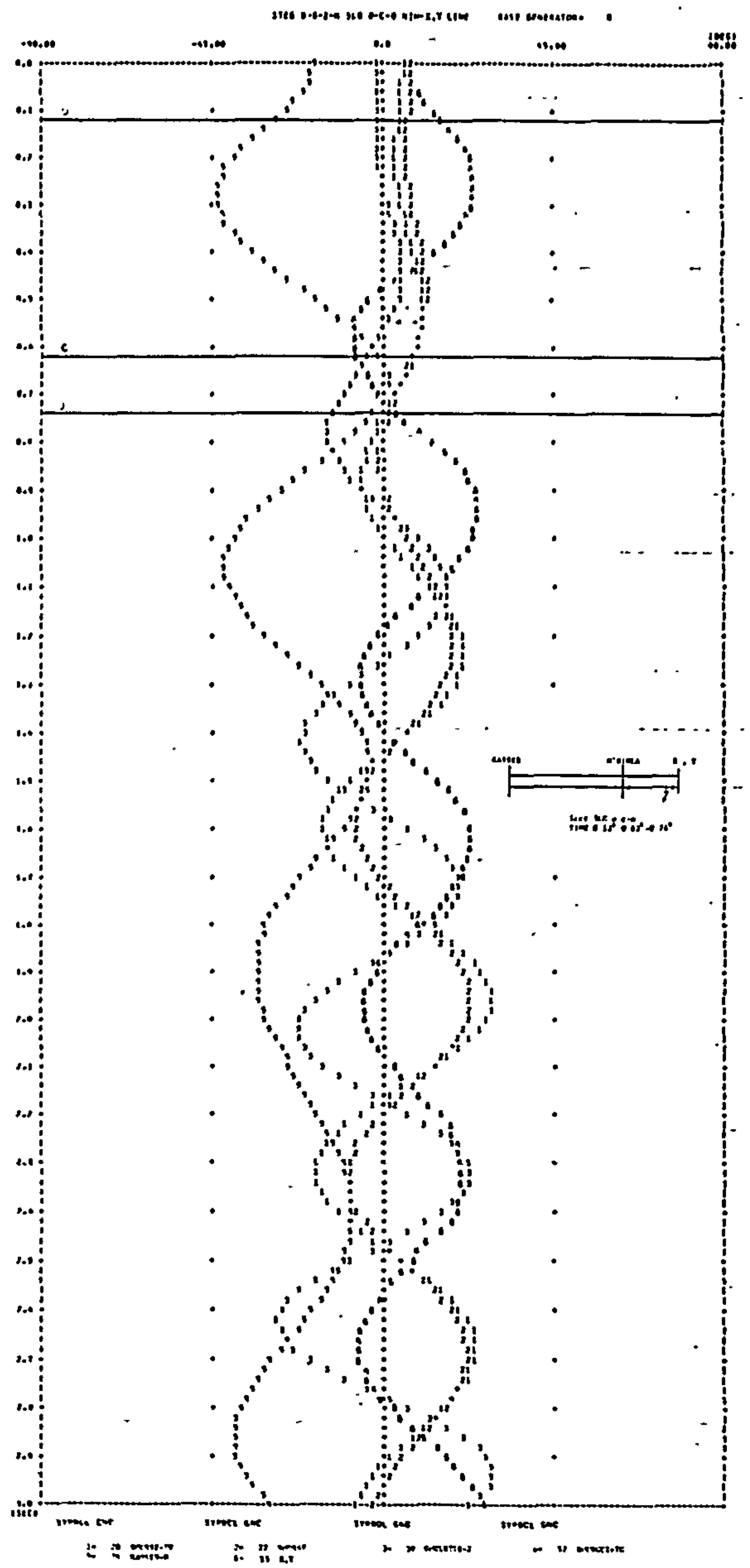

CHART NO.21
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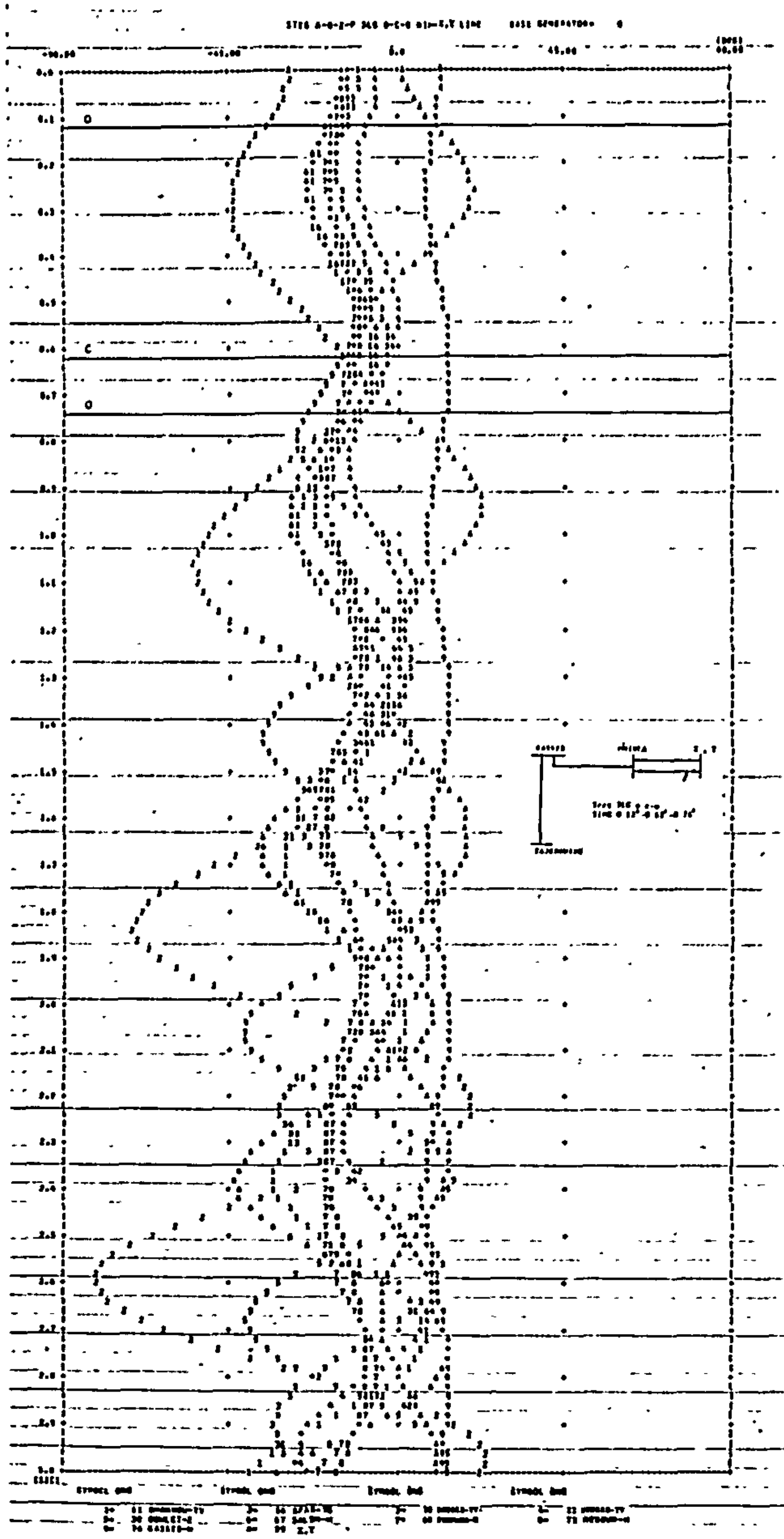
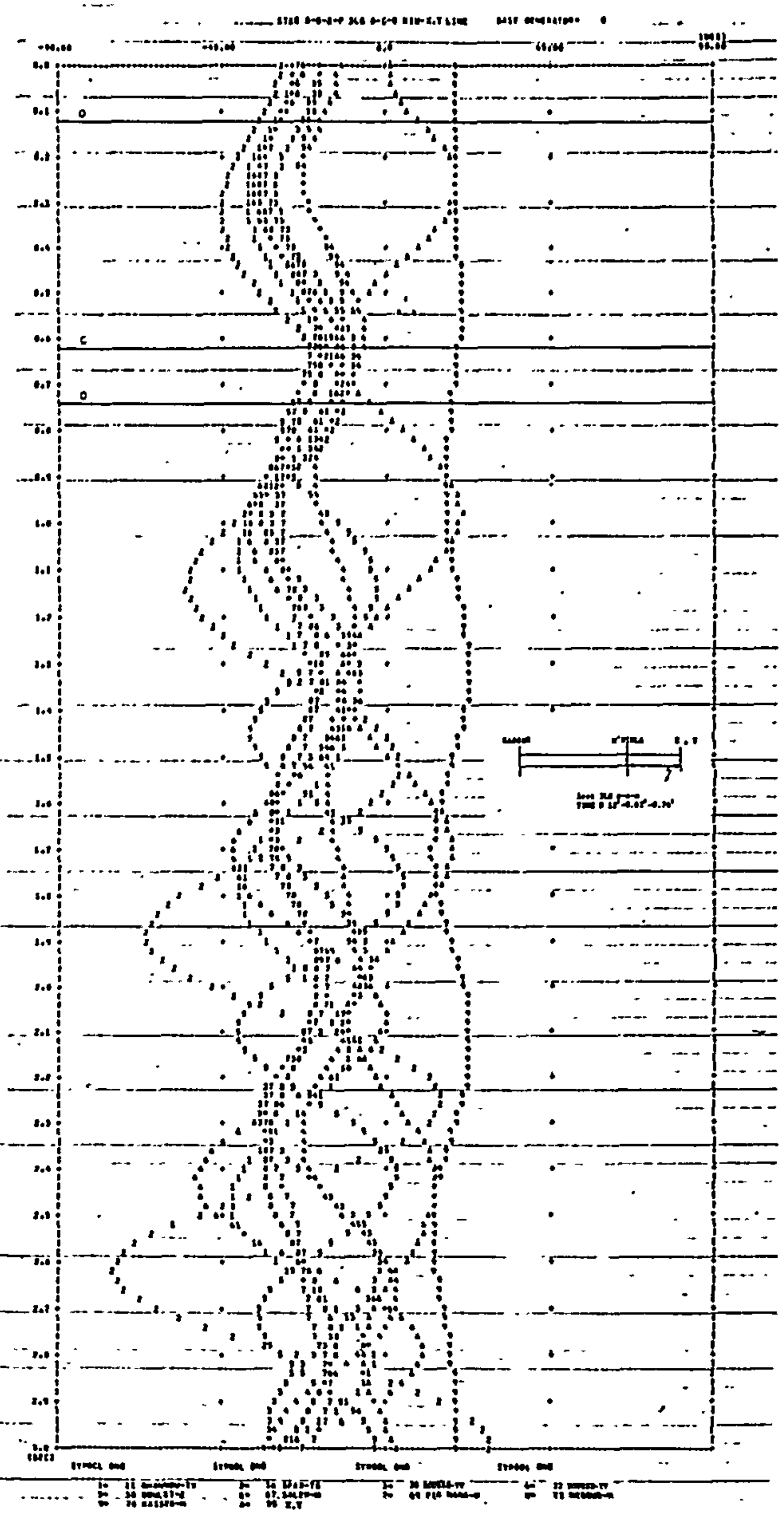


CHART NO.22
Case B-8-2-P X,Y-M'NIHLA O-C-O



A—4

ACTUAL DATA ON INFLOW, PRECIPITATION, POTABLE WATER, DISCHARGE WATER OF GENERATION AT EXISTING KASSEB RESERVOIR

S. T. E. G.

DPP - 14 A-4-(1) BARRAGE DE KASSEB

M O I S	1971	1972	1973	1974		1975		1976	
	Turbinage en m3	Turbinage en m3	Turbinage en m3	Turbinage en m3	Eau traitée en m3	Turbinage en m3	Eau traitée en m3	Turbinage en m3	Eau trait en m3
Janvier	1 006 160	3 198 300	3 738 260	3 035 360	0	0	1 721 160	0	2 509 92
Février	938 880	3 267 640	3 040 960	0	0	0	1 935 360	222 410	2 505 60
Mars	1 044 410	3 216 240	2 435 810	0	370 260	0	2 645 280	190 630	2 439 72
Avril	2 420 690	2 645 260	2 891 860	0	654 120	1 010 090	1 927 510	981 070	3 103 92
Mai	3 002 000	3 075 450	3 705 160	0	999 720	2 050 280	716 680	2 294 900	3 143 34
Juin	2 903 680	2 793 810	3 544 700	269 780	1 036 800	172 630	2 012 210	2 506 100	2 959 56
Juillet	2 526 650	3 168 060	3 850 290	0	864 900	1 198 180	1 987 100	2 413 790	3 214 08
Août	0	3 372 060	3 923 360	1 244 670	4 630 262	427 420	1 952 900	2 138 770	3 214 08
Septembre	2 855 680	3 488 800	3 477 570	0	2 286 360	564 590	1 975 570	2 221 080	2 737 17
Octobre	3 901 030	3 287 210	3 497 080	0	2 286 360	611 360	1 835 980	909 510	2 253 36
Novembre	3 308 310	3 232 130	4 142 220	0	1 519 200	82 400	1 413 040	2 220 040	2 632 32
Décembre	3 639 720	3 849 090	4 394 020	0	921 600	323 810	2 501 890	446 420	2 027 52
T O T A L	27 547 210	38 594 050	42 581 290	4 549 810	15 569 582	6 440 700	22 624 680	16 544 720	32 740 59

Nota :

- Le 1/11/70 : mise en service industriel de la Centrale hydro-électrique de Kasseb
- Le 1/3/74 : mise en service industriel de la station de traitement des eaux potables de Kasseb

S. T. E. G.
DPP-14

MSI/SB
Le 23-2-77

A-4-(2)

BARRAGE DE KASSEB

Pluviométrie et Apports de 1968 - 1969 à 1975 - 1976

Mois	1968 - 1969		1969 - 1970		1970 - 1971		1971 - 1972		1972 - 1973		1973 - 1974		1974 - 1975		1975 - 1976	
	Pluviométrie en mm	Apports en 10^6 m3	Pluviométrie en mm	Apports en 10^6 m3	Pluviométrie en mm	Apports en 10^6 m3	Pluviométrie en mm	Apports en 10^6 m3	Pluviométrie en mm	Apports en 10^6 m3	Pluviométrie en mm	Apports en 10^6 m3	Pluviométrie en mm	Apports en 10^6 m3	Pluviométrie en mm	Apports en 10^6 m3
SEPTEMBRE			81,50	0,542	19,25	0	58,00	0,188	79,95	0,060	14,20	0	16,50	0,078	3,20	0,237
OCTOBRE			193,83	7,612	56,72	0,200	109,97	1,860	51,35	0	86,45	1,727	94,12	1,170	26,60	0,073
NOVEMBRE			12,20	1,247	9,50	0	31,00	0,337	3,50	0,101	2,10	0,121	152,46	13,358	166,50	4,770
DECEMBRE			237,55	33,315	109,12	4,203	31,40	1,488	44,80	0,097	37,20	3,212	37,90	4,682	55,00	5,575
JANVIER			65,91	4,732	143,13	34,605	117,20	9,640	157,65	14,625	5,50	0,035	12,45	0,583	35,10	2,591
FEVRIER	75,40	0,780	65,70	6,247	150,15	67,355	96,25	9,815	100,25	10,158	108,10	5,480	112,40	11,770	65,40	6,734
MARS	19,40	1,620	45,50	9,469	73,90	35,500	35,50	3,728	133,60	31,235	92,30	5,872	43,60	3,894	89,80	9,170
AVRIL	50,85	4,402	29,50	1,174	58,65	26,302	73,80	5,855	29,50	6,672	35,60	3,576	19,00	1,182	33,10	1,709
MAI	0	0,620	30,50	0,244	48,35	1,130	20,75	0	0	0	3,50	1,044	75,90	2,560	32,10	2,721
JUIN	0	0,062	0	0,464	3,00	0,067	9,25	0,278	22,00	0,217	0	0,388	0	0,918	39,50	0,822
JUILLET	0	0	0	0,341	1,50	0,193	0	0,194	0	0,549	2,50	0	0	0,275	48,10	0,706
AOUT	11,10	0	0	0,332	0	0	4,70	0,370	0	0,156	0	0,308	2,25	0,529	32,80	0,418
TOTAL	156,75	7,484	762,19	65,719	673,27	169,555	587,82	33,753	622,63	63,860	387,45	21,763	566,58	55,287	627,20	35,526

NOTA : (1) Pluviométrie mesurée à l'emplacement du Barrage
(2) Le Barrage de Kasseb a été mis en eau en Février 1969

A—5

DATA AND INFORMATION USED FOR PREPARATION OF THE REPORT

A-5 Data and Information Used for Preparation of the Report

No. of data & reference books	Titles	Remarks
1	Repport Sur le Budget Economique 1977	
2	V^e Plan (1977–1981) Sous-Comite de L'electricite	5 Years Plans of STEG
3	Installations de la STEG a Gabes	Generating facilities installed around Gabes
4	Amenagement Hydro-Electrique de Korbous	Sea water pumped storage power project
5	ditto	Drawings
6	Tunisia moves ahead	Introduction to Tunisia
7	Centrale D'Accumulation par Pompage de Kasseb (TECSULT Report) Vol. 1, 2 & 3	
8	Activites et Comptes de Gestion 1975 de la STEG	Annual report of STEG 1975
9	Societe Tunisienne de Banque (exercice 1975)	
10	ditto (exercice 1974)	
11	L'Investissement Industriel En Tunisie 1976	
12	Rapport Annuel Banque Centrale de Tunisie 1975	
13	Made in Tunisia 2 Guide des industries tunisiennes	Publicated in 1976
14	Industrial Investment in Tunisia by Investment Promotion Agency	
15	La Tunisie économique Février 1977 No. II	
16	Annuaire Economique de la Tunisie 1975 ~ 1976	
17	Véme Plan de Developpement Economique et Social 1977~1981 vol. 1	National development plan of Tunisia 5 years plan Vol. 1
18	ditto Vol. II	ditto, Vol. 2
19	Special System Applicable to Exporting Industries	
20	The Industrial Investor's Guide to Tunisia	
21	Social Legislation for Workers and Labour Costs in Tunisia	
22	Law 74-74 of 3 August 1974 Relative to Investments in The Manufacturing Industries (Producing for the Tunisian Market)	
23	Pamphlet for introduction to Tunisia	12 volumes
24	Geographical maps for Kasseb Project prepared by STEG	

No. of data & reference books	Titles	Remarks
25	Drawings related with existing Kasseb dam and its actual water level curves	
26	Topographical maps to 1/50,000 related with Kasseb Project (6 sheets)	Index map attached to the maps.
27	Topographical maps to 1/500,000 (2 sheets)	
28	Technical data related with Kasseb Project prepared by STEG's construction department	
29	ditto (translated to English)	
30	Topographical data on Kasseb Project prepared by STEG	
31	Aerophotography of Kasseb project site (3 sheets)	
32	Maps of Tunisia prepared by Michelin and Hallwag	
33	Outline of Sidi-Salem Hydro Power Project, Oued Bou Heurtma Dam	
34	Data and information of power demand forecast (1977–1981) Load curves estimated by STEG Maximum demand Past record on power demand	
35	Miscellaneous data Elfouladh Iron steel, March 1974 STIR Pamphlet STEG National Dispatching	
36	Annual Year Book 1975 prepared by United Nations	
37	Caracteristiques des Turboalteuro Existants DPE01 MDI/AL 17, 2, 7.	14 sheets
38	Caracteristiques des Lignes 90kV DPE01 MDI/BD 25, 6, 76	4 sheets
39	Caracteristiques des Transformateurs DPE01 MDI/OH 2, 7, 76	11 sheets
40	Caracteristiques de Transformateurs Futuro DPE01 MDI/OH 3, 2, 77	7 sheets
41	Central Thermique, Goulette II	