No. 2

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

NATIONAL ELECTRIC POWER CO. (NEPCO)
THE HASHEMITE KINGDOM OF JORDAN

THE STUDY ON ELECTRIC POWER LOSS REDUCTION OF TRANSMISSION AND DISTRIBUTION NETWORKS IN THE HASHEMITE KINGDOM OF JORDAN

FINAL REPORT

SUMMARY

MAY 1997

TOKYO ELECTRIC POWER SERVICES CO., LTD.

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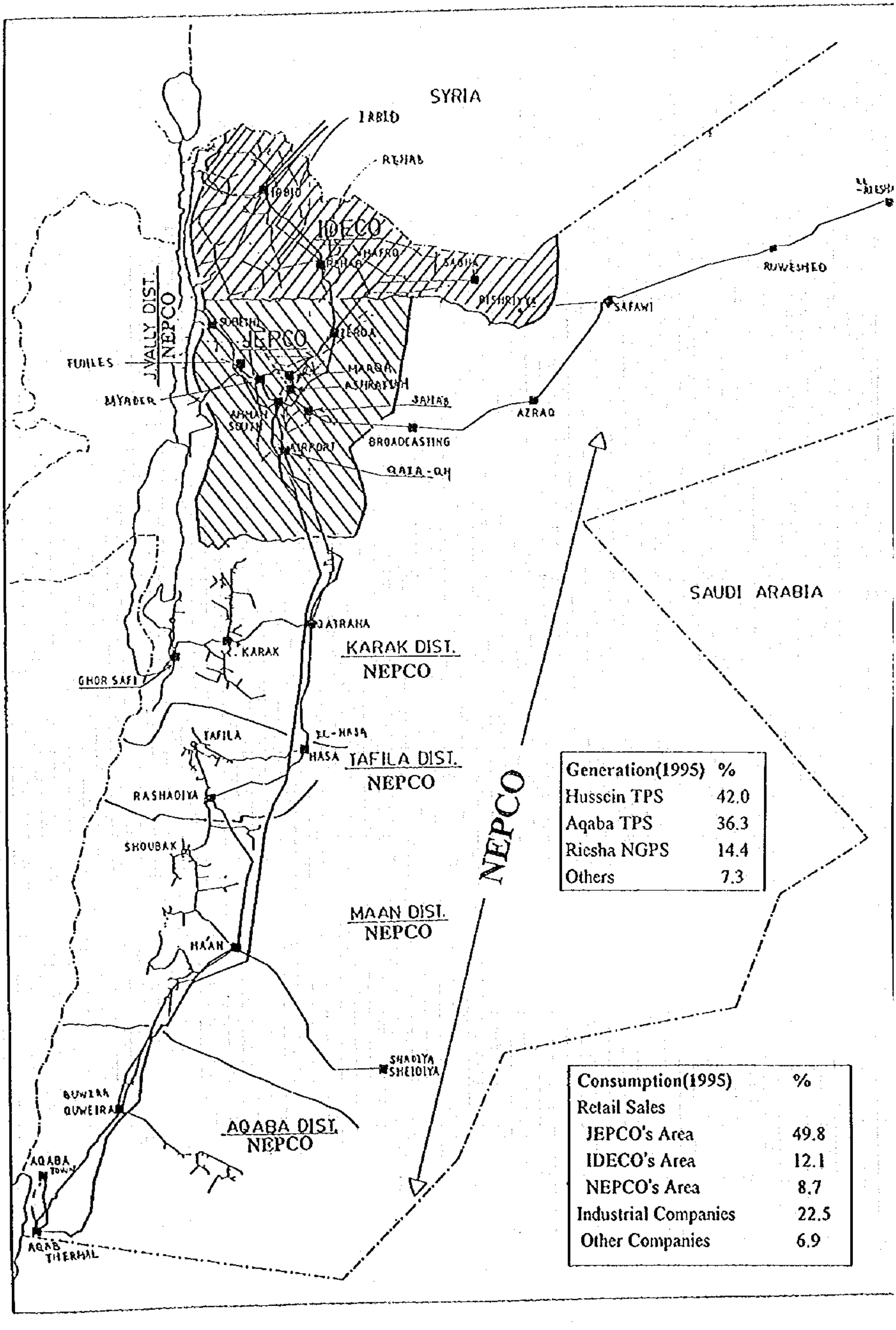

Generation(1995)	%
Hussein TPS	42.0
Aqaba TPS	36.3
Riesha NGPS	14.4
Others	7.3

Consumption(1995)	%
Retail Sales	
JEPCO's Area	49.8
IDECO's Area	12.1
NEPCO's Area	8.7
Industrial Companies	22.5
Other Companies	6.9

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OUTLINE OF THE FORMULATION OF TRANSMISSION AND DISTRIBUTION POWER LOSS REDUCTION PLAN

1 Flow of the Study

(1) Present situations of transmission and distribution loss throughout Jordan

The transmission loss rate and distribution loss rate in 1995 was 2.0 % and 7.4% respectively and the total network loss was 9.4%, according to the annual report of NEPCO. The measurement and calculation of representative LV(Low Voltage) feeders were implemented under this study for the purpose of sorting out the distribution loss into the LV loss and the MV(Medium Voltage) loss. The result showed that MV loss rate and LV loss rate were as 2.2% and 5.2% respectively. These facts indicate that a large portion of the transmission and distribution loss as the objective of reduction is taking place in the distribution systems especially in the LV distribution systems.

(2) The systems chosen as objective of the studied

The JICA Study Team narrowed the study down to the power loss reduction in the LV and MV distribution systems and proposed as a master plan, basing itself on the assumption that any power loss reduction countermeasure should bring about justifiable economic benefits.

(3) The approach to the optimum power loss reduction plan

Since there are nearly 20,000 LV feeders in Jordan, it is entirely impossible to study all of the individual feeders. A sample study method was selected, therefore, for estimating the potential of loss reduction in entire power system.
Firstly, 81 feeders from the LV system and 14 feeders from the MV system were selected as "Sample-1" system. Then they were minutely analyzed by means of software provided by the JICA Study Team. The relation between the feeder current, and cost of power loss reduction were converted into a mathematical model based on the result of the above analysis. Secondly, this mathematical model had to be applied to the entire power systems of Jordan. Two percent (2%) of the entire distribution substations in Jordan was selected by a random sampling method. The LV feeders which were connected to those substations, and all feeders in the 33 kV system were chosen as sample-2". Then the potential of feasible

countermeasures (wherein the benefit exceeds the cost) has been estimated regarding the entire relevant systems, based on the mathematical models.

(4) The priority order of the power loss reduction countermeasures

The three kinds of loss reduction countermeasures are implemented according to the priority order as shown below:

1) The reduction of the unbalanced current in the LV feeder is implemented as the top priority, as it is effective in the loss reduction and does not require any investment.

2) The power factor improvement in the system by installation of capacitors brings about high investment efficiency (high B/C value). The installation is promoted within the limit of not causing over-compensation at the time of light load.

3) As the above two methods will not yield big enough volume of loss reduction, the plans of new line construction should be considered in addition to these two methods. Such plans should be chosen, in principle, from those with bigger value of B/C.

(5) Target fiscal years and annual allocation of the power loss reduction plans

The target year was set to start from 1999 and to end in 2008, allowing two years of preparatory period after 1997 when this study will come to an end.
The work execution period was formulated based on the load conditions in 2008 and annually allocated along with the priority order of Item (4) above and taking into account the scale of benefits, averaging of work volumes and other conditions.

(6) Setting of alternative countermeasure plans

With regard to the potential of the overall power systems in 2008 obtained in Item (3) above, 94.1 MW of power loss is estimated to be reduced with the net cost of JD 6357 million, excluding price escalation and so forth. The alternative plans A, B, C, D and E were formulated on the basis of this potential.

2. Outline of the Plan

The outline of the five alternative plans are as listed below:

Alternative plan		A	B	C	D	E
Capacitor installation	Capacity(MVA)	191	191	191	191	191
LV new line construction	No. of feeder	1,533	1,989	2,599	3,881	6,248
MV new line construction	No. of feeder	0	7	15	22	40
Total cost(1000 JD) for 10 years		20,000	30,000	40,000	50,000	63,570
Power loss reduction(MW) in 2009Y		48.0	61.0	73.5	84.8	99.0
Energy loss reduction rate to generation(%)		1.8	2.3	2.8	3.2	3.8
Estimated network loss rate to generation(%)	Without project 11.0%	9.2	8.7	8.2	7.8	7.2

Meanwhile, the estimated network loss rate of 7.2 % of the plan E is deemed to be the virtually optimum power loss rate.

3. Economic Evaluation and Financial Analysis

According to the results of economic and financial analysis, all the Alternative works are feasible both in the economic and financial viewpoints.

Evaluation values of five alternative plans are listed below.

Summary of Results of Economic and Financial Analyses

Alternative Plan		A	B	C	D	E
Economic Evaluation	EIRR	24.91	20.08	17.80	16.45	15.04
	B/C	1.99	1.63	1.45	1.34	1.23
	B-C (1000JD)	11,155	10,687	10,195	9,604	8,142
Financial Evaluation	FIRR	15.73	12.80	11.36	10.33	9.27
	Net surplus (1000JD)	98,820	117,271	134,097	145,068	154,896

4. Recommendations

The alternative plans proposed in this Study are highly significant in eliminating the waste of valuable natural resources and reducing environmental pollution from a global point of view. Also from economical and financial point of view, these plans are so excellent as to contribute significantly in improving the economical structure of the nation and financial situation of the respective companies.

Out of the five alternative plans, the Plan E is recommended to be adopted by Jordan power sector, since this plan certainly makes it possible to realize an optimum power loss rate in Jordan, and will bring the largest net benefit among the five plans.

The following items should be considered for execution of loss reduction project.

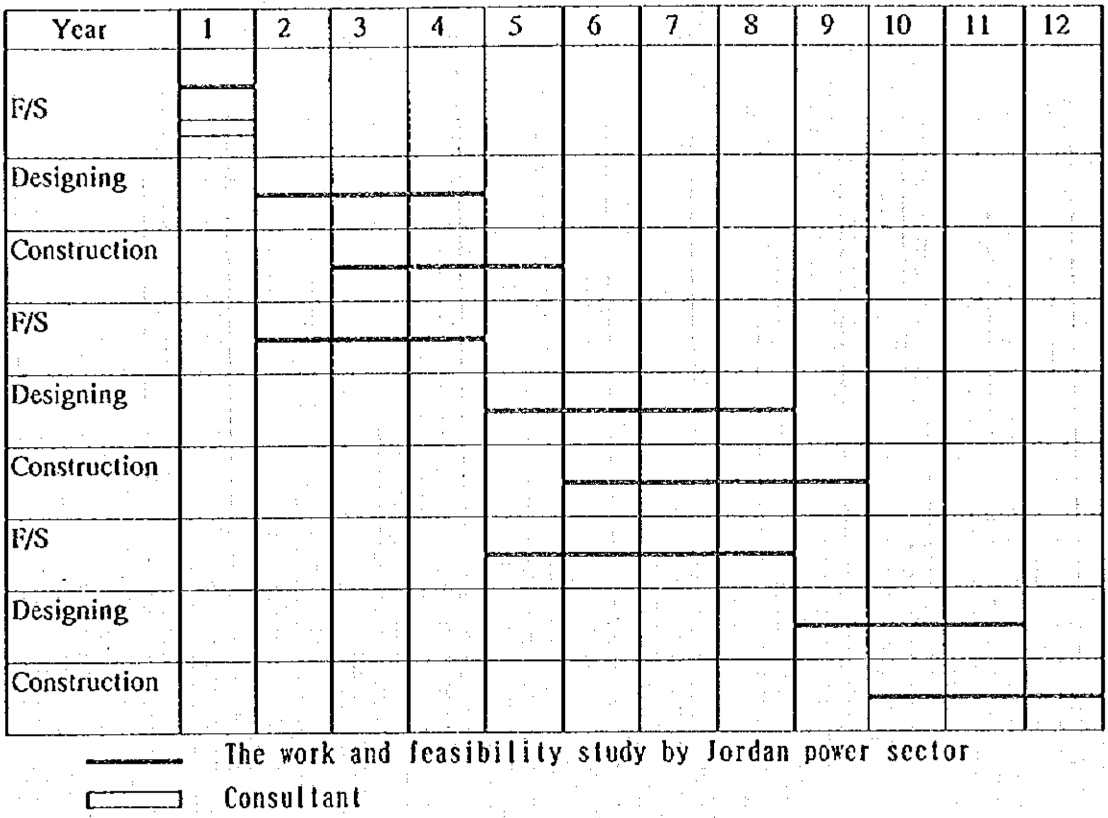
(1) The improvement of the three phase unbalanced current is recommended to be executed at the very beginning, regardless of financing from outside, as it does not require any investment.

(2) In the second place, the improvement of power factor by installing capacitors in the LV system is recommended to be executed by self-financing or local bank loan, because it is executable with a low investment of less than one million JD.

(3) The quantity of loss reduction by improvement of the three-phase unbalance current and improvement of power factor is not sufficient. The loss rate in 2009 will certainly increase by the load growth, if no additional countermeasures are adopted. New line construction countermeasure is recommended to be executed, because it is indispensable to realize loss reduction throughout Jordan.

A large amount of investment and a large volume of work for feasibility study are required for execution of this countermeasure. Besides, efforts to obtain loans from foreign countries may also be required. The outline of schedule of feasibility study and construction work is proposed as the table shown below.

Outline of Schedule for the Program



(4) For smooth and efficient execution of loss reduction program, development of small capacity LV capacitor and study for high conductance line such as multi circuit line, big size conductor line or multi conductor line are recommended.

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

In the Hashemite Kingdom of Jordan, the majority of power generation and transmission is undertaken by the National Electric Power Co. (hereinafter referred to as "NEPCO") [which was renamed and reorganized from the Jordan Electricity Authority (JEA) on September 1, 1996], and power distribution in the areas other than the supply areas of NEPCO are undertaken by two private electric power companies [Jordanian Electric Power Co. (hereinafter referred to as "JEPCO") and Irbid District Electricity Co. (hereinafter referred to as "IDECO"). Both of the private power companies purchase electric power from NEPCO and supply it to their respective consumers.

The peak load recorded throughout the country in 1995 was 894 MW (The peak load in the NEPCO's power system increased by 8.6% to 862 MW from the previous year).

The power consumption has consistently shown steady increase, and marked 4,778 GWh in 1995 roughly doubling the figure in 1986, at a high annual average growth of 8.3% during these ten years' period.

The ten years' average rate of transmission and distribution loss in Jordan between 1996 and 1995 has been 9.4% . When viewed in blocks of five years, the average loss was 8.8% during the first five years with the help of a one-time record low of 7% level. However, the average loss increased to 10.5% during the latter five years, reflecting the demand increase.

The reduction of power loss is a very important task which leads both to the future improvement of the efficiency of energy consumption, and saving of construction cost of power plants and also development of power sources in Jordan, The Government of Jordan has made an official request for the implementation of this Study from necessity of clarifying the causes of such power losses, receiving recommendation of the method of its improvement, and acquiring relevant technical knowledge and know-how of Japan through the training of the staff of power utilities in Jordan.

In response to this request, the Government of Japan, through the Japan International Cooperation Agency (JICA), has determined the implementation plan of this Project, after dispatching a preliminary study team in July 1995, further in November 1995, discussing with relevant local authorities regarding implementation of this project, carrying out field survey and collect data and information.

On November 26, 1995 the JICA Pre-Study Team and JEA reached an agreement on " the Scope of Works (S/W) and Minutes of the Meeting (M/M) concerning the Reduction of Electric Power Losses in the Transmission and Distribution Networks in Jordan". On the basis of these S/W and M/M, the Government of Japan decided to implement full-scale study and entrusted this study work to the JICA.

1.2 Contents of the Study

(1) Objectives of the Study

The objectives of this Study are:

1) to provide countermeasures and recommendations for reducing the power loss in the transmission and distribution network down to a level reasonably attainable for the purpose of improving the energy efficiency of Jordan and sparing electric power equipment in the long run.

2) to carry out the transfer of technology to the Jordanian counterparts concerning the formulation of transmission and distribution power loss reduction plan during the scheduled period of this study.

(2) Scope of the Study

The areas relevant to this study are the electric power supply areas of the NEPCO, JEPCO and IDECO. The power losses to be studied are the technical power losses, excluding the auxiliary consumption in the power stations:

The kind of this study are those that have been carried out to reduce the power losses in the transmission and distribution networks in the relevant study areas to a reasonably attainable level within a target period of the coming ten years.

(3) Items of the Study

The study items are as presented below:

(a) Collection, analysis and study of data and information

(b) Site survey
(c) Investigation of the situations of electric power industry in Jordan
(d) Analysis of the present situations of power system
(e) Execution of power measurement work
(f) Clarification of power losses and analysis of the causes thereof
(g) Estimation of transmission and distribution costs and equivalent cost of power losses
(h) Development of power loss reduction model
(i) Formulation of optimum power loss reduction plan
(j) Economic and financial analysis
(k) Study of fund-raising method
(l) Technology transfer

1.3 Activities of the Study Team and Relevant Personnel in Jordan

(1) Activities of the Study Team in Jordan

In February 1996 through to March 1997, the JICA Study Team has executed the following activities:

The first field investigation: February 24 ~ March 27, 1996

- Explanation of the Inception Report
- Investigation and data collection of the situations of electric power industry
- Study of the method of clarifying the causes of power losses
- Study of the specifications, quantity and procurement methods of equipment and materials to be procured

The second field investigation: June 17, 1996 ~ October 15, 1996

- Execution of the measurement work
- Analysis of the causes of power loss
- Calculation of plan optimization
- Setting the monetary value of cost/benefit power loss reduction
- Formulation of the benefit and cost model
- Development of loss reduction model
- Holding of seminars

The third field investigation: November 22 ~ December 20, 1996

- Explanation and discussion on the Interim Report
- Calculation of potentiality power loss reduction
- Formulation of optimum power loss reduction plan
- Estimation of loss rate after execution of plan
- Economic and financial analysis
- Method of fund procurement
- Holding of seminar

The fourth field investigation: March 3 ~ March 17, 1997

- Explanation and discussion on the Draft Final Report
- Preparation of the Minutes of Meeting
- Holding of seminar

(2) List of Participants

The counterparts of the NEPCO, JEPCO, IDECO and the JICA Study Team are as listed below.

NEPCO	
Mr. ALI. Y. AL-ZUBI	Load Research & Management Section Head
Mr. FALAH ABABNAH	Electric Planning Engineer
Mrs. REEM HAMDAN	Distribution Department Electrical Engineer
Mrs. SUHA QOUSSOUS	Electric Planning Engineer
Mr. KHALIL BADER	Electric Planning Engineer
JEPCO	
Mr. ANWAR ELLAYAN	Electric Planning Engineer
IDECO	
Mr. JEHAD ROUSAN	Head of Planning Section
JICA Study Team	
Mr. KUNIO OKAWARA	Team leader/Power Loss Reduction Plan
Mr. TAKAO NAKAMURA	Optimization Model
Mr. KATSUHIRO MUKAI	Transmission and Distribution Equipment
Mr. TATSUHIKO MURAKAMI	Power Measuring

Mr. YOSHIAKI ISHIZUKA Economic and Financial Analysis

JICA Head Office

Mr. AKIHIKO HOSHINO Administrator

1.4 Grant of Equipment and Materials

The Study Team procured the load analyzers and clamp CTs during the Second Site Survey in Jordan, and used these instruments for power measurement. At the same time, the Study Team purchased personal computers and used them effectively for calculation of power losses, technology transfer and other purposes. Meanwhile, all the measurement instruments and computers procured then were granted by JICA to the Jordanian side when the Forth field investigation ended.

1.5 Preparation of Software

The Study Team used the power loss calculation software and the analysis software developed by Tokyo Electric Power Services Co., Ltd. (TEPSCO). This enables easy calculation for analyzing the power loss and preparing the power loss reduction countermeasures.
The Team granted the end-user's licence of this software to the Jordanian parties so that the local counterparts can use it also after completion of this study.

1.6 Training of the Counterparts

In order for the NEPCO counterparts to follow up the power loss reduction plan during this study period, the training of the counterparts was carried out in Japan as follows, mainly letting them participate in the joint work for preparation of the Interim Report:

Participants: Mr. Ali Yousif Moh'd Al-Zubi
Mr. Falah Qasem Ahmad Ababnah

Period: October 20, ~ November 17, 1996 (29 days)

1.7 Seminars

The Study Team held three times of seminars in Jordan for the purpose of promoting technology transfer to the relevant parties during this study period as follows:

(1) The first seminar

The first seminar was held at the NEPCO's head office on August 20, 1996 and at the IDECO's head office on August 21, 1996.

Mainly for the purpose of explaining the outline of this study, electric power loss analysis model and economic evaluation as well as for introducing the outline of the power facilities of the Tokyo Electric Power Co., Inc. (TEPCO) and actual examples of the trend of power loss reduction of the TEPCO.

(2) The second seminar

The second seminar was held at the NEPCO's head office on December 14, 1996.

The main theme of the seminar was the outline of this study and the contents of the Interim Report as well as a case study of economic and financial evaluation.

(3) The third seminar

The third seminar was held at the NEPCO's head office on March 12, 1997

The main theme of the seminar was the outline of this study and the contents of the Draft Final Report.

CHAPTER 2

SOCIO-ECONOMIC SCENES OF JORDAN

CHAPTER2 SOCIO-ECONOMIC SCENES OF JORDAN

The official name of the nation is the Hashemite Kingdom of Jordan in English (hereinafter referred to as "Jordan"). The capital city of Jordan is Amman. The area of whole nation of Jordan is 89,342 km^2.

Jordan has conducted a Population and Housing Census in 1994. According to statistical data and information from the Department of Statistics on that Census, the total population of Jordan was 4,134.5 thousand with its population density of 46 persons per km^2. Total number of households were around 679,000 and the average family size was 6.1 persons per household. A population growth rate of Jordan was quite high as 4.49 % per annum.

Gross domestic product (GDP) in Jordan is JDs.3,214.6 million in current prices and JDs.2,013.4 million in 1985 constant price as of 1993 at the value of factor cost. According to a statistic data, an economic activity group of finance, insurance, real estate and business services is the highest contribution factor to the GDP as 16.3 % in share rate in current price level and 18.5 % in 1985 constant price level as of 1993, while the second contribution factor is the group of transport, storage and communication as 12.8 % in current price level and 12.1 % in 1985 constant price level. The manufacturing group is the 3rd one, and the construction group is the 4th one both in current price level and in 1985 constant price level.

In 1990 and 1994, the Government finances of Jordan amounted to JDs. 938 million and JDs. 2,099 million in revenue and JDs. 1,033 million and JDs. 1,437 million in expenditure with their rise rates of 22.30 % and 8.61 % per annum respectively. Comparing with the growth rate of expenditure, that of revenue was quite high for these 4 years since 1990. A factor for this high rise in revenue was indirect tax revenues, especially the fees for licenses according to the statistic data.

In 1967 and 1994, the trading amount of Jordan amounted to JDs. 11,327 thousand and JDs. 995,181 thousand in export and JDs. 55,048 thousand and JDs. 2,362,583 thousand in import. In Jordan, the balance of external trading was constantly minus side since 1967. It means that the amount of import was larger than that of export.

In Jordan, 50 % or more of people engaged as workers and they were working for social and administration services, and Jordan has GDP with a high share rate of producers as around 19 %, finance and insurance, real estate and business services as 18 %, transport, storage and communications as 12 % and manufacturing as 11 % in terms of industry of origin as of 1993 at 1985 constant price.

Arable area in Jordan is only in Jordan valley. Considering these situation, almost of all of people in Jordan depend on mining, quarrying and manufacturing industries for their economic activities at the present.

In Jordan as of 1994, there are 6,856 km of road in total consisting of highway : 2,820 km, secondary road : 1,899 km and village road : 2,137 km according to the statistical data.

Jordan has only one sea port in Aqaba. The total handled goods and number of vessels were 10,572 thousand tons and 2,486 ships respectively as of 1994.

Jordan has 1 international airports in Amman, and 1 local airport in Aqaba. The passengers, and volume of freights are 1,222 thousand persons and 54,584 tons respectively as of 1994 by Jordanian Airlines.

Jordan is now in on-going situation of the Economic and Social Development Plan 1993-1997. The various policies and projects in this Plan have aimed at achieving the several economic and social objectives.

To achieve the said objectives, the Plan had set the following framework :

1. On the viewpoint of realization of sustainable growth in excess of population growth rate, the plan aims at realizing a GDP growth rate of 6 % per annum at 1991 constant price. This would raise real per capita GDP by about 3 %.
2. On the viewpoint of correcting structural imbalances and achieving fiscal and monetary stability;

(a) Gradual reduction in the budget deficit to GDP ratio, excluding grants, to no more than 3 % by 1997;
(b) Elimination of the balance of payments current account deficit by 1997;

(c) Reduction of the external debt to GDP ratio to a level not exceeding 100 % by 1997;
(d) Reduction of the external debt service as a percentage of exports of goods and services to a level not exceeding 25 % by 1997;
(e) Reduction of the ratio of consumption to GDP to a level not exceeding 89 % by the end of the planned period; and
(f) Maintenance of the annual rate of inflation at 4 % to 5 %.

On the viewpoint of realization of balanced social development, following to the social dimension that was vital for the success of economic development, the Plan said that, hence the importance attached to solving the problems of poverty and unemployment, improving the quality and raising the standard of social services, and reducing disparities between the regions.

On household income, the highest income level in 1992 was the household engaged in industrial activity, the second : in finance and banking, third : trade, restaurant and hotels with the amount of JDs.6,884, JDs.6,344 and JDs.6,147 respectively. It seems that the said income situation reflects the industrial condition as mentioned previous clause. The average annual income per household may be calculated at an amount of JDs.4,607 in 1992. On the other hand, the average annual expenditure per household was JDs.3,920 in the same year. The balance between amounts of income (JDs.4,607) and expenditure (JDs.3,920) amounting at JDs.687 seems to be reserved for foods, or medical care or others, or saved if remained.

The share rate of expenditure for fuel, electricity and water was 5.84 %. The expenditure for the electricity may be calculated based on the data from NEPCO (former JEA) at the amount of around JDs.160 as the average annual amount in 1992 which is 4.08 % among the said total expenditure for fuel, electricity and water.

The average annual growth rate living index was 3.29 % since 1991 up to 1995 for the general index according to the static data.

The fluctuation of exchange rates with US Dollars and Japanese Yen during the period from 1991 to 1995 is summarized below:

Exchange Rates with US Dollars and Japanese Yen

(J.Fils, middle rate)

Year	1 US Dollar	100 Japanese Yen
1991	680.9	506.4
1992	679.8	537.4
1993	692.9	625.0
1994	698.8	684.5
1995	700.8	749.1
June 1996	709.0	651.0
Annual average decreasing ratio (%)	0.72 %	10.28 %

CHAPTER 3

ELECTRICITY IN JORDAN

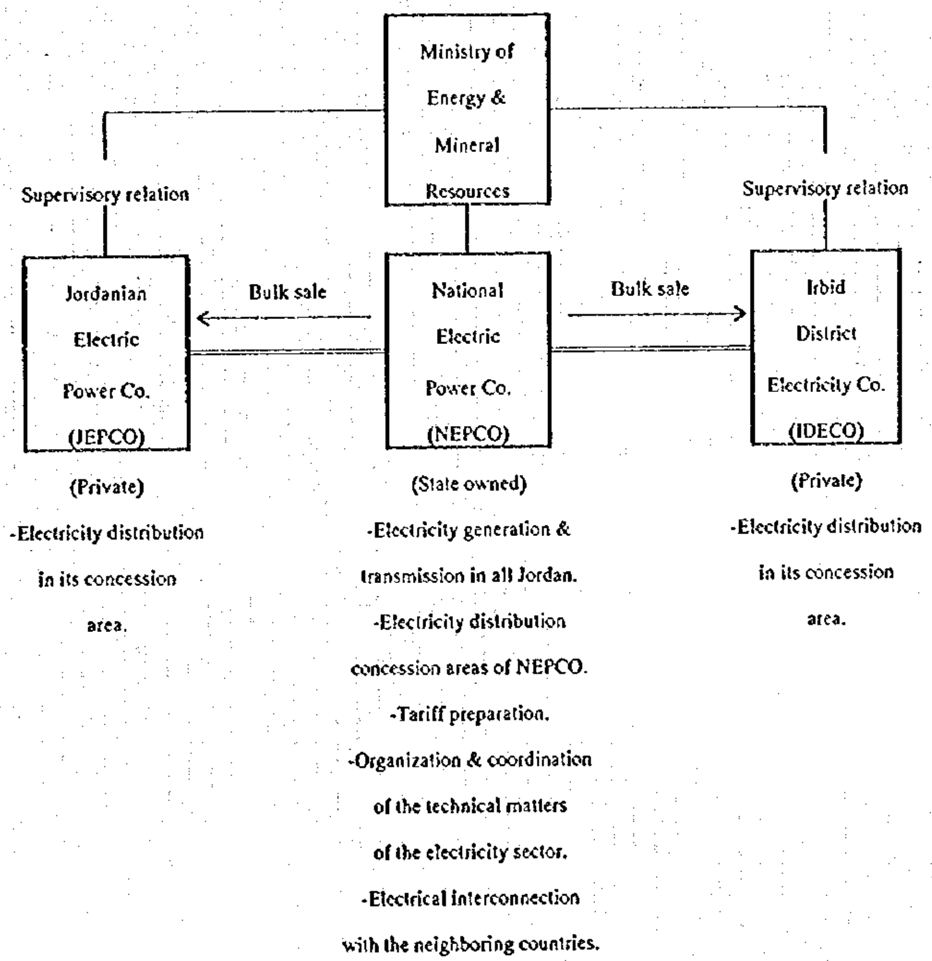
CHAPTER 3 ELECTRICITY IN JORDAN

3.1 Electricity Enterprises in Jordan

There are three electricity enterprises in Jordan. The one is a state owned enterprise belonging to the Ministry of Energy and Mineral Resources named "the National Electric Power Co. (NEPCO) (former called as Jordan Electricity Authority = JEA)". The other two are private enterprises named as the Jordanian Electric Power Co. (JEPCO) and the Irbid District Electricity Co. (IDECO). The function and relationships among them are as described hereunder. Among them, NEPCO and IDECO have generation facilities. JEPCO is a distributing firm buying electricity from NEPCO.

Functions and relationships among the three enterprises are as follows:

Electricity Enterprises in Jordan



NEPCO is not only a generating enterprise but also a energy distributing enterprise too. The energy is sold to JEPCO and IDECO, and other large scale industries as Refinery Co., Cement Factories Co., etc. by NEPCO as bulk sales. NEPCO's interconnecting system network covers Aqaba area, Ma'an and Shoubak areas, Karak area, Tafila area, Jordan Valley area, eastern area, and a part of Amman area for retail sales.

Number of electricity consumers in Jordan in 1995 was 674,000 in total with developing by average annual growth rate of 5.34 % since 1990. Among them, NEPCO shares only 90,000 of consumers with share rate of 13.4 %.

At present, NEPCO has a plan to separate its energy distribution section as a independent private enterprise. A restructuring for this plan was already started since July 1996. Even the energy distribution section will become a private enterprise, the function to sell energy to JEPCO, IDECO and to others as for bulk sales and retail sales seems to be kept as same as the present situation.

JEPCO and IDECO are energy distributing enterprises who are buying energy from NEPCO as mentioned above. Among them, IDECO has its own generating station.

JEPCO has covered the areas of a large part of Amman Governorate and Balqa Governorate including the cities of Amman, Al-Zarqa, Al-Salt, Madaba and Al-Baq'ah, and IDECO has covered the area of Irbid Governorate including the cities of Irbid, Al-Ramtha, Al-Mafrak and Jarash by their network.

According to the data from NEPCO, energy services population in 1995 was 4,254 thousand with electrification rate of 99.2 % to the total population as of 1995.

The situation of income and expenses for NEPCO, JEPCO and IDECO are summarized below.

Summary Statements of Income and Expenses of Enterprises

(JDs)

	NEPCO in 1994	NEPCO in 1995	JEPCO in 1994	IDECO in 1994
REVENUE	128,439,585	138,901,013	88,787,004	21,490,002
Electricity sales	119,242,838	132,012,477	84,567,035	16,887,571
Other income	9,196,747	6,888,536	4,219,969	4,602,431
GROSS EXPENDITURE	114,466694	126,229731	82,828,241	20,726,338
Operation/purchase	70,366,464	77,763,510	65,925,198	18,536,513
Other expenditure	44,100,230	48,466,221	16,903,043	2,189,825
NET PROFIT	13,972,891	12,671,282	5,958,763	763,664

Based on the financial statistics of NEPCO, the actual average tariff may be calculated at a sum of Fils.37 per kWh in average as of 1996 as shown in the following Table.:

Actual Average Electricity Tariff in NEPCO

Sector	Domestic and public building	Bulk industry	Medium and small industries	Commercial	Agricultur e & Water. pumping	Others	Total
Share of consumption(%)	32.35	16.54	13.74	10.96	20.32	6.09	100.00
Share of revenues(%)	36.64	17.26	10.80	14.87	15.63	4.80	100.00
Average tariff (Fils/kWh)	41.67	38.49	29.00	50.00	28.36	29.09	36.88

3.2 Equipment and Facilities in Power Plant, Transmission Lines, Substations and Distribution Lines in Jordan

In principle, the several power plants owned by NEPCO are interconnected to the power systems in the country through 132 kV transmission lines, and after stepping down to 33, 11 and 6.6 kV at main substations and further to 415 V at distribution substations located at the respective load centers, the power is distributed to consumers by 415 V 3-phase 4-wire system.

(1) Power Plant Equipment

As at the end of 1995, the total installed capacity is 1,167 MW. Out of this total, 1,049 MW is interconnected to the power systems throughout the country.

(2) Transmission Facilities

In Jordan, the transmission line voltages are divided into the four 400, 230, 132 and 66 kV classes. Among these classes, the 400 kV 2-ckt transmission line has been provided between the Aqaba Thermal Power Station and Amman South Substation. This transmission line is now operated at 132 kV. Meanwhile, this transmission line is being designed for boosting the voltage to 400 kV by the end of 1997.

Moreover, the 230 kV transmission line, which had been constructed for interconnection with the power system in Syria through the Irbid Substation for power supply to Syria, has so far been shut down. As at the end of 1995, the length of the transmission lines of NEPCO is as listed below:

Transmission Line (kV)	66	132	230	400
Line Length (ckt-km)	17	2,106	17	670

(3) Substation Facilities

The installed capacity of the substations for the power systems owned by NEPCO as at the end of 1995 is as listed below:

Substation (kV)	33/11	66/33	132/6	132/33	230/123
Capacity (MVA)	150	10	75	1,989	200

(4) Distribution Facilities

According to the definition of the power companies in Jordan, the 33 kV or lower voltage facilities are all referred to as the distribution facilities. In the case of the respective power companies: NEPCO, JEPCO and IDECO, the distribution voltages are divided into 2 groups, MV (medium voltage) and LV (low voltage). The 33, 11 and 6.6 kV are called MV, while the 415 V (3-phase 4-wire system) is called LV. As at the end of 1995, the distribution facilities and installed capacity of the distribution substations of NEPCO, JEPCO and IDECO are as listed below:

Distribution Facilities in Jordan

Distribution Line	Company	33kV	11kV	6.6kV	0.4kV
Overhead Lines(km)	NEPCO	1,413.4	306.8	5.2	2,324.1
	JEPCO & IDECO	2,975.1	309.7	264.4	12,799.3
	Subtotal	4,388.5	616.5	269.6	15,123.4
Underground Cable(km)	NEPCO	17.5	102.2	5.8	261.4
	JEPCO & IDECO	399.5	794.7	656.7	1,057.4
	Subtotal	417	896.9	662.5	1,318.8
	Ground Total	4,805.5	1,513.4	932.1	16,442.2

Distribution Substation Capacities in Jordan

Substation	Company	33,11,6.6/0.4kV	33/11,6.6kV	11/6.6kV
Capacities(MVA)	NEPCO	379.9	145.5	2.5
	JEPCO & IDECO	847.4	493.7	1,509.5
	Total	1,227.3	639.2	1,512

3.3 Power Demand

(1) Production of Electrical Energy

In Jordan, the electrical energy producers are largely classified into the electric utilities and non-utility industrial enterprises. The enterprises undertaking electrical energy production are the NEPCO, IDECO, municipalities and so forth. Moreover, the industrial power plants are owned by five companies including cement and steel makers.

Break down in the table below is the electrical energy production by electric utilities and non-utility sectors in Fiscal 1995.

Electrical energy production and its share by sectors in 1995

	Electrical Energy (GWh)	Share (%)
1. Electricity Sector	5,215	92.8
NEPCO	5,201	92.6
IDECO	12	0.2
Municipalities & Others	2	0.0
2. Industrial Sector	401	7.2
Refinery	65	1.2
Cement Factory	39	0.7
Potash Co.	113	2.0
Fertilizer Co.	166	3.0
H. Iron Factory	18	0.3
Total	5,616	100

(2) Sold Electrical Energy

The trend of electrical energy sold by electric utilities and non-utility enterprises and the growth rate thereof in Jordan are presented respectively in Figs. 3.3-3 and 3.3-4.

The total electrical energy sold throughout Jordan in 1995 is 3,373 GWh. Out of which, 2,382 GWh, 576 GWh and 415 GWh was sold respectively by the JEPCO, IDECO and NEPCO in terms of the categories of electric utilities, and about 70% of the total was shared by the JEPCO with its supply area in Amman, the capital city, followed by about 17% of IDECO and about 15% of NEPCO.

As about 71%, 16% and 13% was shared respectively by the JEPCO, IDECO and NEPCO as in 1986, the share of electrical energy sold by the respective suppliers has undergone little changes. Moreover, the electric power demand in 1995 has grown nearly equally throughout Jordan.

(3) Characteristics of Power Demand

(a) Daily and yearly load curves

The daily and yearly load curves in Jordan are presented in Figs. 3.3-1 and 3.3-2. In Jordan, the daily peak load arises in the evening when lighting is turned on. Whereas, the yearly peak load takes during summer in August and September.

(b) Trend of peak load and yearly load factor

The trend of peak load and yearly load factors in Jordan are presented in Fig. 3.3-3. For the past nine years, the peak load has increased to about 1.8 times at an annual average rate of as high as 7.4%. Moreover, he annual average growth rate reached 10% during the period from 1991 through 1995 after the end of the Gulf War.

Although the annual load factor did not undergo so substantial change for the past nine years, the factor was improved to more or less than 70% during the latter half period of four years from an order of 60% during the earlier half period of five years.

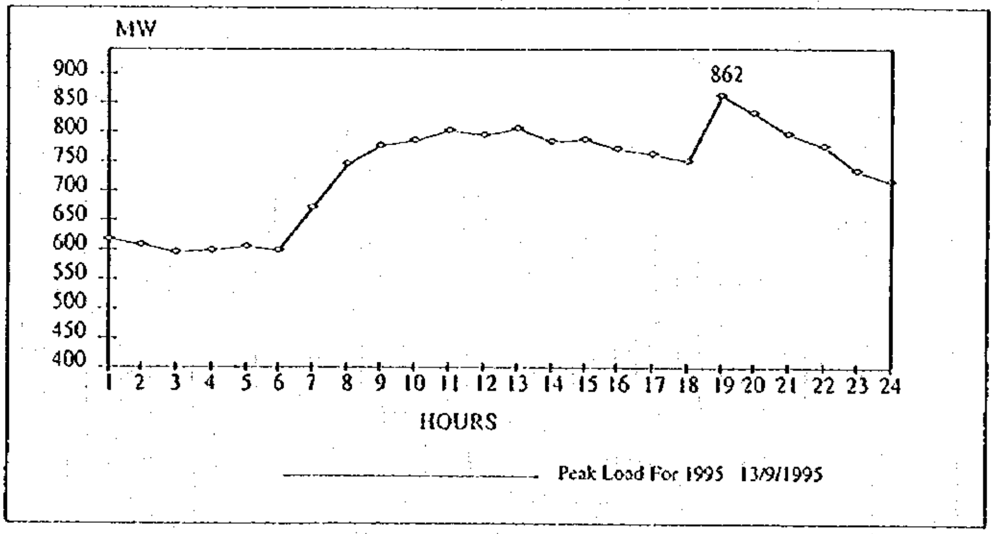


Fig. 3.3-1 Daily load curve in Jordan

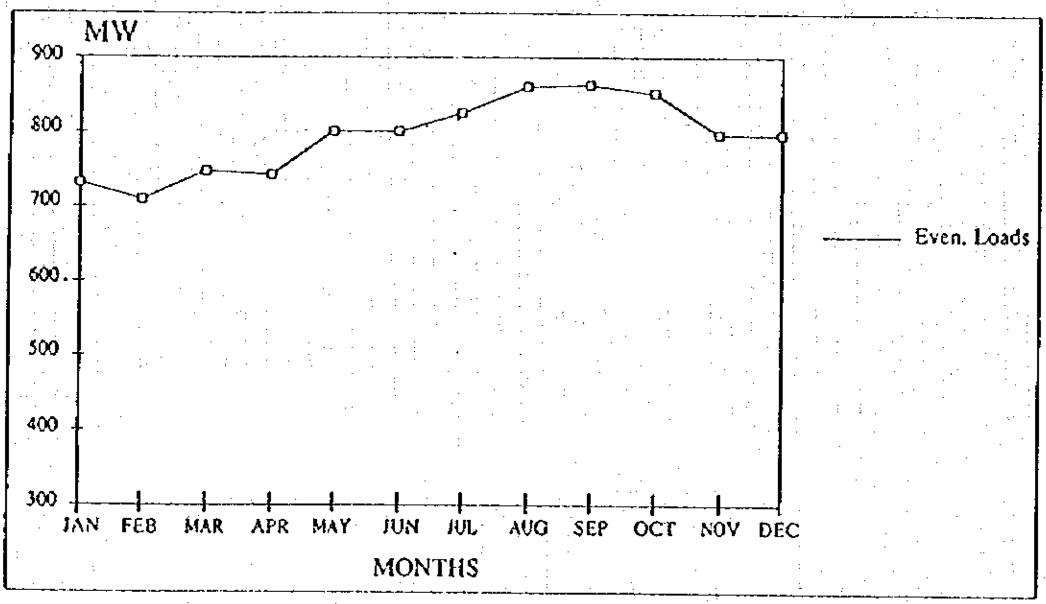


Fig. 3.3-2 Yearly load curve in Jordan

(4) Electric Power Demand Forecast

In Jordan, all the electric power demand forecast including analysis and evaluation of social situations, economic statistics and trend, technological innovation and other dimensions is undertaken by the NEPCO based on the know-how of its planning staff. Such electric power demand forecast values are used for its long term development plan and long term financial plan (study of electricity tariff), business strategies and other purposes.

(a) Electric power demand forecast values

The overall electric power demand forecast values (MW and GWh) and growth rate thereof throughout the country are presented in Figs. 3.3-4 and 3.3-5. However, any portion of electric power sent to Syria is not included in these diagrams:

The electric power demand forecast values (GWh) by the categories of consumption are presented in Fig. 3.3-6.

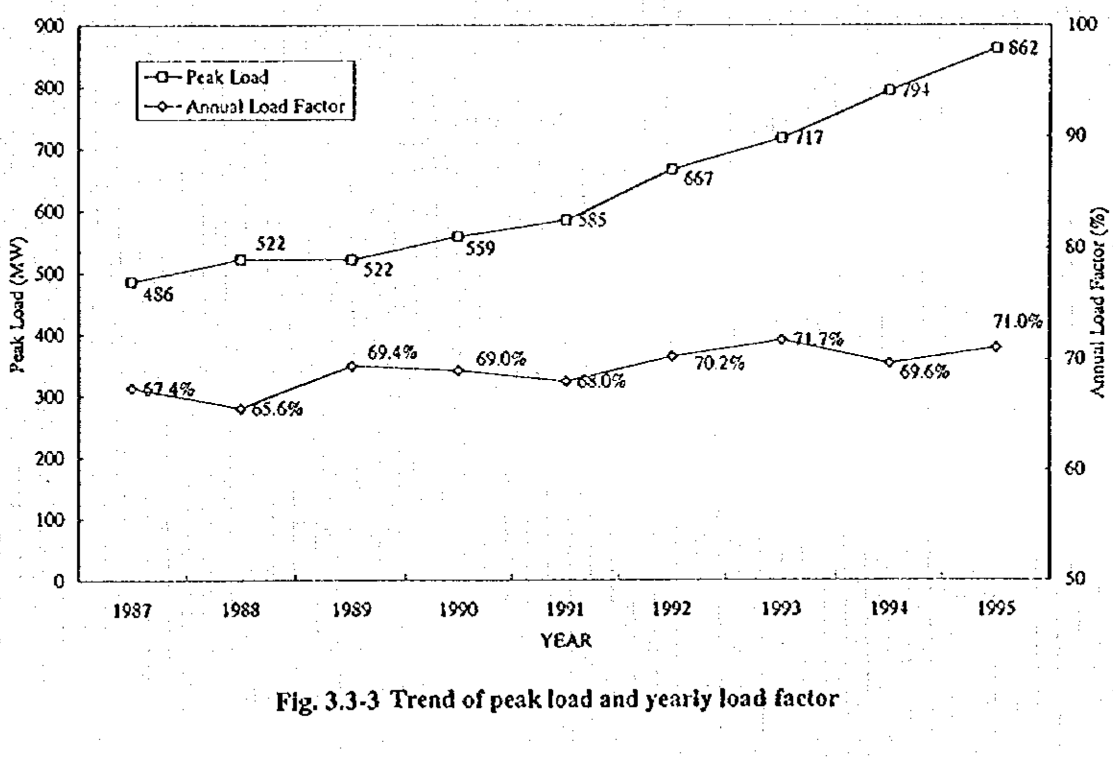


Fig. 3.3-3 Trend of peak load and yearly load factor

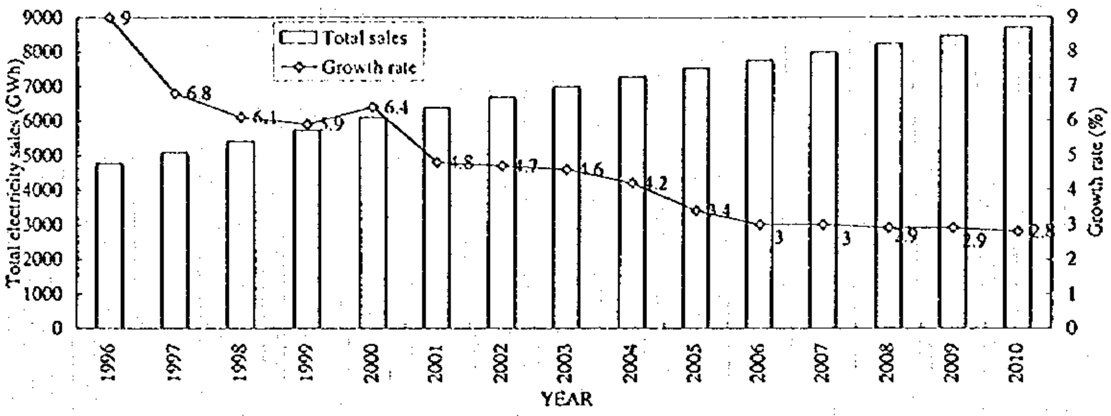


Fig. 3.3-4 Overall electric power demand forecast values throughout Jordan

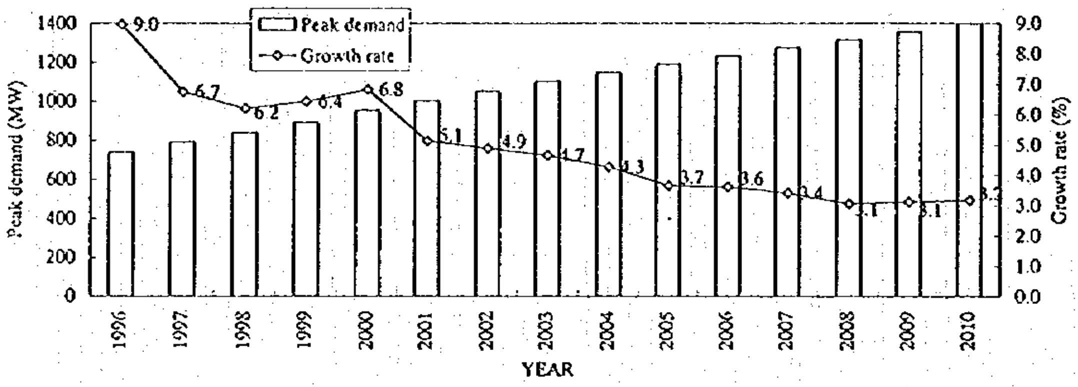


Fig. 3.3-5 Overall peak load forecast values throughout Jordan

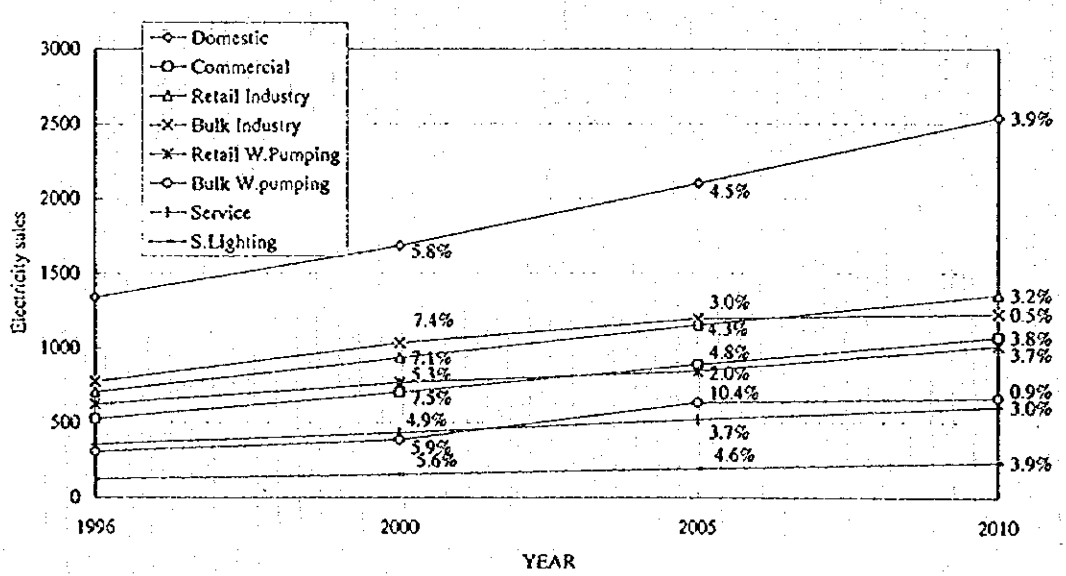


Fig. 3.3-6 Electric power demand by consumption categories

3.4 Electric Power System

(1) Present Situations of the Power Systems and Extension Projects thereof

(a) Present situations of the power systems

The trunk power systems in Jordan are mutually interconnected to the 132 kV transmission lines through the power stations and substations owned by NEPCO throughout the country. Out of a total line length of 2,776 ckt-km, 670 ckt-km is used for interconnection between the Aqaba Thermal Power Station and Amman South Substation through the transmission line with a design voltage of 400 kV. Meanwhile, this transmission line is scheduled to be boosted to 400 kV by the end of 1997. The trunk power systems in Jordan are presented in Fig. 3.4-1.

(b) Power system extension projects

A project has been promoted for interconnecting mutually between Jordan, Egypt, Iran, Syria and Turkey through 400 kV transmission lines in the future.
Thereby, the power systems in Jordan are expected to be reinforced by realizing interconnection to Egypt at the southern part and Syria at the northern part of the country.

(2) Power Supply Reliability

The 132 kV power system in Jordan is of a double-circuit configuration, and each main substation is of two-bank configuration. Therefore, the power supply can be ensured even in the event of one circuit or one bank shutdown. Although the 33 kV or lower MV and LV distribution lines are of a one-circuit configuration, the adjacently located distribution lines have been designed respectively so as to enable switching over mutually to and from the other distribution line. Thus, it is possible to supply power from another distribution line in the event of shutdown of one distribution line, in high density area.

On the other hand, the respective distribution substations are of a one-bank configuration. Thus, when one bank has been shut down, power supply from two or more LV distribution lines receiving power from the corresponding bank will be interrupted. However, in some cases it is possible to supply power from another distribution line by switching over to and from mutually interconnected distribution lines as mentioned above.

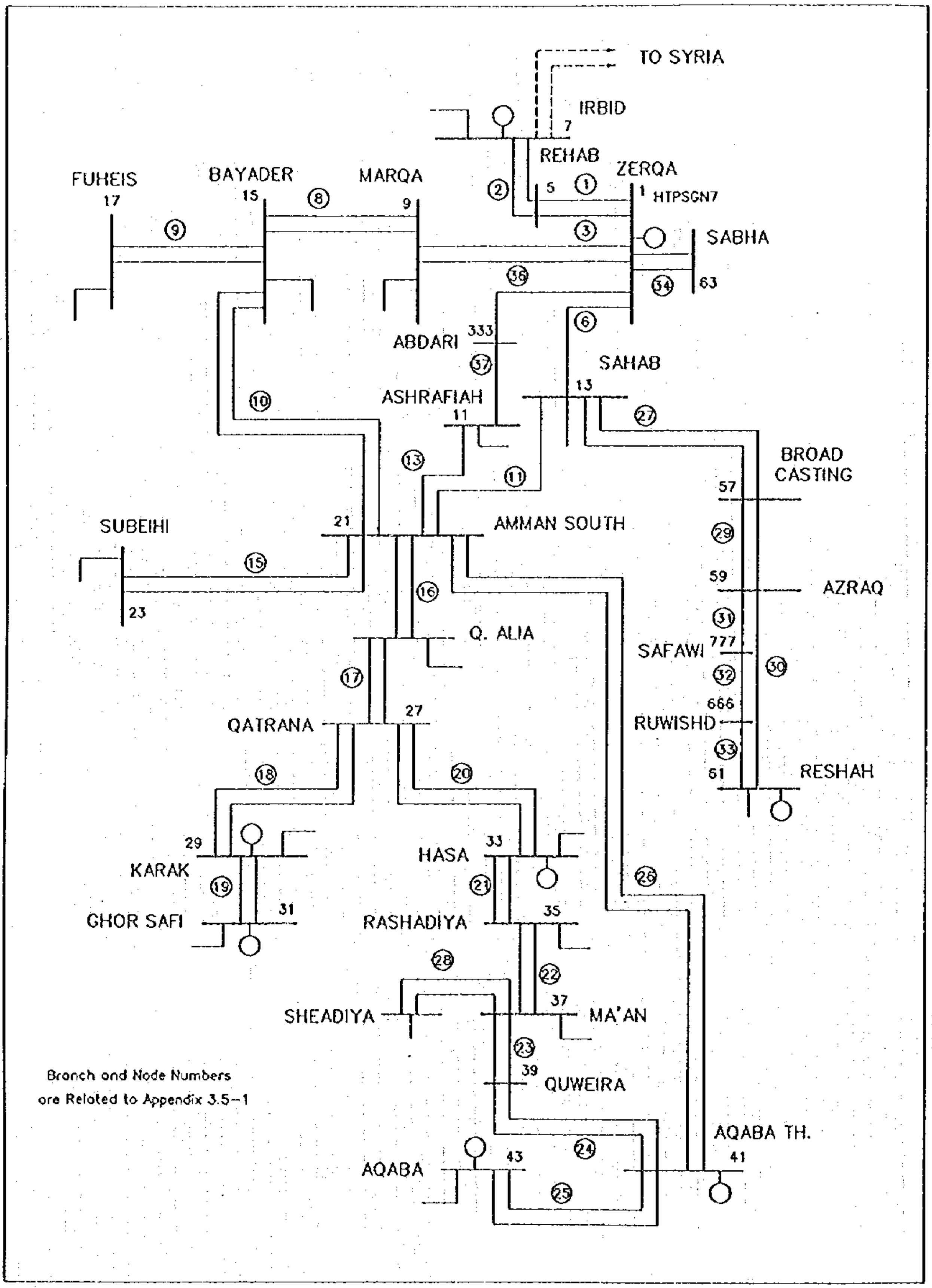


Fig. 3.4-1 Trunk Power System in Jordan

3.5 Present Situations of Voltage Drop and Future Tasks in Distribution Systems for Improvement

(1) Present Situations

According to the present situations in Jordan, it will be necessary to substantially improve the voltages in the low and medium voltage distribution lines. As a result of executing trial calculation of voltage in low voltage distribution line, the voltage is observed to have dropped by as much as 25% or over in some distribution lines.

(2) Future Tasks

The common causes of substantial voltage drop in the low and medium voltage distribution lines deemed to be as follows:

- Overloading in long distance distribution lines
- Application of smaller size conductor
- Low power factor

Moreover, the load to low voltage distribution lines is deemed to be excessively unbalanced.

The improvement of voltage will not only be reflected directly to the improvement in the services to consumers but also lead to reduction of power loss.

CHAPTER 4

PRESENT SITUATIONS OF ELECTRIC POWER LOSS

CHAPTER 4 PRESENT SITUATIONS OF ELECTRIC POWER LOSS

4.1 Present Situations of the Recorded Data of Power Loss

(1) Actual Situations of Transmission and Distribution Loss Rates

The loss rates expressed in terms of the ratios of electrical energy (hereinafter referred to as energy) lost in power plants, transmission and distribution systems to the total energy generated in 1995 are as given below:

Auxiliary energy consumption in PS	:	5.8%
Transmission loss	:	2.0%
Distribution loss	:	7.4%
(Transmission and distribution : network loss	:	9.4%)

In Jordan, the voltage is classified into three classes: namely, high voltage (HV: 132 kV), medium voltage (MV: 33 kV, 11 kV and 6.6 kV), and low voltage (LV: 415 V). As the transmission loss refer to a HV loss, the distribution loss refer to a sum of the MV and LV losses respectively according to the past records, it is difficult to identify the difference between the MV and LV losses. However, only the NEPCO has been metering the energy respectively in its MV and LV systems. Therefore, the distribution loss in NEPCO system is divided into those in the MV and LV systems.

A conceptual diagram of metering the energy is presented in Fig. 4.1-1.

(2) Metering Data Related to Power Loss and Analysis thereof

(a) Trend of the overall energy loss rate in the entire power systems in Jordan

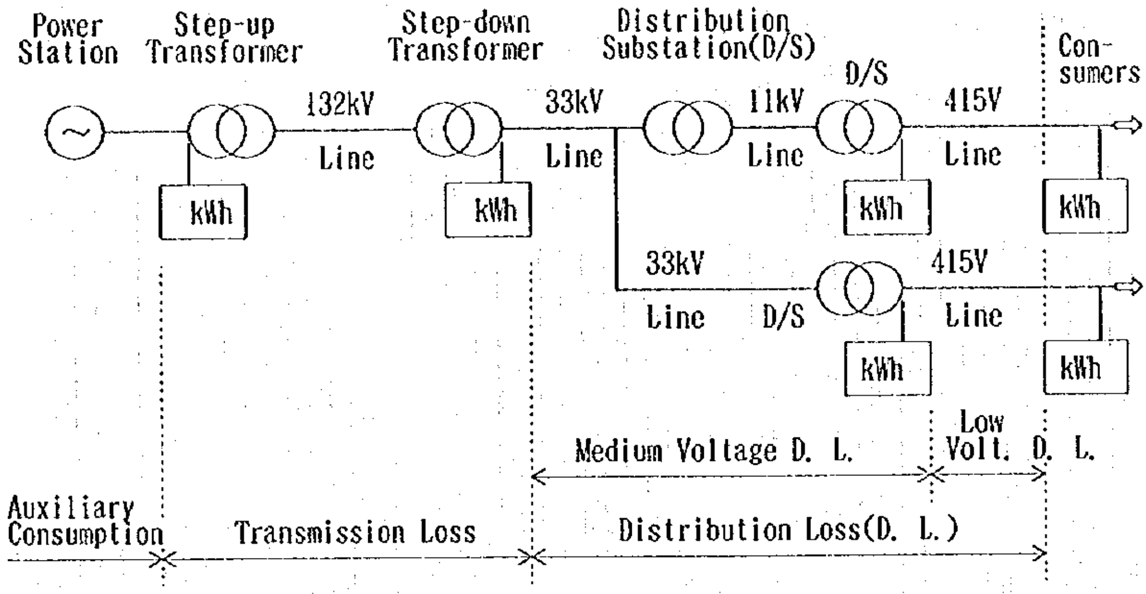
The overall energy loss rate including auxiliary energy consumption of power stations in the power systems of Jordan has been undergoing little changes at a rate of 15% or over for the past several years as presented in Table 4.1-1. Out of this total loss, the auxiliary energy consumption in power plants is about 6%, and the energy loss in HV system is more or less than 2%. Therefore, the majority of network loss is estimated to occur on the distribution side.

Although the distribution energy loss of JEPCO reached as high as 16% two decades before, it has been lowered gradually and recently improved to 8% or over.

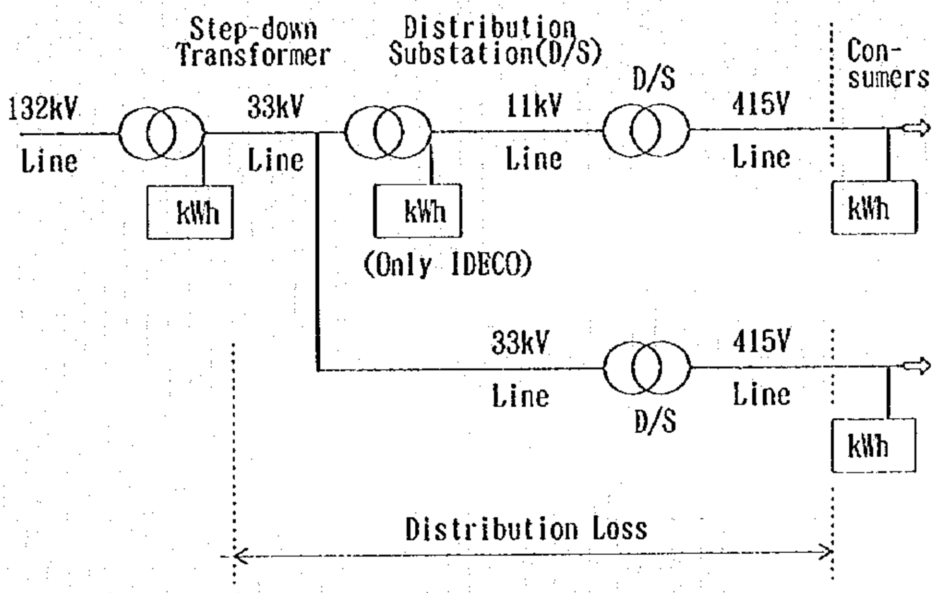
(b) Trend of the energy loss rate in NEPCO s MV and LV systems

The energy sent out to MV system and that sent out to the LV system are respectively metered. Consequently, the energy loss rate in the MV system and that in the LV system have been clarified individually.

According to the metering data in 1995, the overall rate of distribution loss was 15.05%. While the loss rate in the MV system is as low as 5.01%, that in the LV system was so high as even 10.57%.



(NEPCO)

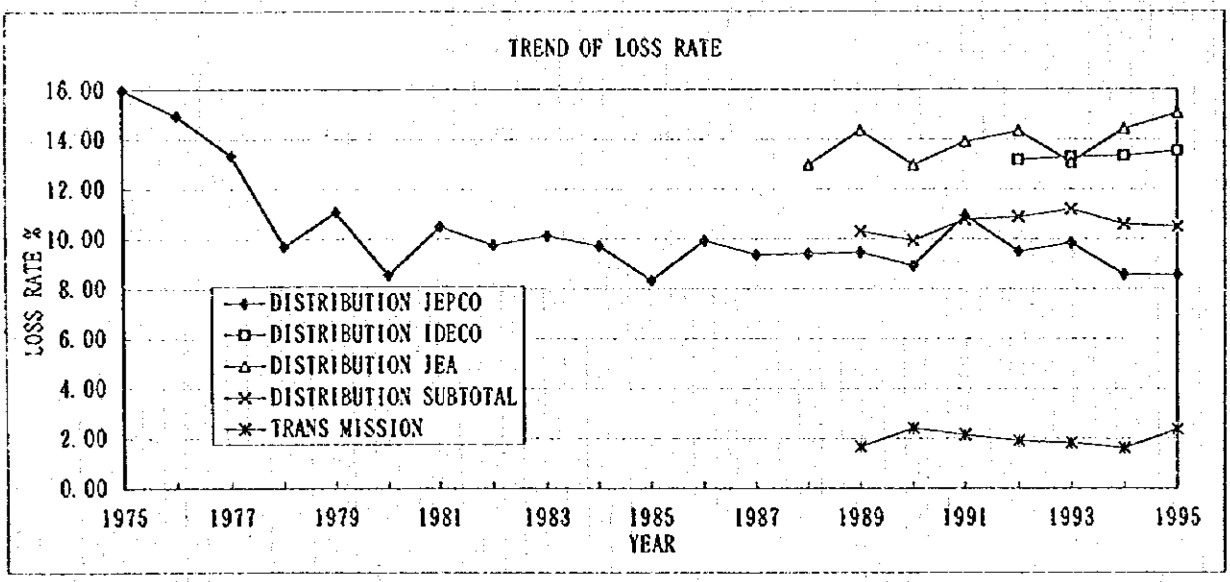


(JEPCO & IDECO)

Fig. 4.1-1 Measurement Point of Energy and Loss Classification

Table 4.1-1 TENDENCY OF LOSS RATE (%)

YEAR	DISTRIBUTION				TRANS MISSION	POWER STATION	TOTAL LOSS %
	JEPCO	IDECO	JEA	SUBTOTAL			
1975	15.97						
1976	14.93						
1977	13.33						
1978	9.70						
1979	11.06						
1980	8.55						
1981	10.48						
1982	9.76						
1983	10.11						
1984	9.71						
1985	8.33						
1986	9.92						
1987	9.36						
1988	9.40		12.96				
1989	9.45		14.35	10.30	1.66	6.62	15.85
1990	8.92		12.97	9.93	2.40	6.63	15.74
1991	10.93		13.89	10.77	2.14	6.60	16.27
1992	9.50	13.17	14.32	10.88	1.90	6.55	15.81
1993	9.83	13.30	13.08	11.19	1.81	6.48	15.79
1994	8.56	13.33	14.42	10.59	1.62	6.06	15.09
1995	8.55	13.53	15.05	10.48	2.36	5.82	15.65



4.2 Measurement of Representative Power Systems for Analyzing the Prevailing Situations

(1) Selection of the Representative Power Systems

In extending this study, it is important to clarify the location and rate of the network losses arising in the power systems in Jordan. Consequently, the distribution loss in the representative systems was measured preferentially to identify the locations of power loss, namely, to classify the energy loss into those arising in the MV and LV systems. At the same time, consideration has been given to make it possible to clarify the outline of the transformer loss in distribution substation included in the MV system and the service wire loss included in the LV system.

In consideration that the distribution loss data by supply areas and voltage classes have already been owned by the NEPCO as described in Section 4.1, the representative power systems were selected from the distribution systems of the IDECO and JEPCO. Meanwhile, the energy losses in the entire distribution systems have been clarified in the case of both of the power companies, and since the loss in MV system can easily be identified where that in the LV system can be clarified, the representative systems have been selected only from the LV systems.
Moreover, the representative systems were selected taking into account the following requirements

- The distribution system selected should adequately represent the features of the entire systems in Jordan;
- It should be possible to measure the energy being sold to any consumer connected to the representative systems for measurement separately from any other system.
- Any representative system should never be switched over during the measurement period.

The system which would meet such conditions as mentioned above is extremely limited. As a result, it could not necessarily be said that any representative system truly represents the entire power systems in Jordan as initially intended. However, the following four systems recommended by the Jordanian counterpart have been selected as the representative systems.

The representative system of JEPCO	- West Theheeba substation - Abu-Zeghan substation
The representative system of IDECO	- Juhfia substation - Al - Rafeed substation

(2) Results of Measurement

(a) Distribution Loss in LV system

The total values of the results of measuring the energy in the transformer secondary circuits of the representative power systems of IDECO and JEPCO for five months as well as those of measuring the energy sold to the respective consumers are presented in Table 4.2-1.

Table 4.2-1 Results of measuring the energy of representative system

(1) Juhfia

Supplied energy from the transformer secondary circuits (A)	Sold energy to the consumers (B)	Energy loss (C=A-B)	Loss rate (C/A*100)
225,850 kWh	195,734 kWh	30,116 kWh	13.3 %

(2) Al-Rafeed

Supplied energy from the transformer secondary circuits (A)	Sold energy to the consumers (B)	Energy loss (C=A-B)	Loss rate (C/A*100)
242,062 kWh	227,534 kWh	14,528 kWh	6.0 %

(3) West Thecheeba

Supplied energy from the transformer secondary circuits (A)	Sold energy to the consumers (B)	Energy loss (C=A-B)	Loss rate (C/A*100)
126,240 kWh	120,654 kWh	5,586 kWh	4.4 %

(4) Abu-Zeghan

Supplied energy from the transformer secondary circuits (A)	Sold energy to the consumers (B)	Energy loss (C=A-B)	Loss rate (C/A*100)
129,847 kWh	109,093 kWh	20,754 kWh	16.0 %

(b) Transformer loss in distribution substation

The power, power factor, current and phase-to-phase voltage in the secondary circuits of distribution substations of the representative systems have been measured.

1) Calculation of power loss and energy losses in transformer

By using the above measurement data in (b), the electrical power and energy losses in transformers have been calculated as presented in Table below:

Power loss in transformers of the representative power systems

	Juhfia	Al-Rafeed	W. Thcheeba	Abu-Zeghan
Peak demand (kW)	129.33	134.03	137.13	76.42
(kVA)	165.60	157.32	178.33	98.86
Energy in secondary circuit of transformer (kWh)	804,400	833,632	852,912	475,283
Transformer Capacity (kVA)	250	250	250	200
Core loss (kW)	0.510	0.510	0.510	0.463
Copper loss (kW)	2.248	2.248	2.248	1.853
Yearly core loss(kWh)	4,467.6	4,467.6	4,467.6	4,055.9
Yearly copper loss (kWh)	4,900.9	4,422.9	5,683.1	2,249.5
Yearly transformer loss (kWh)	9,368.5	8,890.5	10,150.7	6,305.4
(%)	1.16	1.07	1.19	1.33

(c) Calculation of energy loss in service wire

The mean values of the calculated energy loss rate in the respective substations are as presented in Table 4.2-2 below:

Table 4.2-2 Mean values of energy loss in service wires

Substation	Juhfia	Al-Rafeed	West-Thcheeb
Energy loss per energy load %	0.03	0.059	0.155

The energy loss in service wire is quite small when compared with that in the LV system as is clear from the above values. Therefore, this energy loss is judged to be negligible.

4.3 Distribution of Energy Loss in the Representative Systems

(1) Energy loss in service wire

As the values in Table 4.2-2 indicate, the energy loss in service wire is so small that it can be disregarded.

(2) Energy loss in distribution line

As presented in Table 4.2-1, 4.4 ~ 16 % of the energy supplied through a distribution transformer is lost in the LV distribution line.

Juhfia	13.3%
Al-Rafeed	6.0%
West Thcheeba	4.4%
Abu-Zeghan	16.0%
Average	9.9%

(3) Energy loss in distribution transformer

1.1 ~ 1.3 % of the energy supplied to a distribution transformer from the MV system is lost in the distribution transformer.

Juhfia	1.2%
Al-Rafeed	1.1%
West Thcheeba	1.2%
Abu-Zeghan	1.3%
Average	1.2%

Therefore, roughly 1.2% is considered to constitute the energy loss in distribution transformer based on the received energy.

4.4 Distribution of Energy Loss in Jordan

The total energy generated throughout Jordan in 1995 was 5,365 GWh. Out of this total, 4,525 GWh was actually sold. The total energy loss was 840 GWh and corresponds to 15.65% of the total generated energy. The energy loss in transmission and distribution systems was 504 GWh and corresponds to 9.4% of the total generated energy. Meanwhile, the distribution of energy loss in Jordan in 1995 is presented in Table 4.4-1.

(1) Energy loss in the transmission systems

Out of 4,612 GWh of energy transmitted through the 132 kV systems in 1995, 109 GWh or equivalent to 2.0% of the total generated energy was lost in transmission systems.

(2) Energy loss in the distribution systems

The energy sent through the distribution systems in Jordan in 1995 was 3,768 GWh. Out of this total, the sold energy was 3,373 GWh and the distribution energy loss was 395 GWh or equivalent to 7.4% of the total generated energy. Out of 395 GWh of energy loss, 117 GWh (2.2%) is estimated to have been lost in the MV systems. And 278 GWh (5.2%) is estimated to have been lost in the LV systems. (Refer to Table 4.4-1)
Meanwhile, 1.2% of distribution transformer loss based on the received energy described in Section 4.3 corresponds to 0.8 % of that based on the total generation energy.

The network energy losses in 1995 are summarized as follows:

Transmission loss		2.0%
Distribution loss	MV	2.2%
	LV	5.2%
Total network loss		9.4%

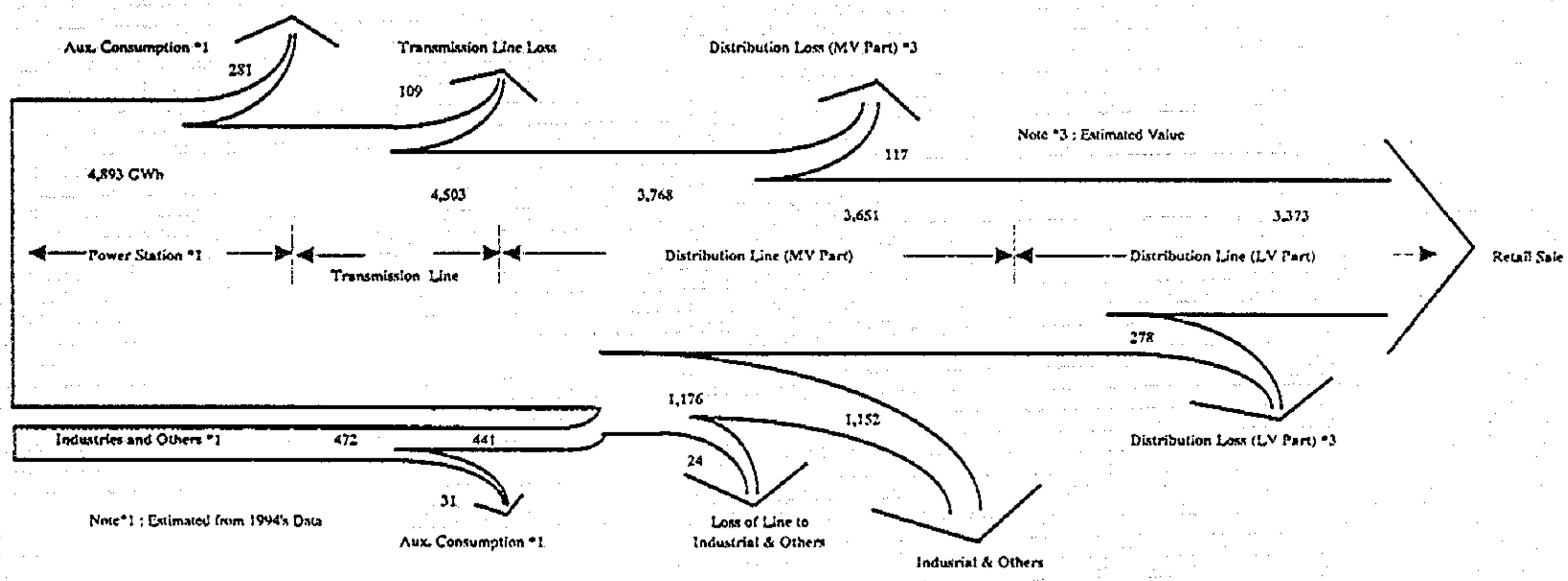
In the light of the above data of energy loss, it can be said that the loss rate in the LV systems tends to be high as a whole. In consideration of such actual situations of loss rate, it would be essential to place a priority on the countermeasures for reducing the power loss in the distribution systems under this study.

Table 4.4-1 Estimation of Energy Flow

Applying Results of Measuring the Electrical Energy of Representative System

Gene.	Aux. Cons.	Supplied to MV Systems	Sent out to Industrial & Others	Sold Energy to Industrial & Others	Sent Out to Retail Sale	Retail Sale	Loss Rate of Aux. (%)	Loss Rate of T/M (%)	Loss Rate of Line to Industrial & Others (%)	Loss Rate of Distribution % MV Part	Loss Rate of Distribution % LV Part	Loss Rate Total (%)
*1 5,365	*1 312	*2 4,944	*2 1,176 (Wmm)	*2 1,152 (Wcm)	*1 3,768 (Wmil)	*1 3,373 (Wcl)	*1 5.8	2.0	0.4	*3 2.2	*3 5.2	15.66

Note *1 : JEA's 1995 Annual Report (P28)   Note *2 : Estimated from JEA's 1995 Annual Report (P28)   Note *3 : Estimated Value



CHAPTER 5

STUDY OF COUNTERMEASURES FOR THE POWER LOSS REDUCTION

CHAPTER 5 STUDY OF COUNTERMEASURES FOR THE POWER LOSS REDUCTION

5.1 Approach to Reduction of Power Loss

In electric power system, there would be an economically optimum level of power loss. It is deemed to be impossible to find out any technique for macroscopically optimum points. Under this project, therefore, it has been determined to carry out this study according to microscopic approaches based on the results of executing the study for optimizing the individual power facilities. Since the number of LV (415V) feeders is as many as even nearly 20,000 in Jordan, it would be impossible to study all of the individual feeders. It has been determined to promote this study roughly according to the following procedures by using selected sample feeders even though this study will be carried out microscopically:

(1) Selection of countermeasures of the systems relevant to this study;
(2) Selection of sample feeders;
(3) Measurement of loaded conditions;
(4) Calculation of power loss before taking any countermeasure;
(5) Optimization of individual countermeasures;
(6) Calculation of loss reduction values, cost and benefit, feasibility and net benefit;
(7) Searching for the parameters correlated closely with the above respective values;
(8) Fitting the power loss reduction values, countermeasure cost and other values according to a least square method (Preparation of mathematical models); and
(9) Estimation of the countermeasure cost and loss reduction values in the entire distribution systems by applying mathematical models to the another sample data which are different from item (2), (Data on all 33 kV system feeders and those on random sampled feeders corresponding to 2% of the total 415 V feeders).

5.2 Options and Selection of Electric Power Loss Reduction Countermeasures

(1) Countermeasures of Power Loss Reduction

At a starting step of the Study, the countermeasures to be workable physically for reducing the loss in the power system of Jordan have been pointed out in the meeting as a "brain storming" by the working group members. The results are listed in Table 5.2-1 .

Table 5.2-1 List of countermeasures for reducing the power losses in transmission and distribution networks

A. Increase of the conductor sizes of:
  (1) 132 kV transmission line
  (2) 33 kV distribution line
  (3) 11 kV distribution line
  (4) 415 V distribution line

B. New line construction for MV(medium voltage , 33 kV and 11 kV) system
  (1) Introduction of higher voltage (Including new transformer construction)
  (2) Construction of same voltage line

C. New line construction for LV(low voltage, 415V) system
  (1) Introduction of higher voltage (Including new transformer construction)
  (2) Construction of same voltage line

D. Improvement of power factor by installing:
  (1) Capacitors in LV feeder
  (2) Capacitors in LV substation
  (3) Capacitors in near-end of load in MV feeder
  (4) Capacitors on 33 kV bus in 132/33 kV substation

E. Improvement in operation/control
  (1) Balancing of 3-phase current in LV system
  (2) High voltage operation of line
  (3) Parallel off of transformer at lighter load
  (4) Optimization of the open point of distribution feeder

(2) Selection of Countermeasures for the Systems to be Studied

Although it will be possible to physically reduce the power loss according to the power loss reduction countermeasures listed in Table 5.2-1, whether these countermeasures are economically feasible or not is unknown. Whether such countermeasures are economically feasible or not has mainly investigated later in this study. When considered in view of the labor, time and so forth required for this study, however, it would not be justifiable to pick up all of these countermeasures as the themes of this study.

As a result of rough study taking into account the cost, occurrence positions of losses, the following combinations of facilities and countermeasures have been determined to be studied:

- [B.-(1)] Introduction of the higher voltage system for MV system
- [B.-(2)] Construction of the same voltage line for MV system
- [C.-(1)] Introduction of the higher voltage system for LV system
- [C.-(2)] Construction of the same voltage line for LV system
- [D.-(1)] Installation of capacitors at LV feeder
- [D.-(2)] Installation of capacitors in LV substation
- [E.-(1)] Balancing of 3-phase current in LV system

5.3 Selection of Sample Power Feeders

Although the countermeasures selected in the previous Section are required to be studied regarding respective feeders, there are about ninety feeders in the MV systems and nearly twenty-thousand feeders in the LV systems. Consequently, it would be impossible to study the above countermeasures for all of the feeders. Thus, it has been determined to select sample feeders and carry out measurement and calculation.

The feeders deemed to be comparatively heavy loaded and require improvement for loss reduction have been selected 81 LV and 14 MV feeders, by the Jordanian counterparts and adopted as sample feeders.

Since comparatively heavy loaded feeders have been selected as sample feeders intentionally, the other sample feeders and work have become necessary to estimate the situations of the power systems throughout the country. However, the results of intentionally selecting such heavy loaded feeders have in turn contributed for effective study to make mathematical models, by increasing feasible case of sample.

The sample group used in this stage is named "Sample-1", so can be distinguished from "Sample-2" which becomes necessary in later stage. The Sample-2 must be represented the condition of entire Jordan. Therefore the Sample-2 feeder has been selected as follows.

- Randomly picked-up systems corresponding to about 2% of the total LV feeders; and
- All of the 33 kV feeders for the MV system

5.4 Measurement of Sample Feeders

(1) Measurement

Since the existing data alone were insufficient for executing this study, the following three feeders in MV system were selected, and the measurement have been carried out to replenish the existing data.

Selected Feeder for Actual Measurement

Company Name	Selected MV feeder	No. of Measured S/S
NEPCO	Jordan Valley Middle (33kV)	88
JEPCO	Duleel (33kV)	61
IDECO	Emrawa (33kV)	126
Total	3	275

The following electric quantities were measured at above selected feeders.

- With regard to the three (3) MV feeders, the sent out current from the 275 distribution substations which connected to the above three MV feeders were measured (respectively once during summer day time).
- The electrical energy, current, voltage, and power factor sent out by 33 kV Duleel line were measured [continuously for one (1) week].
- Moreover ten (10) distribution substations, the electrical energy, current, voltage, and power factors sent out from respective substations were measured [continuously for one (1) day through three (3) days].

These electric quantities obtained by measurement in July through August 1996 were used for analysis with existing data presented by the Jordanian counterparts.

(2) Results of measurements

The average value of voltage and power factor in week day at LV side of distribution substation by respective companies are calculated as table below.

Average voltage and average power factor of each company

Company Name	Average Voltage	Average Power Factor
NEPCO	96 %	0.77
JEPCO	97 %	0.78
IDECO	96.1 %	0.83

After discussion with counterparts, the uniform values to be applied to all Sample-1 feeders were adjusted as follows:

Voltage 97%   Power factor 0.8

5.5 Development of Power Loss Analysis Software

Since a variety of calculation process is required for optimizing even one countermeasure for a single facility, it would actually become necessary to calculate a huge volume of data corresponding to several times the products of the number of relevant facilities and that of countermeasures. Under such situations, two sets of the power flow calculation software owned by TEPSCO have been prepared for this project after modifying to match the power systems in Jordan.

(1) Development of LV System Power Loss Analysis Software, "VLCALC. EXE"

This software was developed for analyzing the voltage and power loss in LV systems in preparation for executing the power loss study by TEPSCO previously in the other overseas country. This software has been modified to "Jordan Version" for this project study.

The software for calculating the 3-phase 4-wire system should basically be possible to calculate the unbalanced current. In this sense, the VLCALC.EXE software has initially been designed to enable calculation of unbalanced current in 3-phase 4-wire system distribution line.

(2) Development of Medium and High Voltage System Power Loss Analysis Software, "FLOW.EXE"

This software is nearly the same as the conventionally used software for calculating power flow and voltage of power system. It is possible to calculate the power flow, by inputting the system configuration and load data at the respective points in the system. The PSS/E owned by NEPCO and the CASTLE owned by TEPSCO are almost the same as this software. Although they would be possible to analyze the medium and high voltage system, they have been strictly restricted to use either of these software in view of protection of the copyright.

To ensure successful implementation of this project study under such situations, the power flow calculation software, FLOW.EXE by means of the Newton-Raphson method (N-R method) developed solely by TEPSCO has been modified to be used for this project. Major modification points are as follows:

(a) Simulation of transformer loss

According to the ordinal power flow calculation software, the core loss among transformer losses is not simulated, and even the copper loss is not simulated in some cases. In consideration that the transformer loss is also an important element in this study, the software has been modified so as to enable such simulation.

(b) Input by using equipment constant table

According to the ordinal power flow calculation software, the impedance and other constants should be normally obtained in advance from the size and arrangement of conductors, transmission distance and so forth, and these constants are input later. However, this software has been modified so as to make it possible to obtain such constants simply by inputting the kinds of conductor and line distance.

5.6 Development of Models and Software for Optimizing Introduction of Higher Voltage System and Same Voltage Line Construction

(1) Countermeasure by Introducing Higher Voltage System

Since the relation between the benefit and the cost in the case of the same voltage line construction can be expressed by a linear equation with respect to the distance, an optimum scale of countermeasure can be found out easily. In the case of introducing a higher voltage, however, it is not so easy to obtain such an optimum scale according to a simple mathematical formula since the construction cost of substation which is not related to the distance to the substation construction site is included in the cost. Moreover, how to allocate the power supply to the load located between the new and existing substations also raises a problem. To solve this problem, an optimum point is required to be obtained by continuing calculation while changing the open point for power supply between the new substation installation site and existing substation. Thus, it is not possible to study a large number of the cases through manual calculation. Under such situations, the optimization software by Introducing Higher Voltage "OPTEL.EXE" has been developed.

(2) **Countermeasure by Constructing the Same Voltage Line**

In the case of the countermeasure by the same voltage line construction, optimization is possible by comparatively simple judgment, because when line current exceeds a certain level (it is called critical current) the benefit by loss reduction countermeasure becomes bigger than its cost.

Therefore, it was not scheduled at the initial stage to develop any particular software for optimizing the countermeasure. In consideration that the work would be promoted efficiently where any software for calculating the cost and benefit be available by using the data prepared for OPTEL without modification, the same voltage line construction optimization software "OPTEL2 EXE" has been developed.

As a result, the actual study has been carried out by using this software due to time restrictions. Meanwhile, since the critical current is a value constituting an important indicator for judging whether it is feasible to execute the power loss reduction countermeasure, the relevant parties of Jordan are recommended to promote study regarding such a value. Table 5.6-1 indicates such an example.

The manuals for the software described in Section 5.5 and 5.6 were made, and are handed to the Jordanian counterparts.

Table 5.6-1 Critical current for each countermeasure by same voltage line construction

415 V Overhead Line Loss Value = 2,564 JD/kW

existing line	current capacity	additional new line	cost JD/km	critical current	merit (JD/km) for designated current (A)					
					80	100	140	180	240	280
WASP	270	WASP 1ckt	11,250	97	-3,543	792	12,352	27,766	58,112	83,159
AL100	Amp.	WASP 2ckt	22,500	118	-12,224	-6,444	8,970	29,522	69,983	103,379
mm^2		WASP 3ckt	33,750	137	-22,190	-15,687	1,654	24,774	70,293	107,864

33 kV Underground Line Loss Value = 2,061 JD/kW

existing line	current capacity	additional new line	cost JD/km	critical current	merit (JD/km) for designated current (A)					
					280	320	360	380	400	440
AL 300	335	AL 300 1ckt	50,000	373	-21,758	-13,112	-3,314	2,017	7,637	19,741
mm^2	Amp.	AL 400 1ckt	60,000	386	-28,357	-18,670	-7,692	-1,719	4,578	18,139

5.7 Data Related to Power Facilities

For the purpose of executing calculation of power loss and that for studying economically feasible countermeasures, the facility and econo (economic cost) table have been prepared to speed up and simplify the calculation process. Meanwhile, it would be possible for NEPCO, JEPCO and IDECO to make effective use of these calculation tables for many years in the future as far as renewal data.

5.8 Criteria for Evaluating the Power Loss

Any countermeasure for reducing the power loss can be evaluated easily by comparing the benefit obtained by reducing the power loss with the cost required for executing the countermeasure.
This benefit is further classified into a yearly kWh value and a kW value at peak load.
The former benefit is attained by saving the amount of fuel consumption through power loss reduction. This kWh value refers to the benefit in terms of the cost attained by saving the amount of fuel consumption.
The latter benefit is also effective for reducing the power demand at peak load and makes it possible to reduce the development volume of power plant equipment and distribution facilities to be developed This kW value refers to a saved portion of equipment investment in terms of the cost thereof.
So, the Study Team calculated the benefits in terms of cost based on the Long-Run Marginal Cost prepared by NEPCO in March 1996. And used them as the criteria for evaluating the power loss reduction countermeasures.

(1) Setting of the Evaluation Constant for Power Loss Reduction

Firstly, when the higher voltage introduction or same voltage line construction countermeasure has been executed, this electrically means that the power loss is reduced by dividing the load current according to the countermeasure. Should the load current (power demand) be increased in each year, the ratio of power loss before and after executing the countermeasure would remain within a constant level. In other words, the power loss reduction has been treated on the assumption that the loss reduction would increase in proportion to the square of the increase rate of power demand.

Secondly, in case a countermeasure has been taken by installing capacitors, the effect of power loss reduction will be increased depending on the increase of power demand in the future. Since the power loss reduction may scatter depending on the number of capacitors installed in the system, however, it would be difficult to indiscriminately clarify the effect of capacitors. Thus, it has been assumed that the effect of installing capacitors upon the power loss reduction in the initial year would continue to remain at least within the same level as that of the initial year in the subsequent years. In other words, this power loss reduction has been treated on the assumption that the power loss reduction in the initial year would continue to remain at the same level in the future.

(2) Loss Evaluation Constant

The loss evaluation constants are as presented in Table 5.8-1. And the calculation chart for LV system in case of new line construction is as presented in Table 5.8-2

Table 5.8.1 Loss Evaluation Constants for Evaluating the Power Loss Reduction Based on Construction Cost

In case of new line construction	
loss reduction in high voltage system	2,186 (JD/kW)
loss reduction in MV system	2,061 (JD/kW)
loss reduction in LV system	2,564 (JD/kW)
In case of capacitor installation for LV system	
loss reduction in MV system	1,577 (JD/kW)
loss reduction in LV system	1,268 (JD/kW)

Table 5.8-2 Loss evaluation constant on construction cost base in case of LV countermeasure

COUNTERMEASURE

Assumed total countermeasure cost	100,000 JD
depreciation periods	25 year
the rate of interest	10 %
the rate of expenses	0.11017
the rate of O&M cost	0.02500

[Annual cost of countermeasure]

year		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	TOTAL
COUNTERMEASURE COST (JD)	A	11,017	11,017	11,017	11,017	11,017	11,017	11,017	11,017	11,017	11,017	110,168
O&M COST (JD)	B	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	25,000
TOTAL ANNUAL COST (JD) C=A+B		13,517	13,517	13,517	13,517	13,517	13,517	13,517	13,517	13,517	13,517	135,168
COEFFICIENT OF COMPOUND INTEREST	D=(1+0.1)^-y	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	0.424	0.386	
PRESENT VALUE (JD)	E=C*D	12,288	11,171	10,155	9,232	8,393	7,630	6,936	6,306	5,732	5,211	83,055

100,000 JD/83,055 JD = 1.204

[Annual benefit cost]

(Marginal capacity cost *1 =99.6(JD/kW/YEAR) ,Loss factor =0.5783 ,Marginal energy cost *1 =0.02243(JD/kWh))

year		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	TOTAL
GROWTH RATE OF PEAK DEMAND (%) *2	F	-	7.5	6.4	6.1	6.3	5.1	5.1	4.5	4.1	3.6	
REDUCED POWER LOSS (kW)	Gn=Gn-1*(1+F)*2	1.000	1.155	1.306	1.470	1.659	1.831	2.024	2.210	2.395	2.570	
REDUCED CAPACITY COST (JD)	H=Gn*99.6	100	115	130	146	165	182	202	220	239	256	1,755
REDUCED ENERGY LOSS (kWh)	I=Gn*8760*0.5783	5,066	5,851	6,618	7,446	8,406	9,277	10,253	11,196	12,131	13,017	
REDUCED ENERGY COST (JD)	J=I*0.02243	114	131	148	167	189	208	230	251	272	292	2,002
REDUCED TOTAL COST (JD) K=H+J		213	246	279	313	354	390	432	471	511	548	3,757
COEFFICIENT OF COMPOUND INTEREST	L=(1+0.1)^-y	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	0.424	0.386	
PRESENT VALUE (JD)	M=K*L	194	204	209	214	220	220	221	220	217	211	2,130

2,130 JD/kW * 1.204 = 2,564 JD/kW

SOURCE :*1 JEA Jordan Electricity System Strict Long Run Marginal Costs
*2 JEA Electricity Demand Forecast 1995-2010 Executive Summary(Draft) Technical Studies Section/Planning Dept. June 1995

5.9 Conditions of Study and Results of Calculation

Results of Calculation are summarized as Table 5.9-1 below

Table 5.9-1 A List of Result by Parallel Study on Loss Reduction Countermeasures for Sample-1 Feeders

Sample	Countermeasure	No. of Economically feasible feeder	Loss Reduction (kW)	Benefit (JD)	Cost (JD)	Net benefit (JD)
LV 81 feeders	Same voltage line construction	58	270.7	694,062	246,274	447,788
	Higher voltage introduction	18	259.2	664,671	335,901	328,769
	Capacitor installation(*1)	81	88.9	140,164	5,565	134,599
	3 phase current balancing	77	58.2	149,206	0	149,206
MV 14 feeders	Same voltage line construction	9	5,846.3	12,049,224	4,988,536	7,060,649
	Higher Voltage introduction	4	4,370.0	9,006,776	8,314,056	692,720
	Capacitor installation (*2)	14	2,215.8	2,809,634	118,090	2,691,545

Note *1 ; Pf : from 0.8 to 0.9 at consumer. *2 ; Pf : from 0.8 to 0.9 at LV side of transformer.

(1) Reduction of Power Loss by New Line Construction for the LV System

With regard to all of the 81 sample feeders, the power loss, voltage and so forth before executing any countermeasure have been obtained at first by executing power flow calculation by using the VLCALC.EXE software. Next, the respective countermeasures have been optimized by using the OPTEL.EXE. and OPTEL2.EXE. software. Subsequent to executing manual modification to the countermeasures which have been optimized with computer system, the power loss, voltage, after executing the countermeasures have been obtained based on the results of power flow calculation carried out again by using the VLCALC software. On the basis of such results, the benefit of executing countermeasures has been studied.

The results of calculation in case the same voltage line is constructed as a countermeasure for reducing the power loss in a LV system. This countermeasure is found out to be feasible (B – C > 0) for 58 sample feeders out of 81 feeders in total.
The results of calculation in case introduction of the higher voltage system is adopted as a countermeasure for reducing the power loss in a LV system. This countermeasure is found out to be feasible for 18 sample feeders out of 81 feeders in total.

(2) Reduction of Power Loss by New Line Construction for the MV System

After obtaining the power loss, voltage and other data prior to executing the countermeasure at first by calculating the power flow in all of the 12 sample-1 feeders (2 out of 14 of sample-1 feeders are used only for capacitor study) by using the FLOW.EXE software, optimization of the respective countermeasures has been carried out by using the OPTEL.EXE and OPTEL2.EXE software. Subsequent to executing manual modification to the countermeasures which have been optimized with computer system, the power loss, voltage, after executing the countermeasure have been obtained based on the results of power flow calculation carried out again by using the FLOW.EXE software. On the basis of such results, the benefit of executing countermeasures has been studied.

According to the study results for the MV sample-1 feeders, due to rise in the construction cost for 132 kV lines and 132 kV substations, the higher voltage introduction countermeasure was concluded to be feasible only for 4 lines. Although these results were worse than same voltage construction countermeasure in economical view point, the higher voltage introduction countermeasure is hardly disregardful. The relevant parties of Jordan are recommended to view these study results from a wider angle toward the direction of future progress of the power system instead of simply reducing the power loss.

(3) Reduction of Power Loss by Improving the Power Factor in LV System

As the results of measurement show, the power factor in the distribution systems in Jordan is considerably low. According to the regulations for transaction between NEPCO and the other two distribution companies, the average power factor at each metering point is kept at 85% or over. Since almost all the reactive power compensating capacitors are installed on the 33 kV bus-bars, however, these capacitors have not been serving so largely for the most indispensable purposes of reducing the power loss and improving the voltage in the LV systems.

Studied herein are the effects of capacitor without switch gear upon the LV and MV systems by installing such a capacitor on the LV system to improve the power factor.

(a) Effect of capacitor upon the LV system

With regard to all the LV sample-1 feeders, the amount of loss reduction has been calculated on the assumption that the power factor has been improved from 80% to 90% by installing capacitors at the near-end of load. Since these conditions can possibly bring about too ideal and over-evaluated calculation results, such the results were corrected to more realistic ones at the stage of applying the mathematical models.

(b) Effect of capacitor upon the MV system

With regard to all the MV sample-1 feeders, the amount of loss reduction has been calculated on the assumption that the power factor has been improved from 80% to 90% by installing a capacitor on the LV side bus in a distribution substation.

(4) Reduction of Power Loss by Improving the Unbalanced Current in LV System

The 3-phase current in the LV system in Jordan is excessively unbalanced. In this stage, loss reduction in the sample-1 feeders were calculated on assumption that 3 phase current can be balanced completely. These impracticable conditions were corrected on the stage of calculation on the sample-2 feeders.

(5) Secondary Effect Associated with the Power Loss Reduction Countermeasure: Improvement of Voltage

Although improvement of voltage is not a main theme of this study, it has been clarified that the power loss reduction work would also bring about a substantially valuable effect according to the results of voltage calculation obtained during the process of calculation for power loss reduction.

5.10 Power Loss Reduction Model

The conventional feeder data are deemed to be available as feeder parameters, and among such parameters, the current, kind of conductor and line length are considered to be most closely related to the power loss. With regard to the two quantities of power loss reduction value and countermeasure cost, therefore, it has been determined to obtain a mathematical model based on the above parameters according to a statistical technique, because of the following reason: Namely, when the values of loss reduction and countermeasure cost have been obtained, it would be possible to obtain the other quantities from the two quantities according to an theoretical formula.

As a result of study, it has been confirmed that the line length among the parameters is not nearly related to the power loss so that the line length has been excluded from the parameters in the mathematical model. Although the kind of conductor has been examined by replacing it with the resistance value and capacity per unit length, it is not correlated to the loss reduction or countermeasure cost. Among the three parameters, only the current has been observed to have a close correlation.

The scatter diagrams in Figs. 5.10-1 and 5.10-2 indicate the loss reduction and countermeasure cost along the vertical axis (y) and the load current along the horizontal axis (x), for LV new line construction. In these diagrams, the mathematical formulas obtained according to the least square method and the curves obtained from these formulas are also indicated.

These formulas are mathematical formulation models for power loss reduction countermeasures. And they were used for estimating the potential of power loss reduction values in the entire distribution systems in Jordan, and also used for making loss reduction master plan.

Fig. 5.10-1 New Line Construction for LV Feeders [I:Loss Reduction] Scatter

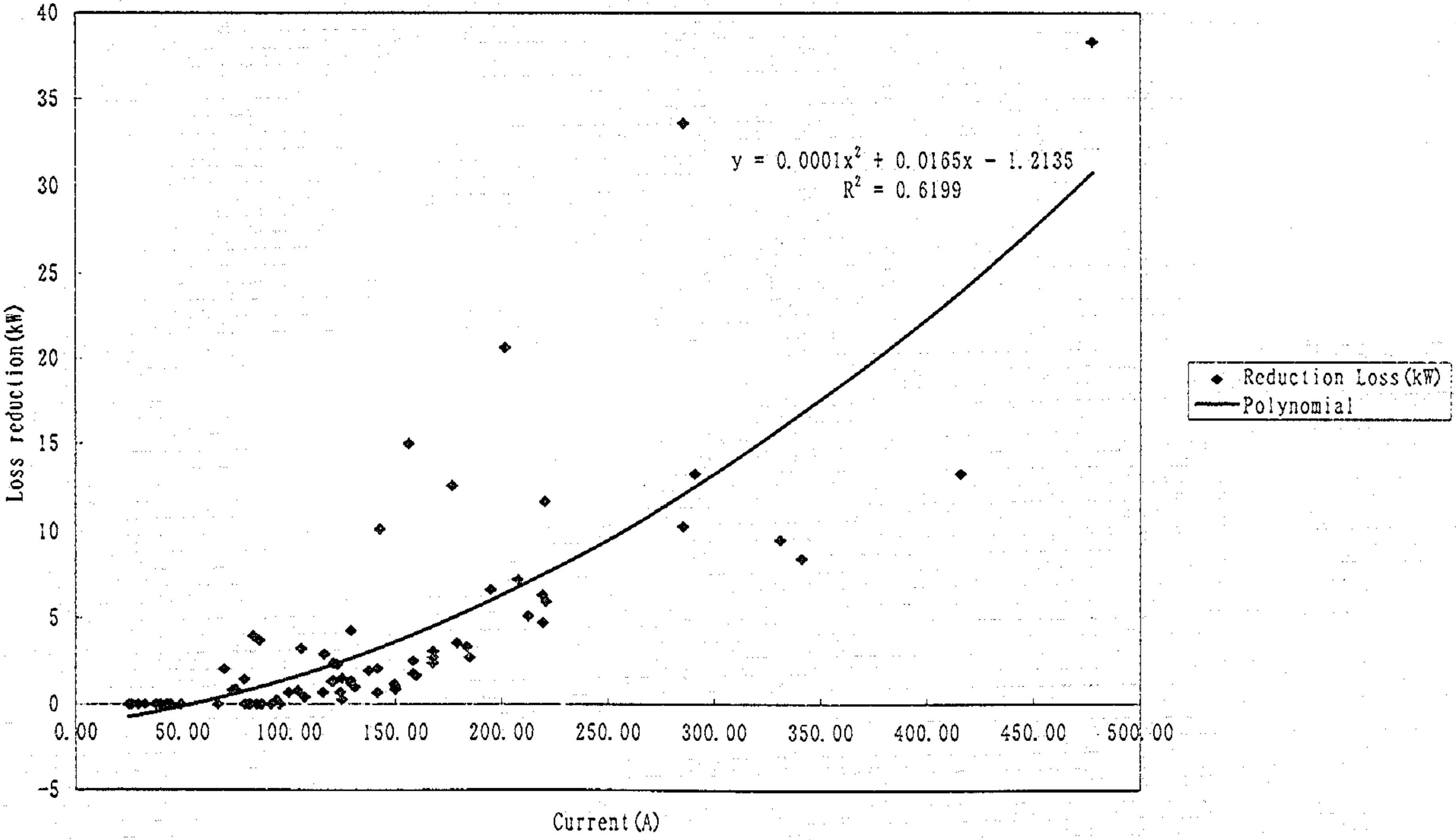
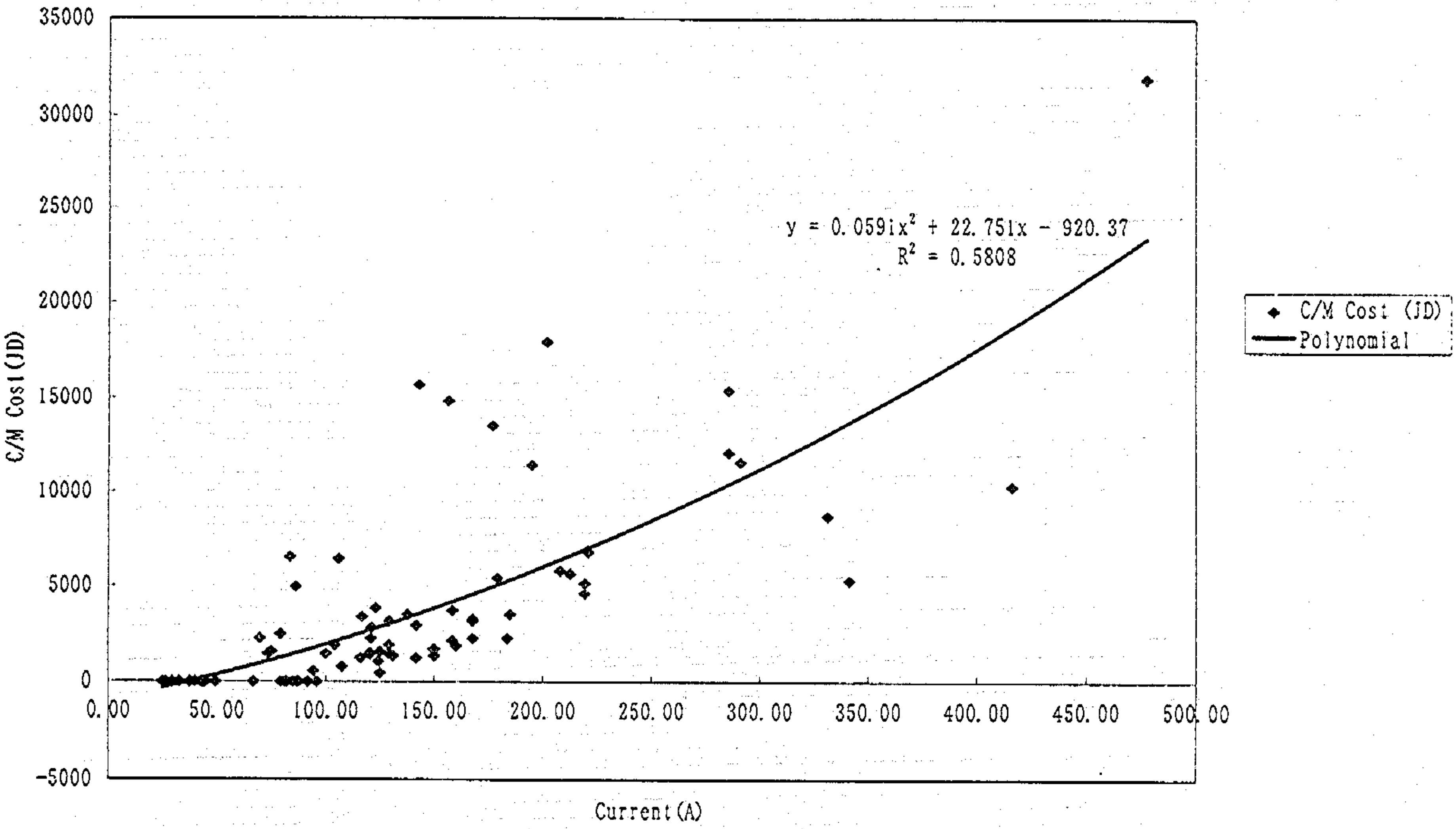


Fig. 5.10-2 New Line Construction for LV feeders [I:Cost] Scatter



5.11 Items to be Considered in Execution Planning

(1) Limit of Mathematical Model

According to the results of investigating the distribution system in Jordan in advance, the feeders are abundant in a variety of shapes. The extent of power loss reduction, etc. are affected largely by such shapes and it would be difficult to express the difference of such forms by using simple parameters. As it is clear from the mathematical models and scatter diagrams described in Section 5.10 above, therefore, substantial scatters would be inevitable. Even though such scatters may be small, it is deemed inappropriate to make use of the models obtained by using such statistic techniques, directly without any modification, for formulating an execution plan.

Until obtaining the mathematical models under this study, the execution plan should be studied strictly as have been carried out regarding that for individual sample feeders. The mathematical models are deemed to be useful for roughly estimating the cost for loss reduction work and extent of loss reduction prior to subsequent studies. These models are also deemed to be useful for finding out the items (problems) to be studied.

(2) Refining of the Plan by Making Utmost Use of Human Knowledge

According to the optimization software: "OPTEL" and "OPTEL2" mentioned previously, an optimum solution is obtained by using a considerably simplified model.

In the case of planning a distribution line and so forth, it is needless to mention that the situation in the area along the line, regional development master plan, relation to the feeders in the surrounding area, conditions of unused facilities, and other sophisticated conditions related to future power system development plan and so forth should be taken into consideration. Since computer calculation is carried out without using such sophisticated information according to this simple model, however, the answers obtained thus would sometimes seem to be primitive and unrealistic for the human being well knowing the actual situations. Therefore, it would be appropriate to recognize that these two software are a tool assisting a person in executing power system planning. In this context, these two software would certainly offer powerful support for covering the human weak point. Instead of simply apply the answers from "OPTEL" and "OPTEL2" directly for the execution plan without modification, it would at least be necessary to study whether the plan is justifiable and whether much more effective method are available or not judging from human knowledge with sophisticated decision-making capability.

CHAPTER 6

FORMULATION OF POWER LOSS REDUCTION PLAN

CHAPTER 6 FORMULATION OF POWER LOSS REDUCTION PLAN

6.1 Preparation for Estimating the Power Loss Reduction in the Entire Power Systems throughout the Country

(1) Pick up of Sample-2 Feeder

Although a mathematical model for power loss reduction countermeasure was obtained by using Sample-1 feeder as described in Chapter 5, this sample-1 feeder consists comparatively heavily loaded feeders. Therefore, it would not be appropriate to estimate the power loss reduction in the entire power systems directly from this sample feeder. Therefore, the power loss reduction was estimated by using another sample-2 feeder.
As described in Chapter 5, the Sample-2 feeder is:

- Randomly picked-up feeders corresponding to about 2% of the total LV feeders; and
- All of the 33 kV feeders for the MV systems

Based on the results of estimating the overall situations of power loss while applying the mathematical models obtained in Chapter 5, a concrete power loss reduction plan was formulated.

Meanwhile, it has been concluded unfeasible to take any power loss countermeasure for the feeders mainly consisting of underground cable among the above feeders, since such feeders are estimated to require excessively high cost for power loss reduction countermeasure and the conductor resistance values being too low so the mathematical model obtained in Chapter 5 were not applicable. Therefore, these feeders have been excluded from those to be studied. The feeders actually picked up for calculation are as listed below:

LV system	:	329 feeders
MV system	:	58 feeders

(2) Electric Power Demand to be Studied and Method of Annual Allocation of Power Loss Reduction Plan

For formulating an optimum power loss reduction plan for the coming one decade, the electric power demand was applied the medium scenario of the long term demand forecast formulated in fiscal 1996 by NEPCO. The target year was set to start from 1999 and to end in 2008, allowing of two years of preparatory period after 1997 when this study will come to the end.

The work execution period was formulated based on the load conditions in 2008 and annually allocated taking into account the scale of benefits, averaging of work volumes and other conditions.

6.2 Potential of Power Loss Reduction in the LV Systems

(1) Load Current of Feeders Constituting the Basis of Calculating the Power Loss Reduction

On the basis of the records of load current values in 1996 and forecast current values in 2008 (1.88 times the data in 1996 based on the peak generation forecast values), the power loss reduction values were calculated as follows by using the mathematical models developed in Chapter 5 as briefly described below

(2) Reduction of Power Loss of LV Feeder by Improvement of Unbalanced Current

Taking into account the feasibility of improving the unbalanced current, the unbalanced current exceeding 30A in feeders were settled to be improved to be less than 30A.

(3) Reduction of Power Loss by Installing Capacitor on LV Feeder

In consideration of the unit capacity of capacitor and effect of improving the power factor, it was studied to install capacitor on feeders which are loaded 100A or greater. Calculation base of improving power factor was settled from 82 % to 90 %.

It is ideal way that if capacitor can be installed at consumer end, however, there is a restriction by unit capacity. Therefore, in this countermeasure, it is estimated possible to attain half the effect obtained by using a mathematical model developed by assuming ideal and perfect compensation. Since this countermeasure for improving the power factor also leads to reduction of power loss in MV system, its effect upon the MV system was also calculated.

(4) Power Loss Reduction on the MV System side by Installing Capacitor on the LV Side of Distribution Substation

1) Target value of power factor improvement

The target value of power factor in the secondary circuit of distribution transformer has been set to 92% in order to prevent over-compensation of power factor in light load time. By the effect of capacitors installed in LV feeders as described in Item (3), the average power factor of LV sample-2 feeders has been calculated as 88.4% in 2008. The average power factor at LV side in distribution transformer was assumed as 90.4% by adding 2% which is improved by existing capacitors installed near distribution substations. Based on these, the target power factor was assumed to be improved from 90.4% to 92 %.

2) Calculation of required capacitor and loss reduction

The required capacity of capacitors, the benefit and cost of power loss reduction, in case the power factor has been improved from 90.4% to 92% as described above were calculated.

(5) Reduction of Power Loss by Construction of Same Voltage Line or Introduction of Higher Voltage System

(a) LV System

In order to exclude the feeders with an small effect of power loss reduction, taking into account the error of mathematical models the feeders wherein the equivalent current after executing the countermeasures in Section 2 and 3 above becomes not smaller than 100A were studied herein.

(b) MV System

Since the current value in the MV feeders where B/C becomes feasible is 137.37A similarly as in the case where the lower limit reduction value in the LV feeders is 100A, this value was adopted as a low limit value for power loss reduction countermeasure by new line construction in the MV system.

6.3 Potential of Power Loss Reduction in Entire Power System

The amount of power loss reduction expected to be attained in 2008 and the cost to be required (net cost excluding price escalation and so forth) were approximately calculated 94.1 MW and JD 63.57 million (about Yen 10 billion) respectively as presented in Table 6.3.1.

Table 6.3-1 Potential of Loss Reduction and Cost for Whole Jordan in 2008

(MW, 1000 JD)

			Loss reduction	Benefit	Cost	Net-benefit
Improvement of LV system	Improvement of unbalance		6.9	17,638	0	17,638
	Improvement of power factor	Effect to LV	6.8	10,732	668	10,063
		Effect to MV	8.1	10,246	0	10,246
		Sub total	14.9	20,978	668	20,309
	New line construction		42.0	107,670	39,344	68,327
Improve. MV system	Improvement of power factor		1.9	2,393	96	2,297
	New line construction		28.5	58,696	23,463	35,234
Total			94.1	207,374	63,570	143,804

6.4 Formulation of Power Loss Reduction Plan

The amount of investment available in power loss reduction is considered to be limited judging from the economic situations, management of electric power industry and other conditions in Jordan. Based on the potential of power loss reduction in 2008 calculated in Section 6.3, the investments were set up JD 20 million, JD 30 million, JD 40 million, JD 50 million, JD 63,570 for A, B, C, D, E alternatives respectively. The volume of works and the investment allocated to one decade taking into account B/C, required execution period and leveling of construction work.

The three kinds of loss reduction countermeasures are implemented according to the priority order as shown below:

1) The reduction of the unbalanced current in the LV feeder is implemented as the top priority, as it is effective in the loss reduction, and it does not require any investment.

2) The power factor improvement in the system by installation of capacitors brings about high investment efficiency (high B/C value). The installation is promoted within the limit of not causing over-compensation at the time of light load.

3) As the above two methods will not yield big enough volume of loss reduction, the plans of new line construction should be considered in addition to these two methods. Such plans should be chosen, in principle, from those with bigger value of B/C.

Formation of concrete projects are as follows:

(1) Formulation of individual project plans

Since the LV systems consist of a number of feeders, it is difficult to concretely specify individual projects, the cost and benefit of power loss reduction were annually allocated in terms of macroscopic quantities for the respective countermeasures. While, the cost of power loss reduction for the MV system was calculated individually as it was possible. They were calculated based on the mathematical models of cost. Therefore, it should be born in mind that the values obtained thus would differ in nature from the results of detailed study for individual projects to be carried out at the execution stage.

(2) Annual allocation of the cost and benefit of power loss reduction

The costs of power loss reduction were annually allocated that the individual LV and MV system projects require one year and two years respectively until completion.

The construction volume and total cost for respective alternative plans are as presented in Table 6.4-1.

Table 6.4-1 Countermeasure Scale and Cost for Respective Alternative Plans

(for 10 years : 1000 JD)

Alternative plan		A	B	C	D	E
Capacitor installation	Capacity MVA	191	191	191	191	191
	Cost	764	764	764	764	764
LV new line construction	No. of feeder	1,533	1,989	2,599	3,881	6,248
	Cost	19,236	22,589	26,376	32,576	39,343
MV new line construction	No. of feeder	0	7	15	22	40
	Cost	0	6,647	12,860	16,660	23,463
Total cost		20,000	30,000	40,000	50,000	63,570

6.5 Estimation of Power Loss

(1) Estimation of Power Loss Reduction

The estimated power loss reduction and the ratio to peak generation in 2009 in case the five alternative plans A, B, C, D and E have been executed are presented in Table 6.5-1.

Table 6.5-1 Power Loss Reduction and the Ratio to Peak Generation in 2009

(Unit: MW, %)

Alternative plan		A	B	C	D	E
L V	Loss reduction	38.0	41.8	45.9	52.4	58.8
	Ratio to generation (%)	2.1	2.3	2.5	2.8	3.2
M V	Loss reduction	10.0	19.2	27.6	32.4	40.2
	Ratio to generation (%)	0.5	1.0	1.5	1.8	2.2
Total	Loss reduction	48.0	61.0	73.5	84.8	99.0
	Ratio to generation (%)	2.6	3.3	4.0	4.6	5.4

(2) Reduction of Electrical Energy Loss

The energy loss reduction, and ratio of loss reduction to energy generation, in the year 2009 are presented in Table 6.5-2.

Table 6.5-2 Energy Loss Reduction and the Ratio to Energy Generation in 2009

Alternative plan		A	B	C	D	E
LV	Loss reduction(GWh)	161.6	177.6	175.1	222.5	249.9
	Ratio to generation (%)	1.4	1.6	1.7	1.9	2.2
MV	Loss reduction(GWh)	45.1	86.9	124.9	146.7	182.2
	Ratio to generation (%)	0.4	0.7	1.1	1.3	1.6
Total	Loss reduction(GWh)	206.7	264.5	320.0	369.2	432.1
	Ratio to generation (%)	1.8	2.3	2.8	3.2	3.8

(3) Estimation of Transmission and Distribution Loss Rate

The loss rate values to energy generation with and without countermeasure till 2009 are presented in Table 6.5-3.

Table 6.5-3 Estimated Loss Rate of Respective Alternative Plans in 2009

Alternative plan	Without countermeasures	A	B	C	D	E
Transmission loss rate	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
M V loss rate	2.7%	2.3%	2.0%	1.6%	1.4%	1.1%
L V loss rate	6.3%	4.9%	4.7%	4.6%	4.4%	4.1%
Transmission & distribution loss rate	11.0%	9.2%	8.7%	8.2%	7.8%	7.2%

CHAPTER 7

ECONOMIC AND FINANCIAL EVALUATION OF PROJECT

CHAPTER7 ECONOMIC AND FINANCIAL EVALUATION OF PROJECT

According the results of economic and financial analysis as shown in the following Table, all the Alternative works are feasible in both the economic and financial viewpoints.

Summary of Results of Economic and Financial Analyses

(%)

Kind of analyses	Alternative A	Alternative B	Alternative C	Alternative D	Alternative E
EIRR	24.91	20.08	17.80	16.45	15.04
FIRR	15.73	12.80	11.36	10.33	9.27

Among them, according to the results of repayability analysis as shown in the following Table which shows a financial wealth of the enterprises who will execute the Project with loan, the Alternative E may be the most ideal countermeasure among 5 alternatives.

Repayability Analyses of Each Alternative

Kind of analyses		Alternative A	Alternative B	Alternative C	Alternative D	Alternative E
Repayability analysis	Repayability	Repayable	Repayable	Repayable	Repayable	Repayable
	Total of net surplus from the commencement of the works to the end of the Project life (JDs.1,000)	98,820	117,271	134,097	145,068	154,896

Results of sensitivity test show the EIRR and FIRR of 10.87 % and 5.66 % respectively under the most pessimistic case of the conditions of 5-year benefit and the cost increased by 30 % in Alternative E. This is to say that, even the most pessimistic case under the conditions as mentioned above shows also still enough high EIRR from the viewpoint that the Project is in developing country. It means that the Project under study is economically sound. And, generally, as suggested by such international institutions as the World Bank, an IRR is expected to at least be cleared a hurdle of 5.0 % from a viewpoint of basic human needs even such a project is in developing countries, and the Project under study satisfies this expectation with the resulted FIRR. Namely, the Project is financially sound too from the viewpoint of basic human needs.

The total construction cost including the contingency for price escalation without the cost for feasibility study stage for formation of crystallized project is estimated at amount of JDs.109,141 thousand consisting of the amount of JDs.93,861 thousand in foreign loan (equivalent in US Dollar, US$132,385 thousand with the exchange rates of US$1=JDs.0.709 in 1996 in average mid rate) and JDs.15,280 thousand in local loan for execution of the countermeasure of the Alternative E.

The said construction cost may be not so much when considered that the Project is for the whole distribution network in Jordan. The above mentioned amount of foreign loan applyed for the repayability analysis is estimated to cover 100 % of the foreign currency portion and 75 % of the local currency portion of the said total investment cost with an interest rate of 2.7 % per annum for repayment period of 30 years with the grace period of 10 years.

According to the existing balance sheets of electricity enterprises in Jordan for past 5 years, the total revenue including the other revenue has been increased with a rate of around 17 % per annum since 1991, while that of expenses including the other expenses has been increased with a rate of 13 %. Comparing with the increasing ratio of revenue, that of expense is rather low during the period for past 5 years. And, the net income in total in 1995 has been reached at the amount of JDs.17,145 thousand.

As mentioned above, the necessary local loan amount is JDs.15,280 thousand for 10 years of construction period. Considering the said existing balance sheet, and demand forecast mentioned in previous sub-clause, the local loan may be easy to be available when it is guaranteed by the said net income. On the contrary, they will be able to borne by themselves within the said net income without any such serious trouble. According to the projected balance sheets up to the end of the period for construction works, they may keep an amount of operation balance (net income) more than JDs.20,000 thousand after commencement of the construction works in the case of Alternative E even if they will pay for local cost of the said works, interest of foreign loan and interest for local loan.

CHAPTER 8

RECOMMENDATIONS

CHAPTER 8 RECOMMENDATIONS

8.1 Recommendations Pertaining to Optimum Plans

The outline of five alternative plans for reducing the power loss proposed under this study is as follows.

Alternative plan		A	B	C	D	E
Capacitor cost (1000 JD) for 10 years		764	764	764	764	764
New line cost (1000 JD) for 10 years		19, 236	29, 236	39, 236	49, 236	62, 806
Total cost (1000 JD) for 10 years		20, 000	30, 000	40, 000	50, 000	63, 570
Power loss reduction (MW) in 2009Y		48. 0	61. 0	73. 5	84. 8	99. 0
Energy loss reduction to generation (%) in 2009Y		1. 8	2. 3	2. 8	3. 2	3. 8
Transmission & Distribution loss rate to generation (%)	Without countermeasure 11. 0%	9. 2	8. 7	8. 2	7. 8	7. 2

These alternative plans are highly significant in eliminating the waste (inefficient use) of valuable natural resources and reducing environmental pollution by combusting power plant fuels from a global point of view. Also from the standpoint of national economy, these plans are better options than constructing thermal power plants and burning imported fuels. From the point of view of respective power utility companies, these plans are so excellent as to contribute significantly in improving the financial structures of the respective companies as described in financial evaluation. The alternative plans are considered to constitute the most preferential options to be adopted at least before "construction of power plants and additional use of fuels".

It has been made clear as a result of executing case studies by changing the interest rates of loan for these alternative plans, that the foreign currency loans with a low interest rate are advantageous but a problem of repayment capabilities arise tentatively as the interest rate increase. Where the upper limit of interest rate is set at 7%, however, the cash balance of the total amount becomes positive in any of the plans.

Out of the five alternative plans, the Plan E is recommended to be adopted by Jordanian power sector, since this plan certainly makes it possible to realize an optimum power loss rate in Jordan, and will bring the largest net benefit among the five plans.

The Study Team has adopted only the feeders of more than 100A in LV as an object of new line construction, considering errors in the model equations in its present master plan. Besides, possible existence of a plan is anticipated which may yield a bigger net benefit with a lager investment than Plan E, as the feeders under 100A may also be made an object provided an accurate calculation is possible. But it is reserved and put aside as a buffer against possible errors of demand forecasts and model equations.

Each of the Plans A ~ D requires much smaller amount of investment than in the case of the Plan E, and the power loss reduction countermeasure is taken according to the most economically advantageous part. Thus the smaller the amount of investment, the greater becomes the B/C (B: Benefit, C: Cost) value as a matter of course, and the smaller becomes the net benefit (B - C) on the contrary. These plans can be adopted in some cases depending upon the financial situations. However, it will be impossible to reduce the power loss rate to less than the present level according to the Plan A requiring the smallest amount of investment among the respective alternative plans. Thus, it is considered essential at least to execute this Plan under any situations coping with the increase of electric power demand.

8.2 Recommendations for Actions and Works Necessary in the Future

The actions and the works to be executed in the future are recommended as follows.

8.2.1 Countermeasure Executable Without Investment---Improving Unbalanced Current---

Improvement of the LV three phase unbalanced current is expected to bring the greatest B/C value as a countermeasure for loss reduction studied this time as it does not require any investment. The improvement of three phase current is recommended to be executed at the very beginning, regardless of financing from outside.

8.2.2 Countermeasure Executable with Low Investment--Improving Power Factor-

For improvement of power factor by installing capacitors in the LV system is possible with a low investment of less than one million JD, and therefore, no foreign loan is necessary. An urgent execution of improvement is recommended by self-financing or local bank loan.

(1) Requirements to be Met for Executing the Countermeasures

Capacitors should be installed as close to the load as possible, but not so as to turn the system into over-compensation, as the load current decreases when the distribution feeders spread into branches and approach the load. Where the load current is roughly one-fourth or one-fifth the load current of the feeder, the existing 25 kVar capacitor as a minimum unit capacity will not be useful at all when installed in the LV system. The Study Team has proposes development of capacitor with a unit capacity of 10 kVar, or 5 kVar wherever possible. Although the B/C value may naturally be reduced due to rise in the unit cost, the advantage of capacitor in power loss reduction will remain unchanged even if the unit cost should be tripled. It may be most important to make good condition for smooth execution of capacitor installation, as long as improvement of LV power factor is concerned.

(2) The Feasibility Study for Improvement of Power Factor

The feasibility study with complicated calculation and sophisticated study are not required for capacitor installation in the LV system It should be carried out mainly with respect to the work execution, the operation and the maintenance after installation. Especially, close attention should be paid to avoid excessive over-compensation, because excessive over-compensation causes loss increase and over-voltage.

8.2.3 Countermeasures for which Investments are Required---New Line Construction---

As mentioned above, improvements of the unbalanced current and the power factor are expected as economically excellent countermeasures because they do not require big amounts of investment. But the quantity of loss reduction by these countermeasures is not sufficient. The loss rate in 2009 will be certainly increased by load growth, if the additional countermeasures are not adopted. New line construction countermeasures are indispensable to realize loss reduction throughout Jordan. Actions and works for execution of new line construction by Jordan power sector are desired.

A large amount of investment and a large volume of work for feasibility study are required for execution of this countermeasure. Besides, efforts to obtain loans from foreign countries may also be required.

(1) Requirements to be Met for Executing the Countermeasures

The objective of new line construction is to realize high conductance for loss reduction. Meanwhile, the size of each distribution line conductor being used at present in Jordan can be said to be too small to realize optimum conductor size as is clear from the results of study on the Sample-1 which concludes that it would be optimum to construct 2 or 3-circuit line along the same route of existing line. While, it is predicted difficulties in some cases to construct an independent line depending on the local situations. It is recommended to promote study for development, adopting and standardization of high conductance line for LV and MV systems such as:

1) Multicircuit line
2) Big size conductor line
3) Multiconductor line

Of course, construction cost of newly developed line should be cheaper than that of two independent conventional line to realize same conductance.

(2) Feasibility Study

Implementation of feasibility studies are necessary for putting the master plan formulated under this study into practice. The request for loan to any international finance institution is also made based on the results of such feasibility study.

Since the feasibility study will amount to a huge volume of work, it would be justifiable to execute the study by dividing ten years of the master plan into three periods:

1) first period-------1999-2001
2) second period---2002-2005
3) third period-------2006-2008

Advised below are the actions and tasks predicted to be required in the future when taking into account the use of the low interest rate loan from international financial institutions.

The respective power companies should carry out the feasibility study and determine the power loss reduction plans. The feasibility study for new line construction will be the most important and require a huge volume of work. Two kinds of data will be required for executing the study on the construction of any new line. One is the system configuration data and the other is the load data.

It is recommended:

1) To collect and accumulate the system configuration data and load forecast data in advance.

2) To adjust the volume of work execution based roughly on the amount of investment given in the master plan as reference values.

(3) Schedule of the Feasibility Study

In case the study is to be carried out by dividing the Plan E into three periods, the number of feeders to be studied will amount roughly to:

1) 750 in the first period
2) 2,150 in the second period
3) 3,500 in the third period

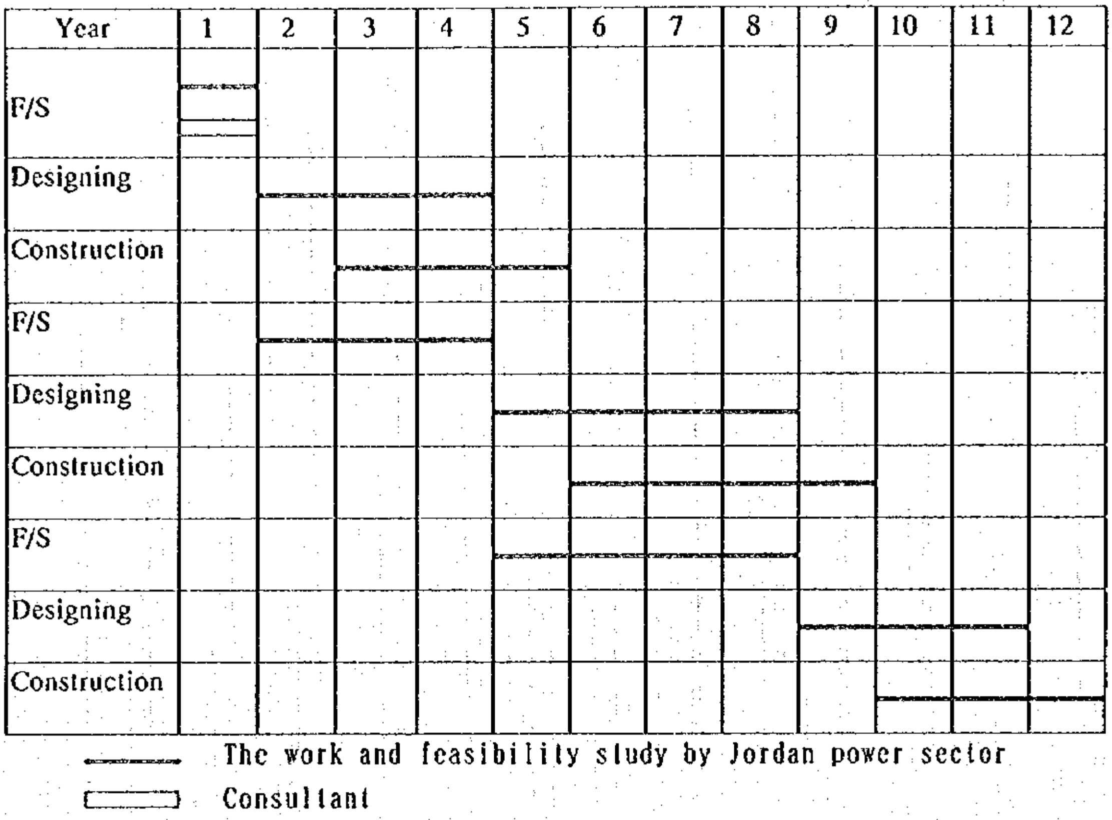
The period required for this study is estimated to be:

1) 1 year during first period
2) 3 years during second period
3) 4.5 years during third period

Judging from the above requirements, the study should be started with a lead time of 2 or 2.5 years before the installation work, carried out continuously and completed roughly one year before starting the third period installation work. It is recommended to start the first period study by the end of 1997.

The outline of work schedule including construction periods is proposed as the table shown below.

Outline of Schedule for the Program



(4) Recommendations for Efficiently Promoting the Feasibility Study

In the case of any distribution system, it is essential to study a large number of items as mentioned previously. As proposed in the above general schedule, both the Second Period and Third Period on the feasibility study should all be carried out by the electric power sector of Jordan.

For this purpose, it is desired to:

1) Study establishment of execution organization in advance.
2) Promote training of the engineers of regional offices and establish study team.
3) Devise speeding up the study along with the progress of the study.

Since the First Period corresponds to a starting period, the first feasibility study is recommended to be carried out in cooperation with the power sector of Jordan and consultant. The power sector of Jordan is desired to acquire sufficient technical knowledge and know-how during this first feasibility study in order to enable the sector to independently execute the Second and Third Period Studies.

The roles of respective parties in the feasibility studies and the organization of the consultant will be as presented below:

(a) The Roles of the Power Sector of Jordan

- Collection of necessary data and site survey
- Assistance in calculation
- Check of the adaptability of planning and designing

(b) The Roles of the Consultant

- Load forecast
- Setting of guidelines for the amount of investment by the respective companies
- Estimation of unit construction cost
- Optimization calculation
- Training on calculation methods
- Feasibility design
- Preparation of work schedule
- Arranging the final plan
- Economic evaluation

(c) Field of Specialties and Volume of Work of the Consultant Team Members

1) Field of Specialties

- Overall team management and demand forecast
- Transmission and distribution planning
- Optimization calculation and calculation training A
- Optimization calculation and calculation training B
- Distribution facilities design A
- Distribution facilities design B
- Economic analysis

2) Volume of work [man/month (M/M)]

- Roughly 40 - 45 M/M is deemed to be sufficient for executing the study.

(5) Application for and Negotiations on Loan

It is essential for the Government of Jordan to decide whether this project should be implemented or not, and if yes, which alternative plans should be adopted. In the case of receiving loans from domestic financing institutions, it may be possible for the respective power companies to select individually different alternative plans.

In the case of requesting loans from any foreign public financing institution, however, the Government will be required to indicate its own uniform intention of choice regarding the Alternative Plans A ~ E after hearing opinions from the respective distribution companies undertaking actual distribution services.
In order that the request of the Government should not be rejected through examination by the international financing institution, the electric power sector of Jordan should direct their efforts for persuading the relevant government institutions (agencies). The domestic ranking of the priority of the power loss reduction projects among the overall projects in Jordan is the most important . In other words, the priority of the power sector itself should naturally be as high as possible to win a top priority in Jordan. As was referred to in RECOMMENDATIONS above, the facts that the power loss reduction projects are ranked higher in priority than any other power plant construction project and that these projects contribute to improving the balance of payment of the country, are persuasive merits. The respective distribution companies are recommended to direct their incessant efforts for persuading the officials of the relevant government agencies.