CHAPTER 5

STUDY OF COUNTERMEASURES FOR THE POWER LOSS REDUCTION

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5.1 Approach to Reduction of Power Loss

Although it tends to be considered generally that the smaller the power loss the better, this concept is not correct when the economic efficiency is taken into account. When the economic loss for supplying electric power equivalent to the loss and the economic cost required for reducing the power loss are taken into consideration, the power loss should not be excessive, but it is not reasonable to pay an excessive cost for solely reducing the power loss. In other words, there would be an economically optimum level of power loss.

As this concept has been pointed out in many electric power engineering handbooks, the individual power system countermeasures are generally studied based on this concept. However, any example of studying the entire power systems consisting of a great many power facilities throughout a country as in the case of this study has not been reported so far. Thus, 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. Where this microscopic study is to be carried out according to the principle, it would be necessary to calculate a huge volume of data equivalent to the products of the number of relevant facilities and that of countermeasures. Since the number of LV(415V) distribution 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 feeders and those on random sampled feeders corresponding to 2% of the total 415 V feeders).

Where the benefit is B and cost is C in case several countermeasures are considered for one facility in general, either of the countermeasures should, in principle, be applied according to the order of greater values of:

$$\lambda = B/C$$

In case B/C is smaller than 1, the countermeasure is not economically feasible so that such a countermeasure should not be adopted. In case any countermeasure of a higher order is executed, the countermeasure of the next order should be studied on the premise that of the higher order has been executed. The benefit of that of the lower order will be decreased. A certain countermeasure will sometimes become entirely unnecessary by executing a countermeasure of the higher order. In other words, it can be said appropriate to study any countermeasure itself based on optimum combination of orders and execute the countermeasure in series. In the case where there are a number of relevant facilities and countermeasures, however, such strict procedures as mentioned above will make the problems further complicated and can possibly make it impossible to even solve the problems.
Therefore, the study on the items (1) ~ (8) above will be carried out in parallel regarding several candidate countermeasures for one sample feeder until obtaining any mathematical model. After any mathematical model has been obtained, the item (9) above will be studied taking into account the preferential order of candidate countermeasures.

After the optimization on the scale of individual countermeasure at the calculation stage for sample feeders, the countermeasure which is concluded to be unfeasible will be excluded, and moreover the optimum order of execution will be taken into consideration. Therefore, an optimum loss of the power system will be realized based on the cost of individual loss reduction countermeasure and the value of power loss calculated in the item (9) above. Since the optimum power loss in a power system consisting of a large number of facilities involves a highly conceptual aspect, and is considered to be realized as a result of executing optimization of individual facilities or portions thereof. The optimum power loss is not always invariable even for one power system and may vary very slowly depending upon the historical background of development and present situations of the facilities, as well as the concept of future equipment planning and so forth. Thus, the numerical value does not make any sense in itself. In the case of a problem regarding to what extent the power loss should be reduced by executing the work for reducing the power loss in a certain already existing facility and in case of another problem regarding to what optimum level the power loss should be set by changing the scale of and amount of investment in the facilities to be constructed later, for example, the answers would naturally vary. Although the cost in the latter case would naturally be lower, the objectives of this study are to reduce the power loss in the existing facilities, the answer may become similar to the former case.

5.2 Options and Selection of Electric Power Loss Reduction Countermeasures

5.2.1 Countermeasures of Power Loss Reduction

Where the resistance of conductor is r, and the load current of the conductor is I, the conductor resistance loss L expressed by the formula below shares the majority of total power loss:

$$L = rI^2$$

Out of above loss, there are many categories of losses in power systems such as the transformer core loss, loss due to leak current through insulator and corona loss. These power losses excluding the transformer core loss are so small that these are not taken into account in studying any power loss reduction countermeasure. The conductor resistance loss can be reduced by making small the resistance r or current I in the above formula.

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 as the results thereof 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 system
(2) Construction of same voltage line

C. New line construction for LV(low voltage: 415V) system

(1) Introduction of higher voltage system
(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 system

5.2.2 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 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. Therefore it has been reduced to a small number of the effective ones by executing following rough study taking into account the cost, occurrence positions of losses.

(1) Generally, the construction cost of high voltage (132 kV) equipment is high, but the power loss in the high voltage system is not large when compared with its construction cost, thus any countermeasure for reducing the power loss in the 132 kV will be almost unfeasible. Similar situations can also be applicable in the case of cable system. (These matter have been confirmed on Clause 5.6.2 "Countermeasure by Constructing Same Voltage Line") Accordingly, countermeasure by construction of 132 kV facility and countermeasure by construction of cable were excluded.

(2) In the area where acquisition of new route is difficult, it would be an effective means of loss reduction to increase the size of conductor. In the execution stage, there will be such the case, but in this stage, it is not easy to get information on new route. If acquisition of new route is not difficult, it is clear that new line construction will be better than to increase the size of conductor, because both the old and new line can be used for loss reduction. Therefore, in this stage, the study of increasing the size of conductor can be considered to be included in the study of new line construction.

(3) The capacitor installation in LV system has an effect both on LV and MV systems, but one installation in MV feeder has an effect only on MV feeders. And, the capacitor installation in 132/33 kV substation is hardly effective for loss reduction at present situation of Jordan. Therefore, only capacitor installation in LV system was studied.

(4) In the field of improvement in operation / control, it looks like that almost maximum effort to reduce loss is being already made within a lot of restrictions. So, only balancing of 3-phase current in LV system was selected, because there is room for improvement.

As a result of above-mentioned consideration, the following combinations of facilities and countermeasures in Table 5.2-1 have been determined to be studied:

- [B.-(1)] Introduction of the higher voltage (132 kV) system for MV system
- [B.-(2)] Construction of the same voltage line for MV system
- [C.-(1)] Introduction of the higher voltage (33 or 11 kV) 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 Feeders

Although the countermeasures selected in the previous clause are required to be studied regarding every feeder unit, 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.

Since the situations of the entire power systems throughout Jordan should ultimately be estimated, it was initially intended that all of the feeders be classified into several groups and each one representative system be selected as a sample system from among the respective groups. Judging from the situations of the data available in Jordan, such a work itself became too large in volume. Thereby, it was found out to be impossible to complete selection of sample feeders within the period of the First Field Investigation . Thus, the feeders deemed to be comparatively heavy loaded and require improvement for loss reduction have been selected by the Jordan side members 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 was named "Sample-1", so can be distinguished from "Sample-2" which becomes necessary in later stage. The Sample-2 must be represent 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

Presented in Appendix 5.3-1 are the selected LV and MV Sample-1 feeders.

5.4 Collection of Existing System Data and Measurement from Sample-1 Feeders

For collecting the system data required for this study, enormous time and labor would have been needed to measure all the sample-1 feeders. For this purpose, it was determined to make effective use of the data owned by the counterpart of Jordan as much as practicable to collect system data by a limited work force within a limited time period. For the purpose of replenishing an insufficient portion of existing data and updating the past measurement data to those applicable under the latest situations, each one feeder of the respective companies was selected from among the MV sample-1 feeders, and miscellaneous data were measured. The feeders selected for such measurement are presented in Table 5.4-1.
However, any current metering terminals have not been provided on the local control boards. Therefore, it was required to carry out the current measurement work while suspending power transmission for measuring the system being sending out power through overhead distribution line. Considering that this work would involve many dangers and require shutdown of power to consumers, it was determined that measurement of the sending terminal by the Study Team would not be carried out. Only in the case of Duleel feeder which is connected by cable with substation buses, the current was measured with a clamp CT and load analyzer. For the other feeders, metering data from the load dispatching office have been used effectively for this study.

Table 5.4-1 Selected MV feeders for actual measurement

Company	Selected MV Feeders	No. of Measured S/S
NEPCO	- Jordan Valley Middle (33kV)	88
JEPCO	- Duleel (33kV)	61
IDECO	- Emrawa (33kV)	126

5.4.1 Collection of Existing System Data

As measurement records related to the distribution system, the voltages in main substations, load currents in MV feeders, LV circuit currents in distribution substations, respective phase currents of LV feeders have been metered and held by the electric power sector of Jordan. Therefore, the Study Team collected these existing data in full cooperation with the counterpart of Jordan.

5.4.2 Method and Schedule of Measurement

(1) Measurement method

The following two kinds of quantities were measured

i) Data of load sent out to MV line; and

ii) Data pertaining to the secondary circuit of distribution substation

Meanwhile, the measurement data in Item i) were intended to clarify the overall characteristics of the entire MV sample-1 feeders, while those in Item ii) were used to correct the existing system data in Jordan.

1) Measurement of load data sent out to the MV line

The data of load sent out to the MV line were measured after installing a load analyzer on the sample feeder at Point A.

- This measurement was carried out for one week and recorded just at each o'clock to clarify the characteristics of the system.

- The load analyzer was used for the measurement.
- The data obtained by this measurement are related to the bus voltage in the secondary circuit of transformer, sent-out power to the line and power factor.
- Except for Duleel feeders, the current values recorded by operator with existing metering instruments have been used.

2) Measurement of data in the secondary circuit of distribution substation

As indicated in Fig. 5.4-1, the respective phase current values in the secondary circuit of Distribution substation were measured by using clip-on meters at all the loads (Point B;275 Substations) connected to the three sample feeders in Table 5.4-1.

- These data were measured by using clip-on meters and recorded once in August, 1996.
- The measured data are the respective phase currents at secondary side of transformer shown Point B.
- The load characteristics were further measured by installing four load analyzers at 4 point of B.

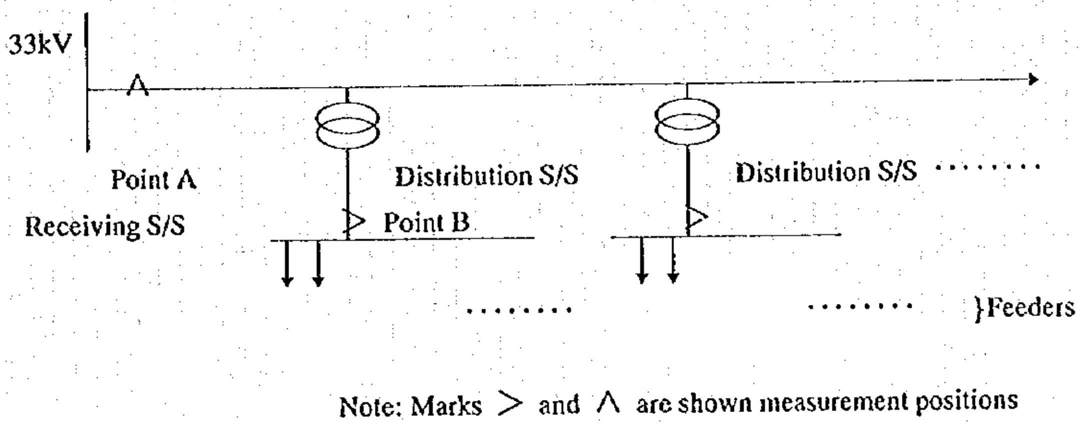


Fig. 5.4-1 Measurement system of actual measurment feeder

(2) Measurement schedule

The period required for measurement was nearly one month from late July through to late August 1996 when the load reached a peak. Moreover, the data pertaining to the representative systems were measured on 14th through 18th August, 1996.
For further detail regarding the measurement schedule, refer to Appendix 5.4-1.

5.4.3 Results of Measurement

(1) Measurement of sending-out data from main substation
For measuring the sending-out data from main substation, the Duleel feeder of JEPCO was measured by automatically recording the data with load analyzers for one week as mentioned previously. For the other feeders, data recorded in the load dispatching office were used for this study.

The results of this measurement and recorded data are presented in Appendices 5.4-2 and 5.4-3. Moreover, the fluctuations of current in these feeders are presented respectively in Figs. 1 to 4 of Appendix. 5.4-4.

Although the peak in the duration curve arises during daytime on the weekdays indicated in Fig. 1 of Appendix. 5.4-4, the load curve remains nearly flat throughout holidays in the Duleel feeder.

Since the three feeders for Jordan Valley are located in farming areas, a particularly remarkable peak load does not appear as indicated in Fig. 2 of Appendix. 5.4-4, and although the demand fluctuates slightly depending on the hour zones, it is difficult to clarify the peak load time zone.

In the case of the four feeders of IDECO, the substantial lighting peak load appears in the evening, as indicated in Fig. 3 to 4 of Appendix. 5.4-4.

(2) Measurement of data in the secondary circuit of distribution substation

The results of measuring the data in the secondary circuits of distribution substations with load analyzers are presented in Appendices 5.4-5 to -7.

The daily average voltage and power factor of the respective utilities have been obtained from the tables in the above appendices are presented in the table below: Based on the results of studies and discussions with the Jordan counterpart, the average voltage and power factor have been set respectively to 97% and 0.8, and the subsequent study will be carried out on the basis of these values.

Average voltage and Average power factor of each utilities

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

The results of measuring the respective phase currents in the secondary circuit of Distribution substation with clip-on meters are presented in Appendices 5.4.8 to -10. The ratio K_1 of the actual measurement data and existing data related to the feeders have been obtained as presented in these tables. Although the number of measurement was extremely limited, it was considered possible to use K_1 indiscriminately for calculating the other existing data in terms of present values. Since this measurement was carried out during daytime in August 1996, also the other converted data by K_1 value are considered to be measured at the same period.

In view of the necessity to obtain yearly peak load for calculation, it was decided to determine the ratio K_2 of the peak load in 1996 to mean daytime load in August 1996 based on the individual load curves of the respective companies.
The coefficient K for calculating the peak load data in 1996 from the existing data can be obtained from:

$$K = K_1 \times K_2$$

Presented in Table 5.4-2 are the values of K_1, K_2 and K for the respective companies.

Table 5.4-2 Coefficients for updating the existing data to present peak values

	NEPCO	IDECO	JEPCO
K_1	0.935	0.659	1.028
K_2	1.45	1.20	1.90
K	1.36	1.23	1.25

The analysis was carried out after correcting the existing data presented in Appendix 5.4-1 to the present peak load data based on the coefficients presented in Table 5.4-2.

5.5 Development of Power Loss Analysis Software

As described in Clause 5.1, the volume of calculations proportional to the products of the number of the relevant facilities and that of countermeasures will be necessary for extending microscopic study. 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 as many as the products of the number of relevant facilities and that of countermeasures. Even after decreasing the number of countermeasures and limiting the relevant facilities to sample feeders, the problem would still remain unsettled. Even by using three personal computers purchased for settling such a problem, these computers alone were insufficient for smoothly calculating such a huge volume of data as intended. Even though "EXCEL", a spread sheet calculation software known to be very helpful also for scientific calculation had been installed, it was still deemed impossible to smoothly handle calculation of a huge volume of sophisticated power circuit data.

Under such situations, two sets of the power flow calculation software owned by TEPCO have been prepared for this project after modifying to match the power systems in Jordan.

5.5.1 Development of (Modification to) 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.

Where the power flow and voltage in the respective power facilities are available, it is possible to obtain the power loss (kW) through calculation. The power flow and voltage are obtained by giving the value of load at the respective load points. In the case of LV distribution line, the load points are provided on almost all of distribution poles, and for extending strict calculation, it would generally be essential to measure the load current per each pole and input the data into a node to be provided for each pole. Since it would be very difficult to repeat such a process for a number of LV systems, the power loss is actually studied on the assumption that the load is uniformly distributed along the line. The software: "VLCALC. EXE" under this study has also been provided so as to be applicable to the above assumption of "uniformly distributed load model". As a matter of course, if the measurement data of concentrated load is available, it is possible to use this data, and if any measurement data of halfway of a line is available, then it would also be possible to calculate the different load density in the remaining section of the line and search for further accurate result. Meanwhile, the uniformly distributed load model is also adopted in the software, "OPTEL" and "OPTEL2", described later.

According to the 3-phase 4 wire system applied in the LV distribution system in Jordan, the 3-phase currents are not necessarily to be balanced. From the actual data in Jordan, the current has also been confirmed to be largely unbalanced, and "balancing of 3-phase current" has been selected as one of the countermeasures described in Clause 5.2.2. The software for calculating the 3-phase 4-fire system should basically be possible to calculate the unbalanced current. In this sense, the VLCALC.EXE software has basically been designed to enable calculation of unbalanced current in 3-phase 4-wire system distribution line.

5.5.2 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 it would be possible to analyze the medium and high voltage system by using these software, they have been strictly restricted to use either of these software in view of protection of the copyright. Therefore, it is impossible to promote technology transfer but also the study work participated by a number of persons.

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:

(1) 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.

(2) 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. Meanwhile, it has been made possible to combine both the conventional and new input systems.

5.5.3 Making Manual for Analysis Software

The manuals for software described Clause 5.5.1 and 5.5.2 have been made, and presented in Appendix 5.5-1 and 5.5-2.

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

Both the introduction of higher voltage system and construction of a same voltage line plans have been selected as countermeasures for reducing the power loss in LV and MV distribution lines. In this case, optimum power loss reduction countermeasures are required to be obtained taking into account the benefit by loss reduction and cost required for executing the loss reduction countermeasure.

In the case of construction of the same voltage line, the current required for executing the countermeasure can be obtained as follows from the kind of conductor used in the existing line, unit construction cost of the new line and so forth.

The benefit B of power loss reduction effect per unit length when the same voltage line is constructed in parallel with the existing line is calculated by the following formula where optimum parallel flow is taken into consideration:

$$B = K_1 \times \{I^2 \times r_1^2 / (r_1 + r_2)\} \times 1000 \text{ (JD)}$$

where K_1: Power loss evaluation criterion (JD/kW)

I: Current of existing line (pu/MVA)

r_1: Resistance value per unit length of existing line (pu/MVA)

r_2: Resistance value per unit length of new line (pu/MVA)

When the cost of unit length $C = K_2$, the current I at B/C=1 can be obtained by following formula.

$$I = \mathrm{SQRT}\ \{K_2 \times (r_1 + r_2) / (K_1 \times r_1^2)\}$$

In this case, I is the critical current determining the open point of whether the countermeasure should be executed or not, and when the actual load current is the greater than this critical current, the greater the benefit of executing the countermeasure. Since the current in any existing line is generally reduced while it is flowing from upstream to downstream, it can be said optimum to execute the countermeasure from the substation outlet to this point.

5.6.1 Countermeasure by Introducing Higher Voltage System

Since the relation between the benefit and cost in the case of the same voltage line construction can be expressed by a linear equation with respect to the distance as mentioned above, 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 at all 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.

To simplify the problem, an extremely simple model has been adopted. According to this model, a single path is selected from among the existing lines, and the data related thereto are input. In this case, the by-path straying from the single path reflects only the load current to the single path. With computer system, the cost and benefit are calculated while changing the substation site along a given path and further changing the open point as well. After all of the change cases have been calculated, the optimum case of the net benefit (B-C) is output as an optimum plan. As it is correct to set the single path to the path where the current is greater, the single path can be searched for by following the branches with the largest current per each branch point after starting from a substation.

Although OPTEL is used for studying only construction of a substation and higher voltage line thereto, it would sometimes be preferable to study the same voltage countermeasure for the secondary system of the substation at the same time. In such a case, further study should be carried out by using OPTEL2 on the basis of the system obtained from OPTEL.

5.6.2 Countermeasure by Construction of Same Voltage Line

In the case of the countermeasure by the same voltage line construction, optimization is possible by comparatively simple judgment as mentioned previously. 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 the 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.

Tables 5.6-1 indicates such an example. In the case of the LV 100 sq. mm (WASP) conductor for the existing LV system and when the same kind of one circuit is arranged in parallel thereto, for example, the critical current is 97 A, and a benefit of 12,352 JD/km is brought about load current at 140 A. Although a benefit of 27,766 DJ/km is brought about at 180 A, the benefit is increased to 29,522 DJ/km in case 2 WASP circuits are provided in parallel. in addition when load current exceeds 240 A, it can be seen that 3 WASP circuits can be get bigger merit.

Moreover, the 300 sq. mm aluminum conductor is used as a standard 33 kV underground cable. In this case, the critical current of 373 A is exceeded the current capacity of 335 A. In the case of the other aluminum underground cable, the critical current also exceeds the current capacity. Therefore, it can be seen that there would be no need to take any power loss reduction countermeasure for the aluminum underground cable. The critical current for several kind of conductors are presented in Appendix 5.6-1 and 5.6-2.

In consideration that the critical current exceeds the rated current in the case of almost all cable systems, any power loss reduction countermeasure has been concluded to make almost no sense. Now that the above situation has been confirmed clearly at this study stage, although such a situation had been predicted in advance, it has been determined not to execute any further study regarding the countermeasure for the systems mainly consisting of cable.

The critical current for 132 kV transmission line is calculated to close to allowable current of the line. It means the 132 kV transmission line is not suitable to take loss reduction counter measure, as presented in Appendix 5.6-3.

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

5.6.3 Making manuals for Analysis and Optimization Software

The manuals for software described Clause 5.6.1 and 5.6.2 have been made, and handed over to Jordanian counterparts. They are presented in Appendix 5.6-4.

5.7 Data Related to Power Facilities

5.7.1 Electric Characteristics

(1) Preparation of model for transformer core loss

By making use of the nature of core loss which is affected not by the load but by the voltage, a resistor will be placed into the transformer primary circuit. Thereby, it will be possible to easily calculate the transformer loss.

(2) Estimation of power loss based on model formula

The distribution transformers used in the 415 V distribution systems of NEPCO, JEPCO and IDECO have a variety of rated capacities ranging from 25 kVA to 3,000 kVA. Moreover, the number of transformers used is also extraordinarily large. In addition, all of the distribution transformers have been imported from a variety of countries including Turkey, Belgium, United Kingdom and many others. Even the rated capacity of transformers are the same, the impedance, core and copper losses, and other electric characteristics are widely scattered. The electric characteristics of some distribution transformers are unknown. Therefore, it would be difficult to input the electric characteristics of so large a number of individual distribution transformers into computer system.

Therefore, the models for estimating the electric characteristics of distribution transformers based on linear regression analysis have been prepared, and such characteristics have been obtained by fitting the characteristic data to the regression formula. Presented in Table 5.7-1 are regression formulas and estimated values of core and copper losses, while the regression formula and estimated values of reactance are presented in Table 5.7-2.

Table 5.7-1 Proposition of Transformer Loss

Medium / Low Voltage 33/.415, 11/.415, 6.6/.415 kV

(Watt)

Code name	Capacity kVA	Fe loss M.Value	Cu loss M. Value	Fe Loss Proposition	Cu Loss Proposition	Pro. Loss m/c. base (%)		Pro. Loss 1MVA base (%)	
						Fe Loss	Cu Loss	Fe Loss	Cu Loss
ML50	50	165	888	322	667	0.644	1.335	0.032	26.693
ML100	100	258	1465	369	1063	0.369	1.063	0.037	10.626
ML200	200	365	1950	463	1853	0.232	0.927	0.046	4.633
ML250	250	553	2695	510	2248	0.204	0.899	0.051	3.597
ML300	300	720	2700	557	2644	0.186	0.881	0.056	2.937
ML315	315	525	2260	571	2762	0.181	0.877	0.057	2.784
ML400	400	760	3040	651	3434	0.163	0.859	0.065	2.146
ML500	500	827	4150	745	4225	0.149	0.845	0.074	1.690
ML630	630	980	4800	867	5252	0.138	0.834	0.087	1.323
ML800	800	950	6300	1026	6596	0.128	0.825	0.103	1.031
ML1000	1000	1290	8575	1214	8177	0.121	0.818	0.121	0.818
ML1250	1250	1530	9700	1449	10153	0.116	0.812	0.145	0.650
ML1500	1500	1600	12500	1683	12129	0.112	0.809	0.168	0.539
ML1600	1600	1680	13100	1777	12920	0.111	0.807	0.178	0.505

trloss2.xls

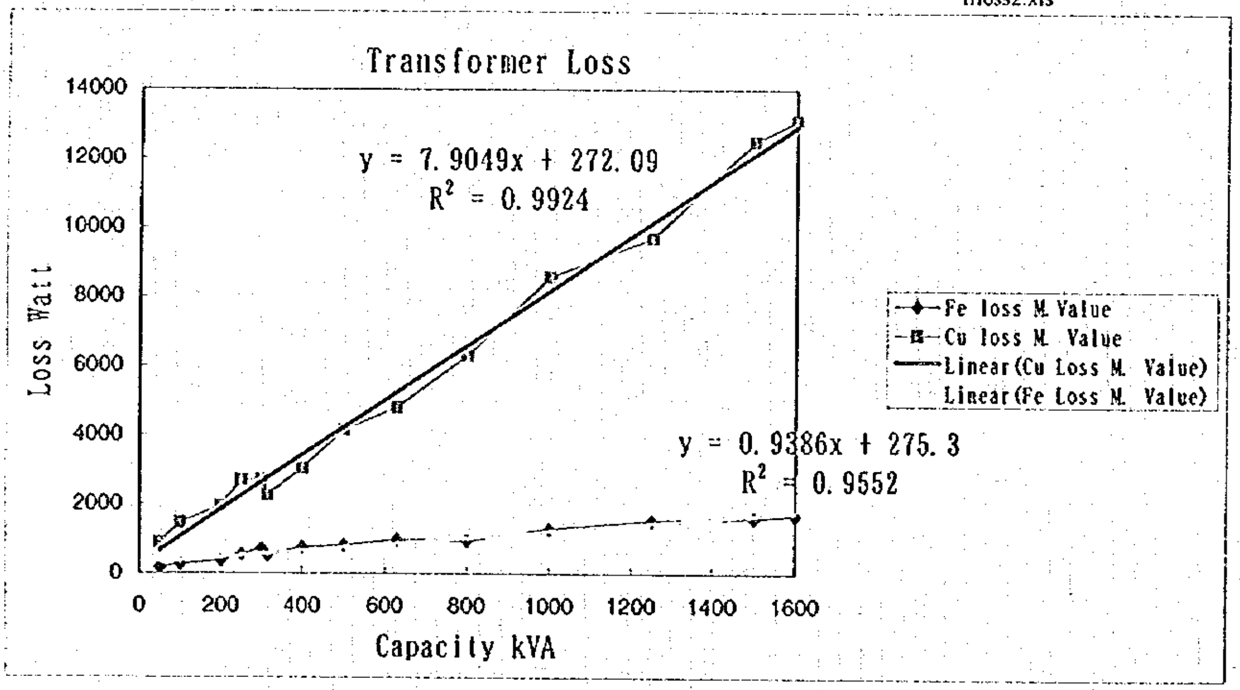
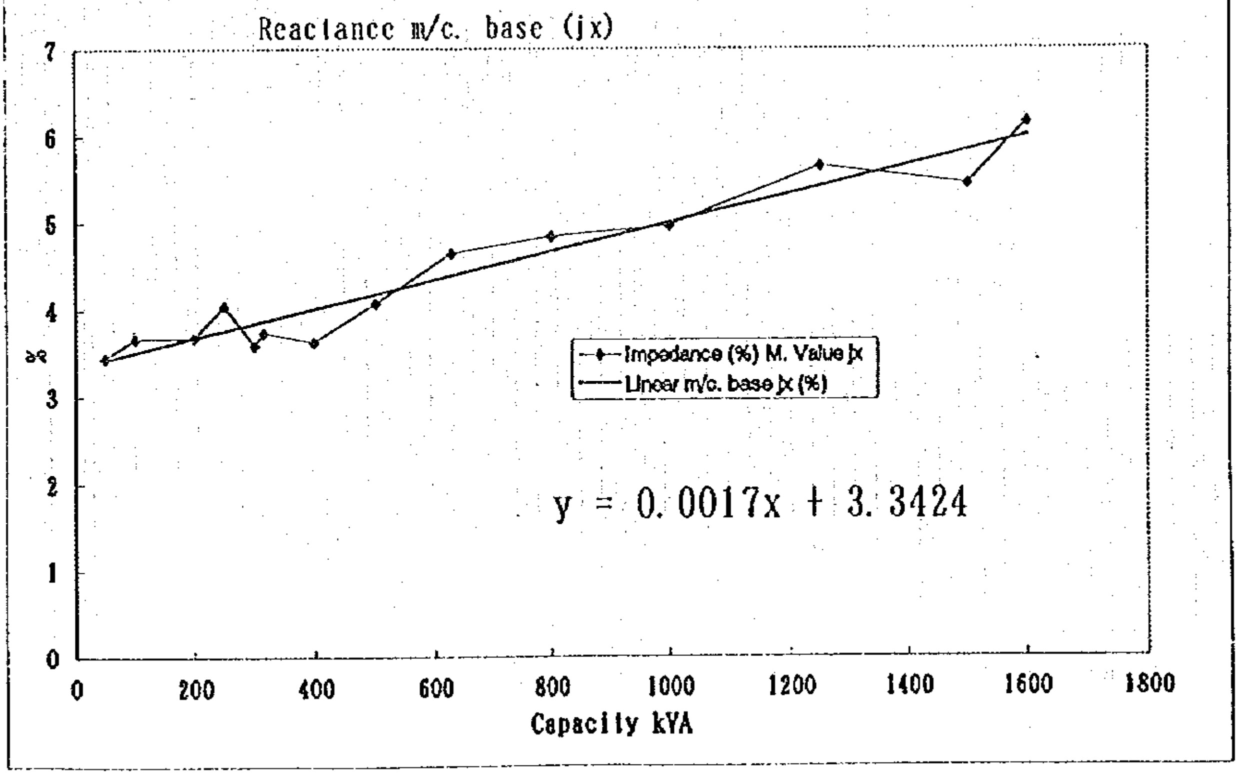


Table 5.7-2 Proposition of Transformer Reactance

trimp-3.xls

Medium / Low Voltage 33/.415 , 11/.415 , 6.6/.415 kV

Code name	Capacity	Impedance (%) M. Value			1MVA base (%)	Proposition 1MVA base(%)		
	kVA	r+jx	r	jx	m/c jx	Core Loss	Cu. Loss(r)	jx
ML50	50	3.88	1.777	3.449	68.983	0.032	26.693	68.548
ML100	100	3.95	1.465	3.668	36.683	0.037	10.626	35.124
ML200	200	3.8	0.975	3.673	18.364	0.046	4.633	18.412
ML250	250	4.18	1.078	4.039	16.154	0.051	3.597	15.070
ML300	300	3.7	0.9	3.589	11.963	0.056	2.937	12.841
ML315	315	3.8	0.717	3.732	11.847	0.057	2.784	12.311
ML400	400	3.7	0.76	3.621	9.053	0.065	2.146	10.056
ML500	500	4.15	0.83	4.066	8.132	0.074	1.690	8.385
ML630	630	4.7	0.762	4.638	7.362	0.087	1.323	7.005
ML800	800	4.9	0.788	4.836	6.045	0.103	1.031	5.878
ML1000	1000	5.03	0.858	4.956	4.956	0.121	0.818	5.042
ML1250	1250	5.7	0.776	5.647	4.518	0.145	0.650	4.374
ML1500	1500	5.5	0.833	5.437	3.624	0.168	0.539	3.928
ML1600	1600	6.2	0.819	6.146	3.841	0.178	0.505	3.789



5.7.2 Construction Cost

The respective costs for constructing the transmission and distribution lines, substations and 33 kV capacitors of NEPCO, JEPCO and IDECO refer to the overall values of costs obtained by cumulating the costs for materials, construction work and so forth.

Construction cost for LV line was estimated based on the construction cost of 1 pole in NEPCO by assumption of 30 poles in 1 km. Meanwhile, the installation cost of low voltage capacitors is estimated to be JD 4 / kVA. The other construction costs are presented in Appendix 5.7-1.

Overhead Transmission Line	132kV Double Circuit	100,000 US$/km Material :60% Construction:40%
Substation (Material + Construction)	132/33kV, 3×40 MVA	1,070,000 US$
	132/33kV, 2×63 MVA	900,000 US$
	132/33kV, 2×80 MVA	1,200,000 US$
Shunt Capacitor	33kV, 1×7.5MVA	90,000 JD (Material + Construction)
	0.4kV, 1×100kVA	Material 282.86 US$ Construction 14 JD
	0.4kV, 1×25 kVA	Material 79.6 US$ Construction 14 JD
Medium Voltage Overhead line	33, 11, 6.6kV	Material 9,080 JD/km Construction 4,205 JD/km Total 13,285 JD/km
Low Voltage Overhead line	0.4kV	Material 305 JD/pole Construction 75 JD/pole Total 375 JD/pole
	30 pole/km	Material 9,150 JD/km Construction 2,100 JD/km Total 11,250 JD/km

5.7.3 Calculation Table

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 the NEPCO, JEPCO and IDECO to make effective use of these calculation tables for many years in the future as far as renew the data.

(1) Facility table

The facility table has been prepared based on the format wherein the resistance, reactance capacity and other miscellaneous data pertaining to the transformer, overhead line, cable and other power facilities can readily be read by computer system according to the categories of power facilities. This table was used for calculating the power loss and power flow as well as for studying economically feasible power loss reduction countermeasures as indicated in Appendix 5.7-2.

(2) Econo (Economic cost evaluation) table

The econo table has been prepared based on the format wherein the capacity, constants which is necessary for loss calculation, and cost of constructing or installing transformer, overhead line, cable and other power facilities can readily be read by computer system according to the categories of the power facilities. This table was used for studying economically feasible power loss reduction countermeasures as indicated in Appendix 5.7-3.

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 energy 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 which to be developed. This kW value refers to a saved portion of equipment investment in terms of the cost thereof.

The Study Team calculated the benefits in terms of cost based on the Long-Run Marginal Cost prepared by the NEPCO (Re JEA) in March 1996. And used them as the criteria for evaluating the power loss reduction countermeasures.

5.8.1 Long-Run Marginal Cost in Jordan

In Jordan, the marginal energy cost corresponding to the kWh value and marginal capacity cost corresponding to the kW value are calculated by the NEPCO as a long-run marginal cost.

The marginal energy cost refers to the cost converted in terms of the respective voltage classes by using the fuel cost per kWh of electrical energy output of generator operated during the respective time zones (peak time, mid-peak time and off-peak time).

Whereas, the marginal capacity cost refers to the cost obtained by calculating the construction cost of peak load power unit (gas turbine power unit) and power distribution facilities in terms of the respective voltage classes.

The dimensions for calculating this long-run marginal cost are presented in Table 5.8-1 below:

Table 5.8-1 Dimensions for calculating the long-run marginal cost

Basic dimensions

Fiscal Year of Initial Study	Final Fiscal Year	Interest Rate	Foreign Exchange Rate
1996	2005	10.0 (%)	0.71 (JD/US$)

Dimensions of fuel cost

	Peak Time	Mid-Peak Time	Off-Peak Time
Proxy Plant	Gas Turbine	Steam + Diesel	Steam & N.Gas
Fuel Used	Diesel	Heavy Fuel Oil	Heavy Fuel Oil
Heat Rate (kcal/kWh)	3,160	2,750	2,300
Fuel Cost (US$/tone)	167	79	79
kcal Per kg	10,200	9,700	9,700
Variable O&M Cost (%) (% to fuel cost)	2.0	5.0	5.0

Dimensions of facilities

	Peak Load Power Unit	Distribution Facilities		
	(Gas turbine unit)	High Voltage	MV	LV
Life Year (year)	20	40	25	25
O&M and A&G Cost (%) (% to capital cost)	1.0	1.0	2.5	2.5

Based on the various dimensions presented in Table 5.8-1, the annual marginal energy cost and annual marginal capacity cost are calculated by NEPCO.

Presented in Table 5.8-2 are the values of the annual marginal energy cost and annual marginal capacity cost.

The annual marginal energy cost is expressed by the cost in terms of the respective classes divided into the respective time zones, while the annual marginal capacity cost is expressed by the total construction cost of the power plant equipment and distribution facilities in terms of the respective voltage classes.

Table 5.8-2 Long-run marginal cost in Jordan

Annual Marginal Energy Cost (Unit: JD/kWh/year)

	Peak Time	Mid-Peak Time	Off-Peak Time
Generator end	0.038	0.018	0.0149
High voltage end	0.0388	0.0181	0.0151
MV end	0.0406	0.0189	0.0157
LV end	0.0445	0.0208	0.0168

Annual Marginal Capacity Cost (Unit: JD/kW/year)

	Generation	Transmission & Distribution				Total
		HV	MV	LV	Subtotal	
HV end	40.548	10.668			10.668	50.204
MV end	42.420	11.160	13.740		24.900	67.320
LV end	46.548	12.240	15.072	25.740	53.052	99.6

Note: Since fractions of 5 and over are counted as a unit and the rest are disregarded, some total values in the above table do not agree to each other.

5.8.2 Setting of the Loss Evaluation Constant

For evaluating the monetary value of reduced power loss under this study, such loss evaluation constants based on the construction cost has been calculated at first by using the long-run marginal cost of NEPCO in Table 5.8-2.

These loss evaluation constants have been calculated in terms of the cost per reduced power loss (kW) in the initial fiscal year. In other words, it will be possible to obtain the benefit of power loss reduction during the service life of the system by multiplying the reduced power loss (kW) in the initial year (obtained from power flow analysis with computer) with loss evaluation constant of power loss reduction.

As described in Clause 5.2.2, the countermeasures selected to studied are those for the MV and LV distribution systems and installation of capacitors, and the loss evaluation constants have also been calculated by classifying such values in terms of the higher voltage introducing and same voltage line constructing countermeasures by the respective voltage classes as well as installation of capacitors. The calculation result of countermeasure for LV system is presented in Tables 5.8-1. And also presented in Table 1 and 2 of Appendix 5.8-1 are the standard loss evaluation constant for evaluating the power loss reduction in the case of the countermeasure for introducing higher voltage classes or construction of same voltage line respectively in the HV and MV systems.

Presented further in Tables 3 and 4 of Appendix 5.8-1 are the loss evaluation constants for evaluating the power loss to be reduced when capacitors are installed respectively in the MV and LV systems.

(1) Concept of the power loss to be reduced in the respective target fiscal years

In case any power loss countermeasure is executed, it will be possible to easily obtain the power loss reduced in the initial fiscal year by computer analysis. However, it would involves difficult jobs to analyze the power loss to be reduced per year in the subsequent fiscal years.

Therefore, the power loss to be reduced in the respective years has been clarified based on the following assumption:

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) Calculation flow of loss evaluation constants

The benefit attained by reducing the power loss has been considered in terms of both the reduced capital cost (kW) and reduced energy loss (kWh) under this study as described previously. The method of calculating the loss evaluation constant based on the construction cost is as described below. The calculation sheets according to the following calculation flow are given in Table 5.8-3 and Appendix 5.8-1:

1) The power loss reduction at peak load in the initial year by executing a certain power loss reduction countermeasure is assumed to be 1 kW.

2) In the case of introducing higher voltage line or constructing the same voltage line, the power loss reduction in the subsequent years next to the initial year is estimated to be increased in proportion to the square of the increase rate of peak load. In the case of installing capacitors, the power loss reduction in the subsequent years is estimated to remain at the same quantities as that in the initial year.

3) The reduced capacity cost (kW) in the respective target years has been calculated according to the following formula:

Reduced capacity cost
= [(Annual marginal capacity cost) x (Power loss reduction at peak load)]
where the annual marginal capacity cost may vary depending upon the voltage class of the system for which a countermeasure is taken:
In case of countermeasure for HV system: 51.204 (JD/kW/year)
In case of countermeasure for MV system: 67.320 (JD/kW/year)
In case of countermeasure for LV system: 99.6 (JD/kW/year)

4) The energy loss reduced annually in the respective target fiscal years has been calculated according to the following formula:

Reduced energy loss
= [{(Reduced power loss) x 8,760 hours x {Loss factor (= 0.5783)}]
where the electrical energy duration curve is divided into three time zones: Peak time, mid-peak time and off-peak time and the loss factor is adopted during the respective time zones is adopted. as in Appendix 5.8-2

5) The reduced energy cost (kW) in the respective fiscal years has been calculated according to the following formula:

Reduced energy cost = [(Annual marginal energy cost) x (Reduced energy loss)]
where the marginal energy cost may vary depending upon the voltage class of the

system for which the countermeasure is taken. Moreover, the average marginal energy cost during the three time zones is adopted as in the case of calculating the loss factor:

In case of countermeasure for high voltage system: 0.01969 (JD/kWh)

In case of countermeasure for MV system: 0.02055 (JD/kWh)

In case of countermeasure for LV system: 0.02243 (JD/kWh)

6) The reduced capacity cost obtained in Item 3) and the reduced energy cost obtained in Item 5) are totaled and adopted as a total reduced cost.

7) The calculated values are transformed in terms of the present worth.

8) The total cost values are transformed totaling the present worth for ten years.

9) The total cost during the service life of the system for which a countermeasure is taken has been converted on the basis of the construction cost for the countermeasure by using the constant (hereinafter referred to as "the conversion factor") obtained from the following formula:

Conversion factor

= [Depreciation cost of construction cost required for service life calculated in terms of present worth]/[Depreciation cost of construction cost and O & M cost required for one decade calculated in terms of present worth]

$= [nK \times r(1-r^m)/r^m(1-r)] / [(nK + aK) \times r(1-r^{10})/r^{10}(1-r)]$

$= [n \times (1-r^m)] / [r^{m-10} \times (n + a) \times (1-r^{10})]$

= 1.204 where the service life is 25 years

1.450 where the service life is 40 years

where m: Service life(years)

n: Rate of expenses

K: Construction cost

a: Rate of operation and maintenance (O & M) cost

r: 1 + Interest

The conversion factor obtained by yearly developed calculation method are given in the upper columns in Table 5.8-3 and Table 1 to 4 of Appendix 5.8-1. The values in Table 1 of Appendix 5.8-1 are those in case the service life is 40 years and those in other Tables are those in case the service life is 25 years.

Table 5.8-3 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

By using this conversion factor, the "loss evaluation constant" for evaluating the power loss reduction based on the construction cost has further been calculated according to the following formula:

Loss evaluation constant based on the construction cost
= [(total cost x (Conversion factor)]

Results of the calculation are as follows:

Table 5.8.4 Loss evaluation constants for evaluating the power loss reduction based on the construction cost

Introduction of higher voltage or construction of same voltage line	
In case of countermeasure for HV system:	2,186 (JD/kW)
In case of countermeasure for MV system:	2,061 (JD/kW)
In case of countermeasure for LV system:	2,564 (JD/kW)
Installation of capacitors	
In case of countermeasure for MV system:	1,577 (JD/kW)
In case of countermeasure for LV system:	1,268 (JD/kW)

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.

5.9.1 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, reduction of loss, voltage, etc. 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.

Presented in Appendix 5.9-1 are 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. Thus, only 58 sample feeders deemed to be feasible to take this power loss reduction countermeasure are given in this table.

Presented also in Appendix 5.9-2 is 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 in total. Thus, only 18 sample feeders deemed to be feasible to take this power loss reduction countermeasure are given in this table.

Summarized in Appendix 5.9-3 are various data for 81 sample feeders as well as the results of calculation regarding the countermeasure by constructing the same voltage line and that by introducing the higher voltage system. The net benefit herein refers to that based on the construction cost for individual countermeasures calculated at this stage.

When the net benefit is indicated 0, it means that the said countermeasure is not feasible for the feeder (B - C ≦ 0), and this indicates that the net benefit is minus or zero. From this summary, it can be seen that the feasible range of the same voltage line construction countermeasure is wider than introduction of higher voltage system countermeasure. Moreover introduction of higher voltage system countermeasure is not feasible when the same voltage line construction countermeasure is not feasible.

As described in "Approach to Reduction of Power Loss" in Clause 5.1, where both of the countermeasures are feasible, the countermeasure with greater B/C should, in principle, dominate over. However, the countermeasure with maximum net benefit (B - C) has been selected herein because of the following reasons: Namely, although the B/C tends to become more disadvantageous in the case of the higher voltage introduction countermeasure because of a heavier burden of substation construction cost, a priority should preferably be placed on this countermeasure as much as permissible in view of the prevailing situations when the effect of voltage improvement and future progress of power systems are taken into account. As a matter of fact, such a minor change of the evaluation criteria are not deemed to deteriorate the economic efficiency (benefit) of this project.

5.9.2 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 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 and its reduction, voltage, etc. 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.

(1) Same voltage line construction countermeasure

Presented in Appendix 5.9-4 are the results of studying the same voltage line construction countermeasure for the twelve sample-1 feeders. Among these feeders, the Jordan Valley North line is explained herein for example.
This line consists of a 3.2 km underground cable section (300 sq. mm aluminum cable) from the outlet of the IRBID, a main substation, and the major section therefrom, namely, a 18.4 km overhead line IBIS (ACSR 200 sq. mm). Here the power is supplied to large scale pumping load as well as to general load from further downstream overhead line DOG (ACSR 100 sq. mm). As a result of calculation, the electrical energy transmitted from the IRBID is 18,100 kW and the power loss in 33 kV line is 1,611 kW before execution of countermeasure. According to an optimum power loss reduction countermeasure obtained with the OPTEL2 software, it has been clarified appropriate to extend two circuit line over a distance of 21.6 km (including underground cable part: to ensure operation reliability) to the large scale pumping power supply point, and one circuit line over a distance of 7.9 km downstream of the above supply point. In case this countermeasure is to be executed, the line loss will be reduced by 1,183 kW and the corresponding benefit amount to JD 2.438 million according to the evaluation criteria. Since the countermeasure cost is JD 1.033 million, a net benefit of as much as JD1.405 million is predicted.

Although the countermeasure for light load line would become unfeasible similarly as in the case of LV system, the countermeasure may sometimes become unfeasible when installation of dedicated circuit breakers is taken into account as in the case of the Madaba-A Line.

(2) Higher voltage introduction countermeasure

Presented in Appendix 5.9-5 are the results of studying the higher voltage introduction countermeasure for the MV sample-1 feeders. Due to the high cost for 132 kV lines and 132 kV substations, this countermeasure is concluded to be feasible only for 4 lines. The higher voltage introduction countermeasure is hardly disregardful in despite of adoption of the same consideration as described in LV system. 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.

5.9.3 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 buses, however, these capacitors have not been serving so effectively for the most indispensable purposes of reducing the power loss and improving the LV systems.
Studied herein are the effects upon the LV and MV systems by installing capacitor without switchgear on the LV system to improve the power factor.

(1) Effect of capacitor upon the LV system
With regard to all the LV sample-1 feeders, the amount of power loss can be reduced 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. Although these conditions can possibly bring about too ideal and over-evaluated calculation results, such results were corrected to more realistic ones at the stage of applying the mathematical models. The study results are presented in Appendix 5.9-6.

This countermeasure is feasible for almost all of the lines as featured by its significantly large B/C value since the cost of capacitor is low. Thus, this countermeasure should be executed with top priority. When installed at these positions of LV system, the capacitor will be effective for reducing the power loss not only in the LV system but also in the MV system. Therefore, this countermeasure will be considered again at the stage of model application.

(2) 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. These conditions were also modified at the model application stage. According to the results of calculation regarding the MV sample feeder presented in Appendix 5.9-7, this countermeasure has been concluded to be feasible for all the feeders. Except in the case of particularly light-loaded feeder, the B/C value is so large that this countermeasure should be executed with high priority.

5.9.4 Reduction of Power Loss by Improving the Unbalanced Current in LV System

The 3-phase current in the LV power 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.. The calculation results are presented in Appendix 5.9-8. Improvement of unbalanced current should be solved with top priority, judging from the fact that Cost = 0.

5.9.5 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 for voltage improvement according to the results of voltage calculation obtained during the process of calculation for power loss reduction.

As the values of voltage drop before and after executing the power loss reduction countermeasure are given in either of Appendix 5.9-1 ~ 5.9-8, the calculation results before execution of the countermeasure indicates serious voltage drop. Since the current values used herein have been assumed on the basis of the maximum current in one year, extremely large voltage drop would be indicated. However, the voltage is estimated to be lowered nearly to such LV at the far end of the system. Every countermeasure of loss reduction is observed to be effective for voltage improvement. Among the countermeasures of loss reduction by new line construction, it can be seen that the higher voltage introduction countermeasure excels particularly in the voltage improvement effect.

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 per unit length and capacity, it is not correlated to the loss reduction or countermeasure cost. Among the three parameters, only the current has been observed to have a high 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. Other scatter diagrams are presented in Figs 1 to 7 of Appendix 5.10-1.

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.

The mathematical models are as listed below.

- **Loss reduction**

LV	New line construction	Y=0.0001X^2 + 0.0165X - 1.2135
	Capacitor installation	Y=0.0158X - 0.7756
	Improve. unbalanced current	Y=0.0001X^2 + 0.0022X - 0.0158
MV	New line construction	Y=3.0076X - 172.68
	Capacitor installation	Y=0.7958X + 18.263

- Cost

LV	New line construction	Y=0.0591X^2 + 22.751X - 920.37
	Capacitor installation	Y=0.5907X + 0.8341
MV	New line construction	Y=2071.4X - 22727
	Capacitor installation	Y=43.357 + 216.66

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

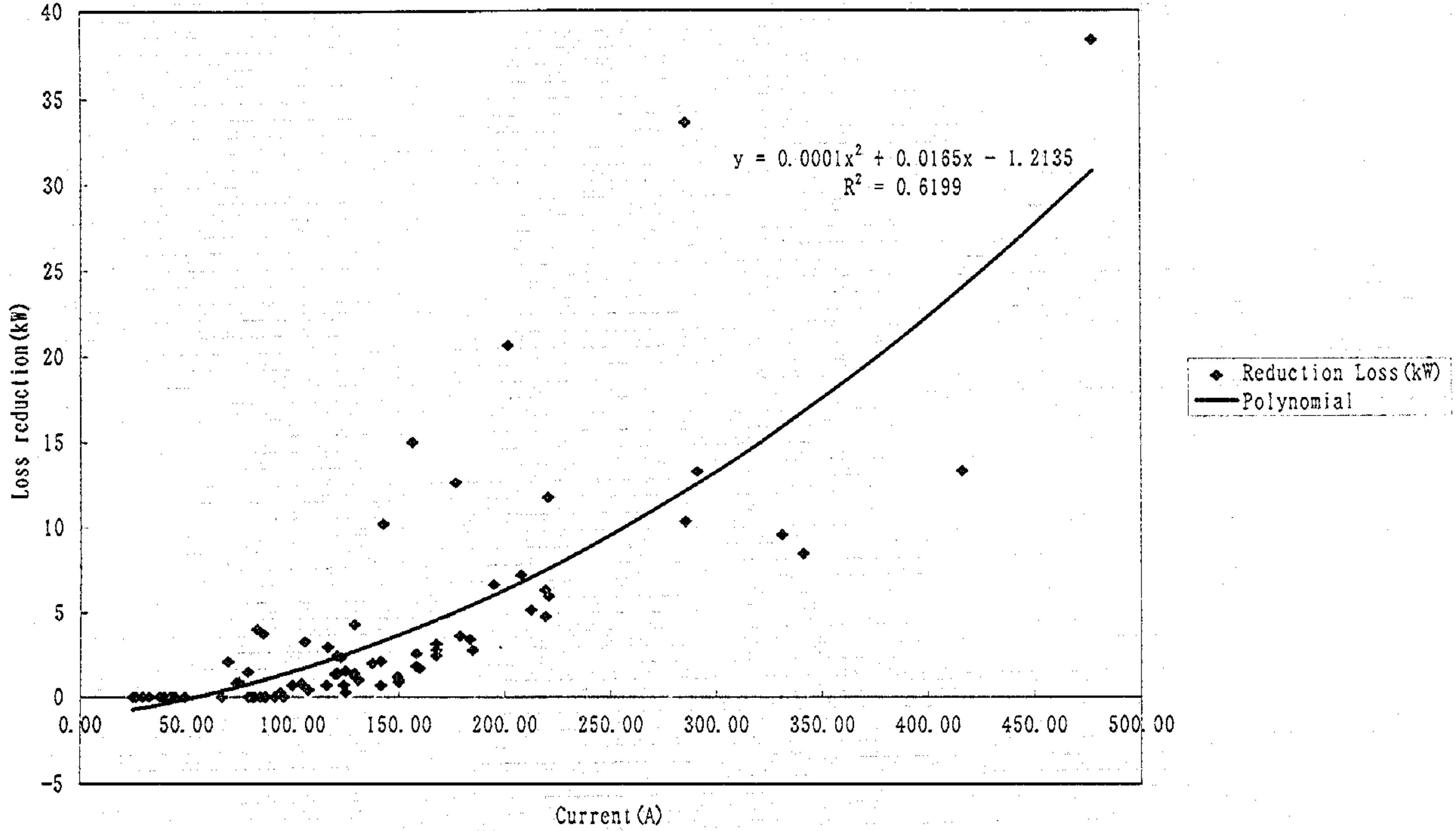
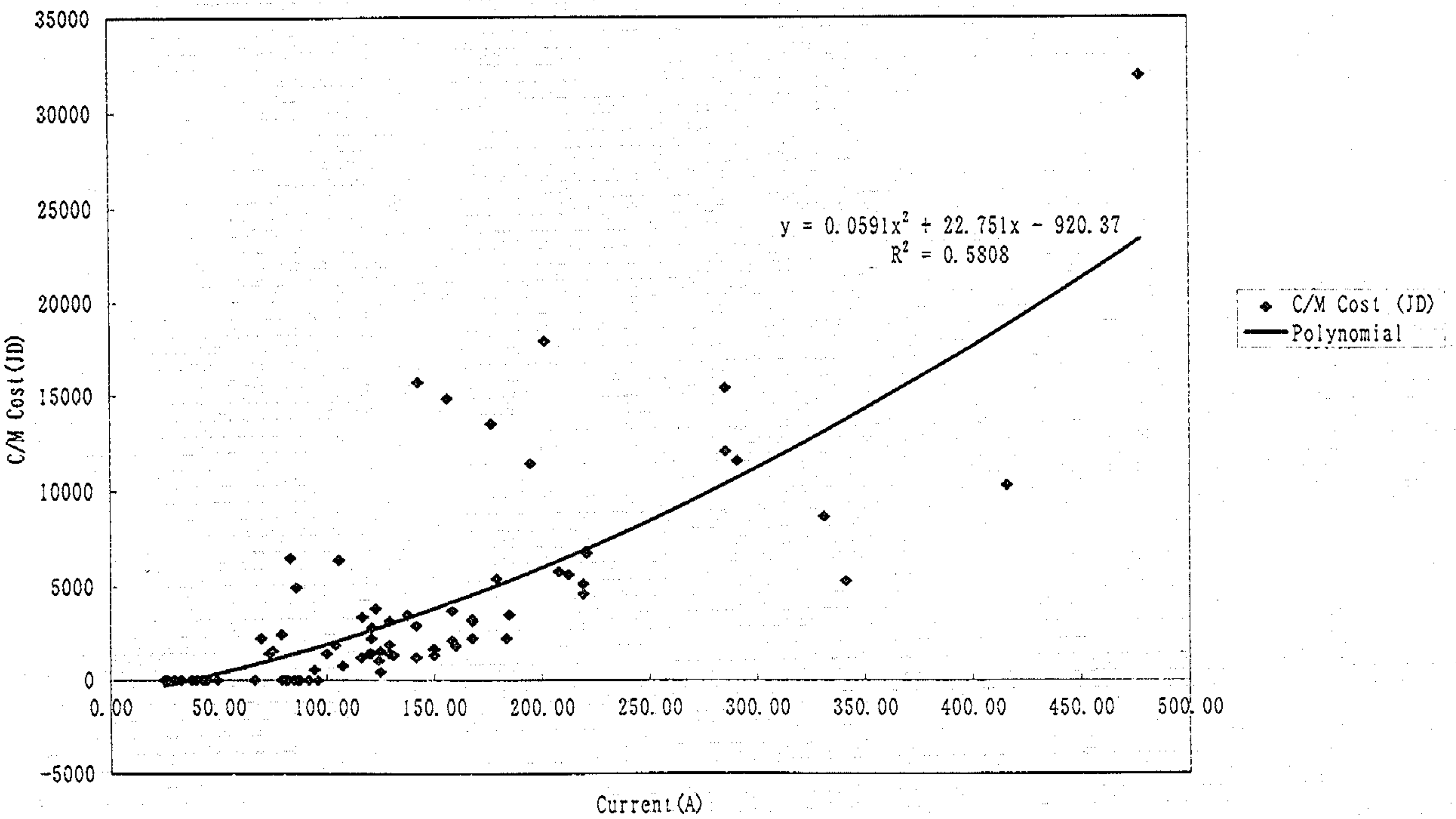


Fig. 5.10-2 New Line Construction for LV feeders [I:Cost] Scatter



5.11 Items to be Considered in Execution Planning

5.11.1 Limit of Mathematical Model

According to the results of investigating the LV 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 forms 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. The execution plan should be studied strictly as have been carried out regarding that for individual sample feeders, same as obtaining the mathematical models under this study. 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 to be studied.

5.11.2 Refining (Finalizing) 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.

Although it has not been included in this study so as not to increase the scatters in the process until obtaining the mathematical models, that a part of the 33 kV sample feeder has been studied while making use of the knowledge of the Jordanian counterparts so as to make it possible for the counterparts to refer to formulating any execution plan in Jordan in the future.

Its study examples are as given below:

(a) Study of Jordan Valley district

The power system for supply to the Jordan Valley district extending in southern and northern directions consists of four(4) 33 kV line, namely Jordan Valley North line from the 132/33 kV IRBID Substation, Jordan Valley Middle and South lines from the SUBEIHI Substation, and further a line from BAYADER Substation to the southernmost district. These systems have been designed to enable interconnection through switching equipment in the flat area of Jordan Valley.

Consequently, the following two alternative plans have been studied based on the results of executing individual system studies obtained from the "OPTEL" and "OPTEL2"software : Namely, one is the same voltage introducing countermeasure plan, by which the benefit can be increased by saving the volume of facilities to be extended, and another is the plan for supplying the load to the central district by introducing a 132 kV line and a substation in the northern district. these 2 alternatives are comprehensively studied with human knowledge. The study results are presented in Appendix 5.11-1. It exactly prove that the effect of study on the basis of human knowledge is highly significant. Refer to Fig 1,2 and 3 of same Appendix

(b) Study of QAIA JEPCO1 line

With respect to the QAIA JEPCO1 line listed in the same Appendix 5.11-1, a solution has been obtained from the "OPTEL2" software (a plan for extending a line in parallel with the existing route so as to pass through two triangular sides). Then, the following 2 alternative plans have been compared: Namely, a plan to adopt one circuit same voltage line by changing the line in the solution to a straight line, and a plan of introducing 132 kV line. Refer to Fig 4 and 5 in same Appendix

(c) Synthesizing study of Emrawa and Samma line

Presented further in the same Appendix 5.11-1 is a power loss reduction plan by synthesizing both of the Emrawa and Samma Lines. In this plan, a consideration has been made that effective use of the existing light load lines and a new line which already planned . Refer to Fig.

6 and 7 of Appendix 5.11-1

As can be seen also from this comparison table (Appendix 5.11-1), only the optimum plans for construction of new line along the existing line can be obtained according to the solutions from the "OPTEL2" software for individual feeders. Therefore, it is essential to search for further effective alternative plan on the basis of human knowledge. The conceptual diagrams related to Appendix 5.9-4, 5.9-5, 5.11-1 are presented in Figs. 5.11-1 ~ 5.11-9. in same Appendix

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

Although a mathematical model for power loss reduction countermeasure was obtained by using Sample-1 feeder as described in Chapter 5, this sample 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.

6.1.1 Pick up of Sample-2 feeder

After numbering in series all the distribution substations in the LV system throughout the country in advance, the substations corresponding to 2% of all substations were picked up by using a table of random numbers, and all the 415 V feeders connected to these substations were selected as LV Sample-2 feeder.

- The LV sample-2 feeders of the respective power companies are as listed below:

Table 6.1-1 Selection of Sample-2 for LV Feeders

Company	No. of target substations	No. of random picked 2 %up S/S	No. of picked up feeders
NEPCO	1,146	23	65
JEPCO	3,100	62	210
IDECO	1,378	28	84
Total	5,624	113	359

- In the case of the MV feeders, all the 87 feeders of 33 kV system were listed.

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 is 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

The electric current distribution conditions in these feeders are presented in Appendix 6.1-1.

Meanwhile, the total load of the 359 LV Sample-2 feeders, connected to the distribution substations corresponding to 2% of the total substation, were calculated to correspond to about 2.3% load of the total feeders. Therefore, the results of study regarding this Sample-2 for LV were multiplied by 44 for applying the nationwide power systems.

6.1.2 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 values 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 Calculation of Potential of Power Loss Reduction in the LV Systems

6.2.1 Load Current of LV 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 briefly described below by using the mathematical model developed in Chapter 5 (For further details, refer to Appendix 6.2-1 - 6.2-2).

6.2.2 Reduction of Power Loss by Improvement of Unbalanced Current

(1) Target Values of Improving 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 less than 30A.

(2) Calculation method

After deducting the value of power loss reduction in the case of the line wherein the unbalanced current not greater than 30A has perfectly been balanced from that wherein the unbalanced current exceeds 30A, the difference obtained thus is deemed to be a portion of the power loss reduction by improving the unbalanced current.

6.2.3 Reduction of Power Loss by Installing Capacitor on LV feeder

(1) Study conditions

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 (Refer to Clause 6.3.2).

(2) Calculation method

On the basis of the equivalent current after improvement of unbalanced current, the capacity of capacitors required for improving the power factor for consumers from 82% to 90% were calculated. At the same time, the difference of current loss reduction between before and after improvement of the factor was calculated as a value of power loss reduction by improving the power factor.

6.2.4 Reduction of Power Loss by Construction of Same Voltage Line or Introduction of Higher Voltage System

(1) Lines to be studied

In order to exclude the lines with a small effect of power loss reduction, taking into account the error of mathematical models, the lines wherein the equivalent current after executing the countermeasures in Clause 6.2.2 and 6.2.3 above becomes not smaller than 100A were studied herein.

(2) Calculation method

The values of power loss reduction, cost and benefit including the net benefit were calculated by using the models, according to a policy of adopting either of the countermeasures with greater effect of power loss reduction from among construction of same voltage line or introduction of higher voltage line.

6.3 Calculation of Potential of Power Loss Reduction in MV System

6.3.1 Load Current of MV feeders Constituting a Basis of Calculating the Power Loss Reduction

Based on the assumed peak load current of respective feeders in 1996 (1.12 times the collected load current data) and the forecast peak load current in 2008 (1.88 times the assumed load current in 1996), the power loss reduction and other values described in Clauses 6.3.2 ~ 6.3.4 were calculated by using the mathematical models developed in Chapter 5 as briefly described below. For further details, refer to Appendix 6.3-1 - 6.3-2.

6.3.2 Power Loss Reduction on the MV System Side by Installing Capacitor on the LV Feeder

By improving the power factor in any LV system, the power factor on the MV system side can also be improved. The values of power factor improvement and power loss reduction to be attained in the MV system through improvement of the power factor in the LV system were calculated.

6.3.3 Reduction of Power Loss 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 6.2.3, 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.

6.3.4 Reduction of Power Loss in the MV System by Constructing Same Voltage Line or Introducing Higher Voltage System

(1) Lines to be studied

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. Refer to Appendix 6.3-3.

(2) Calculation method

The amount of power loss reduction, the cost and the benefit including the net benefit of power loss reduction were calculated by using the mathematical models developed in

6.3.5 Potential of Power Loss Reduction in Entire Power System

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

Meanwhile, assuming that if the above policy were executed in 1996, load condition the power loss reductions, etc. were calculated as presented in Table 6.3-2.

Table 6.3-2 Potential of Loss Reduction and Cost for Whole Jordan in 1996

(MW, 1000 JD)

			Loss reduction	Benefit	Cost	Net-benefit
Improve-ment of LV system	Improvement of unbalance		1.5	3,966	0	3,966
	Improvement of power factor	Effect to LV	2.2	3,506	250	3,256
		Effect to MV	3.0	3,841	0	3,841
		Sub total	5.2	7,347	250	7,097
	New line construction		10.1	25,937	10,934	15,003
Improve. MV system	Improvement of power factor		2.6	3,330	126	3,204
	New line construction		8.8	18,048	7,859	10,189
Total			28.2	58,628	19,169	39,459

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 amount 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

The cost of power loss reduction for the MV system was calculated individually. Since the LV systems consist of a number of feeders, it is difficult to concretely specify individual countermeasures, the cost of power loss reduction were annually allocated in terms of macroscopic quantities for the respective countermeasures. 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 countermeasures to be carried out at the execution stage.

(2) Annual allocation of the cost 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. Annual allocation of cost and construction volume for respective alternative plans are as presented in Appendix 6.4-1 and 6.4-2 .

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

6.5.1 Estimation of Power Loss Reduction

The power loss reduction in the respective years until 2018 in case the five alternative plans A, B, C, D and E have been executed were estimated by the mathematical models of loss reduction. It was assumed that the amount of power loss reduction increases in proportion to the square of growth of electric power demand in the respective years for one decade, one fiscal year after completion of the countermeasures, and continue to remain at a constant level thereafter.

The estimated power loss reduction in the respective years until 2018 in case the five alternative plans A, B, C, D and E have been executed are as presented in Appendix 6.5-1. The power loss reduction, and the ratio to peak generation in 2009 are presented in Table 6.5-1.

Table 6.5-1 Power Loss Reduction and the Ratio to Peak Generation in 2009
(peak generation 1,826 MW)

Alternative plan		A	B	C	D	E
L V	Loss reduction (MW)	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 (MW)	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 (MW)	48.0	61.0	73.5	84.8	99.0
	Ratio to generation (%)	2.6	3.3	4.0	4.6	5.4

6.5.2 Reduction of Electrical Energy Loss

The loss factor for calculating the yearly electrical energy loss has generally been obtained by using the formula of Buller-Woodrow. Moreover, the loss factor has been obtained where the load factor in distribution line was assumed to be the same as that in power generation. Initially, the formula of Buller-Woodrow is designed basically to be used in a wide range including the system in combination with generator so that it is impossible to obtain so accurate values. In the case of distribution line without any generator, further accurate values can be obtained.

At the beginning of this Chapter, it was recommended by the counterpart that they are promoting calculation based on the diversity factor of 1.01 for the MV system and 1.05 for the LV system, respectively. Therefore, it does not necessarily follow that the load factor in distribution line becomes equal to that in generation.

For the purpose of obtaining the electrical energy loss from the power loss obtained in the previous Chapter 5, the method of correcting the loss factor values obtained from the formula of Buller-Woodrow has been studied here. In this case, however, the generator curve in 1995 was used as a duration curve of load before correction by using the diversity factor, and an estimated value of 71.4% in 2008 was used as a load factor.

$$F_1 = \frac{\sum_{1}^{8760} P_i^2}{P_p^2 \times 8760}$$

$$F_2 = 0.7f^2 + 0.3f$$

$$C = F_1 / F_2$$

where

F_1 : Loss factor based on a theoretical formula

F_2 : Loss factor based on the formula of Buller-Woodrow

P_i : Hourly load

P_p : Peak load

f : Load factor

C : Correction coefficient

According to the duration curve in 1995, F1 = 0.5268

F2 = 0.5729

C = 0.9194

The new load factor was calculated by using the diversity factors (1.05 for LV and 1.01 for MV) based on the load factor of 71.4% in 2008. The miscellaneous coefficients for calculating the electrical energy loss reduction are as presented in Table 6.5-2 by using the new load factor.

Table 6.5-2 Coefficients for Estimation of Energy Loss Reduction

	Mean load factor in distribution system	Loss factor F2	Coefficient C	Corrected loss factor	Equivalent hour
L V	68.0 %	0.5277	0.9194	0.4852	4,250.4
M V	70.7 %	0.5620	0.9194	0.5167	4,526.3

The electrical energy reduction values (MWh) in the respective years until 2018 in case the five alternative plans A, B, C, D and E to be executed were estimated by using the above coefficients as presented in Appendix 6.5-2.

The power loss reduction and the ratio to the total energy generation in the respective alternative plans were presented in Table 6.5-3.

Table 6.5-3 Energy Loss Reduction and the Ratio to Energy Generation in 2009
(energy generation 11,424 GWh)

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

6.5.3 Estimation of Transmission and Distribution Loss Rate

From the electrical energy loss obtained in the previous clause, the transmission and distribution loss rates in 2009 after completion of the countermeasure works were estimated. In order to know the distribution loss rate in case the respective alternative plans A, B, C, D and E would be carried out, it is necessary to know the distribution loss rate in case any power loss reduction countermeasure work would not be carried out.

Since a number of assumptions should be made for such a purpose, it is not easy to know the above distribution loss rate in case any countermeasure work is not executed.

As described at the beginning of Chapter 5, an economically-optimum loss rate is considered to exist in any power system. Since the alternative plan E is the one for executing practically feasible countermeasures, an optimum power loss rate is expected to be realized after completion of such countermeasures. If the same level of countermeasure as above is executed in 1996, the present optimum loss rate will be realized. Although the optimum loss rate is not considered to remain unchanged permanently, the optimum rate will not undergo so substantially change by 2009 or so when the countermeasure works are scheduled to be completed when predicting the distribution systems in Jordan. Therefore, the optimum loss rate in 2009 is considered to undergo little changes from that in 1996. On the basis of the concept mentioned above, the optimum loss rate in 1996, namely, the loss rate in case all the power loss reduction countermeasure works are carried out based on the demand in 1996, will be obtained, and the loss rate in 2009 be estimated based on the optimum loss rate obtained above. Meanwhile, due to lack of any data of loss rate in 1996, the loss rate in 1995 was used directly without any modification. Moreover, the transmission loss rate in 1995 was assumed to remain unchanged until 2009, provided that normal system extension work will be carried out continuously in the future as well.

According to the latest records in 1995, the loss rate are as listed below as analyzed in Section 4.

Transmission loss rate : 2.0%
MV system loss rate : 2.2%
LV system loss rate : 5.2%

The effects of power loss reduction in case all the power loss reduction countermeasure works have been executed in 1996 are as presented in Table 6.5-4.

Table 6.5-4 Ratio of Loss Reduction to Energy Generation in 1996

	Loss reduction (MW)	Loss reduction (GWh)	Ratio to generation (%)
MV	14.4	65.2	1.1
LV	13.8	62.5	1.1
Total	28.2	127.7	2.2

Therefore, the optimum transmission and distribution loss rate are:

Transmission loss rate : 2.0%
MV system loss rate : 1.1%
LV system loss rate : 4.1%
Transmission/distribution loss rate: 7.2%

According to the above assumptions, these rates are the optimum loss rates in 2009, namely, those in case the countermeasures in the alternative plan E have been carried out.

The loss rate values estimated in case any countermeasure is not taken by 2009 and in case the respective alternative plans A, B, C, D and E are carried out by that year are presented in Table 6.5-5.

Table 6.5-5 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

CHAPTER 7 ECONOMIC AND FINANCIAL EVALUATION OF PROJECT

7.1 Methodology of Economic Evaluation

7.1.1 Outline

In general, a project will be evaluated taken engineering, economic and financial aspects into consideration. The engineering aspects are studied on the technical feasibility of the project from the viewpoint of construction, operation and maintenance. And with regard to the financial aspects, the financial analysis is to be determined whether the enterprise is likely to be financially viable. The financial analysis focuses on the costs and revenues of the enterprise for the project, but national economic aspects, and is usually summarized in income and cash flow statements, loan repayment and balance sheet. However, the income statement and balance sheet are not included in the financial analysis on the project.

Economic analysis appraises a project under study in terms of a National Economy by comparing and measuring its economic costs and benefits. In other words, economic analysis evaluates a degree of economic impacts on a project under study that would bring about in the national economy.

Project inputs such as construction costs and operation and maintenance costs, including fuel cost in case of a project under study for electricity loss reduction are evaluated in terms of the national economy. These project inputs evaluated in terms of the national economy are called as "economic costs."

Decreased long term investment costs due to reduce the electricity loss such as reduced capacity cost and/or reduced energy cost in case of the said project under study are also evaluated in terms of the national economy. These reduced investment costs evaluated in terms of the national economy are called as "economic benefits." In this case, the benefits should be at least as great as those obtainable from other marginal investment opportunities.

Economic costs and benefits are estimated throughout the project life. The first year of the project life is the year when the first construction disbursement is made. The last year of the project life is the year when the facility constructed by the project is scrapped.

For the economic evaluation, the following steps will be taken:

1. Economic survey in the country,
2. Measurement of costs and benefits and comparison between them, and
3. Sensitivity test to the conclusion of base case of such comparison.

Economic costs and benefits throughout the project life are compared in terms of present values. If the total present value of economic costs equals that of economic benefits (when, B/C=1), the discount rate used to calculate the present value is called as "economic internal rate of return (EIRR)."

7.1.2 Economic Survey

Economic survey is divided broadly into two categories, general economic survey and special economic survey.

The general economic survey is made with regard to such general economic indices as geography, population, agriculture, industry, trade, transport, communication, national income, public finance, prices, consumption, living indices and so on using the national and regional statistic data.

On the other hand, the later is proper survey relating to only a project such as traffic survey for the transport project, survey for damages caused by flood for the river improvement project, or electricity current measurement for such the electricity loss reduction project under survey. The field survey, if circumstances require, will be carried out in addition to the use of the existing data and the statistic data.

7.1.3 Identification of Economic Benefits of Electricity Loss Reduction Project

The economic benefit of a countermeasure under study can be estimated as a difference between the electricity loss "with the countermeasure" and that "without the countermeasure." In this case, the electricity loss evaluated as power value or capacity value and energy value as mentioned below. The electricity loss counting as economic benefits should be considered in total of those values.

7.1.4 Selection of Alternative Countermeasure

For estimation of optimal electricity loss with the countermeasure, the best selection should be made considering the existing situation on both the transmission and distribution systems in Jordan.

For example, the following alternatives are studied:

(1) Construction of the same voltage line for LV system, existing LV feeders + additional LV feeders

(2) Introduction of the higher voltage (33 or 11 kV) system for LV system, existing LV feeders + medium voltage distribution lines

(3) Construction of the same voltage line for MV system, existing medium voltage distribution lines + additional medium voltage distribution lines

(4) Introduction of the higher voltage (132 kV) system for MV system, existing medium voltage distribution lines + higher voltage transmission lines

(5) Installation of capacitors at LV feeder

(6) Installation of capacitors in LV substation

(7) Balancing of 3-phase current in LV system

Both of costs and benefits (reduction values of electricity loss) of the countermeasure will be depend upon these alternatives. These cost and benefits were estimated in terms of long-run-marginal-cost (LRMC) in the countermeasure.

7.1.5 Evaluation of Economic Benefits

In order to evaluate the economic benefits, a power value or a capacity value described as "kW-value" and an energy value described as "kWh-value" are calculated. kW-value represents the construction and fixed O/M costs of power plant for unit kW volume for a year, and is called as "power benefit." kWh-value represents fuel and variable O/M costs of the power plant, and is called as "energy benefits."

A unit value of cost per kW is estimated based on these values, and the benefit (reduction value of the electricity loss) was calculated using this unit value multiplying difference between designed with- and without-electricity losses.

7.1.6 Identification of Economic Cost

Economic cost of a project was identified as opportunity cost[1] of the project.

7.1.7 Evaluation of Economic Cost

(1) Foreign currency portion

The foreign currency portion of the construction costs is estimated in either Cost Insurance Freight (CIF) price or Free on Board (FOB) price. These international prices are assumed to reflect economic cost directly.

(2) Local currency portion

Because it is presumed that local markets in developing countries are distorted by price controls and other regulations, prices in the domestic markets do not reflect economic scarcity of goods and services. This means that the prices can not be used to evaluate economic costs of local procurement and have to be converted into economic prices.

In economic analysis of a project, conversion factors were used to convert the costs in domestic markets into economic costs of a project.

Using export and import statistics, a standard conversion factor (SCF) was estimated. The SCF converted the domestic commodity prices into the economic prices that can be assumed to reflect the economic scarcity of the local costs.

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(1): Definition of opportunity cost : If goods and services would be invested in the project under study, they could no longer be utilized for other projects. This implies that the benefits of the other projects could have been created would be sacrificed. These sacrificed benefits of the other projects are called opportunity cost of the project.

However, the SCF was applied to only tradable goods. The economic cost of non-tradable goods and services have to be separately evaluated. Conversion factors of land, skilled and non-skilled labors, and transportation were respectively estimated.

Then, the weighted average of the conversion factors was calculated, and applied it to the financial cost to convert into the economic cost.

7.1.8 Evaluation Criteria

The economic internal rate of return (EIRR) is calculated and used as an index of economic feasibility. This EIRR is defined by the following formula:

$$\sum_{t=1}^{t=T} \frac{C_{ep}}{(1+R)^t} = \sum_{t=1}^{t=T} \frac{B_{ac}}{(1+R)^t}$$

where,

T = the last year of the project life,

C_{ep} = an annual economic cost flow of the project under study in year t,

B_{ac} = an annual benefit (cost) flow derived from an alternative countermeasure in year t, and

R = the Economic Internal Rate of Return.

The methodology mentioned above is a theoretical one. A practical one will be introduced in the next stage.

7.2. Methodology of Financial Evaluation

7.2.1 Outline

Financial analysis appraises the degree of financial return of a project under study that is expected to earn and is carried out in terms of a project owner's profitability.

Project inputs are evaluated in terms of market prices. The inputs thus evaluated are called as "financial costs." Project outputs are also evaluated in terms of market prices. The outputs thus evaluated are called as "financial benefit."

Financial costs and benefits throughout the project life are compared in terms of present values. If the total present value of financial costs equals that of financial benefits (when, B/C=1), the discount rate used to calculated the present value is called as "financial internal rate of return (FIRR)."

7.2.2. Financial Costs and Benefits

Financial costs include direct construction cost, taxes, compensation, physical contingency, administration, and engineering expenses. However, price escalation is excluded from the costs. Financial benefit is increased sales revenue of electricity.

7.2.3. Financial Internal Rate of Return

The financial internal rate of return is calculated and used as an index of financial feasibility of the project. This FIRR is defined by the following formula:

$$\sum_{t=1}^{t=T} \frac{C_{ft}}{(1+R_f)^t} = \sum_{t=1}^{t=T} \frac{B_{ft}}{(1+R_f)^t}$$

where,

T = the last year of the project life,

C_{ft} = an annual financial cost flow of the project under study in year t,

B_{ft} = an annual benefit (cost) flow derived from an alternative countermeasure in year t, and,

R_f = the Financial Internal Rate of Return.

The methodology mentioned above is a theoretical one. The actual process of the Project evaluation is shown in the following sub-clause.

7.3 Results of Economic and Financial Analyses

7.3.1 Construction Cost

Firstly, a net construction cost was estimated based on unit prices presented by NEPCO as mentioned in previous Chapter. Using this net construction cost, a economic cost of the countermeasure and a financial cost of the countermeasure are estimated. In this case, the unit costs include 4 cost items as (1) materials, (2) construction cost, (3) engineering (consulting) cost for supervision of the works with a rate of 5 % and (4) administration cost with a rate of 2.5 %.

For estimating the economic and financial costs of the countermeasure, following conditions are considered based on the results of discussion with NEPCO;

(1) Share rates of cost for materials and construction works to the cost of each work item based on the said unit prices are applied as 0.700 and 0.300 for overhead lines in medium voltage system, 0.800 and 0.200 for overhead lines in low voltage system, and 0.900 and 0.100 for installing capacitors to the construction amount after deducting the engineering cost and administration cost.

(2) Among the materials to be procured for the construction works, 25 % of materials are to be procured domestically. Therefore, 25 % of costs for materials was allocated in local currency portion.

(3) A cost for construction works was allocated in the local currency portion.

(4) A corporation income tax with a rate of 15 % was applied for contractors and consultation firms for supervision for the construction works.

For estimation of actual necessary construction cost, price escalation rates of 3 % for foreign currency portion and 10 % for local currency portion are applied, and physical contingency with a rate of 2.5 % was applied.

Results of estimation of economic and financial costs are shown in the following Table. In this case, price escalation should be excluded in economic and financial analyses.

Table 7.3-1 Estimation of Project Cost

(JDs.1,000)

Construction works	Economic cost			Financial cost		
	FC portion	LC portion	Total	FC portion	LC portion	Total
Alternative A	12,023	8,255	20,278	12,203	9,112	21,315
Alternative B	18,017	12,372	30,389	18,284	13,657	31,941
Alternative C	24,047	16,509	40,556	24,407	18,223	42,630
Alternative D	30,059	20,637	50,695	30,509	22,779	53,288
Alternative E	38,414	26,371	64,785	38,992	29,107	68,099

Annual allocation of the said Project costs are shown in Appendix 7.1-1 to 7.1-5.

7.3.2 Economic Benefit

In the case of without-countermeasure, electricity enterprises should pay additional capacity cost and energy cost for construction of facilities to cover electricity losses so that customers may be supplied necessary electricity without any trouble. If the countermeasure is executed, these additional costs will be saved. These saved costs are given as economic benefits in the case of this kind of project.

Using the long run marginal cost (LRMC) as mentioned in Chapter 5, a unit marginal capacity cost and a unit marginal energy cost are estimated by low voltage line and medium voltage line. The results are as follows:

Table 7.3-2 LRMC for Capacity and Energy

System	Capacity cost (JDs./kW/Year)	Energy cost (JDs./kWh/Year)
Low voltage system	99.60	0.02243
Medium voltage system	67.32	0.02055

Capacity loss reduction volume (kW) may be estimated by the Current Analysis as mentioned in Chapter 5, and energy loss reduction can be calculated based on this capacity loss reduction by using mWh coefficient as 4.2504 for low voltage system and 4.5263 for medium voltage system. In this case, the capacity loss reduction was estimated by the improvement of unbalance current, installing of capacitor and construction of new line. Therefore, the energy loss reduction is also estimated by these countermeasures.

The amount of the electricity loss reduction is estimated from these capacity and energy loss reduction volumes multiplying the said unit marginal capacity and energy costs. The countermeasures are designed for 10 years electricity loss reduction after completion of the works and the works will need 10 years from their commencement, so that the electricity loss reduction volumes will be increased up to the year 2018 when the works are started from 1999. The results of estimation of maximum electricity loss reduction are as follows as of 2018:

Table 7.3-3 Estimation of Maximum Electricity Loss Reduction in 2018

(JDs.1,000)

Electricity loss reduction item		Alternative A	Alternative B	Alternative C	Alternative D	Alternative E
LV system	Power loss	4,627	5,124	5,663	6,495	7,317
	Energy loss	4,428	4,904	5,419	6,216	7,003
MV system	Power loss	671	1,490	2,272	2,723	3,452
	Energy loss	927	2,059	3,139	3,762	4,769
Total		10,653	13,577	16,493	19,196	22,541

Detail of annual loss reduction by countermeasure during the construction period and effective period of the works is shown in Appendix 7.2-1 to 7.2-5. After reaching the maximum electricity loss reduction, it is assumed that the same amount of loss reduction is generated up to the end of the Project life which ends 25th year after completion of each works. The amount of these electricity loss reduction is given as economic benefit as mentioned above.

7.3.3 Economic Evaluation of Project

The economic evaluation of the Project is made by using cash flows of the said economic costs and economic benefits. The results are shown in Appendix 7.3-1 to 7.3-5 and summarized below. In this case, B/C rates are comparison of benefit and cost in present value of them, and B-C means net cash balance between benefits and costs also expressed by their present value. For calculation of present value, a discount rate of 12 % is applied as same as in similar projects.

Table 7.3-4 Result of Economic Evaluation

	EIRR (%)	B/C	B-C (JDs.1,000)
Alternative A	24.91	1.99	11,155
Alternative B	20.08	1.63	10,687
Alternative C	17.80	1.45	10,195
Alternative D	16.45	1.34	9,604
Alternative E	15.04	1.23	8,142

7.3.4 Financial Benefit

If the Project is executed, the operation and maintenance cost (the OM cost) will be decreased corresponding to the electricity loss reduction. In this case, the OM cost means all the cost for electricity sales. Therefore, a margin between the OM cost and sales amount of electricity will be increased. This incremental increased margin to be called as a probable revenue is a financial benefit for financial evaluation of the Project.

For estimation of the said probable revenue, a unit OM cost was estimated from the past 5 years financial data presented by NEPCO, IDECO and JEPCO shown in Appendix 7.4 at amount of Fils29.00 per kWh as of 1996.

Using this unit OM cost and the said energy loss reduction volume, the probable revenue is estimated at the amount of JDs.7,034 thousand in Alternative A, JDs.9,246 thousand in Alternative B, JDs.11,438 thousand in Alternative C, JDs.13,347 thousand in Alternative D and JDs.15,785 thousand in Alternative E. In this case, these benefits could be resulted using the existing facilities too. Usually, the benefit derived from the existing facilities should be deducted for project evaluation because that the benefit derived from the existing facilities is not due to the project.

If possible, the actual benefit should be clarified based on the original cost of such existing facilities, used time period, and depreciation of them. But, these data could not available this time. Therefore, a negative benefit is assumed as a sunk cost with a rate of 30 % of the said total benefit.

7.3.5 Financial Evaluation of Project

The financial evaluation of the Project was made by using cash flows of the said financial costs and the probable revenue to be given as a financial benefit by the same manner in the economic evaluation. The results are shown in Appendix 7.5-1 to 7.5-5 and summarized below. In this case, B/C rates are comparison of benefit and cost in present value of them, and B-C means net cash balance between benefits and costs also expressed by their present value as same as in the case of economic evaluation. For calculation of present value, a discount rate of 12 % is applied too as same as in similar projects.

Table 7.3-5 Result of Financial Evaluation

	FIRR (%)	B/C	B-C (JDs.1,000)
Alternative A	15.73	1.26	3,075
Alternative B	12.80	1.06	1,002
Alternative C	11.36	0.95	-1,075
Alternative D	10.33	0.88	-3,421
Alternative E	9.27	0.82	-6,941

7.3.6 Repayability Analysis

It has been presumed that the interest for both the foreign and local loans will be paid by enterprises' own fund within the amount of probable revenue. In this case, it is assumed that the foreign loan amount consists of 100 % of foreign currency portion and 75 % of local currency portion of the total construction cost, and the remaining is the local loan amount. The contingency for price escalation should be included in this case so that the Project is executed safely. Appendix 7.6 shows the parameters for repayability analysis.

Appendices 7.7-1 to 7.7-5 show the results of loan repayability and these repayability are illustrated in the Appendix 7.8-1 through 7.8-5. As shown in Appendix 7.7-1 through 7.7-5, the project will start producing surplus profit at the time of 2nd year in all of 5 alternatives, and there is no case to cause a deficit during the project life in every alternatives. It means that the Project in every 5 alternatives will be repayable enough including the interests for both loans within the probable revenue.

Accumulated net surplus in Alternative E is the highest in these 5 alternative. Following Table shows a summary of repayability analysis:

Table 7.3-6 Result of Repayability Analysis

Countermeasure	Repayability	Accumulated outflow from the commencement of the works to the end of Project life (JDs.1,000)	Accumulated inflow from the commencement of the works to the end of Project life (JDs.1,000)	Accumulated net surplus from the commencement of the works to the end of Project life (JDs.1,000)
Alternative A	Repayable	102,534	201,354	98,820
Alternative B	Repayable	152,622	269,892	117,271
Alternative C	Repayable	203,829	337,926	134,097
Alternative D	Repayable	255,628	400,696	145,068
Alternative E	Repayable	327,811	487,708	154,896

7.3.7 Capital Recovery Analysis

Capital recovery analysis is made for clearing the turning point in the Project from the deficit to the surplus using the Project cost and the probable revenue as shown in Appendix 7.9-1 through 7.9-5. In this case, the contingency for price escalation should be included.

Following Fig. 7.3-1 show such turning point of capital as results of the capital recovery analysis. As shown in the Figures, the turning points of each Alternative are July 2009 in the case of Alternative A, July 2010 in the case of Alternative B, April 2011 in the case of Alternative C, October 2011 in the case of Alternative D and August 2012 in the case of Alternative E respectively when the works commence on January 1999.

On the viewpoint of turning point of capital, the Alternative A will be the most advantageous countermeasure. However, from the viewpoint of accumulated cash balance from the commencement of the works to the end of Project life, the Alternative E will be the most profitable as shown in Appendix 7.9-1 through 7.9-5 and summarized in the following Table:

Fig. 7.3-1 Financial Turning Point of Each Alternative

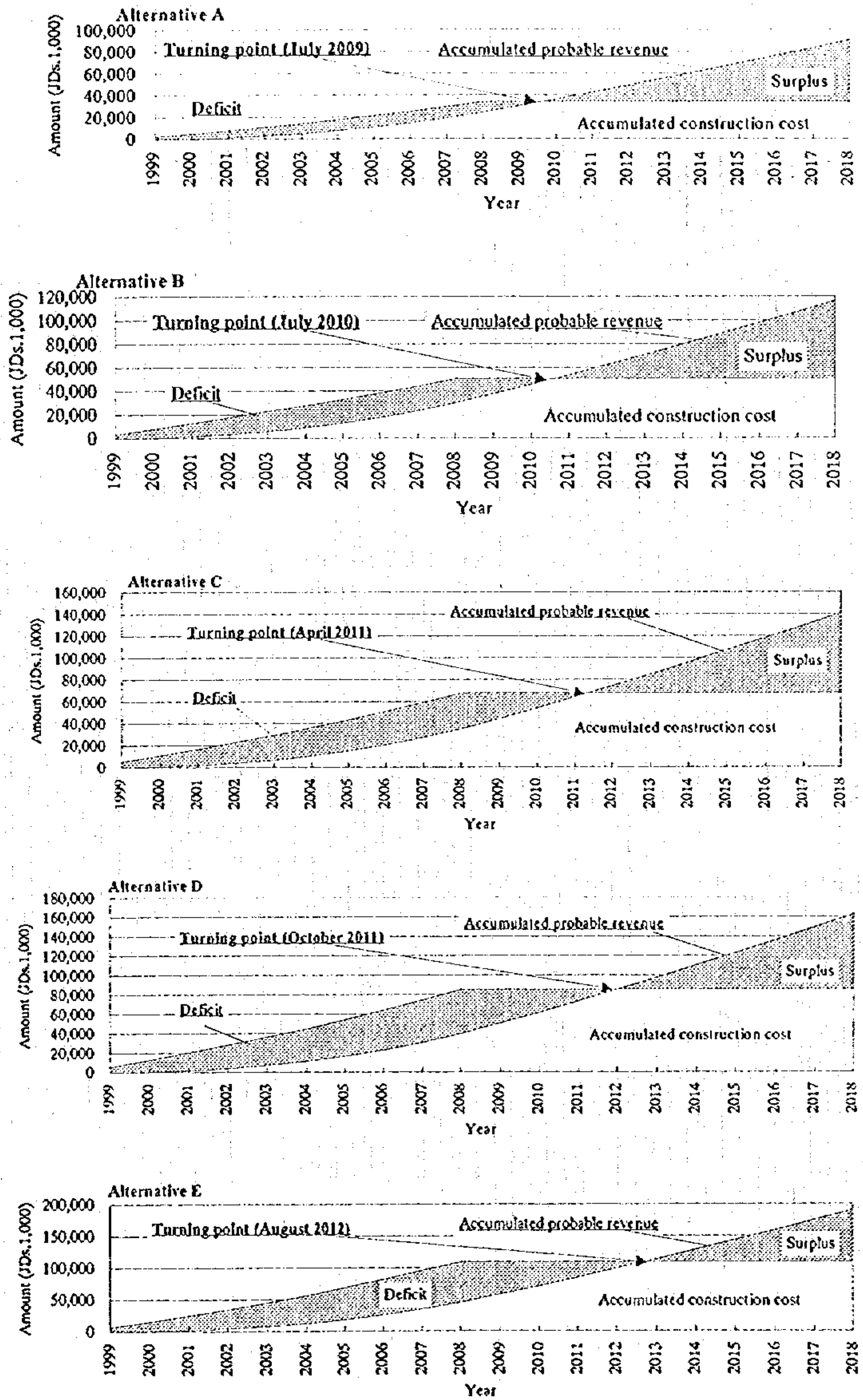


Table 7.3-7 Result of Capital Recovery Analysis

Countermeasure	Turning point of capital	Total investment cost (JDs.1,000)	Accumulated probable revenue from the commencement of the works to the end of Project life (JDs.1,000)	Accumulated net cash balance from the commencement of the works to the end of Project life (JDs.1,000)
Alternative A	July 2009	34,132	162,837	128,705
Alternative B	July 2010	50,676	212,471	161,795
Alternative C	April 2011	67,717	261,302	193,585
Alternative D	October 2011	85,018	304,599	219,581
Alternative E	August 2012	109,142	359,540	250,398

7.3.8 Cost Saving

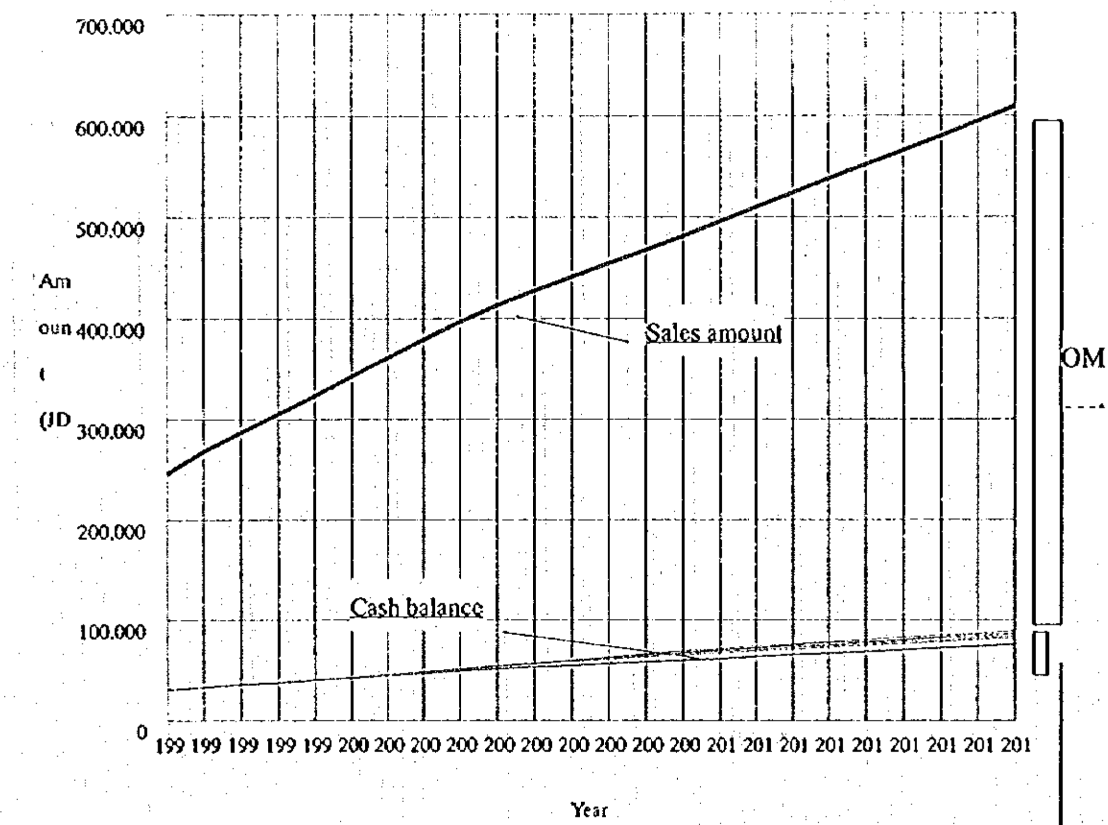
As mentioned above, the Project will produce cost saving when the works of countermeasure for electricity loss reduction are executed. This cost saving is given as a difference between the OM cost for electricity sales without the countermeasure and the OM cost for electricity sales with the countermeasure. In this case, it should be considered that an additional OM cost will be necessary for operation and maintenance for the new facilities due to the works.

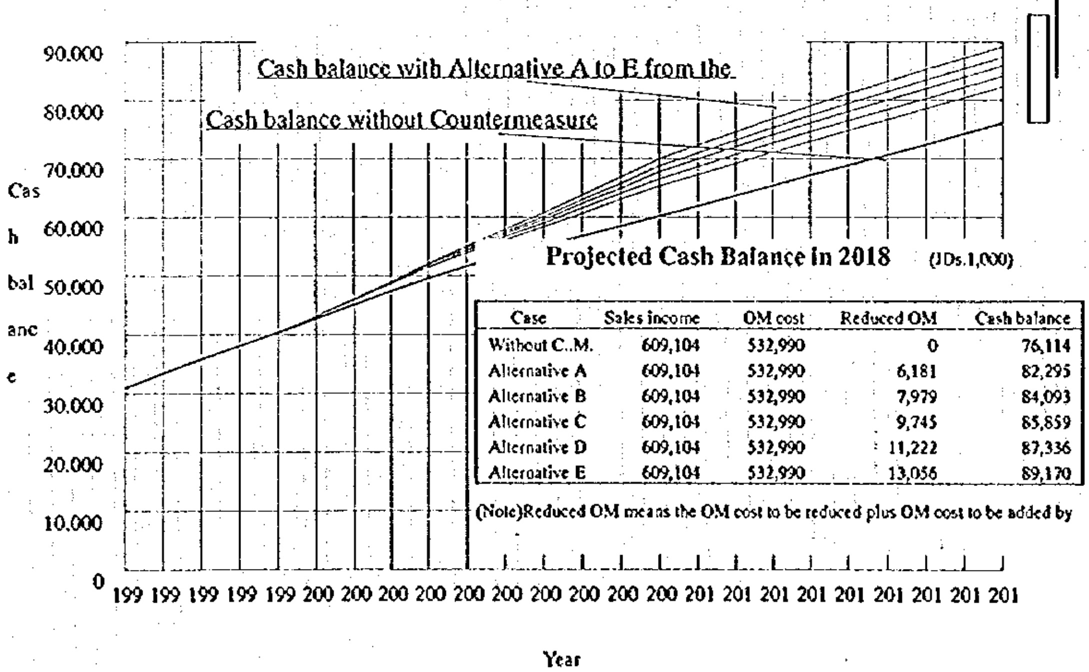
NEPCO has made a demand forecast in power generation basis from 1996 to 2010. The actual OM cost in 1995 was JDs.215,149 thousand as shown in Appendix 7.4 in average, and the actual sales amount of electricity was JDs.246,183 thousand as shown in Appendix 7.10.

Using the above mentioned data, the annual OM cost during the effective period of the works of countermeasure for electricity loss reduction up to 2018 in the case of without the countermeasure is firstly calculated as shown in Appendix 7.11. In this case, a forecast of operation expressed by sales amount of electricity enterprises from 2011 to 2018 is made by extraporation based on the said existing demand forecast presented by NEPCO, and the sharing rate of OM cost to the total sales amount in 1995 is assumed to be continued for the future too.

Here, the OM cost to be saved due to the Project is the same amount of the probable revenue as mentioned in previous sub-clause. The additional OM cost for the new facilities after completion of the works for electricity loss reduction is already given in Appendix 7.7-1 through 7.7-5 for repayability analysis which includes the contingency for price escalation . Using these 2 data, the net OM cost to be saved in Alternative A, Alternative B, Alternative C, Alternative D and Alternative E can be calculated as JDs.6,181 thousand, JDs.7,979 thousand, JDs.9,745 thousand, JDs.11,222 thousand and JDs.13,056 thousand respectively.

Fig. 7.3-2 Forecast of Operation With and Without Countermeasure





Projected Cash Balance in 2018 (JDs.1,000)

Case	Sales income	OM cost	Reduced OM	Cash balance
Without C..M.	609,104	532,990	0	76,114
Alternative A	609,104	532,990	6,181	82,295
Alternative B	609,104	532,990	7,979	84,093
Alternative C	609,104	532,990	9,745	85,859
Alternative D	609,104	532,990	11,222	87,336
Alternative E	609,104	532,990	13,056	89,170

(Note)Reduced OM means the OM cost to be reduced plus OM cost to be added by

From the above mentioned calculation results, the net maximum cash balance in 2018 in the case of without the countermeasure, Alternative A, Alternative B, Alternative C, Alternative D and Alternative E are estimated as JDs.76,114 thousand, JDs.82,295 thousand, JDs.84,093 thousand, JDs.85,859 thousand, JDs.87,336 thousand and JDs.89,170 thousand respectively. The calculation process is shown in Appendix 7.11 and illustrated in the above Fig.7.3-2.

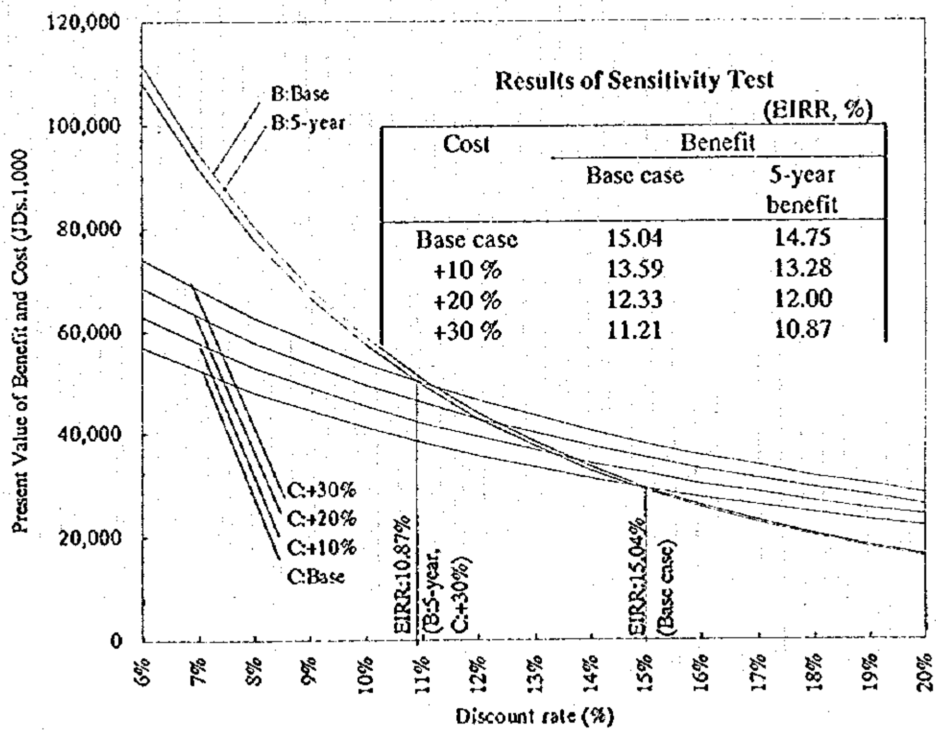
7.4 Sensitivity Analyses of Project

7.4.1 Sensitivity Analysis of Economic Aspect

There are constant fluctuations in prices of construction materials for these kind of projects as a reflection of the state of the economy.

It also gives a impact to the economic benefit because that the said benefit is estimated based on the LRMC as a alternative construction cost for generation of electricity to cover the electricity loss as mentioned in aforementioned sub-clause.

Fig. 7.3-3 Sensitivity of EIRR



Results of Sensitivity Test

(EIRR, %)

Cost	Benefit	
	Base case	5-year benefit
Base case	15.04	14.75
+10 %	13.59	13.28
+20 %	12.33	12.00
+30 %	11.21	10.87

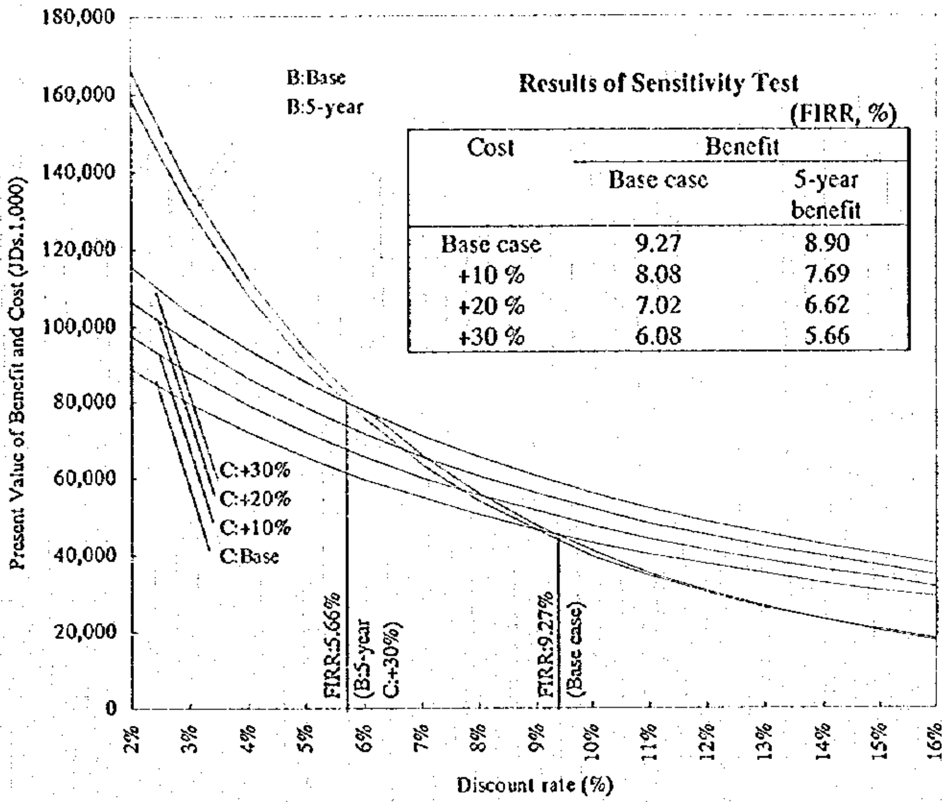
Considering these situation, a sensitivity analysis is made for 8 combined cases including base case under the conditions that the benefit will be increased only by 5 years after completion of the Project (5-year benefit) and for the cost of +10 %, +20 % and +30 % for Alternative E. The above Fig.7.3-3 including summary table shows the results of sensitivity analysis for economic features.

As shown in the above Figure, the EIRR under both the benefit and the cost in the base case is resulted at 15.04 % as already studied in the aforementioned sub-clause which is reasonable high rate comparing with similar projects. However, even the most pessimistic case under the conditions of 5-year benefit and the cost increased by 30 % shows also still enough high EIRR as 10.87 % from the viewpoint that the Project is in developing country. It means that the Project under study is economically sound.

7.4.2 Sensitivity Analysis of Financial Aspect

Following Fig. 7.3-4 shows the result of sensitivity analysis for financial aspect for Alternative E..

Fig. 7.3-4 Sensitivity of FIRR



(FIRR, %)

Cost	Benefit: Base case	Benefit: 5-year benefit
Base case	9.27	8.90
+10 %	8.08	7.69
+20 %	7.02	6.62
+30 %	6.08	5.66

In this case, the same conditions in the sensitivity analysis for the said economic aspect are considered.

The FIRR under both the benefit and the cost in the base case resulted at 9.27 % as already studied in aforementioned sub-clause which is enough high rate from the viewpoint that the Project is in developing country comparing with similar projects. While in the most pessimistic case under the conditions 5-year benefit and the cost increased by 30 %, the FIRR is resulted at 5.66 %.

Generally, as suggested by such international institutions as the World Bank, a EIRR is expected to at least be cleared a hurdle of 5.0 % of IRR 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 from the viewpoint of basic human needs.

7.5 Summary and Conclusion of Economic and Financial Analyses

Among the 5 alternatives, the Alternative E is the case to completely realize the targeted electricity loss reduction from the technical viewpoint as mentioned in previous Chapter. The results of economic and financial evaluation of the Project was summarized here-under, and feasibility of the Project was studied with those results.

7.5.1 Project Cost

Firstly, a net construction cost was estimated based on unit prices presented by NEPCO as mentioned in previous Chapter. Using this net construction cost, a economic cost of the Project and a financial cost of the Project are estimated. In this case, the unit costs include 4 cost items as (1) materials, (2) construction cost, (3) engineering (consulting) cost for supervision of the works with a rate of 5 % and (4) administration cost with a rate of 2.5 %. The estimation of Project costs resulted as shown in the following Table.

Table 7.5-1 Estimation of Project Cost

(JDs.1,000)

Construction works	Economic cost			Financial cost		
	FC portion	LC portion	Total	FC portion	LC portion	Total
Alternative A	12,023	8,255	20,278	12,203	9,112	21,315
Alternative B	18,017	12,372	30,389	18,284	13,657	31,941
Alternative C	24,047	16,509	40,556	24,407	18,223	42,630
Alternative D	30,059	20,637	50,695	30,509	22,779	53,288
Alternative E	38,414	26,371	64,785	38,992	29,107	68,099

7.5.2 Economic Benefit

In the case of without-project, electricity enterprises should pay additional capacity cost and energy cost for construction of facilities to cover electricity losses so that customers may be supplied necessary electricity without any trouble. If the Project is executed, these additional costs will be saved. These saved costs are given as economic benefits in the case of this kind of project. The estimated results are shown in Appendix 7.2.1 to 7.2.5.

7.5.3 Financial Benefit

If the Project is executed, the operation and maintenance cost (the OM cost) will be decreased corresponding to the electricity loss reduction. In this case, the OM cost means all the cost for electricity sales. Therefore, a margin between the OM cost and sales amount of electricity will be increased. This incremental increased margin to be called as a probable revenue is a financial benefit for financial evaluation of the Project.

For estimation of the said probable revenue, a unit OM cost was estimated from the past 5 years financial data presented by NEPCO, IDECO and JEPCO shown in Appendix 7.4 at amount of Fils29.00 per kWh as of 1996.

Using this unit OM cost and the said energy loss reduction volume, the probable revenue is estimated at the amount of JDs.7,034 thousand in Alternative A, JDs.9,246 thousand in Alternative B, JDs.11,438 thousand in Alternative C, JDs.13,347 thousand in Alternative D and JDs.15,785 thousand in Alternative E as a maximum in 2018.

7.5.4 Summary of Economic and Financial Evaluation of Project

Using the above mentioned cost and benefits, the evaluation of the Project is made. The results of the said analyses are summarized in Table 7.5-2 in next page.

As shown in this Table, all the Alternative works are feasible in both the economic and financial viewpoints. Among them, according to the results of repayability analysis 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. 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 the Project in the case of the Alternative E will be economically and financially sound even if the electricity loss reduction will be continuously increased by only 5 years after the completion of the works and the cost will be increased by 30 % from the viewpoint of basic human needs.

7.5.2 Summary of Results of Economic and Financial Analyses

Kind of analyses			Alternative A	Alternative B	Alternative C	Alternative D	Alternative E
Economic feasibility	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	(JDs.1,000)	11,155	10,687	10,195	9,604	8,142
Financial feasibility	FIRR	(%)	15.73	12.80	11.36	10.33	9.27
	B/C		1.26	1.06	0.95	0.88	0.82
	B-C	(JDs.1,000)	3,075	1,002	-1,075	-3,421	-6,941
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
Capital recovery analysis	Turning point		July 2009	July 2010	April 2011	October 2011	August 2012
	Accumulated net cash balance from the commencement of the works to the end of Project life	(JDs.1,000)	128,705	161,795	193,585	219,581	250,398
Cost saving as of 2018		(JDs.1,000)	6,181	7,979	9,745	11,222	13,056

7.6 Financing Availability for Investment Cost

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 considering that the Project is for the whole distribution network in Jordan. The above mentioned amount of foreign loan amount applying for the repayability analysis is estimated based on a condition to cover at a rate of 100 % for the foreign currency portion and at a rate of 75 % for the local currency portion of the said total investment cost with a 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 as shown in Appendix 7.12, 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 Appendix 7.13. As indicated in Appendix 7.13, 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.

7.7 Alternative Study on Repayability

Alternative studies are made for making clear the repayability of loan amount when the interest rate for foreign loan is changed in 2 cases as 5.00 % and 7.00 % for 5 alternative countermeasures each. In this case, such other conditions as objective amount (or rate to the total construction cost) of foreign loan, repayment period, and grace period are assumed to be the same in the analysis as mentioned in previous sub-clause.

The results are shown in Appendix 7.14-1 to 7.14-5 for the case of 5.00 % of interest rate and in Appendix 7.15-1 to Appendix 7.15-5 for the case of 7.00 % of interest rate both for foreign loan.

7.7.1 Repayability of Loan in Case of 5.00 % of Interest Rate for Foreign Loan

As shown in the said Appendix 7.14-1 to 7.14-5, the Alternative A, B and C will still be repayable. But, the first year of repayment period of foreign loan, namely the year of 2009, will not be able to repay the loan amount fully in the case of the Alternative D, and the first and second years of repayment period of foreign loan, namely the year of 2009 and 2010, will not be able to repay the loan amount fully in the case of the Alternative E assuming that the repayment amount should be paid from the probable revenue due to the Project.

The amounts of shortage in each case mentioned above are JDs.660 thousand in the Alternative D in 2009 and, JDs.2,135 thousand and JDs.1,236 thousand in the Alternative E in 2009 and 2010 respectively.

When those shortage will pay from the net total income as indicated in Appendix 7.11, the net income in 2009 in the case of Alternative D, in 2009 and in 2010 in the case of Alternative E will be reduced at the rate of 0.96 %, 3.05 % and 1.71 % respectively.

7.7.2 Repayability of Loan in Case of 7.00 % of Interest Rate for Foreign Loan

As shown in the said Appendix 7.15-1 to 7.15-5, the Alternative A and B will still be repayable. But, 2 years from the first to second year of repayment period of foreign loan, namely the year of 2009 and 2010, will not be able to repay the loan amount fully in the case of the Alternative C, the first, second and third years of repayment period of foreign loan, namely the year of 2009, 2010 and 2011, will not be able to repay the loan amount fully in the case of the Alternative D, and the first, second, third and fourth years of repayment period of foreign loan, namely the year of 2009, 2010, 2011 and 2012, will not be able to repay the loan amount fully in the case of the Alternative E assuming that the repayment amount should be paid from the probable revenue due to the Project.

The amounts of shortage in each case mentioned above are JDs.919 thousand and JDs.290 thousand in the Alternative C in 2009 and 2010 respectively, JDs.2,123 thousand, JDs.1,348 thousand and JDs.274 thousand in the Alternative D in 2009, 2010 and 2011 respectively and, JDs.4,012 thousand, JDs.3,020 thousand, JDs.1,651 thousand and JDs.330 thousand in the Alternative E in 2009, 2010, 2011 and 2012 respectively.

When those shortage will pay from the net total income as indicated in Appendix 7.11, the net income in 2009 and 2010 in the case of Alternative C, in 2009, in 2010 and in 2011 in the case of Alternative D and, in 2009, in 2010, in 2011 and in 2012 will be reduced at the rate of 1.36 % and 0.41 % in the case of the Alternative C, 3.09 %, 1.90 % and 0.37 % in the case of the Alternative D and, 5.73 %, 4.17 %, 2.21 % and 0.43 % respectively.

7.7.3 Conclusion of Alternative Study on Repayability

When the enterprises in Jordan have a willingness to pay such shortage as mentioned above from their net income by means of adding an amendment to existing tariff system drastically, the said loan amount with its interest can be paid back to institutions who give such accommodation of loan to them.

As mentioned in Chapter 2, the existing share rate of electricity consumption to the total expenditure is around 4 % with the amount of JDs.160 per annum per household. This rate is already reasonable high one for people in Jordan. Therefore, the drastic amendment of existing tariff system may be quite difficult if the amended rate will be higher than an increased rate of people's income.

Accordingly, the Alternative C will be the best selection when the interest rate for the foreign loan is set at 5 %, and the Alternative B will be the best selection when the interest rate for the foreign loan is set at 7 % except that the electricity enterprises in Jordan have the willingness to pay back such loan amount with interest from their net income even if it would be reduced.

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

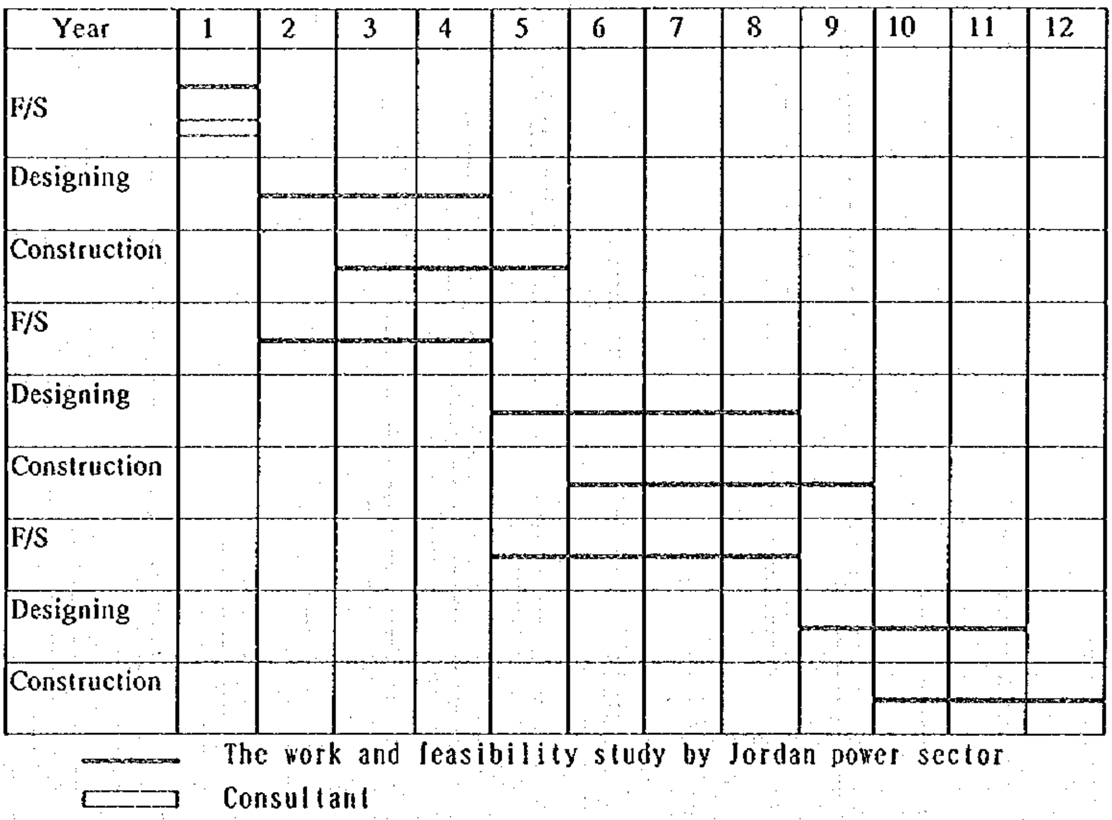
The period required for this study is estimated to be:

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.

JICA