The Arab Republic of Egypt
Ministry of Electricity and Energy
Egyptian Electricity Holding Company

PREPARATORY SURVEY REPORT ON IMPROVEMENT IN ENERGY EFFICIENCY OF POWER SUPPLY IN THE ARAB REPUBLIC OF EGYPT

FINAL REPORT

Executive Summary

March 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

TOKYO ELECTRIC POWER SERVICES CO., LTD.(TEPSCO)

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PREFACE

In response to the request from the Government of The Arab Republic of Egypt, the Government of Japan decided to conduct the "Preparatory Survey on Improvement in Energy Efficiency of Power Supply in The Arab Republic of Egypt", and entrusted it to the Japan International Cooperation Agency (JICA) conducted.

JICA selected and dispatched a Study team headed by Mr. Atsushi Fujisawa of Tokyo Electric Power Services Co., LTD. (TEPSCO) to Egypt for three times from July 2009 to December 2009.

The Study Team held discussions with the officials concerned of the Government of Egypt, Ministry of Electricity and Energy and Egyptian Electricity Holding Company, and conducted field surveys. After the team returned to Japan, further studies were made. Then, the Study Team prepared this final report.

I hope that this report will contribute to development in The Arab Republic of Egypt, and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of The Arab Republic of Egypt for their close cooperation extended to the teams.

March 2010

Nobuhiro IKURO
Chief Representative
Japan International Cooperation Agency
Egypt Office

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Chapter 1 Introduction

Section 1 Background

(1) In recently, electricity demand in Egypt has rapidly increased 7.1 % per year on average since 1996. During the last Fiscal Year 2007/2008, it was a challenge for Egypt to meet the high growth rate of electricity demand; the peak demand reached 19,738 MW and energy generated 125 TWh.

(2) The government of Egypt plans completion of 8,547 MW of new power development in the 6th Five-Year Plan (2007/8 to 2011/12) in order to increase 9.1% of power generation per year.

(3) Currently Egypt is one of 11 countries which mean the most growth of emission of greenhouse gases (GHG), so that the emission in 2017 will be reached to over 3 times as compared with 2006.

(4) Within the framework of the Energy Strategy of Egypt, the strategy of the power sector has focused on the diversification of the use of fuel resources, promoting the use of renewable energy and conventional energy resources. Moreover, the energy efficiency and conservation has been strongly requested as well.

(5) The government of Egypt has planned National Sustainable Development Strategy and has considered establishment of Energy Efficiency Agency and enactment of Energy Conservation regulation, so that the related low and organization has been constructing.

Therefore, it is considered that JICA study should be conducted to formulate the Japanese ODA loan Projects under Cool Earth Partnership Initiative for improvement of energy efficiency in Egyptian Power Sector including Power plant, transmission, Distribution and Demand Management.

Section 2 Objective of the Study

The objective of the Study is to propose and formulate the candidate projects regarding improvement of energy efficiency of Egypt to be supported by Japanese ODA loan, based upon the review of the needs of improvement in energy efficiency in Egypt.
The candidate projects expected to be formulated through the study are included in the following field in power sector.

1) Power generation
2) Transmission
3) Distribution
4) Demand side management

Section 3 Terms of Reference

(1) To study the current effort to improvement in energy efficiency of power sector in Egypt.
- To study progress and current situation of improvement in energy efficiency of power sector in Egypt
- To study outline of energy consumption condition in Egypt
- To study policy and activity regarding improvement in energy efficiency in Egypt
- To study energy efficiency projects supported by other donors

(2) To study potential of improvement in energy efficiency of power sector in Egypt and propose the candidates of Japanese ODA loan project.
- To figure out the potential of improvement in energy efficiency of power generation, transmission, distribution and demand side management and to point out the problems and countermeasures
- To propose "Long List" of energy efficiency projects regarding power generation, transmission, distribution and demand side management
- To propose the candidate (Model) projects of Japanese ODA loan

(3) To formulate model project of Japanese ODA loan in the area of power distribution.
- To study the outline and activities of power distribution company such as Alexandria. North Delta and North Cairo distribution company
- To study the current condition and plans to improve the energy efficiency in the distribution companies
- To propose the project scope (e.g. system configuration, project size, implementation schedule, packaging, appropriate tariff, capacity development)
- To calculate the project cost
- To calculate economic viability (e.g. IRR)
- To confirm the problems of environmental consideration for the power distribution project
- To check the problems to formulate the project of Japanese ODA loan

(4) To hold a workshop in Egypt for the purpose of sharing recognition and opinion of Egyptian stakeholders to the above.

Section 4 Study Member

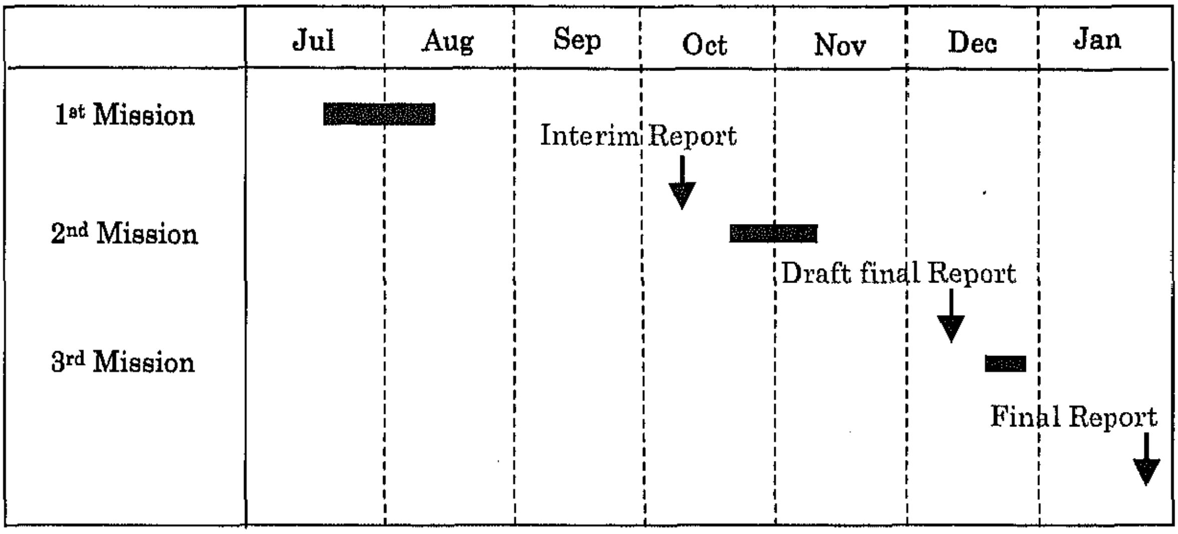
(1) Study Team Members
The study team consisted of 9 specialists as indicated below:

Name	Specialty
Mr. Atsushi FUJISAWA	Team Leader and Transmission/Distribution expert
Mr. Hiroyuki SHINOHARA	Power planning and Generation Expert
Mr. Kenichi KUWAHARA	Distribution Expert
Mr. Keita AKAKURA	Demand Side Management Expert
Mr. Hirokazu TUJITA	Transmission and Substation Expert
Ms. Akiko URAGO	Environmental & Social Consideration Expert
Mr. Misaki KITTAKA	Power system Expert
Mr. Kazunori TAKASAWA	Economy and Management Expert
Mr. Toshio AKI	Distribution Expert

(2) Local Consultant
The following local consultants have been hired to support the study Team.
✓ EPS (Electrical Power System Engineering Co.): Power sector, Transmission, Distribution and Demand side issues
  - Chairman: Eng. Hosni El-kholy
  - Team Leader: Wahead S.A. Fattah El-Hageen

Section 5 Study Schedule

The schedule of the study is shown in the following table.



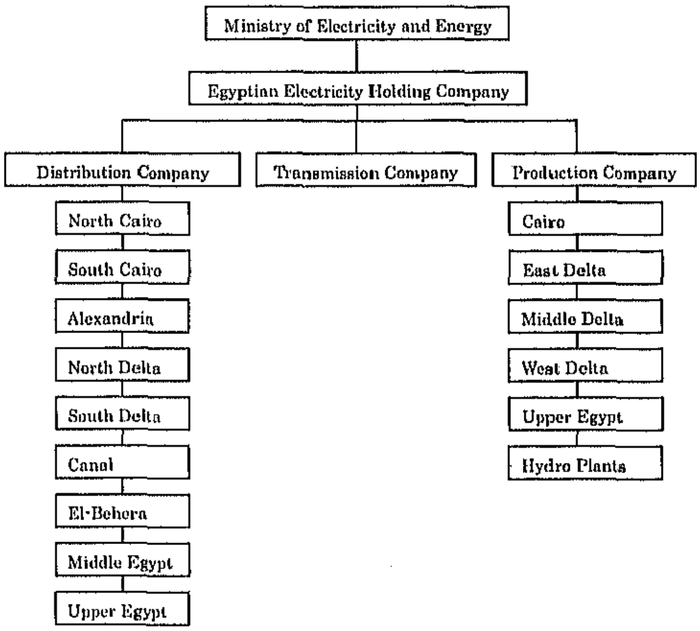
Chapter 2 Current effort to improvement in energy efficiency of power sector in Egypt

Section1 Current Status of Power Sector in Egypt

Clause1 Structure of Power Sector

(1) Electricity Utilities in Egypt

Fig. 2-1-1-1 shows the organizational structure of EEHC as of 2009, which is a state owned utility and a main power player in Egyptian power sector. It consists of six generation, one transmission and nine distribution companies.

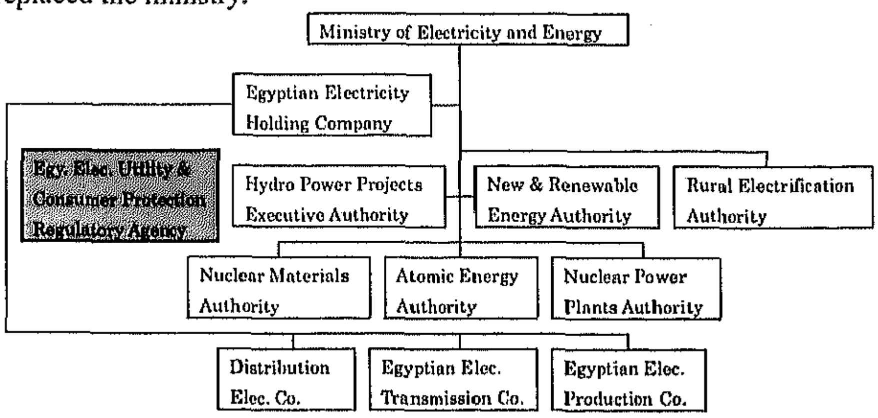


Sources: EEHC Annual Report 2007/2008

Fig. 2-1-1-1 EEHC Organizational Structure (as of 2009)

(2) Regulatory Organization in Power Sector

Fig. 2-1-1-2 shows a government organization in Egyptian power sector. MOEE had been responsible for regulation of power sectors in Egypt for long time. Now Egyptian Electric Utility and Consumer Protection Regulatory Agency (herein after refer to "EEUCPRA") replaced the ministry.



Sources: MOEE H.P.

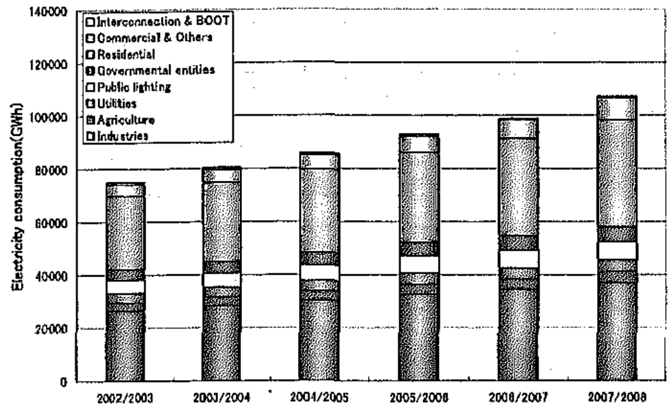
Fig.2-1-1-2 Government Organization related to Power Sector

Clause2 Power Supply & Demand

(1) Current Situation of Power Supply & Demand in Egypt

1) Electricity Consumption

Fig. 2-1-2-1 shows yearly records of electricity consumption in Egypt. According to this, the consumption has reached 107,226GWh in fiscal year (FY) 2007/08. The growth rate during the period 2002/03-2007/08 is 7.4%.



Electricity Consumption	unit	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
Industries	GWh	26,525	28,386	30,284	32,701	34,569	37,045
Agriculture		2,991	3,280	3,460	3,719	3,789	4,209
Utilities		3,565	3,719	4,011	4,206	4,228	4,380
Public lighting		5,026	5,302	5,919	6,489	6,653	6,759
Governmental entities		4,040	4,331	4,710	5,054	5,562	5,691
Residential		27,717	29,823	31,311	33,900	36,596	40,271
Commercial & Others		4,256	4,801	5,393	6,016	7,046	8,240
Total		74,120	79,642	85,088	92,085	98,443	106,595

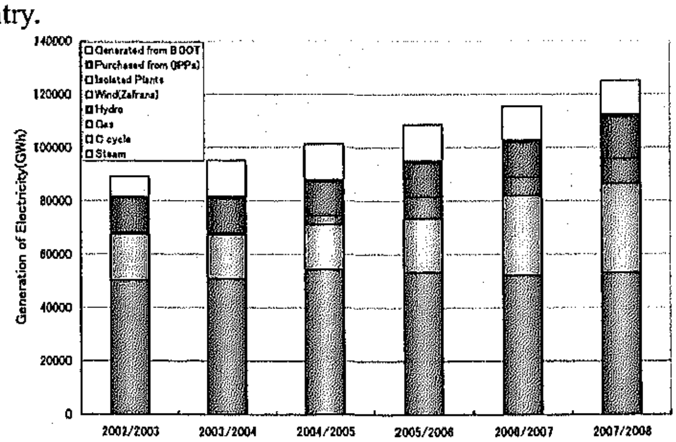
Sources: EEHC Annual Report

Fig. 2-1-2-1 Yearly Electricity Consumption

2) Generated Electricity

In order to meet their remarkable growth of electricity consumption, Egyptian power sector has been making efforts to increase generated electricity. As shown in Fig. 2-1-2-2 the generated electricity including that by IPP has reached 125,129GWH and Egypt has succeeded in increasing the energy at annual rate of 7% during the resent 5 year period FY 2002/03-2007/08.

Steam turbine (ST) plants which use natural gas & heavy or light oil generate the most electricity in amount. In addition BOOT plants are also same type. Hence, amount of electricity generated by ST plants accounts for 53% in FY2007/08. Since recently Egypt has promoted to introduce combined cycles(C cycle), electricity by them becomes accounting for 27% of total. These means that electricity generated by plant utilizing natural gas account for about 80% and natural gas is core energy in this country.



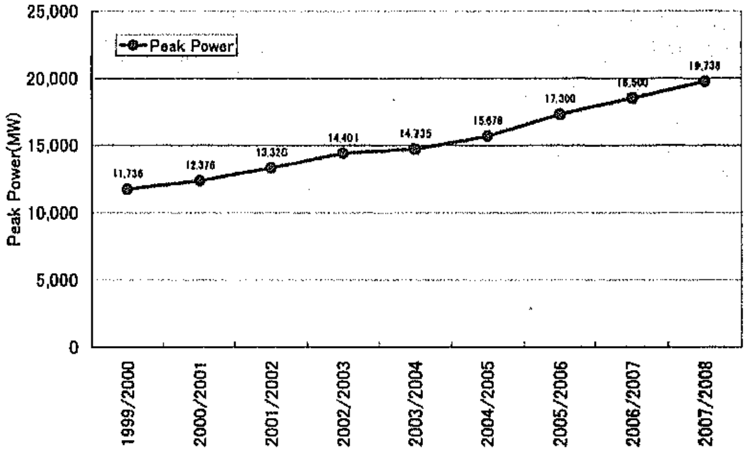
Type	unit	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
Steam	GWh	50,278	50,781	54,300	53,285	52,082	53,076
Gas		670	584	3,380	8,044	6,888	9,381
C cycle		17,256	16,603	16,900	20,236	29,892	33,345
Thermal total		68,204	67,948	74,580	81,565	88,862	95,782
Hydro		12,859	13,019	12,644	12,644	12,925	15,510
Wind(Zafrana)		204	368	523	552	616	831
Renewable total		13,063	13,387	13,167	13,196	13,541	16,341
Grid total		81,267	81,335	87,727	94,761	102,403	112,123
Isolated Plants		239	270	303	322	347	350
Purchased from (IPPs)		77	77	69	38	32	14
Generated from BOOT		7,607	13,501	13,200	13,571	12,625	12,642
Grand total		89,190	95,183	101,299	108,690	115,407	125,129

Sources: EEHC Annual Report

Fig. 2-1-2-2 Yearly Generated Electricity

3) Peak Power Demand

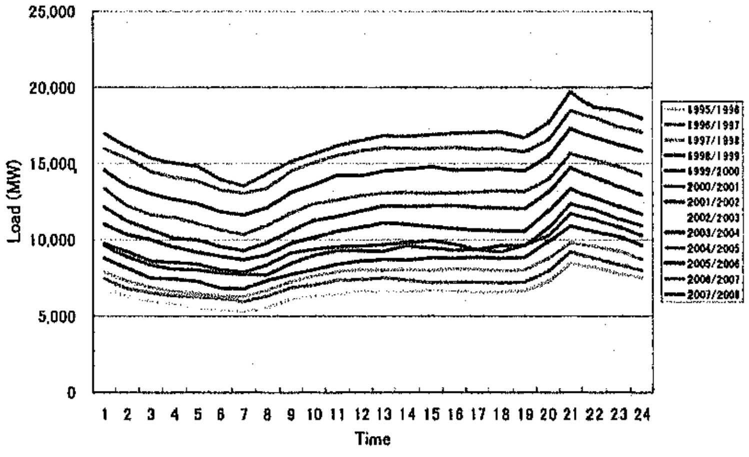
19,738MW of maximum peak power was recorded on June 30, 2008. Fig. 2-1-2-3 represents peak power recorded during the period FY1999/00-2007/08. Peak power has been increasing since FY1999/00 and the growth rate during the period reaches 6.7%.



Sources: EEHC Annual Report

Fig. 2-1-2-3 Peak Power Demand

Fig. 2-1-2-4 shows daily load curves on the day when peak power occurred and it indicates that in Egypt power demand peaks at around 21:00. This implies that the power demand may be not only air conditioners but also for lighting & water heater.



Sources: Data by EEHC

Fig. 2-1-2-4 Daily Load Curve on the day when peak demand occurred

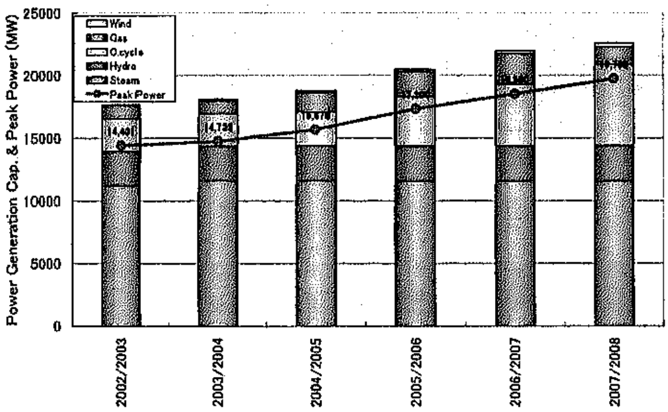
4) Power Supply Capacity
General features of Egyptian power generation capacities are as follows;

- Total power generation capacity (installed capacity) : 22,583MW
- ST plant: 19 plants, 9,598MW in installed cap. (Accounting for 42.5%)
- C Cycle: 10 plants, 6,449MW in installed cap. (Accounting for 28.6%)
- Hydropower: 5 plants, 2,842MW in installed cap. (Accounting for 12.6%)
- Wind power: 1 plants, 305MW in installed cap. (Accounting for 1.4%)
- BOOT plants: 3 plants, 2,047MW in installed cap. (Accounting for 9.1%)

Particularly it should be noted that power generation capacity by natural gas & oil fired ST dominates in the total capacity and no coal-fired thermal plant is installed.

Fig. 2-1-2-5 shows generation capacities by plant type. Followings are notified hereby.

- Generation capacity by ST is almost constant and proportion of it has been decreasing year by year.
- On the contrary C Cycle development has been promoted since FY2005/06 and the proportion of the capacity has been increasing.
- Little hydropower has been developed and, however, its role has become minor compared with it in old days.
- Wind power has been introducing since 2000.



Unit : MW

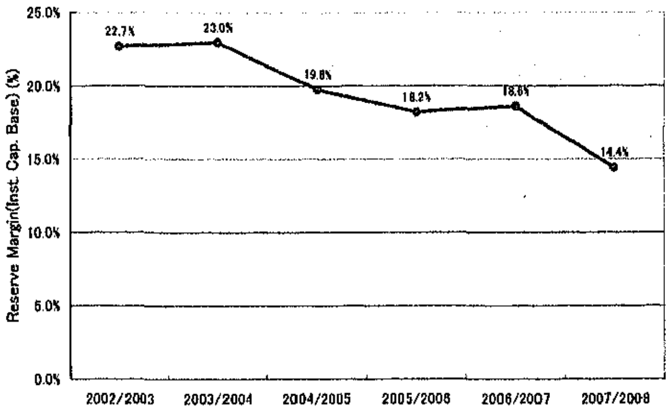
Type	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
Wind	63	140	140	183	225	305
Gas	1,055	1,019	1,537	1,966	2,416	1,416
C.cycle	2,605	2,605	2,699	3,949	4,949	6,449
Hydro	2,745	2,745	2,783	2,783	2,783	2,842
Steam	11,203	11,610	11,616	11,571	11,571	11,571
Total	17,671	18,119	18,775	20,452	21,944	22,583
Peak Power	14,401	14,735	15,678	17,300	18,500	19,738

Sources: EEHC Annual Report

Fig. 2-1-2-5 Generation Capacity by Energy Source

5) Reserve Margin Rate (based on Installed capacity)[1]
Fig. 2-1-2-6 shows yearly reserve margin rate based on installed capacity in Egypt. The rate has been decreasing and in FY2007/2008 it's become less than 15% in the end. Egyptian criterion of loss of load expectation (LOLE) is 8 hour/year and the required reserve margin rate corresponded with this is about 18-20%. Hence balance between power demand and supply may have been in very severe situation currently.

1 Reserve Margin Rate(Installed Capacity Base) : RMR = (Total installed cap.-Peak power)/Peak power - 1



Sources: EEHC Annual Report

Fig. 2-1-2-6 Reserve Margin (Installed Capacity Base)

(2) Forecasts of Electricity Consumption & Peak Power Demand

Table2-1-2-1 shows forecast of electricity consumption and peak power demand during the period FY2007/08-2012/13. Egypt prospects their peak power will grow up to 26,753MW in FY2012.

Table 2-1-2-1 Demand Forecast of Electricity Consumption & Peak Power for Future 5years

Year	Peak Load (MW)	GR (%)	Energy Consumption (GWh)	GR (%)	Require Cap. Based on reserve margin rate18%
2007/2008	19,738.0	6.7	107,189.1	8.5	23,290.8
2008/2009	20,999.6	6.4	114,211.8	6.6	24,779.5
2009/2010	22,329.8	6.3	121,628.8	6.5	26,349.2
2010/2011	23,729.0	6.3	129,443.9	6.4	28,000.2
2011/2012	25,199.8	· 6.2	137,673.3	6.4	29,735.8
2012/2013	26,752.7	6.2	146,326.0	6.3	31,568.2

(3) Power Development Planning

EEHC annual report says that in ordered to meet the demand prospected in the previous section, they has plan to develop 8,547MW of additional & indicative plants including 7,550MW of C Cycle during the period FY2007/08-2011/12.

Table 2-1-2-2 PDP in 6th Five Year Plan

FY	2007/08	2008/09	2009/10	2010/11	2011/12	Grand Total
Total annual added cap.	964	2,275	1,843	1,515	1,950	8,547

Sources: The 6th Five Year Plan

Fig. 2-1-2-7 shows a power balance based on the demand forecast and the power development planning.

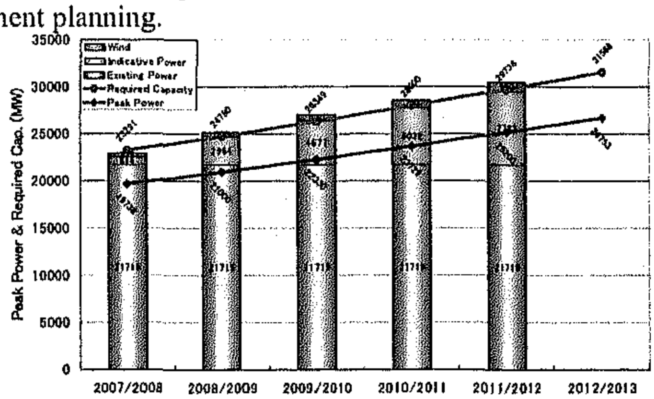


Fig. 2-1-2-7 Power Balance based on Demand Forecast & PDP

Clause3 The 6th Five Year Plan in Power Sector

(1) Target in Power Sector

Targets of the plan in their power sector are as follows;

- ✓ To add generation capacity of 8,547MW of which 964MW is planed during the Plan's first year
- ✓ To expand the use of renewable generation sources to reach 12% of total additional capacities to diversify energy sources and gradually substitute renewable friendly-environment for traditional sources based on heat generation
- ✓ To add transformation stations with total capacities of 16,950MVA
- ✓ To extend air networks and ground cables for total length of 52,330km
- ✓ To increase average per-capita consumption of energy by an annual rate of 7%

(2) Development Plan

Followings represent development plan in each sector in detail.

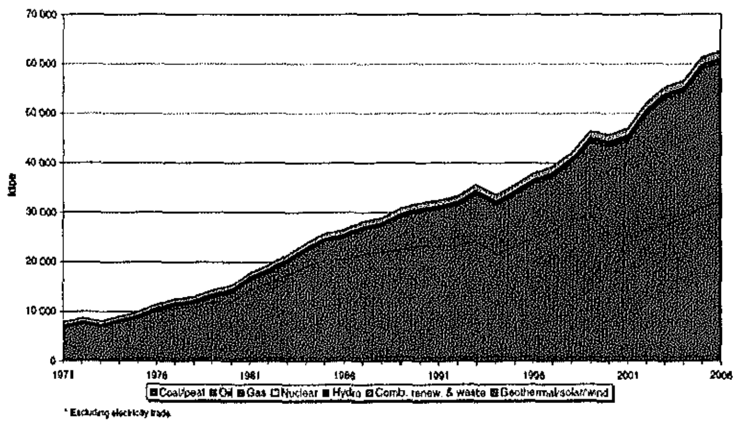
a) Generation Sector

- Thermal Power: The plan includes implementation of thermal power plans that are expected to increase capacities of 7,550MW with 750MW in the first year. About 4,500MW will be generated through C Cycle and the rest additional capacities will be supplied by ST. EHCC and EEPC are assigned to implement the entire power plant projects.
- Wind Power: In the plan, there are a number of projects to generate electricity from renewable sources. It's targeted to add electric power of about 765MW through wind power, to reach a total wind generation capacity of 1,050MW by the end to the plan.
- Hydropower: It's expected to add capacities of 82MW, of which 64MW will be added within the first year 2007/08.
- Solar Heat Generation: The plan includes adding 150MW of solar heat energy in Korymat area.

Section 2 Energy Efficiency in Egypt

Clause1 Primary Energy Consumption

Fig. 2-2-1-1 indicates trend of yearly total primary energy supply. Hereby total primary energy supply has been increasing year by year and reached 62,501ktoe (ton of oil equivalent) in 2006. Particularly natural gas supply has been growing since 2000 dramatically.



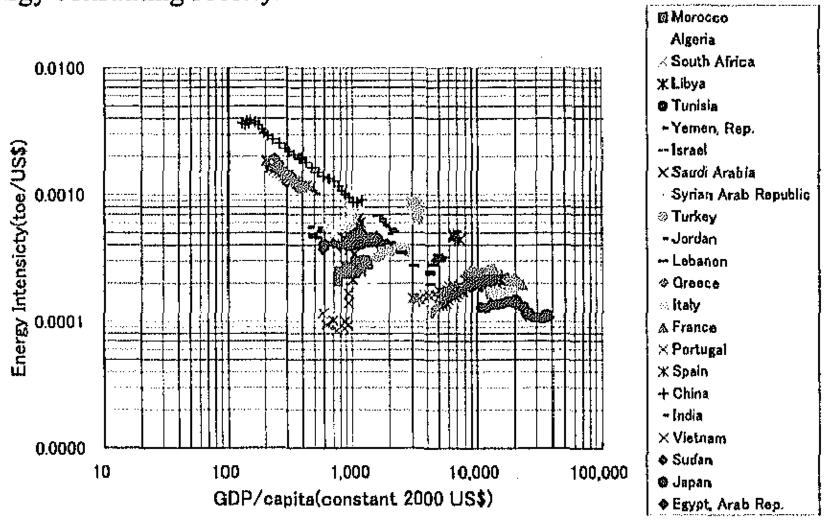
Sources: IEA HP

Fig. 2-2-1-1 Primary Energy Supply in Egypt

Fig.2-2-1-2 represents Energy Intensity which indicates a amount of energy consumed to produce a USD of GDP and it means a measure of the energy efficiency of a nation's economy.

In this graph, the bottom-righter hand data locates in, the more developed country it means that of. Those of emerging countries located in the center of the chart.

The Energy Intensity of Egypt is approximate $4.6x10^{-4}$toe/US$ in 2003 and four (4) times more than $1.1x10^{-4}$toe/US$ in Japan. On this view point, Egypt is expected to be shifting to energy saving society based on promotion of changing their industrial structure and energy consuming society.



Sources: World Development Indicators 2006 ; World Bank

Fig.2-2-1-2 Correlation between GDP & Energy Intensity

Clause2 Plan and activity of Egypt regarding improvement of energy efficiency in Power Sector

Energy efficiency measures which EEHC is taking are basically same as what Egypt government is implementing.

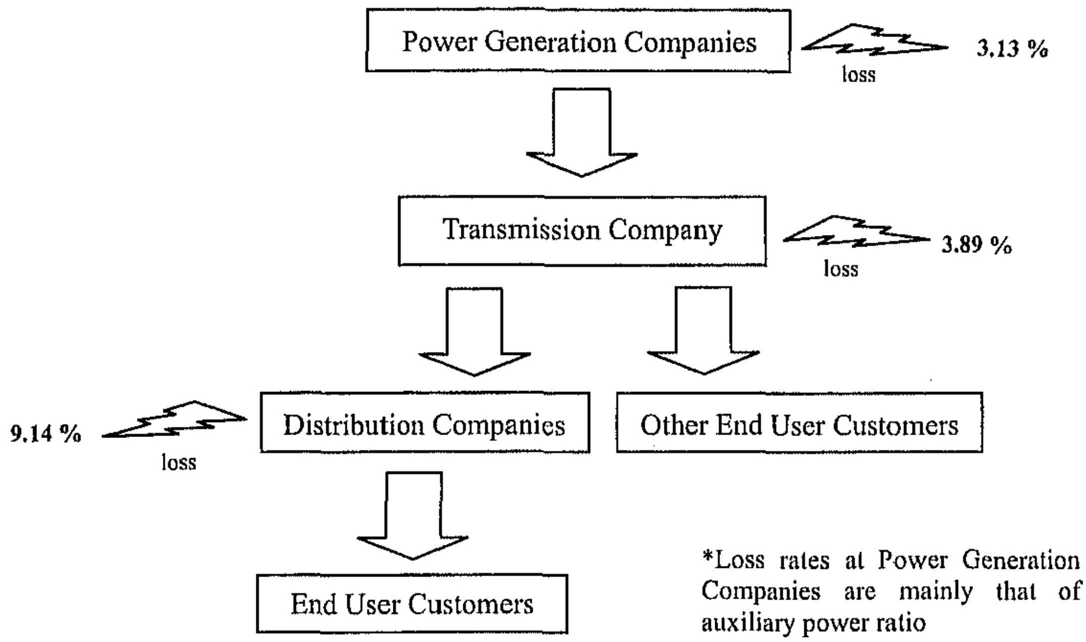
They have three main points. The first one is promotion of developing renewable energy including significant wind power, hydro power and solar power. The second one is to utilize natural gas effectively by maximizing use of C Cycle. The last one is to diffuse compact fluorescent light bulbs (CFLB) and to replace incandescent lights for road lighting with fluorescent lights actively.

In respect to CFLB, EEHC's subsidies corresponded with a half value of purchasing cost for CFLB are promoting to be installed in residential and commercial sector. As result approximately five(5) millions of CFLBs have been introduced until now. In regard with fluorescent lights for read lighting six(6) millions of the lights have been installed so far.

The 7th five year plan, the next plan, is now been examining and did not finalized yet. According to EEHC it's envisage that the plan would comprise not only the three main points of the 6th five year plan but also promotion of nuclear, bench mark activity of energy intensities, construction of framework for introducing energy efficiency buildings and installation of LED road lighting.

Clause3 Loss in Electric Power System

In the year of 2007/2008, 4,663GWh of energy loss has been observed in Transmission Company as shown in Fig. 2-2-3-1.
This is nearly half of the loss that has been observed from distribution of energy to end user customers.



Data source: EEHC / prepared by the Team

Fig. 2-2-3-1 Electric Power Energy Flow (DATA 2007/2008)

Loss data in electric power system is shown in Table 2-2-3-1. The data shows that the loss in transmission line is not larger than that of the distribution network. Moreover, the loss is about half of distribution network's.

Table 2-2-3-1 Loss in Electric Power System

Year	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
Generation loss %	3.63	3.64	3.43	3.25	3.13
Transmission loss %	3.78	3.72	3.73	3.71	3.89
Distribution Network Losses %	10.38	10.28	9.38	9.24	9.14

Data source: EEHC / prepared by the Team

Section3 Plan and activity of other donors regarding energy efficiency

At the current, WB, AfDB, USAID, KfW, GTZ, UNDP, AFD, GEF maintain their local office in Egypt (of course including JICA) and make activities as a donors. The team has been studying on their cooperation activities on energy saving projects in Egyptian power sector based on some interview surveys, desk research through some publication, HP and so on.

Table 2-3-1 Interview Survey on Activities for Energy Efficiency

	World Bank	African Development Bank	KfW
Responder	Dr. Mohab Halloud	Dr.Khaled EL-ASKARI	Mr. Andreas Holtkotte, Ms. Sherine ElGhatit
On-going projects regarding energy efficiency	Non	**<El Kureimat C Cycle Power Plant Project>** **Type :** C Cycle **Installed capacity :** 3x250MW **Total project cost :** 340 million USD	**<Rehabilitation of Thermal Power Plant>** **Feature :** In a case of electricity generation sector of Egypt, KfW is financing to improve the efficiency level of power station.
Plan of energy efficiency projects	Making consultant EEHC about implementation of fact finding study on energy efficiency and North Cairo Electricity Distribution Company about diffusing compact fluorescent light bulb. (however not having obtained the EEHC's reaction yet)	Non	KfW is focusing in DSM including prevalence of Energy efficiency light and consulting manufacturer for energy saving.

	UNDP
Responder	Dr. Mohamed Bayoumi Dr. Ibrahim Yassin Mahmoud (EEIGGR Director)
On-going projects regarding energy efficiency	**<Energy Efficiency Improvement & Greenhouse Gas Reduction(EEIGGR)>** **EEIGGR Feature:** EEIGGR consists of three components. The objectives of the components are as follows; ○ Component 1: Loss Reduction, Load Shifting and Load Management in the UPS ○ Component 2 : Energy Efficiency Market Support ○ Component 3 : Cogeneration **【Component 1】** The activities of Component 1 comprise followings. ● To Reduce Transmission Losses ● To Set Priorities for Dynamic Response of Generating Unit ● Network Analysis & Control Strategies ● Load Shifting through (TOU) Tariff The activities have already been completed. **Project costs :** 5.9MUSD(GEF:4.1MUSD, Egypt gov. : 1MUSD, UNDP : 0.8MUSD) **【Component 2】** ● The activities of Component 2 comprise followings. ● Energy Efficiency Industry Support by ESCO ● Energy Standard & Labeling ● Energy Codes for New Buildings ● Energy Efficiency Center ● Component 2 is now at stage of approving procedure. **Prospected project costs :** 0.8MUSD 【Component 3】 ● The activities of Component 2 comprise followings. ● Legal Framework for Cogeneration ● Agriculture Waste
Plan of energy efficiency projects	Non

Table 2-3-2 Desk Research on Activities for Energy Efficiency

USAID	Improving hydropower efficiency based on rehabilitation of existing plants(Aswan High Dam)
GTZ	Training on EEHC operators for operating thermal power plants efficiently
GEF (Global Environment Facility)	Supporting NGO to diffuse energy efficiency appliances to residents by Small Grant Programme (SPG)

Based on the survey and research, it's envisaged that other donors would not deal with energy saving projects in Egyptian distribution sectors which JICA focus on yet.

Chapter 3 Potential of improvement and Candidates of project in energy efficiency of power sector in Egypt

Section 1 Potential of Energy Efficiency

Clause1 Potential of Energy Efficiency Improvement in Power Generation

(1) Optimal Generation Mixture (Best Mix)

First in this section, a study on a power generation mixture which utilizes energy and fuel most efficiently shall be implemented with "Screening Curve Method" (refer to appendix 3.1-1 which represents the methodology in detail).

Table3-1-1-1 represents the optimal generation mixture in Egypt based on analysis with Screening Curve Method. Table3-1-1-1 also indicates proportions of current power system and that in the end of the 6th Five Years Plan. It shows both of ST portions are larger and both of C Cycle portion are smaller compared with the optimal mixture. Meanwhile Egypt government and EEHC declared to promote to develop C Cycle, it's expected to prompt it furthermore.

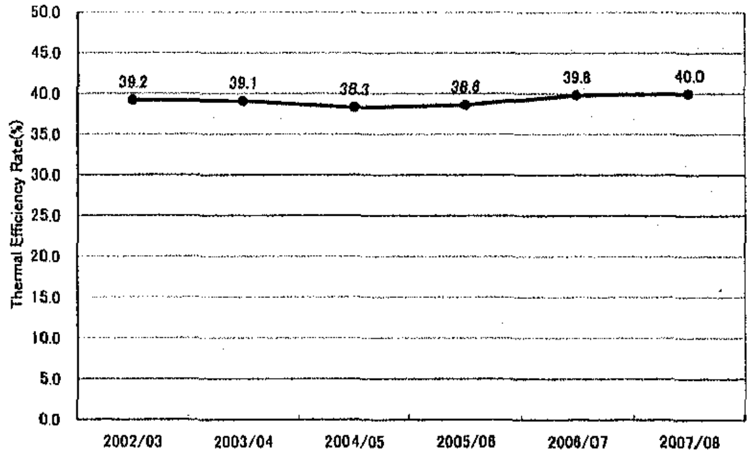
Through the analysis, the promotion of C Cycle can be selected as an option of energy saving projects. The 6th Five Year Plan still has many conventional ST projects. Hence, only in the view of energy efficiency, not only existing old ST plants but also these future ST projects should be replaced with C Cycle projects.

Table 3-1-1-1 Optimal Generation Mix (Best Mix)

Power plant type		Opt. Mix. Ratio	Existing Ratio	Plan in 2013
Peak power plant	GT	5-10%	6%	5%
Middle power plant	Conventional ST	15-25%	51%	50%
Base power plant	Conbined Cycle (or Hydro, Wind)	65-80%	43%	46%

(2) Thermal Efficiency Rate in Egypt

Fig. 3-1-1-1 indicates comprehensive thermal efficiency rates year by year. The thermal efficiency rates have been almost constant and about 40%. Compared with those of other countries, Egyptian efficiency rate is at a high level in the world because most of the power plants are run by firing natural gas.

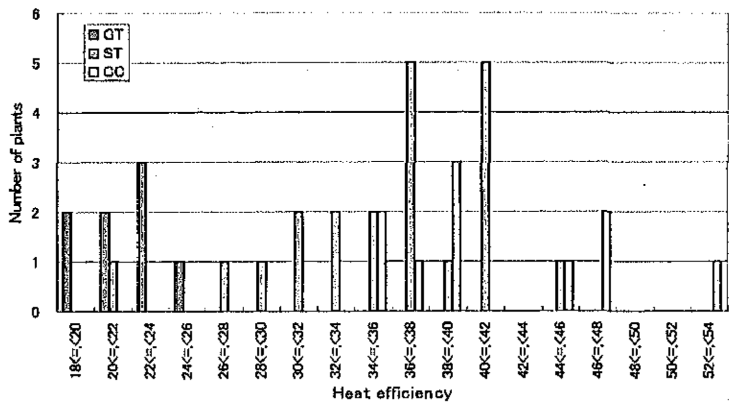


Sources: EEHC Annual Report

Fig. 3-1-1-1 Yearly Thermal Efficiency in Egypt

On the other hand Fig. 3-1-1-2 shows histogram of thermal efficiency plant by plant. Followings are notified hereby.

- ✓ Efficiency rates of GT are distributed between 18% and 26% and there are 2 plants which have low efficiency of less than 20%.
- ✓ Efficiency rates of ST are distributed between 20% and 46% and there are 3 plants which have extremely low efficiency of less than 30%.
- ✓ Efficiency rates of C Cycle are distributed between 34% and 54% and there are 2 plants which have low efficiency of less than 36%. However one of these has not been completed and under testing operation. This can conclude that there is one inefficient C Cycle.
- ✓ Egyptian comprehensive thermal efficiency is not low. However, they have some extremely inefficient plants. Consequently these plants should be overhauled or retrofit based on additional inspections.
- ✓ They have many ST which is lower efficient than C Cycle. So more efforts are required for EEHC to maximize the use of C Cycle up to the optimal generation mixture as mentioned in the previous section.



Sources: EEHC Annual Report

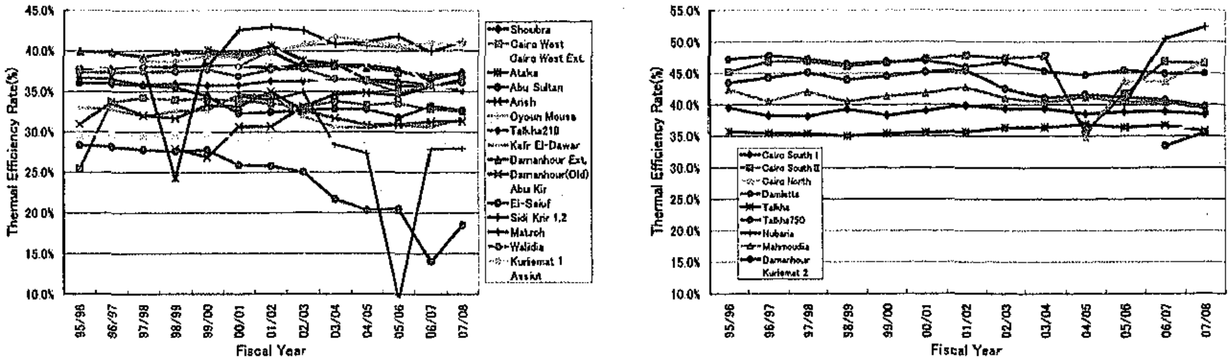
Fig. 3-1-1-2 Histogram of Thermal Efficiency

The team reviewed yearly records by plant as shown in Fig.3-1-1-3 and 4. These figures show that the thermal efficiencies of EL-Suez, Matroh and Damanhour station are becoming worse in these five years. When an index of decrement of thermal efficiency is defined as a formula below, it can classify power plants with inefficiency as shown in Table3-1-1-2.

Decrement of efficiency = Highest record of thermal efficiency – Efficiency in 2007/08

The plants indicated in the table are expected to be replaced or rehabilitated. Particularly Matroh station have been generating at more than 50% of capacity factor though generally inefficient plants should be operated at low capacity factor. Hence it should be notified that the power station wastes precious fuel.

C Cycle plants in the table such as Damahour, Demiette and Mahmoudia have been run at high efficiency level. However the thermal efficiencies have been decreasing since 2000. Considering this situation, these plants are also needed something like overhauls.



Sources: EEHC Annual Report

Fig.3-1-1-3, 4 Yearly Record of Thermal Efficiency by ST Plant (left hand) & CC Plant (right hand)

Table3-1-1-2 Power plants of which thermal efficiency have decreased

Decrement of Effi.	Combined Cycle Plant	Conventional ST plant
2%=<	Demietta,Mahmoudia	Ataka,Abu Sultan,Kafr El-Dawar, Damanhour Ext,Damanhou(old),Abu Kir
5%=<	Damanhour	El-Seiuf,Matroh

(3) Potential of Energy Efficiency in Power Generation

Taking into account these situations, following potential of energy efficiency can be selected.

- ✓ For inefficient plants of GT, ST and C Cycle, retrofitting project can be adopted.
- ✓ For existing ST, (depending on conditions) repowering project that will make existing plant combined with new GT can be adopted
- ✓ For planed ST, promoting project to develop advanced C Cycle (ACC) can be adopted. (For existing ST, replacing can be one option.)

Clause2 Potential of Energy Efficiency Improvement in Transmission

(1) Current overview of power transmission system

Maximum voltage level is 500kV, while the voltage of trunk (backbone) power system is 220kV, 140kV and that of local to be 66kV.

Basically, the transmission line is built in 2 circuits and in parallel.

(2) Energy Efficiency in Transmission Line

The power sources are equally installed and located for each zones although Cairo and Delta zones are in northern part of the country which are the power-consuming area.

The available power energy of each Distribution Companies, when appointing them approximately to each zone still has trend of even distribution except for Cairo which has more than double of the available power energy compared to other Distribution Companies.

In General terms, when the power supply is evenly distributed through out the land and so as the power demand, there are no high-needs for long transmission lines with large capacity. This is know as, "local production for local consumption".

Here, it is obvious that the power-consuming center is around Cairo and northward area and the existence of the 500kV transmission line fulfills the large consuming region with low transmission loss.

Topologically, the power system in Egypt is in a fine balance.

(3) Current Situation of Substation

In distribution substations, the standard capacity of transformers (66kV/11kV) is around 25MVA, and they consist of around 4 banks. The voltage and power factor adjustment is manually done by opening and closing of capacitor, and tap changer when necessary.
The mainstream for Substation is indoor or half-outdoor type, and that for transformer is oil-immersed self-cooled or oil-immersed air-cooled type. The internal consumption rate (auxiliary power ratio) is relatively low for there are no specific large scale auxiliaries.

The facts found in this study of distribution substation, is as follows.

- ✓ The transformers are operated basically around 4 placed in parallel with configuration of appropriate load changing through bus bars, are preferable from the point of view of loss reduction.
- ✓ Unit capacity of each transformer is selected to be around 25MVA which is not so large and the rated current in secondary side is suppressed moderately, which is preferable from the point of view of reducing copper loss and cable loss etc.
- ✓ The transformer is equipped with tap changer. Also on the middle voltage side, equipped with phase modifying condenser. In this substation the voltage is monitored in full-time and when necessary to use these equipments. The mentioned way of operation is preferable contributing to reduce power loss.

(4) Potential of Energy Efficiency in Transmission

Below summarizes the energy efficiency in the field of transmission lines.

- ✓ There are few lines under heavy loaded then there are few cases that transmission loss is too high.
- ✓ Operation of the network voltage and reactive power are in good condition. It shall be difficult to reduce further more of the losses by reactive power control.
- ✓ To cope with the growth of demand, there already exist plans for increment and augmentation of transmission lines, especially in Cairo and Canal zones which are the center of the heavy load. From this point, there are little possibilities of transmission loss to still increase.
- ✓ In the future, when development of large scale wind farm along the Red Sea coast around the depopulation electric power area, there might be transmission lines with its power flow bottle necked and from this point, an optimal plan to install transmission facilities taking into account the transmission loss.

Below summarizes the energy efficiency in the field of substations.

- ✓ Auxiliary machine loss is adequately low, to have difficulties for reducing loss any further.
- ✓ Voltage class is integrated basically at 500kV, 220kV and 66kV. 220kV is directly dropped to 66kV near the consuming area so the electric transforming loss is relatively less.
- ✓ Along with the increasing electricity load, there are new construction and enhancement plans for 220kV/66kV substations near the consuming area and 500kV/220kV substations at trunk lines to have, for the moment, little possibilities of noticeable increase of losses coming up from voltage metamorphic.

Clause3 Potential of Energy Efficiency Improvement in Distribution

(1) Current overview of power distribution system and its control system

Distribution facilities in Egypt are operated by nine distribution power companies which have specific franchise area and responsibilities to supply power. The electricity distribution system is supplied from the transmission system of the Egyptian Electricity Transmission Company.

There are around five 11kV feeders in each 11kv bus in distribution substation and divided again in distribution point in the center of power demand. There is distribution transformer "DT" (11kV/0.4kV) in each Kiosk and supply power at 400V to the customers.

In urban regions the transformer, together with its medium voltage and low voltage switchgear are housed either in a metal enclosures or kiosk, or put within a room in the ground level of a residential building or a workshop depending on the area served and the availability of space. In rural areas and in village pole mounted or pad mounted transformers are generally used.

Distribution Company has Distribution Control Center (DCC) under national and regional control center. Distribution system data such as current, voltage, active and reactive power are monitored by DCC of model distribution companies. They monitor and operate distribution system efficiently to keep good condition of its power quality and reliabilities. But communication system does not cover all their supply area. Then some of switchgears can be manipulated by remote control but the most of switchgears are manual and they need to dispatch staff to manipulate them.

DCC of three model distribution companies are established more than 10 years ago and they also have many troubles in current DCC because of its out of date system. It is the time to replace DCC system and expand their control area to all supply area.

(2) Existing Condition of Energy Efficiency in Distribution

The rapid extension of the distribution networks goes with increasing its demand resulted in the increase of the electric energy the resistance of the system components. The efforts have been exerted by the electricity distribution companies in Egypt to reduce the network losses in the last decade and it was possible to reduce the percentage energy losses to 9.31% in the year 2007. However, this percentage of energy losses is still high in comparison to that in other developing countries.

Table 3-1-3-1 Distribution Loss of Nine Electric Power Co.

Distribution Companies	1	2	3	4	5	6	7	8	9
Available Energy* mkWh]	14,026	17,199	6,805	7,657	7,139	14,301	5,360	7,370	6,375
Sold Energy [mkWh]	12,195	14,928	6,073	7,190	6,724	13,427	4,976	6,800	5,890
Distribution Loss [%]	13.06	13.20	10.75	6.10	5.81	6.11	7.17	7.74	7.61
	1: North Cairo E-Disco. 2: South Cairo E-Disco. 3: Alexandria E-Disco. 4: North Delta E-Disco. 5: South Delta E-Disco.				6: Canal E-Disco. 7: El- Behera E-Disco. 8: Middle Egypt E-Disco. 9: Upper Egypt E-Disco.				

**Available Energy = buying Energy + Self Generated*

(3) *Current measurement to improve energy efficiency in distribution*

Nine distribution companies are trying to reduce distribution loss supporting with EEHC. But there are no specific plan and goal mentioned in official report. Most of the measurements are strengthening network facilities to prevent overload condition and improve power factor to supply power efficiently. Currently the measurements listed below are conducting by distribution companies.

1) Strengthening to develop new feeders and transformers
   -- Construction of additional 11 kV feeders and LV line to reduce over loaded feeder
   -- Replacing old transformers to new low loss DT

2) Improvement of power factor
   -- Install 11kV Capacitor 20% of maximum load until 2010
   -- Final goal is 30% of maximum load
   -- New inventive tariff system will be introduced to industrial customers.

3) Proper conductor connection

(4) Potential and counter measurements for energy efficiency in distribution sectors

In general, technical loss reduction of distribution system is the greatest challenge for distribution sectors. Distribution network losses can vary significantly depending on the large current power flow caused by overload and load unbalance. Additionally low power factor will lead to increased current and hence increased loss and voltage drop.
Here are the potential for energy efficiency in distribution sectors.

1) Strengthening conductor (Wire and Cable)
   Basic measurement is to reduce the current of the power flow, in other words, improve overloading situation in wires and cables, for example, introducing higher voltage level or large size of conductors, developing of new feeder, or shortening LV line.

2) Strengthening distribution transformer (DT)
   Energy losses in the electricity distribution system is the energy losses in medium voltage/low voltage transformers due to copper losses as well as the hysteresis and eddy current losses in the magnetic circuit. In addition, the long length of LV line connecting to DT also causes to increase the technical loss.
   To replace overloading distribution transformer to bigger size or to develop new kiosk in order to allocate appropriate load in transformer itself and shortening low voltage line are potential measures.

3) Improving low power factor situation
   In Egypt motor load of factories and agricultural pumping motors lead to low power factors and this low power factor leads to increase current of the distribution system.
   Capacitors may be connected at low power factor customers or at load centers in order to improve the power factor, hence reducing the current and the energy losses in the conductors of the network.

4) Improving unbalanced load current allocation of three phase line
   When the load currents are not balanced on the three phase lines, a current will run through in the neutral line of the system. That causes additional heat losses contributing to the total losses of the distribution system.
   The measurement of this problem is to monitor and find the unbalance situation and shift the load in the appropriate phase.

Clause4 Potential of Energy Efficiency Improvement by Demand Side Management

(1) Conceptual Benefit of Demand Side Management

One of the main difficulties of power business is that the company has to build generation capacity enough for peak demand and this is because the electricity cannot be stored. However, if demand curve is flat, they can avoid building peakers that only operate in limited peak hours. This is the major benefit of demand side management. In Japan, heat storage or pumping hydro are the major contributors in this effort. They enable the energy storage by changing the form of energy from electricity to heat or physical energy. Other than these, NAS battery is an option for this effort.

(2) Successful example of Demand Side Management in Japan

1) Peak Shift by Heat Storage AC

AC consumption is significant in the peak time in Japan. By applying heat storage, 40% of peak load of AC can be shifted. This is only applicable to large customers, but so far 1700MW of peak load has been shifted by this measure, which is equivalent to 1BUSD of power plant construction costs.

2) Incentives to enable Peak-Shift

In order to enjoy such benefits, TOU tariff is introduced. Rough calculation indicates that 100kW office building can recover their initial costs for heat storage AC in 10-15 years by the TOU benefit.

(3) Energy efficiency in Egypt

1) Energy consumption and economical development

Annual GDP grows at 7% which concise with annual power demand growth rate.

2) Energy Demand status in Egypt

Despite the hot weather, the demand curve does not correspond with temperature variation, indicating either a lack of AC diffusion or Energy Conservation practice.

(4) Demand status of Alexandria

Peak appears in evening and 70% of customer is household. This trend reflects the life pattern of people, working 8 to 15 without lunch break and have a dinner in late evening. As for the AC demand, it is assumed to be 30% taking the difference between summer peak and other season. One of the notable efforts of the power company is the experimental installation of AMR that may contribute to DSM promotion.

(5) Demand status of North Delta

North delta also has its peak in night, demand curve not corresponding with temperature. Another unique point is that there is not much gap between peak and off peak. These characteristics indicate lack of AC diffusion. The customers are mostly household users and no sign of development into an industrial area. The power company in the region also promotes AMR with GPS communication.

(6) Demand status of North Cairo

Peak appears in night and 30% of demand is assumed as AC from the gap between peak and off peak. This area is also mostly residential, but development of industrial customer is evident. The power company also promotes AMR installation to cope with power theft and erroneous meter reading.

Section2 Candidates of projects for improvement in Energy Efficiency

Clause1 Candidate List of Power Generation Project

Table 3-2-1-1 Project Feature 1

Project	Introduction of C Cycle with 1,300 degree class GT (ACC)	Retrofitting inefficient power plant	Combining existing plant with new GT
Technical Feature	Advanced Combined Cycle (ACC) has achieved 55% of efficiency under LHV condition (50% under HHV) by using 1,300 degree gas turbine and ST which can be operated under higher temperature and pressured steam conditions.	This project is to retrofit an existing plant using technology and knowhow of operation & maintenance which power utilities possess. The efficiency improvement depends on existing plant situations.	This project is to make an old existing ST plant combined with a new GT unite and to utilize exhausted gas heat from GT for the existing ST boiler.
Merit	Higher efficiency accomplish to decrease energy consumption and emission of CO_2 & NOX	This project can decrease capital costs compared with replacing (scraping & building).	
Demerit	Higher capital costs	When this project is implemented, the existing plant should be stopped. The duration depends on a project. However in some cases a few years should be required.	
Issue about introduction of technology	Thermal efficiency of a combined cycle plant depends on the gas turbine firing temperature. In Egypt, it's necessary to study on gas supply & storage system in addition.	In some case, it may take much time to inspection on subordinate system such as circulator, circulation pump). The inspection is necessary for improving captive energy fact.	This project should select a proper size of boiler based on investigating in detail and study on firing more fuel additionally and alternative heating system of supply water. In Egypt, it's necessary to study on gas supply & storage system in addition.
Mitigation & Benefit	Large	Medium	Medium
Costs	Large	Small	Medium

Clause2 Candidate List of Transmission Project

The following methods shown in Table 3-2-2-1 can be conceivable for countermeasures on loss reduction for transmission and substation sector.

Table 3-2-2-1 Potential Methods for Energy Efficiency in Transmission

Conceivable Methods	Conceivable Outcome	Application Issues
Countermeasure for Transmission Line		
Augmentation of heavy loaded transmission line	Lessening the power flow to reduce transmission loss	Currently, problems due to heavy load are not observed. Moreover, the advantages of injecting large amount of cost aiming for loss reduction is very little. But in the future, along with the increase of pôwer demand, the loss will likely to rise, so enhancement plans for the transmission lines are needed.
Improving power factor of heavy loaded transmission line	Maintaining proper voltage level and improvement of reactive power flow reduction	Currently, most of the transmission lines have power factor nearly to 1. There are still transmission lines with room for improvement of power factor but this will not be effective enough for loss reduction.
Voltage rising of heavy loaded transmission line		When in long-distance transmission lines, the losses will not be ignorable. In this case rising voltage may be effective to reduce transmission loss.
Countermeasure for Substation Facility		
Reduction of in-house power of substation	Loss reduction from in-house power load	Most of the transformers are self-cooling type, so the space for loss reduction is very small.
Simplification of the using voltage levels	Simplifying voltage metamorphosis to reduce transformer loss	In Cairo and Canal zones where main power generation and center of the demand exists, the voltage levels are already set to 500, 220 and 66kV.
Installation of automatic voltage regulator	Installation of voltage regulator, VQ controller	Power saving in adjusting voltage and rapid response to sudden change.

Basically regional balance of power generation facilities and demand are appropriate, also mid- and long-term development plans of transmission lines and substations are adequately made to have the result of relatively less occasion of noticeable loss occurring to high voltage facilities.

But in the future, revised plans for the mid- and long-term development plans of transmission lines are needed considering the development of large scale wind farm along the Red Sea coast around the depopulation electric power area which might cause bottle necked transmission lines in its power flow.

In current situation, the voltage adjustments by reactive power of high voltage transmission facilities are properly done, but in some substations voltage control is done manually. In these facilities, installation of automatic voltage regulator for power saving can be thought of.

Clause3 Candidate List of Distribution Project

There are eight potential methods for energy efficiency in electric distribution sector. After conducting the site survey, the study team evaluated these eight potential methods and concluded two of the methods are not feasible in Egypt because of the cost benefit.

Table 3-2-3-1 Potential Methods for Energy Efficiency and Priority

	Potential Methods	**Evaluation**
1	Higher voltage of distribution feeder	× Loss reduction is effective but large investment is needed due to Various changes on many facilities
2	New construction of 11kV feeders	○ Big effectiveness to strengthen supply capacity and allocate overloaded feeders but Space to develop new feeders is needed
3	Large size of cable and line conductor	× The most of existing conductors are enough large size
4	Shortening LV line by installing small size DT	○ Big effectiveness of loss reduction for OH network △ The most of existing LV lines for UG are enough short and the loss is not so large
5	Replace old DT to new low loss DT	○ Big effectiveness to reduce cupper and iron loss The most of existing DTs are old.
6	Improvement of power factor by installing capacitor	○ Big effectiveness and potential to reduce current and loss Installed capacitors should be controlled appropriately
7	Balancing distribution feeder load and phase of LV side	○ Effectiveness of loss reduction is expected but is limited to overload feeder and phase-unbalance feeder.
8	Install Step Voltage Regulators to improve its voltage drop	○ Effectiveness is limited to big voltage drop location such as OH feeder with long distance

(1) Higher voltage of distribution feeder
Current voltages levels are appropriate for the capacity in Egypt and to introduce another higher voltage level takes not only cost a lot but also causes various changes on facilities itself and O&M of Distribution Company. Therefore, higher voltage of distribution feeder is not good measures in Egypt.

(2) New construction of 11kV feeders
New constructions of 11kV feeders are beneficial to reduce system power flow on 11kV feeders. Distribution companies plan their development schedule and conduct properly their measures to expand and develop new 11kV feeders.

(3) Large size of conductor of cable and line
In these condition, install and replace large size of conductor on distribution line can NOT expect the big effect to reduce distribution losses.

(4) Shortening LV line by installing small size distribution transformers
There are some potential cases to reduce loss to shortening LV line by installing small capacity DT, but these cases are NOT many for UG network and can not expect big effects.

(5) Replace old distribution transformer (DT) to new low loss DT
According to hearing from distribution companies, they are planning to replace old transformers to new low loss ones and proximally 75% of transformers are still old type and about 80% of transformers are overloaded during peak time. There are potential to reduce distribution loss by installing low loss transformers.

(6) Improvement of power factor by installing capacitor and control it
Distribution companies regulate its power factor and set its target on 0.95 that current average power factor is 0.85. They believe that the ideal capacity of capacitors is about 30% of total system capacity and they expect Japanese side to support this option. Then should be controlled on and off its capacitor consistently can keep its power factor at a best condition.

(7) Balancing distribution feeder load and 3 phase of load
The dispatchers of control center supervise the load and try to balance it among some existing feeders. Installing remote controlled switchgears and frequent controlling its load balance enables them to reduce feeder current and improve its reliability in addition.

(8) Install Step Voltage Regulator (SVR) to improve its voltage drop
There are many cases that voltage drop sometime exceeds the regulating values especially in rural area which power line are long. Installing SVR can be expected to improve voltage level. Stepping up voltage can reduce its electric current, so that distribution loss can be reduced in square ratio.

Clause4 Candidate List of Power Demand Side

(1) DSM by AMR
AMR is being tested everywhere in Egypt. This is useful for accurate meter reading and power theft prevention while also contributing to better monitoring of demand status. This effort should be thoroughly continued.

Section 3 Candidate of Japanese ODA loan project

Clause1 Evaluation for candidates of projects

In order to prioritize the potential in the candidate lists and select model projects for Egypt among them, the team made evaluation criteria taking into account project effectiveness, feasibility, promptness and so on.

- ✓ Total costs (A : Small, B : Medium, C : Large)
- ✓ Costs & Effectiveness (A : Very Good, B : Good, C : Medium)
- ✓ Implementation period (A : Short, B : Medium, C : Long)
- ✓ Impact to reliability of power system during implementation period (A : Non, B: Minor Little, C : Significant)
- ✓ Necessity of additional technical study (A : a little, B : Some, C : Much)
- ✓ Urgency (A: Urgent, B: Medium, C: Moderate)

Table below shows a rough estimation of prioritizing each project based on the criteria.

	Project	Total costs	E/C	Imp. period	Impact to Sys. Reliability	Necessity of tech study	Urgency	Total
Power Generation								
1	Introduction of C Cycle	C	A	B	A	B	B	**B**
2	Retrofitting & rehabilitation for inefficient power plants	A	A	A	C	C	B	**B**
3	Combining existing plant with new GT	B	A	C	C	C	B	**C**
Transmission								
4	Newly-built high voltage transmission line	C	C	B	A	B	C	**C**
5	Reduction of load factor by increasing the number of paralleled transmission line	C	C	B	A	B	C	**C**
6	Augmentation of transmission line (heavy lining, usage of multiple conductor)	C	C	B	A	B	C	**C**
7	Reduction of in-house power of substation	B	C	A	B	B	C	**C**
8	Reduction of load factor by expansion of transformers	B	C	A	B	B	C	**C**
9	Installation of automatic power factor adjusting device	B	C	A	B	B	C	**C**
10	Installation of automatic voltage regulator	B	B	A	B	B	C	**B**
11	Utilization of transformer waste heat	B	C	B	A	C	C	**C**
Distribution								
12	Higher voltage of	B	C	A	A	B	C	**B**

	distribution feeder							
13	New construction of 11kV feeders	A	A	A	A	B	A	**A**
14	Large size of cable and line conductor	B	C	A	A	B	C	**B**
15	Shortening LV line by installing small size DT	A	A	A	A	B	A	**A**
16	Replace old DT to new low loss DT	A	A	A	A	B	A	**A**
17	Improvement of power factor by installing capacitor	A	A	A	A	B	A	**A**
18	balancing distribution feeder load	A	B	A	A	B	A	**A**
19	Install Step Voltage Regulators (SVR) to improve its voltage drop	A	B	A	A	B	A	**A**
DSM								
20	Efficiency Improvement by DSM targeting on AC	A	B	A	A	C	C	**B**
21	DSM by AMR	A	A	A	A	B	B	**A**

Chapter 4 Model projects in Distribution

Section 1 Overview and Activities for Improving Energy Efficiency of Executing Agency of Model Projects

Clause1 Overview of Model Distribution Companies and Model Areas

(1) Model distribution companies

There are nine distribution companies under the EEHC. Out of the nine companies, the following three are selected as model distribution companies for this study: North Cairo Electricity Distribution Company (NCEDC), Alexandria Electricity Distribution Company (AEDC), and Delta North Electricity Distribution Company (NDEDC).

Table 4-1-1-1 Number of Shares and Capital of Distribution Companies

Distribution company	No. of Shares	Capital (Million EGP)	No. of Medium Voltage Distributors (No.)	No. of Customers
North Cairo*	5,292,200	52.922	327	3,240,201
South Cairo	5,967,800	59.678	295	4,066,723
Alexandria*	19,544,316	195.443	177	1,952,913
Canal	15,287,087	152.87	1007	2,719,509
North Delta*	21,359,723	213.597	138	2,669,062
South Delta	22,274,638	222.746	102	3,016,718
El Behera	9,775,073	97.75	225	1,499,097
Middle Egypt	17,688,702	176.887	103	2,636,356
Upper Egypt	10,153,900	101.539	93	1,981,632

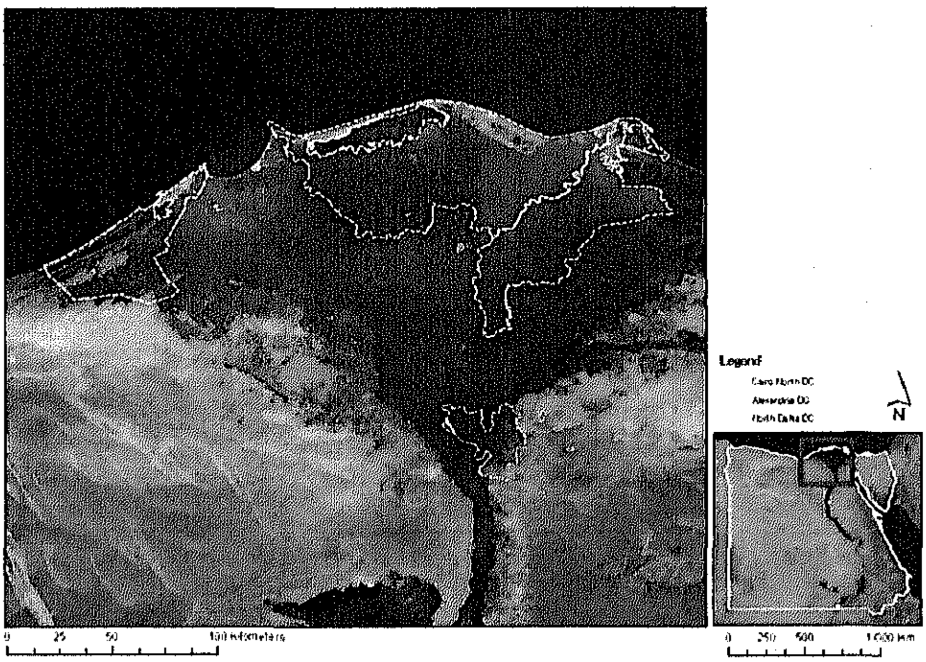


Fig. 4-1-1-1 Supply Area of Model Distribution Companies

(2) Model areas

Three model areas (sectors) are selected from three model distribution companies. The selected model areas are West Alex (Alexandria), North Dakhalia (North Delta), and Helmya (North Cairo). The main reason of the selection is percentage of technical loss. Technical loss of the selected model area is higher than the other sector. The technical loss of West Alex, North Dakhalia, and Helmya is 8.38%, 6.70%, and 12.20% (See Table 4-1-1-2).

Table 4-1-1-2 Distribution loss of each sector

EDC	Sector	Tec. Loss	Non Tec. Loss	Total	Selected reasons of model area
Alexandria	Central Alex	8.05	5.49	13.54	- The technical loss of West Alex sector is highest in 5 sectors. - There are many important industries in West Alex area. - West Ales area is a new town which has new and planned residences/ commercial buildings, so that a lot of peoples have moved to this area from old town in Alexandria.
	East Alex	7.97	5.32	13.29	
	El Sahel	7.97	5.23	13.20	
	Montaza	8.14	5.27	13.41	
	West Alex*	**8.38**	**5.38**	**13.76**	
	Total	8.15	5.39	13.54	
North Delta	Damietta	4.10	1.90	6.00	- The technical loss of North Dakhalia sector is highest in four sectors. - Potentials of technical loss reduction in North Dakhalia sector is large due to high ratio of OH feeder, long distribution lines and growing demands. - North Dakhalia sector is important due to concentration of industries, commercial activities and growing new
	Kafr El Shikh	4.90	3.10	8.00	
	North Dakhalia*	**6.70**	**5.30**	**12.00**	
	South Dakahlia	3.50	2.70	6.20	
	Total	4.80	3.25	8.05	
North Cairo	East	5.61	2.58	8.19	- The technical loss in Helmya sector is highest in four sectors. - Helmya sector is important due to governmental buildings, hospitals and concentration of industries/ commercial activities/ residences. - Outage duration in Helmya sector is relatively longer.
	Helmya*	**12.20**	**5.60**	**17.80**	
	Heliopies	9.37	4.31	13.70	
	North	7.09	3.26	10.40	
	Total	6.08	5.57	11.65	

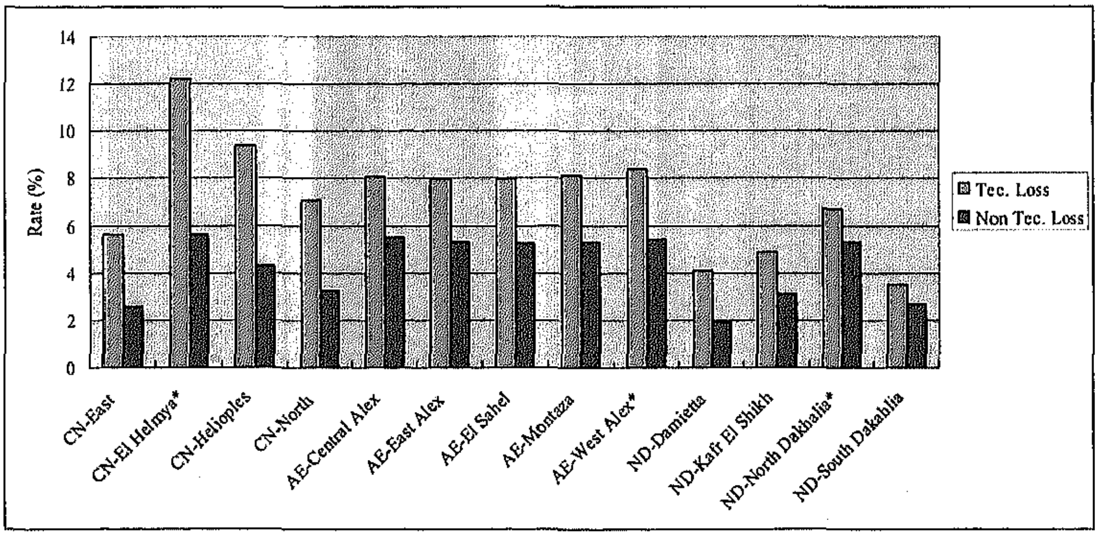


Fig. 4-1-1-2 Distribution loss by sector

Clause2 Existing Distribution Facilities in Each Model Distribution Company and Model Project Area

(1) Outline of Model Distribution Company

The JICA team nominated three potential candidates of distribution companies among nine distribution companies in Egypt with the agreement from EEHC.

These three companies are Alexandria Distribution Power Co., North Cairo Distribution Power Co. and Delta North Distribution Power Co. As these three candidates are the biggest distribution companies in Egypt, they have large potential of energy efficiency.

(2) Features and Characteristics of Distribution Facilities

In Egypt, there are two environmental variations, one is city area that concentrated population and the other is outskirts area around the city.

Distribution facilities in city area, electric power are supplied by underground cables. These 11kV cables are relatively large capacity and transformers are located near each other because of high load density. 400V low voltage cable are installed underground or hanged along the wall of the building.

On the contrary, in outskirts area of the city, electric power is supplied by overhead line. The distribution facilities in this area are weak and do not have priority of investment compared with that of city area. Furthermore facilities strengthening schedule tend to delayed due to the international increase of the equipment cost.

In city area, the distribution facilities are strengthened properly to prevent over load and keep high quality of power supply. The rated load current of the most of the feeders are around 40-60% but during peak time some of the feeders become overloaded.

In these situations distribution losses are around 8-14% (about half of that is non technical loss) in general, the percentage losses are decreasing in decade, however, it is still higher than the values internationally acceptable. There are still potential to improve both technical and non-technical loss.

Table 4-1-2-1 Comparison of three Candidate Company

Power Company	Distribution Loss	Power Factor
Alexandria Dis Co.	8.15%(Tech) 5.39%(Non-Tech)	0.85 average
North Delta Dis Co.	4.8%(Tech) 3.3%(Non-Tech)	From 0.86 to 0.95
North Cairo Dis Co.	6.08%(Tech) 5.57%(Non-Tech)	From 0.84 to 0.89

Clause3 Current Distribution Loss

Egyptian counter part and JICA team decided one project area in each three project distribution companies. Distribution loss in these project areas are high around 12 to 18% comparing with other area and these parentages will increase according to the high consumption growth rate.

Distribution Loss consists of technical loss and non-technical loss. The factor of non-technical loss mostly causes by human factor that should be ideally almost nothing. There is still potential to reduce the technical loss, that is, currently 6 to 12%.

(1) Distribution Loss and consumption growth rate in project area

1) Alexandria Distribution Company
Project area in Alexandria Distribution Company is **"West"** area one of which technical loss is bigger than any others supply area. There are new industrial parks and the wealthy people immigrate from downtown to West area. The portion of DT loss has the obvious causes and could have much potential to improve it.

2) North Delta Distribution Company
Project area in is "**North Dakhalia**" area which technical loss and consumption growth rate are especially bigger than any others supply area. This area is huge area and has some development project. Therefore, it could have much potential to improve distribution loss especially in 11kV distribution feeders.

3) North Cairo Distribution
Project area in North Cairo Distribution Company is **"Helmya"** area one of which technical loss is bigger than any others supply area. This area is big demand density and it is expected overload and load unbalance. Therefore, it could have much potential to improve distribution loss especially in DT and LV distribution line.

Table 4-1-3-1 Comparison of contents of growth rate

Power Company		**Alexandria**	**North Delta**	**North Cairo**
Area		**West**	**North Dakhalia**	**Helmya**
Technical loss	11kV OH Feeder	0.32	4.0	1.80
	11kV DT	5.36	1.2	7.20
	LV line	2.19	1.1	2.30
	Connection/Meter	0.51	0.4	0.90
	Total	8.38	6.7	12.20
Non Technical loss		5.38	5.3	5.60
	Total loss	**13.76**	**12.0**	**17.80**
Consumption Growth rate	2009	5.6	8.6 (11.4)*	
	2010	8.1	5.0 (11.4)*	2.5
	2011	8.0	5.0 (11.3)*	3.0
	2012	8.0	4.5 (11.2)*	3.5
	2013		4.5 (10.9)*	4.0
	Average	7.4	5.7 (11.2)*	3.25

**( ): percentage data is only for industrial area*

(2) Potential measurement for reduce technical losses

1) LV (Low Voltage) feeder

LV underground cables in three Distribution Company have sufficient capacity for load current at present. On the contrary, it is worth while to examine the possibilities to upgrade overhead cable in case of small conductor and long distance line.

2) 11kV Feeder

In North Delta and North Cairo, there are around 40% overloaded 11kV feeders that load current exceeds more than 80% of rated capacity. It is necessary to upgrade and develop new 11kV feeders especially high demand increase area

3) DT (Distribution Transformer)

There are still many old types DTs which have high iron and cupper loss. They are carrying out to replace to new one when old DT is out of order. But replacement schedule is slow and takes long years. In Alexandria and North Cairo, there are potentials to improve distribution loss to accelerate DT replacement plan.

4) Installation of capacitor

Power factor in three distribution companies are around 0.85. In order to improve power factor to 0.95, to install new capacitor in both 11kV feeders and LV feeders are best countermeasures. Existing capacitors are fixed operated and to remote control according to system load condition can improve its power factors more efficiently.

Clause4 Improvement Project to Reduce the Distribution Loss

(1) Reduction of technical loss

Technical losses in distribution network primarily consist of 11kV distribution line loss and LV (400V) line loss.

The 11kV / 0.4kV distribution line loss can be improved by the following projects.

- ✓ Construction of new distribution feeders
- ✓ Avoiding voltage drop by Step Voltage Regulator (SVR)
- ✓ Shortening of distribution line distance
- ✓ Replacing to new DT with lower core loss
- ✓ Keeping load balance of feeders by Upgrading DMS (DAS)
- ✓ Improving power factor

The recommendable method based on Egyptian Distribution Company's requirement is shown in Table 4-1-4-1.

Table 4-1-4-1 Recommendable method of technical loss reduction

Project	Current plan of Egypt	Effect for loss reduction	Investment	Recommendation as model project	Evaluation
Construction of new distribution feeders	Planned	○	△	Apply	Loss can be reduced and the investment is effective for load growth and loss reduction.
Avoiding Voltage drop	No	○	○	Apply for OH network	SVR can be easily installed in OH line and the loss can be reduced.
Shortening of distribution line distance	No	○	○	Apply (For LV line in OH network)	LV line can be shortened by transformer of small capacity, so that the loss can be reduced.
Replacing to new DT with lower core loss	On going	○	○	Apply	Technical loss can be reduced by replacing from old DT to new one and the investment is effective by promoting with lower core loss and large capacity for avoiding overload operation.
Keeping load balance of feeders and improvement of LV phase unbalance by Upgrading DMS (DAS)	Planned (needs)	○	○	Apply	Technical loss can be reduced but the investment of Upgrading DMS (DAS) is large. The communication network of Upgrading DMS (DAS) can be useful for other projects such as AMR, DSM and future business, so that the investment is synthetically effective.
Improving power factor	Planned (needs)	○	○	Apply	Technical loss can be reduced and the investment is moderate.

Good ○ > △

(2) Reduction of non-technical loss

Non-technical loss is mainly due to low WHM efficiency and theft. The plan in Egypt and effect against non-technical loss is introduced in Table 4-1-4-2.

Table 4-1-4-2 Recommendable method of non-technical loss reduction

Project	Current plan in Egypt	Effect for loss reduction	Investment	Recommendation as model project	Evaluation
AMR	Planned	◎	○	Apply	Effective for theft and low characteristics of WHM
Pre-paid meter	Planned	◎	△	Not Apply	Effective for theft. Similar function as AMR
Measurement for DT current	Not planned	○	△	Apply	Effective by Upgrading DMS (DAS)
Outdoor meter	Not planned	△	△	Not Apply	Effective for theft. The investment is huge.

Good ◎ > ○ > △

Clause5 Distribution Reliability in Model Distribution Company

(1) Distribution system reliabilities

System reliabilities in three distribution companies are improving for the past 10 years after introducing DCC. Index of reliabilities is as follows,

This shows that power distribution reliability in Egypt is inferior to the international standard, and there could be potential to raise distribution reliability by improving electric power supply facilities and their operation.

Table 4-1-5-1 SAIFI and SAIDI of each distribution company

Power Company		SAIFI [times]	SAIDI [minutes]
Alexandria Dis Co.	Total	2.85	120.00
	West	3.62	146.21
North Delta Dis Co.	Total	2.93	344.30
	North Dakhalia	3.90	428.50
North Cairo Dis Co.	Total	1.56	110.19
	Helmya	1.20	462.00

System Average Interruption Frequency Index (SAIFI) is the average number of interruptions that a customer would experience

SAIFI [times] = Total Number of customer interruption / Total Number customer served

System Average Interruption Duration Index (SAIDI) is the average outage duration for each customer served

SAIDI [minutes] = Sum of all customer interruption duration / Total Number customer served

(2) Analysis of outage

The most of distribution facilities of Alexandria and North Cairo distribution companies are underground cable. That is the main reason the power reliabilities of these two companies are relatively good. Annual outage duration hours per customer is around 100 minutes.

Compare these companies with underground facilities. Delta North Distribution Company has mainly overhead line. SAIDI of this company are more than 300 minutes around three times.

(3) Main countermeasures for improving power qualities
The following procedures are effective to improve continuity of supply indices in the distribution company.

- ✓ Analysis of the causes in case of increased un-planned interruptions and relate it to network renovation and rehabilitation plans.
- ✓ Monitor and grasp the quality of the services by Upgrading DMS (DAS) and call centers in case of interruptions.
- ✓ Intensive field inspections and data about interruptions collected, these data are compared with the recorded data to check for accuracy.
- ✓ The use of automatic restoration devices for overhead lines with high interruption rates, this system enable quick restoration for minor faults which result in reducing interruption rates also they help in locating the place of major fault resulting in reducing restoration time.

Setting annual plan for the rehabilitation and extension of system components in order to meet the growth of demand and reduce interruption rates.
In addition, introduction of Upgrading DMS (DAS), which can reduce outage durations caused by fault and maintenance work, can improve the power qualities.

Clause 6 Current Tariff Structure

The current tariff structure has the following characteristics.

(1) Tariffs are generally very cheap, about 1/4 of that of Japan. Considering that the thermal generation tariff being about 4-8 cents, the tariff is not enough to recover the costs therefore the power business is not considered to be autonomous.

(2) Step tariff like Japan indicates that they intend to protect people of low income.

(3) Step tariff also indicate that they intend to suppress excessive consumption.

(4) Public Lighting tariff paid by government is set high. This may indicate the government's intention to financially support the power company.

(5) There is no TOU. DSM by TOU is not carried out yet.

Annual report of EEHC shows significant subsidy being paid by the government to sustain the current cheap tariff level. For the promotion of Energy Conservation, excessively cheap tariff can be a disturbance and abolishment of such subsidy in concurrent with increase of tariff to enable autonomous operation of Power Company could be necessary.

Section 2 Project Scope

Clause1 Overview of Projects

Major purpose of projects is to improve distribution loss, so that the following recommended projects are estimated based on Table 4-1-4-1 and 4-1-4-2.

(1) Technical loss reduction projects

Project	Necessary major facilities as scope
① Construction of new distribution feeder	11kV OH feeder 11kV UG feeder
② Avoiding Voltage drop for OH	SVR
③ Shortening of distribution line distance for LV line of OH	Distribution Transformer (DT) of small capacity such as 50KVA
④ Replacing to new DT with low core loss and big Capacity	DT
⑤ Keeping load balance of feeder for 11kV feeder	Upgrading DMS (DAS) (Control center, Substation equipment, communication network,
⑥ Improvement of Phase unbalance for LV line	Upgrading DMS (DAS) (Control center, Substation equipment, communication network, etc) CT and RTU for LV side of DT/Kiosk/Distributor
⑦ Improvement of power factor	Capacitor, RTU, LBS, Distributor

(2) Non- Technical loss reduction projects

Project	Necessary major facilities
⑧ Metering with AMR	Control center of AMR Communication network Advanced WHM including communication device and SW

In addition, Upgrading DMS (DAS) can improve not only distribution loss but also reliability by outage duration.

Clause2 System configuration

(1) System configuration

The basic system configuration including all of projects (① – ⑧) is shown in Fig. 4-2-2-1.

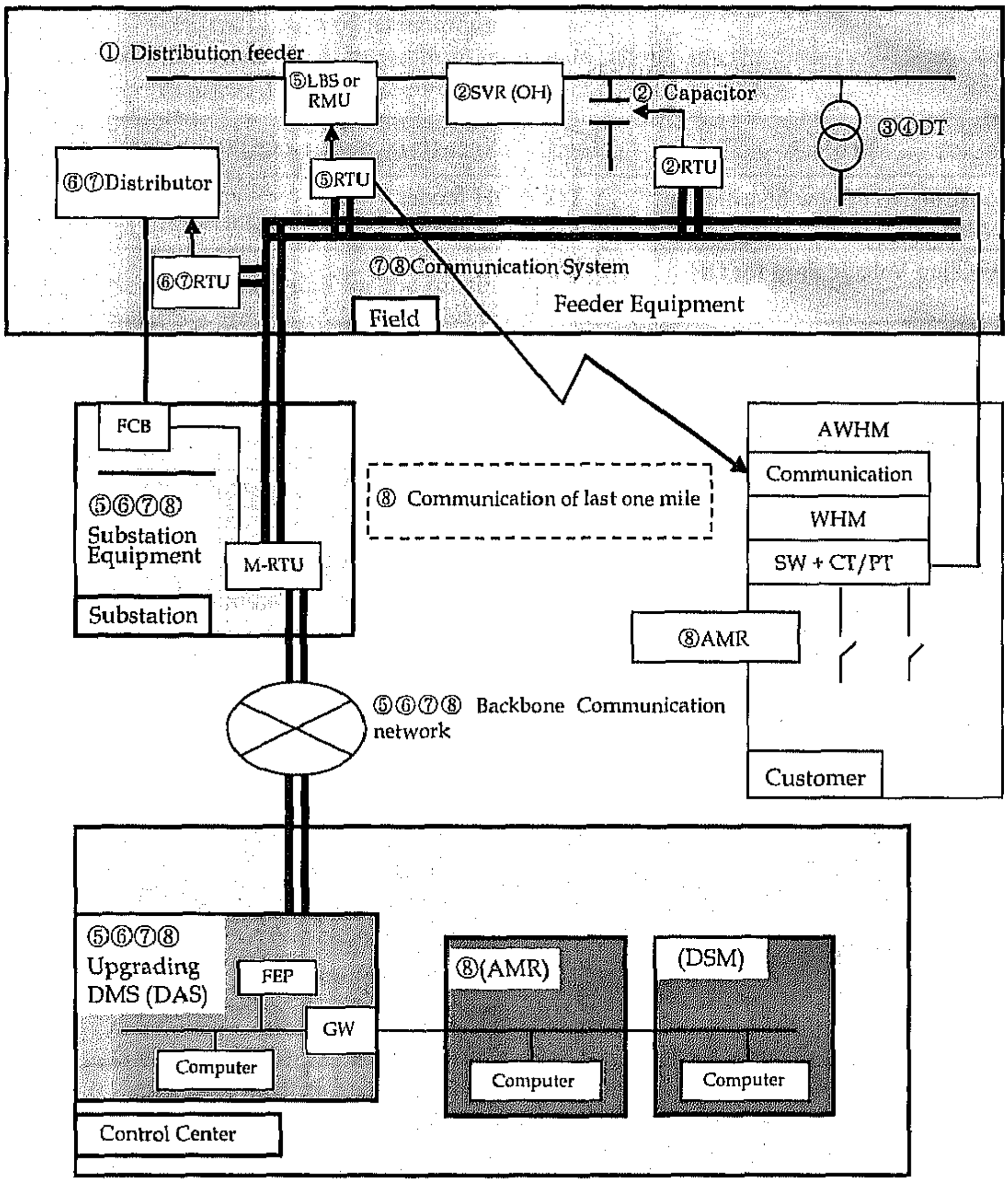


Fig. 4-2-2-1 System configuration of Project

LBS: Load Break Switch for OH, RMU: Ring Main Unit, RTU: Remote terminal Unit, M-RTU: Master – RTU, SVR: Step Voltage Regulator, DT: Distribution Transformer AWHM: Advanced Watt Hour Meter, FCB: Feeder Circuit breaker, FEP: Front End Processor, GW: Gate Way, DAS: Distribution Automation System (=DMS: Distribution Management System), AMR: Auto Meter Reading, DSM: Demand Side Management

A lot of AWHM data are transmitted to RTU through communication of last one mile (GPRS/ZigBee ets). The gathered data including LBS/RMU/Capacitor/DT are transmitted to the control center through backbone network and M-RTU in substation.
AWHM consists of communication device, WHM, PT/CT and SW for future peak-cut.

(2) Technical analysis>

1) Upgrading DMS
Existing DMS in AEDC and NDEDC will be needed to replace due to long term-use, so that DMS (DAS) upgrading the functions will be applied.
The upgrading DMS (DAS) will be considered to use the existing facilities as many as possible.
As for NDEDC, the existing DMS is new, so that the upgrading is not necessary.

2) Communication network
The backbone-network from RTU to Control center will be recommended to apply Fiber Optic due to communication capacity / reliability / expansion of the function in future. Regarding communication route to be unable to install Fiber Optic, digital UHF / GPRS / Leased line will be considered.
The branch communication network from AWHM to RTU will be recommended to apply ZigBee as radio wave due to many quantity / low cost / low consumption / capacity / reliability.

Clause3 Scope and Project Cost

Proposed scope and rough project cost for 3 model areas in 3 Distribution companies are introduced as follows and the reason of project cost is also explained in Appendix 4.2-5 in details.

(1) Alexandria Distribution Company
Proposed scope in project area (West Alex zone) is shown in Table 4-2-3-1.

Table 4-2-3-1 Proposed scope and cost in project area (West Alex zone)

Scope	Quantity	Cost	
		Foreign MUS$	**Local MUS$**
1, DT replacement	970 units	30.0	3.0
2, DMS upgrading	1 system	33.5	3.3
3, AMR installation	1 system 200,000 WHM	24.0	1.2
4. Capacitor	100 units(New) 175 units(Existing)	5.6	0.4
5, Communication	-	Included in item 2	Included in item 2
	Total	93.1	7.9

(2) North Delta Distribution Company
Proposed scope and cost in project area (North Dakahlia) is as shown in Table 4-2-3-2

Table 4-2-3-2 Proposed scope and cost in project area (North Dakahlia)

Scope	Quantity	Cost	
		Foreign MUS$	Local MUS$
1, New construction of 11kV feeder	140 feeder	-	-
2, DT replacement	600 units (for UG)	10.2	1.1
3, Small DTs installation	200 units (OH)	3.2	0.3
4, Capacitor and SVR installation	70 units (Capacitor) 150 units (SVR)	8.0	0.8
5, AMR system installation	1 system 600,000 WHM	74.0	7.4
6, Communication upgrading	-	1.0	0.1
	Total	96.4	9.7

(3) North Cairo Distribution Company
Proposed scope and cost in project area (Helmya sector) is shown in Table 4-2-3-3

Table 4-2-3-3 Proposed scope and cost in project area (Helmya sector)

Scope	Quantity	Cost	
		Foreign MUS$	Local MUS$
1, DT replacement	1,500 units	32.0	3.2
2, DMS upgrading	1 system	16.2	1.6
3, AMR installation	1 system 600,000	74.0	3.7
4, Capacitor	424 (New) 42 (Existing)	17.4	0.7
5, Communication upgrading	1 system	7.0	0.7
	Total	146.6	9.9

Clause4 Tentative Implementation Schedule

The tentative implementation schedule is estimated as shown in Fig. 4-2-4-1 based on experiences. The detail implementation schedule will be determined in the later stage.

	Item	2010	2011	2012	2013
Preparation	Basic design and appraisal by JICA				
	Governmental dialogue and Commitment by GOJ				
	E/N and L/A				
	Selection of consultant				
Engineering Service	Detailed Design				
	P/Q, Tendering Stage				
	Selection of Contractor				
Construction	Design				
	Manufacturing				
	Installation and test				
	Commence				

Fig. 4-2-4-1 Tentative Implementation Schedule

Clause5 Procurement Package

Full Tern Key (FTK) is basically recommended but the packages as option will be recommended to consider in the later stage.

Section 3 Economic Analysis

Clause1 Expected Distribution Loss Reduction by Model project

(1) Expected Effect for technical loss reduction

1) New construction of Distribution feeder

The technical losses are originated in proportion to the square of the load current, so that the reduction of load current is effective for the improvement of technical losses.

New construction of 11kV feeder can contribute to reduce the load current of 11kV feeder.
The load current shall be considered to increase based on growth of consumption.

<AEDC>
In case of West Alex zone in AEDC, the growth rate is around 8.0% on average, so that the new construction of 11kV feeders is needed in order to improve 11kV feeder loss by the increment of load current. New construction of 180 feeders in West Alex is recommended, so that the loss reduction can be achieved as around 30%.

<North Delta>
In case of North Dakhalia sector in NDEDC, the growth rate is around 5.7% on average, so that the new construction of feeders is needed in order to improve 11kV feeder loss by the increment of load current. New construction of 140 feeders in North-Dakahlia is recommended, so that the loss reduction can be achieved as around 30%.

< North Cairo >
In case of NCEDC, the growth rate is not so large, so the new construction of feeders is also needed in order to improve the increment of load current per feeder. New construction of 200 feeders in El Helmia is recommended, so that the loss reduction can be achieved as around 30%.

2) Improvement of power factor by Capacitor
In case that Capacitors are installed to 11kV feeder, the power factor can be improved and the technical loss of 11kV feeder can also be reduced.
The loss can be improved around 28% as one example case which the power factor can be improved from 0.85 to 0.95 by installation and control of the Capacitor. In case that the condition of the reduced reactive power is assumed to continue during 20H based on Table 4-3-1-5, the actual reduction of loss is around 23.3% (28% x 20/ 24H) levels.
The location of capacitor is normally installed to around 2/3 load point, so that the improved percentage is around 16% (=23.3 x 2/3).

3) Improvement of voltage drop by SVR
In case SVR will be installed on OH feeder, the voltage drop at the end of OH feeder will be improved and the loss in the load side line of SVR can be reduced.
SVR will be installed in OH feeder of North-Dakahlia in NDEDC.
The voltage drop has occurred in OH feeder due to the long distance, so SVR is recommended to install at the middle of OH feeder.
When the voltage drop can be improved around 15% (Max of voltage drop: 15%), 15% of the feeder current can be reduced, so that the technical loss of OH feeder can be improved around 28% [$= (0.85/ 1.0)^2 = 0.72 \rightarrow 28\%$].
As SVR will be installed at the middle of the OH feeder, the half of 28% can be reduced.
The loss reduction rate excluding UG is around 9.5% (= 28 x 1/2 x 2.7/4.0).

4) Improvement of feeder load-unbalance by Upgrading DMS (DAS)
Upgrading DMS (DAS) can improve the load balance of feeder by moving overload section to light load feeder. The loss for 11kV line can be reduced around 33% by Upgrading DMS (DAS). In case that the unbalanced condition is assumed as 30% in whole feeders, the actual reduction of the loss is around 10% (= 33% x 0.3) levels.

5) Replacement of DT from high loss to low loss type.
Iron loss of existing DT is around 0.89kW at 500KVA and 1.4kW at 1000KVA. The new Egyptian DT with low core loss is around 0.70 KW at 500KVA and 1.22KW at 1000KVA.
The copper loss of existing DT is around 7.90kW at 500KVA and 14.23kW at 1000KVA. The new Egyptian DT with low copper loss is around 5.46KW at 500KVA and 9.45KW at 1000KVA.

Table 4-3-1-1 Loss Calculation at DT

Item	500 KVA		1000 KVA	
	Iron loss	**Copper loss**	**Iron loss**	**Copper loss**
(a) Existing DT	0.89KW	7.90KW	1.40KW	14.23KW
(b) New DT	0.70KW	5.46KW	1.22KW	9.45KW
(a) – (b)	0.19KW	2.44KW	0.18KW	4.78KW
(c) loss factor	1.00	0.432	1.00	0.432
[(a) – (b)] x (c)	0.19KW	1.05KW	0.18KW	3.44KW
(d) Total	1.24 KW		2.24 KW	
Effect (d) / [(a) x (c)]	0.29 (29% reduction)) [= 1.24 / (0.89x1.00 + 7.9x0.432)]		0.30 (30% reduction) [= 2.24 / (1.4x1.00 + 14.23x0.432)]	

Therefore, approximate 30% of technical loss caused by high loss DT can be reduced by replacing to low loss DT.

As DT in AEDC and NCEDC has been operated under overload condition (around 90%), the loss factor "P" is around 0.837.
Therefore, DT under overload condition in AEDC and NCEDC is recommended to replace high loss / small capacity DT to low loss / large capacity DT in order to reduce the technical loss moreover.

P = 0.7f2 + 0.3f   P: Loss factor   f: Load factor
In case of f = 0.9 at 500kVA, P is of 0.837.
Copper loss: 0.837, Iron loss: 1.0
In case of f=0.45 at 100kVA, P is of 0.277

New DT of 1000kVA / Existing DT of 500kVA
(1.22x 1.0 + 9.45 x 0.277) / (0.89 x 1.0 + 7.9 x 0.837) = 0.536

Therefore, around 50% of DT loss in AEDC and NCEDC can be reduced by low loss and large capacity DT.

6) Shortening of distribution line distance by small capacity DT
In case of UG network, the length of LV line is not so long and the installation space of DT for UG is limited, so it is not effective to replace from DT of large capacity to DT of small capacity.
In case of OH network, the length of LV line is long and there is no limitation for installation of DT, so that it is effective to replace from DT of large capacity to small capacity in order to shorten the LV line length.

It is assumed that the length of LV line can be shortened about 30% - 50% (loss reduction = 30% as assumption) by replacing from large capacity to 50KVA DT

7) Improvement of LV phase-unbalance
There are large phase unbalance loss in AEDC and NCEDC but there is no unbalance loss in NDEDC. Most of the difference means phase unbalance loss because LV line length in NDEDC is longer than AEDC and NCEDC.
Therefore, the loss by phase unbalance is assumed more than 50% in LV line loss in AEDC and NCEDC.

The phase unbalance can be detected and improved by Upgrading DMS (DAS) as follows.

- CT is assembled to each phase of LV line of DT
- RTU is also installed to DT including existing Kiosk
- The phase unbalance data is transmitted to control center of Upgrading DMS (DAS) through RTU and communication network
- The report for phase unbalance is made by CPU in control center
- Maintenance crew can change the phase connection of consumers based on the report

As Upgrading DMS (DAS) can not improve all of phase unbalance, the half of phase unbalance (more than 50%) can be reduced as assumption. Therefore, LV loss can be assumed to reduce around 30% (= more than 50% phase unbalance x more than 50% improvement by Upgrading DNS (DAS)).

8) Replacement of Meter from mechanical to electrical (for AMR) type
Existing Watt Hour Meter (WHM) is normally of mechanical type whose consumption power is around 3VA. WHM for AMR is of electrical type and the consumption power is around 1VA, so that the meter loss can be reduced around more than 60% (1/3 = 0.67) if the existing WHM will be replaced to electrical WHM for AMR.

(2) Conclusion of technical loss reduction in 3 project areas
The current technical loss in model zones (Sectors) can be reduced by adopting the all of projects based on above mentioned reason, so that the technical loss can be realized as shown in Table 4-3-1-2, 4-3-1-3 and 4-3-1-4.

Table 4-3-1-2 Effect for reduction of technical loss in West Alex in AEDC

	Location	**Loss**	**Item**	**Loss reduction**	**Loss after project**
Technical loss	11kV feeder	0.32	~~New construction of 11kV feeder~~	~~0.11 (△34%)~~	0.24
			Capacitor	0.05 (△16%)	
			Improvement of load unbalance	0.03 (△10%)	
	11kV DT	5.36	Low loss and large capacity DT	2.68 (△50%)	2.68
	LV line	2.19	Improvement of phase unbalance	0.66 (△30%)	1.53
	Meter (WHM)	0.51	Low loss WHM for AMR	0.31 (△60%)	0.20
	TOTAL	8.38	-	3.73 (△44%)	4.65

Table 4-3-1-3 Effect for reduction of technical loss in North- Dakahlia in NDEDC

	Location	Loss	Item	Loss reduction	Loss after project
Technical loss	11kV feeder	4.0	~~New construction of 11kV feeder~~	~~1.20 (△30%)~~	2.98
			Capacitor	0.64 (△16%)	
			SVR for OH	0.38 (△10%)	
			~~Improvement of load unbalance~~	~~0.40 (△10%)~~	
	11kV DT	1.2	Low loss DT	0.36 (△30%)	0.84
	LV line	1.1	Shortening LV line by small DT	0.33 (△30%)	0.77
	Meter (WHM)	0.4	Low loss WHM for AMR	0.24 (△60%)	0.16
	Sub TOTAL	6.7	-	1.95 (△29%)	4.75

Table 4-3-1-4 Effect for reduction of technical loss in Helmya sector in NCEDC

	Location	Loss	Item	Loss reduction	Loss after project
Technical loss	11kV feeder	1.8	~~New construction of 11kV feeder~~	~~0.54 (△30%)~~	1.33
			Capacitor	0.29 (△16%)	
			Improvement of load unbalance	0.18 (△10%)	
	11kV DT	7.2	Low loss and large capacity DT	3.60 (△50%)	3.60
	LV line	2.3	Improvement of phase unbalance	0.69 (△30%)	1.61
	Meter (WHM)	0.9	Low loss WHM for AMR	0.54 (△60%)	0.36
	Sub TOTAL	12.2	-	5.30 (△43%)	6.90

(3) Expected effect for non-technical loss reduction

Non technical losses can be improved by AMR because AWHM in AMR can monitor theft action/operation. In case that these projects can cover whole area in model zone, the non technical loss by Meter problem and theft can be reduced as shown in the following Tables.

1) In case of theft problem>

AWHM can detect to open the cover for theft or manipulation and to drop instanteneously the supply voltage by direct connection works, so that non-technical loss can be reduced.

In addition, the theft by direct connection can be monitored by Upgrading DMS (DAS) and AMR as follows.

- Upgrading DMS (DAS) can monitor the power consumption (A) of LV line at DT.
- AMR can monitor the power consumption (B)for all of consumers connected to the DT.
- Operator can grasp the difference between (A) and (B) and can specify the theft consumer.

Upgrading DMS (DAS) can monitor load / consumption of DT and AMR can monitor consumption of consumers connected to the DT, so that the difference by theft can be estimated. Therefore, this project using Upgrading DMS (DAS)/AMR can make a pressure to consumers, so that the non-technical loss will be expected to improve more and more effective.

2) In case of Meter problem>

CT / PT are assembled in AWHM, so that the defects of circuitry in CT/PT are not occurred.

Performance of electrical type for AWHM is excellent compared with existing mechanical type. In addition, the alarm will be send to computer for AMR when occurrence of the performance trouble, so that the loss by non performing meter can be reduced.

Mistake of the meter reader can be improved by auto meter reading using computer and electrical devices in AWHM.

Table 4-3-1-5 Effect for reduction of non-technical loss in West Alex in AEDC

Non-technical losses		(a)Current loss in model divisions (by Indian case)	(b) West Alex in AEDC (a) x 5.38/9.0	(b)Reduction by Projects	Target in model divisions (a) – (b)
Meter	Non performing meter	0.47	0.28	0.28 (100%)	0
	Under performing meter	0.28	0.16	0.08 (50%)	0.08
	Defects of circuitry in CT/PT	1.33	0.80	0.80 (100%)	0
	Mistake of meter reader	2.37	1.42	1.42 (100%)	0
Theft	Pilferage by manipulation of meters	0.47	0.28	0.28 (100%)	0
	Energy theft by direct tapping	2.37	1.42	0.71 (50%)	0.71
	Direct connection without meters	1.7	1.02	0.51 (50%)	0.51
Total Non-technical losses		9 %	5.38%	4.09 % (76%)	1.29 %

Table 4-3-1-6 Effect for reduction of non-technical loss in North –Dakhalia in NDEDC

Non-technical losses		(a)Current loss in model divisions (by Indian case)	(b) North Dakhalia (a) x 5.3/9.0	(b)Reduction by Projects	Target in model divisions (a) – (b)
Meter	Non performing meter	0.47	0.28	0.28 (100%)	0
	Under performing meter	0.28	0.16	0.08 (50%)	0.08
	Defects of circuitry in CT/PT	1.33	0.78	0.78 (100%)	0
	Mistake of meter reader	2.37	1.40	1.40 (100%)	0
Theft	Pilferage by manipulation of meters	0.47	0.28	0.28 (100%)	0
	Energy theft by direct tapping	2.37	1.40	0.70 (50%)	0.70
	Direct connection without meters	1.7	1.00	0.50 (50%)	0.50
Total Non-technical losses		9 %	5.3 %	4.02 % (76%)	1.28 %

Table 4-3-1-7 Effect for reduction of non-technical loss in Helmya in NCEDC

Non-technical losses		(a)Current loss in model divisions (by Indian case)	(b) Helmya (a) x 5.6/9.0	(b)Reduction by Projects	Target in model divisions (a) – (b)
Meter	Non performing meter	0.47	0.29	0.29 (100%)	0
	Under performing meter	0.28	0.18	0.09 (50%)	0.09
	Defects of circuitry in CT/PT	1.33	0.83	0.83 (100%)	0
	Mistake of meter reader	2.37	1.47	1.47 (100%)	0
Theft	Pilferage by manipulation of meters	0.47	0.29	0.29 (100%)	0
	Energy theft by direct tapping	2.37	1.48	0.74 (50%)	1.74
	Direct connection without meters	1.7	1.06	0.53 (50%)	0.53
Total Non-technical losses		9 %	5.60 %	4.24 % (76%)	1.36 %

(4) Summery of Distribution loss reduction
Total loss reduction for 3 project areas is summarized as follows.

Table 4-3-1-8 Summery of Distribution loss reduction for 3 model areas

Model Project area in Distribution Company	Type of loss	Current loss	Loss after projects*
West Alex in AEDC	Technical	8.38 %	4.65 %
	Non-technical	5.38%	1.29 %
	TOTAL	13.76%	5.94 %
North-Dakahlia in NDEDC	Technical	6.70%	4.75 %
	Non-technical	5.30%	1.28 %
	TOTAL loss	12.0%	6.03 %
Helmya in NCEDC	Technical	12.2 %	6.90 %
	Non-technical	5.60%	1.36%
	TOTAL	17.8%	8.26 %

** This effect is assumed that AWHM will be installed to all of consumers in project area.*

(5) Effect of reduction for outage duration (SAIDI) by Upgrading DMS (DAS)
According to AEDC, NDEDC and NCEDC, the outage durations of distribution network for 3 model areas were recorded as shown in Table 4-3-1-9, 4-3-1-10 and 4-3-1-11.

Table 4-3-1-9 Current Outage Duration and Possibility of Reduction by Upgrading DMS (DAS) in West Alex in AEDC

Facility of Fault	Current Outage Duration (min/y, customer)	Effect by Upgrading DMS (DAS)	Target outage duration after Upgrading DMS (DAS)
SAIDI	146	116	30

(Source: by AEDC)
** Effect is influenced by the condition of model*

Table 4-3-1-10 Current Outage Duration and Possibility of Reduction by Upgrading DMS (DAS) in model area (North Dakahlia Sector) in NDEDC

Facility of Fault	Current Outage Duration (min/y, customer)	Effect by Upgrading DMS (DAS)	Target outage duration after Upgrading DMS (DAS)
SAIDI	428	340	88

(Source: North Dakahlia data by NDEDC)
** Effect is influenced by the condition of model*

Table 4-3-1-11 Current Outage Duration and Possibility of Reduction by DAS in Helmya in NCEDC

Facility of Fault	Current Outage Duration (min/y, customer)	Effect by Upgrading DMS (DAS)	Target outage duration after Upgrading DMS (DAS)
SAIDI	462	367	95

(Source: by NCEDC)
** Effect is influenced by the condition of model*

Clause2 Financial and Economic Analysis

(1) General

Financial analysis and economic analysis (tentative) was conducted for the proposed projects. The detail analyses as well as cost estimates will be conducted in the later stage.

For financial and economic analysis, the following pre-conditions are applied.

General

1. Project commissioning is in 2013.
2. Project life is 2 years construction period and 30 years operation period.
3. Both technical loss and non-technical loss sustain at the level in 2009 until the commissioning year. And, the losses are reduced by the project in the commissioning year, and the reduced losses will sustain at the same level during the operation period.
4. In case without the project, both technical loss and non-technical loss will sustain at the level in 2009 before and after the assumed commissioning year.
5. Sales energy in the commissioning year is estimated from the forecasted growth rate on the average with applying the distribution losses.
6. For the operation and maintenance, followings are considered:
   - For spare parts, 3% of financial cost/economic cost is considered in every 5 years.
   - Replacement of a Remote Terminal Unit (RTU) is considered in 20th operation year, in case of the Option 3.
   - Assuming that general operation and maintenance cost (O&M) is needed in any case "with" or "without" the project, the general O&M cost is not considered in the cash flow analysis.
7. Exchange rate of 5.5 LE/US$ (=0.182US$/LE) as of Oct. 2009 is applied.
8. Tariff and purchase price are assumed to increase by 5% annually from the 1^{st} construction year until the 5^{th} operation year.

Other

9. With taking account that West Alex is newly developing, further energy growth was assumed until 2028 by 8% of annual growth rate for calculation of financial/economic benefit for the West Alex case. And, and 2% of the cost for the following items of the project was also considered in the cash flow until 2028, in addition to the spare parts.

New capacitor :	6.0 million US$
11kV – Improvement of load unbalance:	19.8 million US$
Replace DT with new and low loss DT	33.0 million US$
LV line – Improvement of LV phase unbalance:	14.8 million US$
Total	73.6million US$

(73.6 million US$ @ 2% = 1.5million US$ per annum)

(2) Calculation of financial benefit

Financial benefits are estimated annually with taking account of annual sales energy during the operation period. Financial benefits are calculated by applying following formulas.

■ Financial benefit by reduction of technical loss and non-technical loss

Increase of revenue = Increase of electricity sales x Average tariff

Where,
Increase of electricity sales = Annual electricity sales / (1- Total Loss) x Loss reduced

- Financial benefit by reduction of outage duration

Increase of revenue = Increase of electricity sales x Tariff

Where,
Increase of electricity sales = Annual electricity sales x (Reduction of outage duration/ 8,760hrs)

(3) Calculation of economic benefit

Economic benefits are estimated annually with taking account of annual sales energy during operation period. Economic benefits are calculated by applying following formulas.

- Benefit by reduction of technical loss

Saving fuel consumption = Decrease of electricity loss x Cost of alternative plant (GAS) per kWh

Where,
Decrease of electricity loss = Annual electricity sales / (1- Loss) x Loss reduced

The cost of alternative plant was calculated assuming 40% of thermal plant efficiency and Gas price of 7US$ per MMBTU.

- Benefit by reduction of non-technical loss

Willingness to Pay = Increase of electricity sales x averaged Tariff

Where,
Increase of electricity sales = Annual electricity sales / (1- Loss) x Loss reduced

- Benefit by reduction of outage duration

Benefit by reduction of outage duration = Reduction of un-served energy x Un-served energy cost*

Where,
Reduction of un-served energy = Annual electricity sales x (Reduction outage duration/ 8,760hrs)

As the un-served energy cost, 2,000US$/MWh was applied.

(4) Saving the fuel consumption at Thermal Plant (GAS)

Reduction of technical loss by the project will decrease electricity loss, and contributes to saving fuel consumption at thermal plants. In order to evaluate the decrease of electricity loss, an equivalent power plant corresponding to the decrease of electricity losses are calculated by following formula.

$$\text{Equivalent power plant} = \frac{\text{Decrease of electricity loss (technical)}}{\text{8,760hrs x pf}}$$

Where,
pf = Plant factor of assumed plant
(In this study, 60% was assumed.)

(5) Result of Analysis

Main features of the project and results of the financial analysis and economic analysis are summarized in the following Table.

Table 4-3-2-1 Summary of financial and economic analysis

Basic data of the area:		**AEDC**	**NDEDC**	**NCEDC**
Project target area		West Alex	North Dakhalia	Helmya
Averaged Tariff in 2009		0.188 LE/kWh (= 3.42 US Cent/kWh)	0.204 LE/kWh (= 3.709 US Cent/kWh)	0.200 LE/kWh (= 3.660 US Cent/kWh)
Averaged Purchase price from transmission company in 2009		0.119 LE/kWh (= 2.16 US Cent/kWh)	0.146 LE/kWh (= 2.655 US Cent/kWh)	0.149 LE/kWh (= 2.727 US Cent/kWh)
Consumed energy	2008 (2008/09)	999 GWh	1, 986 GWh	4, 538 GWh
Sales energy	2008 (2008/09)	862 GWh [1)]	1,748 GWh [1)]	3,730 GWh 1)
	2013 (2013/14)	1,266 GWh [2)]	2,306 GWh [2)]	4,377 GWh 2)
	2028 (2028/29)	4,016 GWh [3)]	---	---
Distribution losses	Technical	8.38%	6.70%	12.20%
	Non-Technical	5.38%	5.30%	5.60%
	Total	13.76%	12.00%	17.80%
Outage Duration		146 minutes/year	428 minutes/year	462 minutes / year
Project description:				
Project cost [4)]		125.0 million US$	131.1 million US$	190.7 million US$
Distribution Losses after project	Technical	4.65% (△44%)	4.75% (△29%)	6.90% (△43%)
	Non-Technical	1.29% (△76%)	1.27% (△76%)	3.47% (△38%)
	Total	5.95%	6.02%	10.38%
Outage Duration after project		30 minutes/year (△116 minutes / year)	N.A	95 minutes/year (△367 minutes / year)
Financial Analysis: FIRR		5.9%	3.5%	8.2%
Economic Analysis: EIRR [5)]		9.3%	5.4%	16.1%
Saving fuel consumption at Thermal Power Plant				
Decrease of electricity (Annual average)		136Wh/year	51GWh/year	282GWh/year
Equivalent power plant		25.9MW	9.7MW	53.7MW

1) Derived from consumed energy with taking account of the losses
2) Derived from consumed energy forecast with taking account of the assumed losses.
3) Derived from 8% annual growth rate assumed
4) Assuming Engineering Services, Tax and Contingency
5) Calculated based on fuel price of 7 US$/MMBTU

Section 4 Capacity Development and Tariff

Clause1 Capacity Development

The model projects can be classified into following two terms.

<To Reinforce Distribution System>
- New construction of 11kV UG feeder
- Capacitor (New installation, Using existing capacitor)
- Replacement of DT from 500kVA/high loss to 1000KVA/low loss

<To enhance Distribution Control System>
-Improvement of load unbalance by LBS of DAS
-WHM (Replace from mechanical to electrical WHM)
- AMR system

It's necessary to enhancement capacity to manufacture low loss modules and construct facilities effectively regarding former one and to operate and maintain control system with understanding the system, regarding later one.
Egyptian side is interested in manufacturing low loss DTs, Improvement of load unbalancing by LBS of DAS and AMR system. In the case, following capacity building option in Table 4-4-1-1 would be notified.

Table4-4-1-1 Capacity Development Option

Model Project	Capacity Development Option
Low Loss DT	Site visit to & discussion with Japanese manufactures Design & technology capacity building
Improvement of Load Unbalancing & AMR system	Site visit to & discussion with Japanese DAS manufacture & power utilities Technology, operation & maintenance capacity building

Clause2 Appropriate Tariff Structure

Having studied the current status of EEHC and power business of Egypt, the following changes to tariff system may be worth considering.

(1) Tariff revision to promote DSM
Considering the peak in evening and that the peak demand 30% higher than lowest demand, experimental TOU which has higher peak tariff and lower off peak tariff should be implemented. Since AMR, which can measure consumption in selective time frame is tested in various regions, those TOU can be tested at the same time.

(2) Tariff revision for the power company to be independent
For autonomous operation of power business, abolishment of subsidy and general tariff raise may be recommendable, however if the subsidy is being provided for political reasons, we refrain from opining on political decision.

Section5 Environmental and Social Consideration

Clause1 Relevant Laws, Regulations and Guidelines

The legal system on Environmental Impact Assessment (EIA) in Egypt is laid down by the Environmental Law and Executive Regulation. The Environmental Law (Law Number 4 of 1994) states that the environmental impact of certain establishments or projects must be evaluated before any construction works are initiated or a license is issued by the competent administrative or licensing authority. The Executive Regulation of Law Number 4 of 1994 identifies establishments or projects that are subject to an Environmental Impact Assessment. The Environmental Effect Assessment Principles and Procedures Guide (Egyptian Environmental Affairs Agency, Ministry of State for Environmental Affairs, January 2009) defines the projects by Categories A, B, and C. Category A requires no EIA report. Category B requires a scoped EIA report. Category C requires a full EIA report. Although establishment of electric transmission lines are categorized as B, it means transmission lines which has high towers. Low voltage transmission lines managed by the distribution companies are not included in Category B. According to the guideline, this electricity project will be categorized as A.

Clause2 Impact Assessment for the Projects of the Applied Projects

(1) Project information
Applied eight projects are studied for impact assessment. Table 4-5-2-1 shows outlines of the projects.

Table 4-5-2-1 Outline of the projects

	Project	Outline of the Project	Location	Project Size
Expansion of electricity area	(1) Construction of 11kV OH/UG feeder	Construct 15m poles and lines or 2m underground lines.	Along the road	OH line 2124km, UG line 1878km.
	(2) Installing Step Voltage Regulator (SVR) of OH feeder	Install SVR on the poles.	On the poles	226 SVR (At most 1/feeder (17.7km))
	(3) Installing Distribution Transformers (DTs)	Install the equipment in the Kiosk.	New Kiosk	2002 DT (About 5/feeder (10km))
Upgrading of existing area	(4) Replacement of old DTs	Replace existing DTs with new low-loss DTs	In the existing Kiosk	4000 points
	(5) Installing Upgrading DMS (DAS) control center system	Install computers in the room.	New Control Center	400 m²
	(6) Installing equipment related to Upgrading DMS (DAS)	Monitoring devises and communication tools	In the new Kiosks, poles and substations	7000 points
	(7) Replacement with advanced WHM for AMR	Install AMR for each customer.	Each house	1.3 million points
	(8) Installation of Capacitor	Install the equipment in the Kiosk.	In the existing Kiosks	500 points

(2) Study area
The study area is model areas including Helmya (North Cairo), West Alex (Alexandria), and North Dakhalia (North Delta).

(3) Anticipated Environmental Impact

According to the scoping five negative impacts are anticipated.

1) Pollution by hazardous waste
Replaced old distribution transformers might cause pollution. The estimated number of old transformers is around 4,000. It is known that some types of transformers contain PCBs or SF6. However, the possibility would be very low in terms of this project because transformers with PCBs have been prohibited in Egypt. The study team also confirmed that the three distribution companies are not using transformers which contain PCBs. SF6 is usually used for high voltage transformers, but not for low voltage ones. Thus pollution by hazardous waste might occur, but the risks are low.

2) Industrial waste
2,002 distribution transformers (DTs) and 1.3 million Watt Hour Meters (WHMs) will be replaced with new ones. The removed DTs and WHMs will be carried to demolition places and separated into recycle materials and waste. Old oil will also be collected by oil companies. Thus industrial waste will not be a serious problem.

3) Space acquisition
Small space for electric pole will be needed when 11kV OH feeders are constructed. If the area for the pole is private land, the distribution company concerned has to sign a rental space contract with the owner. Although many poles are planned, possibilities of involuntary resettlement are very low. Then space acquisition will not be a serious problem.

4) Impact on lifelines
Underground oil pipelines, water lines, and gas pipelines might be destroyed by earth work for underground feeder. Although such possibility is high, rehabilitation work can be done in a relatively short time. Thus the impact on lifelines would not be serious.

5) Impact on cultural assets
Earth work for underground feeder might destroy unknown buried cultural assets. However, such earth work is to be done neither deeply nor widely. Thus possibilities of an impact on cultural assets are low.

(4) Suggestions for mitigation and monitoring

1) Confirmation of waste management system
A hazardous waste management system should be confirmed during the detailed design stage. If hazardous substances are found, a reliable hazardous management system is needed.

2) Monitoring on waste management
Monitoring on waste management is recommended during the construction stage. Monitoring should be on whether decomposed old equipments are properly separated, and whether industrial waste is treated properly.

3) Survey on cultural assets
Before construction, a survey on cultural assets is recommended. If there is a possibility of buried cultural property, negotiation and agreement with regulatory authorities will be needed.

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