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ENERGY LOSS REDUCTION STUDY

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SUMMARY REPORT
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1.0 Introduction

Black & Veatch International (BVI), in association with Sabbour Associates (SA) has provided technical consulting services to the Egyptian Electrical Distribution Holding Company (EDHC) and the United States Agency for International Development (USAID), performing a technical analysis of the study of loss reduction prepared for EDHC by the Electric Power Systems Engineering Company (EPS). This Summary Report presents a summary of BVI/SA activities during the project, a technical review of the EPS Final Report, and BVI recommendations concerning the EPS conclusions and recommended program of energy loss reduction.

1.1 Background

The development, operation, and maintenance of the electric power systems in Egypt are the responsibility of the Ministry of Electricity and Energy. The electric distribution system, with voltages of 20 kV, 11 kV, and 380 volts, is owned, operated, and maintained by the Electric Distribution Holding Company (EDHC), comprising eight Distribution Companies. The EDHC purchases energy from the Egyptian Electricity Authority (EEA), which is responsible for the bulk power supply system, including generation and transmission. The EDHC was, at the initiation of this project, an Authority (EDA) under the Ministry of Electricity and Energy, but has been changed into a Holding Company according the Law number 203/1991.

Because of rapid growth in the demand for electrical energy, the EDHC gave priority to the installation of equipment and network to serve this demand at low initial cost. Limiting energy losses was of secondary concern. With the increase in the cost of energy in recent years, the importance of energy losses in the distribution system has taken on more importance.

Energy losses in individual Distribution Companies, based on a comparison of energy purchased and energy sold, range from 9 to 16 percent of the total energy purchased. The total system energy losses

have decreased from 14 percent in 1980/81 to 10.3 percent in 1990/91, but are still higher than the economic level. Besides high energy losses, the rapid growth in demand has resulted in unacceptably low voltages in many parts of the system and severe voltage fluctuations.

The EDHC, recognizing the need for system improvements, contracted with EPS for a study to determine the amount and source of energy losses on the distribution networks, develop criteria for reducing losses to the optimum, and develop a program of loss reduction for the Distribution Companies.

1.2 Objectives

1.2.1 BVI/SA Objectives

The objective of the BVI/SA technical consulting services is to provide a critical technical analysis of the EPS Study of Losses Reduction in Distribution Systems. BVI/SA will assure that the report is technically sound and that the recommendations of EPS are technically appropriate and financially and economically justified. The following areas have been identified as requiring special attention:

- The magnitude of energy losses in the various elements of the distribution network (transformers, cables, conductors, metering, connectors, etc.)
- The effect of feeder power factor on voltage levels and circuit losses.
- The design standards being used for distribution system planning and construction.
- The sizing of transformers, cables, and conductors for the distribution system.
- The proposed program of phased loss reduction for each distribution company studied giving order of priorities.
- Order of magnitude cost estimates associated with the activities in the phased loss reduction programs.

1.2.2 EPS Objectives

The objectives of the EPS study are:

1. Find the optimum level of power losses in the various elements (transformers, conductors, cables, metering, etc.) of the Egyptian electrical

distribution systems while considering the technical, economical and financial considerations applicable to Egypt.

2. Develop criteria for reducing losses to the optimum.
3. Recommend a program of phased loss reduction for each distribution company studied, giving order of priorities, activities per company, and activities.
4. Develop order of magnitude cost estimates associated with the activities in the third objective.

1.3 Scope of Work

1.3.1 BVI/SA Scope of Work

The scope of work of BVI/SA comprises the following advisory services:

1. Review available data and reports prepared by EDHC, EPS, and the respective Distribution Companies, and identify any additional data, reports or other information required to accurately present the operating condition of the distribution networks.
2. Analyze engineering, design, operation and maintenance standards and criteria for completeness and suitability. Recommend appropriate changes or additions to the current design and construction standards or criteria, so that they may be applied uniformly throughout the EDHC and Distribution Companies.
3. Assist in analyzing system performance to determine proportions of losses in or caused by the following elements:
   a. Uncorrected inductive load.
   b. Metering errors.
   c. Undersized 11 kV and 20 kV primary conductors.
   d. Undersized transformers.
   e. Undersized secondary and service conductors.
   f. Splicing and termination conditions subject to failure.
   g. Theft or diversion.
4. Assist in the evaluation of construction standards and planning, design or construction criteria now in use in relation to accepted practices in modern

utility systems as they relate to standards of service, capacity, reliability, voltage drop, losses, economics, finance, etc.

5. Recommend changes to standards and criteria that are needed to meet the minimum needs of the consumers, consistent with the requirements of individual classes of customers and the state of distribution network development.
6. Assist in the development of a distribution rehabilitation program of phased investments for each Distribution Company based on rehabilitation activities ranked by their return on investment.
7. Assist in the preparation of an order of magnitude cost estimate for each Distribution Company using both foreign exchange and local currency, maximizing the use of local currency to purchase in-country manufactured material, equipment and services.
8. Recommend to EDHC the extent of offshore expertise needed to initiate a phased loss reduction program in each Distribution Company which would include engineering, designing material procurement, construction supervision and the duration of such services.
9. Review and update the list of instruments to be used by EDHC in measuring various system characteristics (instruments will be purchased on a small value procurement basis).

1.3.2 EPS Scope of Work

The scope of work of EPS corresponds to the BVI/SA scope of work, except that Task 9 of EPS is to develop a necessary training program and train electricity distribution personnel to carry out similar studies.

The EPS contract with EDHC further defines the methodology by which the scope of work will be carried out. This methodology includes a program of field investigations and measurements for ten sample regions in six Distribution Companies. These samples are analyzed in depth and form the basis for estimates of loss allocation and investments for the other regions within the six Distribution Companies. Cairo Electric Distribution Company and Alexandria Electric Distribution Company are not included in the samples.

2.0 BVI ACTIVITIES

During the project, the BVI Distribution Engineer made three trips to help with and review the loss reduction study performed by EPS. The first trip was from 23 June 1991 to 12 September 1991. The second trip was from 13 April 1992 to 19 May 1992. The final trip began on 1 February 1993 and continued through 11 February 1993. During these trips, BVI reviewed available data, reports, standards, and criteria. BVI also reviewed the work being done by EPS, recommended various study modifications, and helped develop analysis methods.

2.1 Data and Reports

Very little detailed system data was available in English, so review has been limited. BVI has received and reviewed the following:

- EDA Annual Statistical Reports - 1988/1989, 1989/1990, and 1990/1991.
- "Optimization of Losses in Cairo Medium Voltage Distribution System, Shobra District - Final Report." EPS made this study in 1989 . The study was similar in scope to the present study but was limited to the analysis of a single Cairo Distribution Company district. This study was of a high use urban area, different from samples in the present study. EPS refined many analysis methods from this report and used them in a study of the Docci district.
- Work Order Procedure for Urban Electric Distribution Systems Rehabilitation and Expansion, USAID Loan 263-K-043, 1983. This contains a few underground distribution construction standards. The standards are project specific and are not being generally followed by the Distribution Companies.
- Outage reports for each distribution company were summarized in tables and translated by EPS.

EPS anticipated the lack of data. For this reason, the methodology specified in their contract with EDA includes an extensive measurement program. Measurements made during the project allowed detailed analyses of distribution systems in sample districts. These analyses, along with available statistical information, provided a method of estimating loss allocations and deciding on system modifications for the remaining districts. The sample districts analyzed were:

- Tanta - South Delta Distribution Company.
- Ashmoun - South Delta Distribution Company.
- Bilqas - North Delta Distribution Company.
- Domiat - North Delta Distribution Company.
- Beyala - North Delta Distribution Company.
- Ismailia - Canal Distribution Company.
- Abo Bakr - El Behiera Distribution Company.
- Souhag - South Upper Egypt Distribution Company.
- Samalut - North Upper Egypt Distribution Company.
- Tamya - North Upper Egypt Distribution Company.

The BVI Distribution Engineer made field visits to several measurement sites to review the methods.

2.2 Standards and Criteria

Very few engineering, design, and operations and maintenance standards and criteria were available from the Distribution Companies. The Rural Electricity Authority (REA) normally designs the systems with REA standards. EPS was unable to obtain REA standards.

Because no formal standards and criteria are in general use by the Distribution Companies, EPS and BVI developed a questionnaire to learn what criteria they are using. This questionnaire was distributed to the distribution companies during BVI's last trip and responses were received from North Delta Distribution Company and Cairo Distribution Company. BVI has reviewed these responses.

BVI believes that further EPS efforts to collect standards and criteria would not be worthwhile. Enough information is known to find out if design and construction standards or criteria are uniformly used throughout the EDA and distribution companies. They are not.

2.3 Allocation of System Losses

BVI reviewed the methods used by EPS for the allocation of system losses in sample systems. Several recommendations were made by BVI and incorporated into the analysis by EPS. BVI reviewed one example calculation of each type to verify the methods and computer programs used. The check was sufficient to verify the

methods but did not include all cases and did not include verification of all input data.

2.3.1 Medium Voltage Circuit Analysis

EPS made the analysis of losses on medium voltage circuits with a computer program written by them in Fortran and based on impedance matrix calculations and a constant kVA load model. BVI reviewed the computer model by performing the calculations with a different method and comparing the results. This review showed that the EPS computer model provides valid results.

The input and results from the Koras 11 kV feeder of Ashmoun Substation Extension were reviewed to find out if the computer model was being applied properly. The review showed that EPS correctly performed the analyses.

2.3.2 Low Voltage Circuit Analysis

EPS initially attempted to allocate the losses on the low voltage system by measuring energy into and energy out of different parts of the system. BVI recommended the following modifications to the method of allocating the losses:

- Measure low voltage connector losses by measurement of current through the connector and voltage drop across the connector instead of attempting to measure the power in and power out of the connections.
- Determine low voltage system losses by mathematical models with measured loads instead of measuring power in and power out of different sections of the system.

EPS has incorporated BVI's recommended modifications into their study.

EPS used two separate methods for analysis of the low voltage system, depending on the type of field data available. Where the number of customers is known at each node, EPS used a Quattro spreadsheet model developed jointly by BVI and EPS. Where the current at each node is measured, EPS used a Fortran program developed by EPS.

BVI confirmed the spreadsheet model by hand calculations. BVI confirmed the Fortran program method by using a spreadsheet to make calculations for the El Zeraeen Kiosk in the Samalut sample of North Upper Egypt Distribution Company.

2.3.3 Administrative Losses

The difference between energy purchased and energy sold can be allocated to technical losses such as resistance loss in conductors and to administrative losses. Administrative losses include metering errors, energy theft, and errors in estimating the amount of energy used in non-metered applications such as street lighting. In order to estimate the contribution of metering error contributed to administrative losses, BVI recommended that the Distribution Companies test a sample of customer energy meters. South Delta Electricity Distribution Company tested a sample of 169 meters.

2.3.4 Allocation of Losses in Non-Sample Districts

The approach that EPS used to allocate losses in areas not included in the samples was to use clustering techniques to classify districts, or Handasat. Each sample area chosen for detailed study became the center point for a group, or cluster, of Handasat. Losses measured for each sample were apportioned to Handasat in the same cluster by means of weighting factors.

The success of a clustering technique depends on selecting significant statistics, such as energy sales, resistance of main feeders, etc. EPS tested the statistics by reducing the number of clusters and including one of the measured samples in a cluster with another sample. In this manner, predictions of losses were compared to actual results for the sample. For all but one of the samples, the predictions were acceptable. The one sample where this test was unsuccessful, Beyala, was the center of the largest cluster. Removing this cluster apparently had too much of an effect on the results. The selection of statistics was tested by trying different combinations of statistics. The final combination of statistics chosen was based on improvements in the performance of the clustering.

BVI has reviewed the clustering methodology used by EPS and believes that the approach is appropriate.

2.3.5 Loss Measurement Results

BVI reviewed the following three Progress Reports issued by EPS which explain the methodology used by EPS in calculating the losses and give the results of loss measurements made in the samples. The reports are comprehensive and provide a firm basis for loss allocation.

- Losses Reduction in Electricity Distribution Systems in Egypt, Progress Report, October 1991.
- Losses Reduction in Electricity Distribution Systems in Egypt, Progress Report, December 1991.
- Losses Reduction in Electricity Distribution Systems in Egypt, Progress Report, April 1992.

2.4 Evaluation and Recommendations for Standards and Criteria

2.4.1 General

One component of this project is the evaluation of and recommendations for improvements to engineering standards and criteria. Standards and criteria that provide guidelines for loading distribution facilities are particularly important in reducing system losses.

Because there are few standards and criteria to review, EPS developed guidelines for optimizing the use of distribution facilities such as transformers and conductor. These guidelines will allow the distribution companies to design new facilities for the lowest total cost of ownership or life cycle cost.

BVI assisted EPS in the development of the guidelines and has reviewed the methods used and a sampling of the calculations made.

2.4.2 Load Growth

Considering the expected high rate of load growth in Egypt, it is important to correctly account for growth in any economic optimization analyses. Part of the load growth is reflected in expansion of the area served and is not relevant to the optimization of a particular installation, which serves an existing area. The load on a particular installation will, however, increase with increased numbers of customers in the area served and with increased load per customer. A previous study by EPS in Cairo showed that approximately half of the load growth was an increase in the load per customer.

BVI assisted in developing analytical methods and computer spreadsheets that account for load growth in a proper manner. EPS has incorporated these methods into the optimum design guides.

2.4.3 Procedures for Optimization

2.4.3.1 General Optimization. BVI recommended that EPS find breakeven loading points between adjacent equipment ratings or sizes. Loads above the breakeven point would be most economically served by the larger size. Loads below this point would be best served by the smaller size. BVI believes that this method provides more useable design standards than does a mathematical cost minimization method. The results are a range of loads for each standard rating, whereas the result of a minimization technique would be a single "optimum" load for each rating. Allowance for load growth can also be readily incorporated into the breakeven approach.

BVI assisted EPS in developing computer spreadsheets using the breakeven load approach for optimum transformer and conductor sizing and economic conductor relief loads. EPS used these analyses in their optimum design guides.

2.4.3.2 Transformer Spacing. Previous EPS studies have addressed transformer spacing optimization by minimizing the cost of transformers and secondary feeders, using equations developed for substation spacing. This approach does not consider losses in the feeders or voltage drop limitations.

Attempts by both BVI and EPS to develop a general method for optimizing transformer spacing have led to agreement that a general method is not practical. Instead, EPS has developed a low voltage system design guide to allow the Distribution Companies to design specific systems with economically sound criteria.

2.4.3.3 Low Voltage System Design Guide. The design guide developed by EPS provides a procedure for low voltage system design that includes transformer sizing, conductor sizing, and voltage drop analysis.

The design guide does not address transformer spacing directly, but provides maximum low voltage feeder lengths based on the limitation of voltage drop. BVI assisted in developing the methods of calculating maximum feeder lengths and has reviewed the final guide. BVI made sample calculations to assure that the final guide was technically correct.

2.4.3.4 Power Factor Correction. EPS used a method of optimizing capacitor installations on the 11 kV system based on IEEE papers published by M.M.A.

Salama and E.A.A. Mansour of Ain Shams University, Cairo; A.Y. Chikhani of Royal Military College, Canada; and R. Hacham of the University of Windsor, Canada. BVI has reviewed these papers and finds them to be technically sound in general. BVI has provided comments on the papers that concern the application of the theory.

Because of certain questions on the theory of the optimization method, BVI recommended that the results be checked by using the EPS medium voltage load flow program. This was done by EPS with BVI assistance. A circuit was chosen for test that benefitted from the addition of capacitors according to the EPS method. Losses for the circuit were calculated with the load flow program before and after adding capacitors recommended by the theory. The net savings were then be calculated and compared with the theoretical value. Other tests were made by running the load flow program with different size capacitors and with the capacitors in different locations. BVI also separately calculated the loss savings using a different method.

Calculation of loss savings with variations in size and location confirmed that the theory gives a good estimate of the optimum size and location. The net loss savings calculated with the optimization method did not agree closely with the load flow calculations or with BVI's separate calculations, however. This problem being reviewed by EPS, but BVI does not know the resolution of this matter. If the loss savings calculated are in error, the effect on the overall report conclusions would be overstating the contribution of power factor compensation to loss reduction. Since power factor compensation has a relatively small recommended investment, three percent of the total, BVI does not believe that any overstatement would be significant.

2.4.3.5 Optimum Operating Scheme. EPS has developed a computer program that determines the optimum location for open points on MV loop circuits. The method is based on determining the point at which power flow would be at a minimum if the loop were closed.

Calculations of the optimum operating scheme for Old Beyala Distribution Point Feeders 1 and 8 in the North Delta Distribution Company Beyala sample were reviewed. The method of determining the optimum scheme and calculating the loss savings is acceptable. BVI developed an alternate method which is equivalent.

2.4.3.6 Low Voltage Unbalance. The optimum level of unbalance on the low voltage system is zero, but this is not achievable. EPS has used the low voltage network computer model to determine how much loss savings could be achieved by decreasing the unbalance to a 50% level.

Low voltage unbalance reduction calculations for El Central Kiosk in the North Upper Egypt Distribution Company Samalut sample were reviewed. The calculations are valid, but rely on achieving a theoretical unbalance factor without regard to how this would be achieved. The conservative target unbalance factor of 50% should be achievable, however, and represents a reasonable approach to estimating the loss reduction that can be achieved.

2.5 Investment Programs and Cost Estimates

Part of the scope of this project is to recommend a program of phased activities of loss reduction for each distribution company. EPS has made order of magnitude cost estimates and has provided return on investment information for various activities. BVI has reviewed these estimates and rankings and believes that they are technically sound.

The approach that EPS has taken is to develop investment programs for the measured samples and make investment estimates for other Handasat using the clusters developed for loss allocation. BVI believes that this approach is appropriate.

Investment programs that have been investigated include:

- Reinforcement of MV feeders.
- Reinforcement of LV feeders.
- Install capacitors on the MV system.

The programs were not ranked in order of return on investment as normally defined in accounting terms. Rather, the amount of investment needed to reduce losses by one kilowatt-hour was calculated for each program. BVI agrees that this measure is more appropriate for establishing investment priorities in loss reduction programs.

In addition to capital investment programs, EPS has investigated loss reductions possible through operating practices such as optimizing MV circuit configurations, relocating distribution transformers, balancing LV network loading, and improving connectors. BVI has reviewed the calculation methods for each of the practices and finds that they are technically correct.

2.6 Measuring Instruments

EPS developed a technical specification for multi-channel and three-phase instruments to be used in follow-on studies for load measurements. BVI reviewed the technical specifications and recommended minor changes. The changes were incorporated into the specifications and were submitted to EDA for procurement. BVI's Kansas City office has also provided information on potential U.S. suppliers and model numbers of instruments that meet the specifications. At EDA's request, BVI also assisted in the distribution of tender documents to prospective bidders in the United States.

3.0 REVIEW OF EPS FINAL REPORT

BVI has reviewed the Final Report on Losses Reduction In Electricity Distribution Systems In Egypt, prepared by EPS for EDHC. This review included a technical analysis of calculations and methods used by EPS, as described in the section on BVI Activities. BVI has also confirmed that concerns and recommendations made by BVI have been taken into account.

The Final Report presents a comprehensive analysis of the six Distribution Companies studied. The EPS project objectives have been met by the measurements and analyses described in the report.

3.1 Executive Summary

The Executive Summary accurately reflects the salient points of the detailed study report.

3.1 Chapter One: The Electricity Distribution System

This chapter provides descriptions and statistics on the service areas, distribution networks, and load characteristics of the six Distribution Companies. The statistical data gathered by EPS is presented at the Handasa (District), Governorate, and Distribution Company levels in a series of tables and graphs. This data provides a comprehensive view of the areas studied and forms the basis for grouping, or clustering, the entire distribution system to enable extending the results of the samples analyzed to the entire system.

3.2 Chapter Two: Losses In Electricity Distribution Systems

This chapter addresses the overall problem of demand and energy losses. General equations for losses, loss factor, and load factor are given. The methodology used for economic evaluation of the losses is explained. Examples are given from two sources of percent losses in American distribution systems for comparison purposes.

The chapter provides a useful and technically correct explanation of the basic concepts involved in evaluating losses in the distribution system.

3.3 Chapter Three: Study Methodology

This chapter explains the general methodology used by EPS in measuring, calculating, and allocating losses to the different parts of the distribution system. These methods have been reviewed by BVI, and recommendations made previously by BVI have been incorporated.

3.4 Chapter Four: Review of Standards of Service and Design Criteria In Force

This chapter provides a compilation of the responses to the questionnaire on standards and design criteria that was developed by EPS and BVI. Responses were received from North Delta Distribution Company and Cairo Electricity Distribution Company.

A series of tables are also included in this chapter that present the reliability statistics of the Distribution Companies down to the Handasa level. Both reported statistics and calculated indices are presented. The statistics include frequency of outages in cables, overhead conductors, and distribution transformers as well as the percent of faults by various cause such as overload, short circuit, faults in cable junctions, malfunctioning switches, etc. Calculated indices include mean time to repair, mean down time, and mean time between failures. Sections describing service voltage standards and general methods available to improve reliability are also included in this chapter.

This chapter provides an adequate fulfillment of the project task of evaluation of standards and criteria in force. The scope of this task is limited by the lack of standards and criteria in force. This limitation does not impact the main project goals of loss reduction, however.

3.5 Chapter Five: Optimum Design and Operation of Distribution Systems

In lieu of recommending improvement in standards and design criteria, EPS has developed a series of design guides for the economic design of different portions of the distribution system. Chapter Five presents these design guides and describes the bases of economic evaluation and the methodology used in developing the guides. Guides are provided for:

- Selection of transformer size

- Selection of low voltage feeder conductor size
- Maximum length of low voltage feeders
- Reinforcement of medium voltage networks

The methods for transformer sizing, low voltage conductor sizing, and maximum length of low voltage feeders are combined into a single guide for the optimum design of low voltage systems. This guide, if implemented by the Distribution Companies, should result in a significant loss reduction in new low voltage installations. The limitation of low voltage feeder length is based on maintaining an acceptable service voltage standard. This will improve the quality of service to the customers as well as result in decreased losses.

In addition to the guides that can be directly used by the Distribution Companies, descriptions are provided of recommended methods for optimum operation schemes for urban medium voltage networks and for reactive power compensation in the medium voltage networks. These methods depend on computer analysis of the networks, so cannot be reduced to a guide for manual calculations.

BVI has reviewed and assisted in the development of the analyses and guides presented in this chapter. The guides are based on technically sound principles and methods. The example calculations reviewed by BVI were technically correct. Table 5-4-1 contains a typographical error; the economic relief load for 150 AL XLPE cable should be 73.8 not 738.0.

The chapter does not contain a guide for the selection of medium voltage overhead conductor and cable sizes. EPS has not developed these guides because the responsibility for designing new medium voltage lines lies with the Rural Electrification Authority, not with the Distribution Companies. Should this responsibility be moved to the Distribution Companies, a medium voltage design guide could easily be developed using the same methodology that was used for low voltage conductor sizing.

3.6 Chapter Six: Losses Isolation and Optimization in Sample Districts

This chapter presents the results of loss measurements and calculations for the samples where detailed analyses were made. The results of alternative loss reduction programs are also shown, along with the required capital investment costs. EPS also

presents the results of energy meter tests in South Delta EDC where an average metering error of 27 percent was found.

The methods used in developing the loss isolation and optimization for the sample districts have been reviewed by BVI and are technically correct. The results should form a sound basis for an overall assessment of losses in the distribution system, loss reduction potential, and an order of magnitude estimate of required investments.

As noted by EPS in the report, however, the analyses of the samples are based on 1991 loads, system configurations, and measurements. During the implementation phase, these will have to be reviewed and the analyses updated before developing detailed plans for investment programs.

3.7 Chapter Seven: Grouping of Distribution Handasat (Clustering)

This chapter presents the methodology used in allocating losses to Handasat not included in the measuring program. The same method was used to estimate the loss reductions possible and the amount of investment required in each Handasa.

The clustering was based on predetermined centers, the samples chosen for measurement and detailed analysis. Normally, if clustering is used in a study, the clusters would not be predetermined, but would be determined from statistics of all systems under study. The samples for detailed analysis would be chosen from the clusters.

The method used by EPS allowed the measurement program to start early in the project, before all of the Handasa statistics were gathered and analyzed. Samples were chosen based on a knowledge of the system and a logical categorization by system type. The ability to obtain clusters with a high performance index shows that this method was successful. The performance index is a measure of how close the Handasat in a particular cluster are to each other in terms of the statistics chosen.

The method used by EPS is valid and can be expected to provide reasonable estimates of loss allocation and investment requirements.

3.8 Chapter Eight: Actions and Investments Required for Losses Reduction in Distribution Networks

This chapter develops the estimates for loss allocation and investment programs for the six Distribution Companies. Allocation of losses to the medium voltage system, transformers, and low voltage system are given for each Governorate. Projected loss reductions and estimated investment costs are given for each capital investment program in each Handasa. In addition to developing investment programs for rehabilitation, EPS describes activities that should take place during the system design and operations stages. EPS also makes recommendations for the provision of computers and meters to the Distribution Companies and for training of EDC engineers.

Loss allocations are based on sample measurements and calculations, extrapolated to the other Handasat by using the clustering methods described in other chapters. There are differences in the estimates of technical losses of the different Governorate between the draft report and the final report. These differences arise because of a change in the way that sample losses were generalized to the Governorate level.

Loss reductions and the required investments for each Handasa are based on achieving the same percentage losses with the same cost per kWhr reduction as the sample that forms the center of the cluster.

Although administrative losses (non-technical) are not estimated as such, the excess of energy purchased over energy sold is given for each Governorate. The difference between this figure and the total of the estimated technical losses is the result of several factors such as:

- Errors by Distribution Companies in estimating unmetered service, e.g. street lighting and municipal loads.
- Meter errors, including connection errors.
- Energy diversion by customers.
- Inaccuracy of extrapolation of sample results to Handasat.

Differences between estimated technical losses and total energy losses were small. These small differences indicate that non-technical losses are small and also give added confidence in the accuracy of the technical loss estimates.

The results presented in this chapter are based on methods reviewed by BVI and found to be technically correct. The results should give a reasonably accurate view

of the where the losses occur in the distribution system and their approximate level. The estimates of investments required should be adequate for overall budgeting of resources. Loss savings estimated for the investment programs should be achievable.

As indicated by EPS, detailed system analysis and studies will be required for the implementation of the investment programs. The detailed analysis of such a large number of networks will require enormous amounts of data, manpower, and computer cost as shown in Chapter 3. EPS does not, however, recommend any offshore expertise for the loss reduction program. A desire on the part of EPS to use local consultants to support the EDC engineers is understandable. BVI believes, however, that offshore expertise can play a valuable role in the enormous tasks of detailed analysis, planning, design, procurement, and construction management that will be required for full implementation of the investment programs.

4.0 BVI RECOMMENDATIONS

Based on its review of the methods, measurements, calculations, and presentation of the EPS study, BVI recommends acceptance of the study and implementation of the recommended actions. Implementation of the design guides developed by EPS should begin immediately. Implementation of the phased investment program requires detailed study of each Handasa and development of detailed designs, specifications, tender documents etc. for the specific loss reduction activities. Initiation of the detailed studies at an early date will enable the realization of considerable savings in losses on the distribution systems.

A relatively high proportion of losses occur on the low voltage system. Energy losses in transformers and low voltage conductors were over 8 percent, compared to the quoted World Bank target level of 0.6 percent. The measured medium voltage energy losses of 2.2 percent are much closer to the World Bank target level 2 percent. This difference reflects the typical European style distribution system with large distribution transformers and extensive low voltage networks. The World Bank study quoted bases its targets on a North American style system, with small transformers and limited low voltage networks.

The costly low voltage system losses are reflected in the high recommended amount to be invested in reinforcement of low voltage networks, 64 percent of total investment. The rankings of investment programs, however, show that reinforcement of the low voltage networks in many governorate requires more capital investment per kilowatt-hour loss reduction than other investments. The implications of this are that while there are greater opportunities to reduce losses economically on the low voltage system, the capital requirements are high.

Once the extensive, inefficient low voltage networks are built, they are difficult to correct. The design guide for low voltage systems presented by EPS can be of great long term benefit to the EDHC if it is used to design new, more efficient low voltage networks in the future. BVI recommends that this design guide be made available in Arabic to the engineers who will be designing future distribution systems. Example designs should be added to aid in understanding the concepts, and appropriate training sessions established.