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OPTIMIZATION OF ELECTRIC POWER SYSTEMS

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CHILE

Technical report: Electric power distribution systems *

Prepared for the Government of Chile
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

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Vienna

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1. Introduction

This three-week technical mission to Chile from May 15 to June 8, 1987 was undertaken under the auspices of the United Nations Industrial Development Organization (UNIDO). In addition to research and development activities concerned with the optimization of the Chilean electric power distribution system planning and operation, this project is also providing advanced training to the technical personnel in Chilean utilities and universities.

The research and development activities are conducted by the faculty members and students of the three foremost engineering schools in Chile, that is, at Universidad Technica Federico Santa Maria, Pontificia Universidad Catolica de Chile, and Universidad Catolica de Chile, and Universidad de Chile in cooperation with several Chilean utilities.

Distribution system planning is essential to assure that the growing demand for electricity can be satisfied by distribution system additions which are both technically adequate and reasonably economical.

This UNIDO project, through a well planned utility industry and university cooperation, guarantees that all the crucial problems associated with power distribution engineering are considered and that the research, development, and training activities are beneficial and practically oriented. The wide scope of this UNIDO project covers various aspects of distribution engineering from load forecasting to distribution

system planning and from distribution system operation to distribution system automation.

2. Project Objectives

The main scope of this technical mission was on the area of electric power distribution systems of the Chilean power system. The primary objectives were including the following:

1. Analyze power distribution modern trends and the application of new techniques and equipment in these systems.
2. Study information on the Chilean distribution power systems, equipment, and methods of analysis and design being used at present.
3. Meet personnel from universities and electric utilities and take part in technical discussions to supplement the basic information available.
4. Provide a course on power distribution systems.
5. Provide typed notes for the course that will be distributed to the course participants.
6. Prepare a report on the visit and make recommendations for future activities in the project.

3. Background

Distribution system planning is essential to assure that the growing demand for electricity can be satisfied by distribution system additions which are both technically adequate and reasonably economical. Such growing demand for electricity, in terms of increasing growth rates and high load densities, can be

satisfied in an optimum way by additional distribution systems, from the secondary conductors through the bulk power substations, which are both technically adequate and reasonably economical. Such growing demand for electricity, in terms of increasing growth rates and high load densities, can be satisfied in an optimum way by additional distribution systems, from the secondary conductors through the bulk power substations, which are both technically adequate and reasonably economical. All these factors and others, e.g., the scarcity of available land in urban areas and ecological considerations, can put the problem of optimal distribution systems planning beyond the resolving power of the unaided human mind. Distribution engineers must determine the load magnitude and its geographic location. Then the distribution substations must be placed and sized in such a way as to serve the load at maximum cost effectiveness by minimizing feeder losses and construction costs, while considering the constraints of service reliability.

As a result of the increasing cost of energy, equipment, and labor, improvised system planning through use of efficient planning methods and techniques is inevitable and necessary. The distribution system is particularly important to an electrical utility industry for two reasons: (1) its close proximity to the ultimate customer and (2) its high investment cost. Since the distribution system of a power supply system is the closest one to the customer, its failures affect customer service more directly than, for example, failures on the transmission and

generating systems, which usually do not cause customer service interruptions.

Therefore, distribution system planning starts at the customer level. The demand, type, load factor, and other customer load characteristics dictate the type of distribution system required. Once the customer loads are determined, they are grouped for service from secondary lines connected to distribution transformers that step down from primary voltage. The distribution transformer loads are then combined to determine the demands on the primary distribution system. The primary distribution system loads are then assigned to substations that step down from transmission voltage. The distribution system loads, in turn, determine the size and location, or siting. In other words, each step in the process provides input for the step that follows.

There are, of course, some other factors over which the distribution engineer has no influence but which, nevertheless, have to be considered in good long-range distribution system planning; e.g., the timing and location of energy demands, the duration and frequency of outages, the cost of equipment, labor and money, increasing fuel costs, increasing or decreasing prices of alternative energy sources, changing socioeconomic conditions and trends such as the growing demand for goods and services, unexpected local population growth or decline, changing public behavior as a result of technological changes, energy conservation, changing environmental concerns of the public,

changing economic conditions such as a decrease or increase in gross national product (GNP) projections, inflation and/or recession, and regulations of federal, state, and local governments.

The number and complexity of the considerations affecting system planning appears initially to be staggering. Demands for ever-increasing power capacity, higher distribution voltages, more automation, and greater control sophistication constitute only the beginning of a list of such factors. The constraints which circumscribe the designer have also become more onerous. These include a scarcity of available land in urban areas, ecological considerations, limitations on fuel choices, the undesirability of rate increases, and the necessity to minimize investments, carrying charges, and production charges.

4. Technical Discussions

Based on the National Energy Commission's recommendation, the Government of Chile has passed a new law called Electrical Generation Act. According to the new law, there are now two independent and large electrical companies, namely, ENDESA and CHILECTRA-GENERATION and twenty-three (smaller) distribution companies. The formation of the new central body called CDEC, made up of members of the two largest companies, has been facilitated to oversee the economic operation of the electrical industry.

The author visited various electric companies and/or held technical discussions with their technical and/or managerial

staff. The listing of such companies includes, the ones located in Santiago, CGEI, CHILECTRA-METROPOLITANA, CHILECTRA-GENERATION, ENDESA (DISTRIBUTION), in Valparaiso, COMPAÑIA CHILENA DE DISTRIBUCION ELECTRICA V REGION (CHILECTRA V REGION), and in Vina del Mar, CONAFE. Furthermore, extensive discussions and presentations were held with faculty and students from Universidad Tecnica Federico Santa Maria, Pontificia Universidad Catolica de Chile, and Universidad de Chile.

A large number of technical issues have been discussed and closely examined in terms of current practice, current equipment, progress examination, technical consultancy, general discussions, and recommendations.

5. Course

A course of 20 lecture hours was given to about 85 participants at Universidad Técnica Federico Santa Maria at Valparaiso Approximately, 45 participants were distribution engineers from the utility companies and the rest were made up of students and faculty members from the three universities involved in the program. The course title was "Curso de Perfecionamiento en Distribucion Electrica". It covered basic issues in distribution engineering, distribution system planning using mathematical modeling and computers, distribution engineering practices, and distribution automation. Each course participant has been given 390 pages of typed notes including the following subjects: (1) modeling of power distribution systems; (2) distribution

planning and design; (3) distribution system losses; (4) primary substation equipment and design; (5) load management and forecasting; (6) control of reactive power in distribution systems; (7) safety and economic considerations; and (8) application of new technologies on power distribution systems.

6. Technical Contacts in Chile

6.1 COMPAÑIA GENERAL DE ELECTRICIDAD INDUSTRIAL (CGEI)

The author visited the CGEI utility (distribution) company in Santiago and met and held discussions with its technical and managerial staff. Information was given on the history of and nature of the Chilean electric power industry as well as the history and operation of the distribution system of CGEI. The meeting was attended by a large number of engineers of CGEI as well as lay Professor Julian Bustos of Universidad Tecnica Federico Santa Maria and by Professor Sebastian Rios of Pontificia Universidad Catolica de Chile. The meeting has provided background information on the principal seven regions and on basic characteristics of the chilean electric utility system. Also, an in depth information was provided on the primary generating sources, main primary links and load-demand characteristics.

6.2 CHILECTRA METROPOLITANA

Discussions were held with technical and managerial staff of this distribution company.

The meeting was also attended by Professor Julian Bustos of Universidad Técnica Federico Santa Maria and by Professors Hugh

Rudnick and Sebastian Rios of Pontificia Universidad Catolica de Chile. Various topics were discussed in terms of distribution system operations and planning. The author was impressed by the openness and clarity of their discussions and left the meeting with a positive image of the company. A two-hour short course was given during a second visit.

6.3 CHILECTRA-GENERATION

Various technical discussions were held with the engineers of this utility company. The author was asked a large number of technical questions and answers and/or recommendations were provided accordingly. The engineers were well informed and very competent.

6.4 ENDESA (DISTRIBUTION)

Technical matters were discussed with ENDESA'S engineers and quite a large number of questions were answered. The author was impressed with the clarity and honesty of the discussions.

6.5 COMPANIA CHILENA DE DISTRIBUCION ELECTRICA V REGION (CHILECTRA V REGION)

Specific questions have been asked on their specific technical problems. There was keen interest in the new techniques used in mathematical modelling of distribution systems. The author was consulted on a vast number of technical issues associated with distribution systems, and provided oral as well as written answers to such problems.

CONAFE

This distribution company has been visited twice during the author's

stay in Valparaiso. It is a small (and urban) distribution company with progressive engineers and management. They were very much interested in computer applications in distribution systems. Consultations were given on a large number of technical issues including the ones in system reliability, underground cables, and subtransmission problems. All the meetings were also attended by Professor Julian Bustos of Universidad Técnica Federico Santa Maria.

6.6 UNIVERSIDAD DE CHILE

The author was given information by Professor Oscar Moja on ongoing research activities at Universidad de Chile.

6.7 PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE

Several visits were made to this University during the course of this stay in Chile. The visits were hosted by dynamic chairmen of the Electrical Engineering Department, Professors Hugh Rudnick and Sebastian Rios. Information has been provided on ongoing research topics and projects, educational issues, the characteristics of electric power utility industry, utility planning and operations in Chile. The author has been made familiar with their power engineering laboratories as well as having reviewed power engineering curriculum. Furthermore, researchers have been met and consultations were arranged on a number of topics.

6.8 UNIVERSIDAD TÉCNICA FEDERICO SANTA MARIA

Most of the stay in Chile was hosted by this university and particularly by its dedicated Professor Julián Bustos. His cheerful companionship and 'guardian-angel' attitude were highly

appreciated. Contacts were arranged with Mr. Jose Gundelach and Mr. Daniel Alkalaj, Dean and Associate Dean of Engineering, respectively, and discussions were held with them on various issues of engineering education in Chile. The author has been informed in detail on B.S. and M.S. programs in Electric Power Engineering at this university. Professor Ricardo Fuentes, Chairman of the Electrical Engineering Department was also met and the author expressed his appreciation for the kind assistance during the visit.

Furthermore, various discussions were held with Professors Homero Capona, Nelson Leiva, Jörg Müller, Juan Luis Dinamarca, Sergio Fuentes, José Rodriguez, Alfredo Munoz, and German Stolz. It was impressive to see the quality of power engineering laboratories as well as the quality of the professors involved in this program.

7. **General Discussions**

The UNIDO project is very useful to the Chilean industry in terms of transferring knowledge and modern technology. It delivers some useful engineering technique and technological know-hows for immediate applications and builds up a crucial body of technical knowledge for the country.

In the long run, the UNIDO project will substantially contribute to the future research activities and interchange of technical information between the universities and the industry by establishing strong university-and-industry ties. Such ties, in turn, will facilitate continuous updating of technical knowledge and skills of engineers and researchers. Further, the UNIDO project is also serving as a catalyst for improved

technical relationships between the industry and the universities. Such cooperative efforts are crucial to the utilities, universities, and Chile overall, being a developing country.

8. **Recommendations**

My recommendations are two fold (a) short range and (b) long range. In the short range, such UNIDO program should continue in order to have a strong impact on this developing country. In the long range, the UNIDO should offer support for establishing an Electric Power Research Institute (similar to the EPRI in the U.S.A.) in Chile. Such research institutes can then be used as a center for research and development not only for Chile but also for other Latin American countries and their industries and universities. The proposed research institute can be used for the transfer of technology in terms of cooperative efforts within the region.

Furthermore, in the long run, the utility engineers can be trained and educated by the three universities in Chile in a cooperative effort so that the utility engineers can receive a Master of Engineering degree for their continuous education while they are working full-time. The masters degree can be awarded, without any thesis work, after completion of 30 credits in the graduate engineering program. Such a program can be used not only for Chile but also other countries within the region. The courses can be taught by the professors from Universidad Técnica Federico Santa Maria, Pontificia Universidad Catolica de Chile,

and Universidad de Chile. Some of the technical courses can be supported, partially or fully, by experts from the industry or other countries. Both the members of the three universities and the industry are very supportive of such ideas and programs.

9. Conclusions

The UNIDO project must continue in order to have a substantial impact on the Chilean industry and on the industry-and-university cooperative efforts. It is crucial that the utilities involved in such programs finance the efforts to receive direct benefits and impact of such programs.

Furthermore, the key technical personnel of the industry and academy should be sent to the U.S.A., or other developed countries, for a technical trip to observe and learn about the technology. Also, visiting foreign experts to Chile should be assigned to a utility company for the duration of a few days (up to a week) in order to serve as an "in-house technical expert" to solve (or consult) on technical problems. These changes will enhance the financial support of utility companies for such programs.