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OPTIMIZATION OF ELECTRIC POWER SYSTEMS

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CHILE

Technical report: Economic operation of the Chilean power system*

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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1. INTRODUCTION

The author of this report undertook a three-week technical mission to Chile from Dec. 5 - December 26, 1986 under the auspices of the United Nations Industrial Development Organization (UNIDO). This mission was part of the activities of the UNIDO-sponsored Optimization of the Electric Power System Project. The principal players in this project are several engineers from Chilean universities and utilities. This is a highly important project aimed at investigating the optimal economic operation and effective planning of the country's generation-transmission-distribution system. In addition to research and development activities concerned with the optimization of the Chilean power system operation and planning, this Project is also providing advanced training to the technical personnel in Chilean utilities and universities.

The research and development activities are undertaken by the faculty and students of the three leading engineering schools in Chile at Pontificia Universidad Catolica de Chile, Universidad de Chile, and Universidad Tecnica Federico Santa Maria in cooperation with several Chilean utilities. The training program utilizes the services of power system specialists from throughout the world. These specialists have provided courses on topics such as State Estimation, Power System Security, and Computer Graphics.

This UNIDO Project is a highly imaginative and unique undertaking. The Project is concerned with a critically important need for the orderly growth of a developing country such as Chile. A well planned and efficiently operated power system ensures the availability of adequate electric energy resources to meet current and future needs reliably and economically. The

Project is the first to consider the entire problem from a systems point of view. Previous UNIDO-sponsored projects have concentrated on various aspects and components of the electric energy system, e.g., alternative energy sources and microgeneration. However, this project constitutes the first instance where the large-scale electric energy system in its entirety is the focus. This uniqueness of the Project is of considerable importance since the systems approach is the only one which can adequately account for all the diverse aspects of the problem within one integrated framework. A further important aspect of the Project is the utility-university collaboration which is most appropriate to ensure that all the important aspects of the problems considered are taken into account and that the research, development, and training activities are useful and practically oriented. The broad scope of the Project encompasses a wide range of areas from load forecasting to state estimation and from loss calculation to security dispatch. Technical activities include research, analysis, development, and implementation of algorithms and training. Several international experts who have visited Chile to teach advanced courses on specific power system and computer system topics and to undertake technical visits to the universities and utilities participating in the Project.

This report summarizes the activities of the author's recent visit to Chile. In the next section the objectives of the visit are stated. This is followed by a summary of the technical activities of the visit. The contents of the course given during this visit are discussed. This is followed by a section discussing the principal findings during my visit. This report concludes with a section of recommendations for future activities.

2. OBJECTIVES OF THE TECHNICAL MISSION

The principal focus of the technical mission was on the area of economic operation of the Chilean power system. The three major objectives were to:

1. Engage in technical discussions with personnel from the Chilean utilities, universities, and the National Energy Commission on topics related to the economic operation of the nation's electric utilities.
2. Prepare and present a set of lectures and notes on Power System Economic Planning and Operation with coverage to include the following topics:
 - . Economic Dispatch
 - . Unit Commitment
 - . Load Forecasting
 - . Hydro-Thermal Coordination
 - . Reliability
 - . Expansion Planning
 - . Production Costing
3. Prepare a report summarizing the activities of the mission and presenting the findings of the technical discussions and a set of recommendations for future activities in the area of economic operation of the Chilean power system.

3. TECHNICAL DISCUSSIONS

The majority of time on this visit was devoted to visits and discussions with technical personnel from the universities and utilities participating in the Project and current and previous employees of the National Energy Commission. Several meetings were held with managers and engineers from ENDESA, CHILECTRA Generacion and CHILECTRA Metropolitana. Extensive discussions were held with the faculty and students from Pontificia Universidad Catolica de Chile, Universidad de Chile, and Universidad Tecnica Federico Santa Maria. There was a visit to the offices of the National Energy Commission and a meeting with the founder of the Commission. The program for this visit is given in Appendix A. The major issues covered in these discussions are discussed next.

3.1 ENDESA

Several meetings and discussions were held with the technical/managerial staff of ENDESA. The first meeting served as a general introduction to the bulk generation and transmission system in Chile. This meeting was attended by members of both the planning and operating departments at ENDESA. The attendees from ENDESA included Julio Doggenweiler, Head of the Electrical Engineering Department; Guillermo Espinosa, Head of the Operations Department; Rodrigo Chamorro, Head of the Operational Planning Section of the Operations Department; Igor Rodriguez, Head of the Studies Section of the Electrical Engineering Department; Esteban Skoknic, Planning Engineer; and Andres Tirapegui, Operational Planning Engineer. In addition Professors Oscar Moya, Luis Valenzuela, and Luis Vargas from Universidad de Chile and Professor Hugh Rudnick and Sebastian Rios from Universidad Catolica attended.

The meeting started with an overview of the principal seven regions and basic characteristics of the Chilean electric utility system. The major generating sources, key transmission links, and load demand characteristics were described. The principal focus was on the Sistema Interconectado Central (SIC), the Central Interconnected System, which was described by Guillermo Espinosa. Esteban Skoknic outlined the basic planning approach used by ENDESA. He emphasized the important role that hydro plays in SIC. He also stressed that the consideration of uncertainty is a key aspect of resource planning at ENDESA.

The topic of energy transport, usually referred to as wheeling, was discussed. This is an area of looming importance in the electrical sector in view of the establishment of the national dispatch center CDEC (Centro de Despacho de Carga). Topics included the allocation of transmission losses to the appropriate entities, the evaluation of wheeling costs, and the setting of tariffs. It was interesting to note that the interest in this topic was just as acute as in the USA in light of the current thrust of deregulation in the US utility industry.

The entire topic of regulation of US utilities and the recent steps toward deregulation was discussed. The changing nature of the environment in which US utilities operate was described and the impacts of the new competitive atmosphere were delineated. There are very strong parallels between the moves for 'privatization' of the Chilean electric utility industry and the competition faced by American utilities.

Other topics discussed were Automatic Generation Control (AGC), highlighting the situation in Chile where in the SIC a single unit provides frequency control. Certain long-term planning issues particularly in the area of hydro and some transmission planning considerations, especially those related to VAR support at ENDESA. Comparison of ENDESA and PGandE practices and of organizational structures and procedures were made throughout the discussions.

This first meeting was followed by a number of other meetings with the ENDESA people. One was a visit to the ENDESA Control Center. The author was able to get a good understanding of the system configuration and the applications software. The tour of the Center was hosted by Rodrigo Chamorro. At a subsequent meeting we were able to discuss problems in the operations and operational planning area. Topics included the frequency control practice of ENDESA, scheduling problems and issues in the hydro-thermal coordination area.

The final meeting with the ENDESA people took place on Saturday, December 20 with Messrs. Guillermo Espinosa, Rodrigo Chamorro, Patricio Caro, and Andres Tirapegui present. The principal topic of discussion was the possibility of setting up a one-year internship at PGandE for Andres Tirapegui. We discussed the benefits and the possible framework for such a training program. In addition, other training programs in North America and abroad were discussed. The next step in this process, it was decided, would be a formal letter from ENDESA to PGandE.

The meetings with ENDESA were fruitful in establishing a basis for future discussions and exchange of technical information.

3.2 CHILECTRA Generacion

A meeting lasting several hours was held at the offices of CHILECTRA Generacion. The meeting was hosted by Francisco Aedo, Head of the Operation and Energy Sales Division. In attendance were Julio Briones, Juan Inostroza, Alberto Ugalde, and Juan Vasquez, engineers from CHILECTRA Generacion. In addition, Professors Hugh Rudnick and Sebastian Rios from Universidad Catolica and Luis Valenzuela from Universidad de Chile were present.

The first part of the meeting was dedicated to a presentation of planning issues by Juan Vasquez. Particular attention was paid to the marginal costing signal computed by the model Laja. This emphasis was appropriate in light of the ensuing discussion on several issues related to the new CDEC framework.

The creation of CDEC for the SIC was described and the principal functions and goals of this body were outlined. The concerns of CHILECTRA Generacion about operating within the CDEC framework became evident. Given that the creation of CDEC in the first time that the Chilean generation and transmission utilities will be operating together on an integrated basis, these concerns were quite natural and healthy. From this meeting it was not entirely clear whether CDEC will be more like a club or more like a regulatory agency.

Several other issues were discussed. The reactive power problems in the CHILECTRA network were described. These problems are particularly of interest because of the new wheeling arrangements under the CDEC framework. An interesting aspect of these problems is the very narrow range that exists for maintaining voltages at interconnection points with the ENDESA transmission

system. The operational policies for the CHILECTRA thermal-generating units and economic considerations were discussed. The hydro-thermal coordination was another topic of discussion. I registered my favorable impression with the appropriate consideration accorded to the use of marginal costing in the long-term planning of the CHILECTRA system.

The meeting gave a good overview of the strong steps taken at CHILECTRA for it to operate effectively under the new policy of opening the energy markets in Chile to competition.

3.3 Comision Nacional de Energia (CNE)

A highlight of the technical mission was a visit with two members of the National Energy Commission (CNE) -- Sebastian Bernstein, the Executive Director and Renato Agurto, Head of the Electrical Sector. It was an important part of the technical program since it gave an opportunity to learn firsthand the framework and foreseen operation of the CDEC. The meeting was attended by Professors H. Rudnick and S. Rios of Universidad Catolica and Professor J. Bustos of Universidad Tecnica Federico Santa Maria.

In the meeting, Messrs. Bernstein and Agurto provided an outline of the CDEC framework. They reviewed the provisions of the new General Law of Electrical Services enacted in 1982, the goals of CDEC, and the status of the implementation of the provisions of the Law. The majority of the discussion that ensued focused on:

- . Marginal Cost-Based Pricing

- . Determination of Costs for Wheeling
- . Implementation of Wheeling Services and Tariffs

The importance of marginal costing based prices for the economic operation of the interconnected system was emphasized. The CNE people reviewed the concepts of the basic models in use for achieving economic operation of the SIC. We also discussed the question of losses and how to allocate them among the interconnected utilities. The difficulty of setting up equitable wheeling tariffs and the allocation of costs of reactive equipment for improving transmission service were also topics of discussion. Finally, the possibility of breaking up the electrical sector into separate companies (unregulated generation companies and a regulated transmission company) was discussed.

3.4 Dr. Bruno Philippi

Professor S. Rios arranged a meeting with Dr. Bruno Philippi, the former Executive Director of CNE. Dr. Philippi may be considered the "father" of CDEC because of his strong involvement in the enactment of the General Law for Electrical Services. He went carefully over the background and motivation for the new law. He explained the political and technico-economic objectives for the creation of CDEC in SIC. The program of the Chilean government to 'privatize' the electrical sector was explained in the larger context of the economic strategies of the country. The rationale for CDEC and what it was aimed to accomplish became very clear.

An interesting aspect of this meeting was the strong evidence presented of the role played by operations research/management science/systems engineering

methodologies and techniques in the establishment of policies of the Chilean government. The government has well-trained technocrats who make extensive use of such methodologies and techniques in the promulgation of new policies and legislation. The meeting with Dr. Philippi was very useful in putting the CDEC creation within the larger context of Chile's economic planning picture.

3.5 CHILECTRA Metropolitana

An evening was spent with two engineers from the distribution company CHILECTRA Metropolitana. One of the objectives of the engineers was to interview me for an article to appear in the company's publication. Several topics in the distribution, planning, and operations areas were discussed. Some of the practices at CHILECTRA Metropolitana were compared to those at PGandE. The advent and implications of CDEC for the distribution companies were discussed.

This meeting also offered an opportunity to explore issues in the training and formation of engineers in the Chilean utility industry. The basic educational system for engineers and the opportunities for further education in industry were described. The challenges of attracting excellent and competent engineers to the utility industry were a major focus of our discussions.

3.6 Universidad de Chile (U de C)

The Universidad de Chile is one of the principal players in the UNIDO-sponsored Project. An afternoon was spent at the university to become acquainted with the research topics currently under investigation. Professor Oscar Moya hosted the presentation. Two of Professor Moya's

advisees, Luis Valenzuela and Luis Vargas who recently joined the U de C's faculty, also participated.

Luis Vargas presented some of the research work on real-time security enhancement. This work is based on the use of linear models. Some good physically-based intuition is used to derive simplified models for the evaluation of losses in the system and for the improvement of static security. Luis Vargas presented some results on small test systems to indicate the effectiveness of the methodologies he developed.

Luis Valenzuela discussed the problem of short-term scheduling with the uncertainty in hydro taken into consideration. He presented a Markov chain-based model for stochastic optimization to evaluate the optimal schedule of the power system taking into account the stochasticity in the hydrology. This appears to be a very promising approach since the uncertainty in the hydro generation is explicitly considered. The stochastic dynamic programming approach will be useful if the state space can be constrained sufficiently to avoid the 'curse of dimensionality.'

Professor Moya also discussed some of the other work in the Electrical Engineering Department at U de C. Some of the other research projects currently under investigation are:

- . Dynamic Security Determination
- . Economic Dispatch for Systems with Distributed Loads
- . Optimal Generation Allocation for Systems with Interchange
- . Load Modeling

Digital Relay Protection

This meeting afforded an opportunity to obtain a feeling for the nature of the undergraduate and graduate programs at U de C. Topics covered included the faculty and their interests, the composition of the student body, and the curriculum. During the visit the author had several additional opportunities to meet and discuss at greater length both research topics and educational issues with Oscar Moya, Luis Vargas, and Luis Valenzuela.

3.7 Universidad Catolica de Chile (UC)

The visit to Chile was hosted by Professors Hugh Rudnick and Sebastian Rios, Chairman and faculty member, respectively, of the Electrical Engineering Department at UC. Many meetings were held with them, other faculty members, and students at which research subjects, educational issues, and particularly topics specifically related to utility planning and operation in Chile were discussed at length. The author visited the laboratories of the Department and the UC Library and reviewed the curriculum of the undergraduate program. In addition there was an opportunity to meet most of the Electrical Engineering Faculty, the Systems Engineering Faculty, the Dean of the Engineering School at UC, several other faculty members, current students and former graduates. Through these meetings it was possible to obtain a good understanding of the educational system for engineers, the research work on power systems, and the cooperative efforts with the Chilean utility industry.

Many of the research projects underway as part of the UNIDO-sponsored work were reviewed. The presentations by the students working with Professors

Rudnick and Rios and my discussions with them afforded an opportunity to become familiar with certain aspects of their work. The work encompasses a broad range of topics in the power systems area.

One of the early projects was in the area of short-term load forecasting. A relatively thorough review of the state-of-the-art in short-term load forecasting was performed. The researchers developed a data base of hourly loads and weather (temperature) data and a time series (Box-Jenkins) based forecasting methodology for the Santiago metropolitan region. In collaboration with CHILECTSA Generacion, the methodology was applied to that utility's system.

The work on unit commitment and economic dispatch for the Northern Interconnected System SING was described. For this principally thermal system with approximately 25 generating units, the UC researchers developed a Lagrangian Relaxation-based methodology. The approach is capable of handling the various system-wide and unit specific constraints.

A current research project is concerned with the identification of the parameters of a voltage regulator of an actual generating unit. The approach to this problem using frequency response and time response techniques was described. A microcomputer will be used for real-time data acquisition. Measurements will be taken under actual operating conditions.

The other research presentations were concerned with transient stability and reactive power problems. One of the students is doing research on the application of direct methods of the Lyapunov-type (energy functions) for sta-

bility evaluation. Another research project recently begun is concerned with the evaluation of reactive power needs in the CHILECTRA Generacion network. The scope of the project was outlined.

Some of the time in the meetings was spent with a review of all previous activities on the UNIDO project. In addition to the research work, the equipment acquired with UNIDO funds and its applications was reviewed, the set of specialized courses presented by the previous visitors under the auspices of the UNIP) project, the increased cooperation with the Chilean utilities and government, and some of the future work. Professors Rudnick and Rios were particularly successful in putting these various elements into an integrated whole to support the objectives of the UNIDO project.

In the meetings with the Faculty of the Departments of Electrical Engineering and Systems Engineering, the author was able to get a good appreciation of the courses they offered, their research efforts, and cooperation with industry and government. There is a strong affinity between the two departments because of the strong systems orientation of the Electrical Engineering Department. In the meeting with the Systems Engineering Department, the Chairman, Professor Pedro Gazmuri and the faculty members, Professors Luis Contesse, Gonzalo Cortazar, Raul Espinosa and Jose Robles, described in detail the spectrum of activities of this small but important department. It was very encouraging to learn that both departments have good cooperation with industry and government. This is an important factor for making the educational process more relevant to the student engineers.

3.8 Universidad Tecnica Federico Santa Maria (UTFSM)

A half day was spent to visit UTFSM in Valparaiso. The principal objective was to give a presentation to students and faculty. A brief overview of the PG and E system was presented at a seminar at UTFSM. Discussions were focussed on the characteristics of PGandE's electric system, the nature of its generation resource mix, the transmission network, and some important operational characteristics. Several students and Professor Julian Bustos and Nelson Leiva attended.

From the discussions with Professor Bustos and Leiva, the author obtained a good picture of the program at UTFSM. They described the various projects in which their students were involved. Plans were also discussed for a course on distribution system planning that Professor Bustos is organizing as part of the UNIDO project. A number of recommendations were made concerning the topics that should be covered in such a course.

4. THE COURSE

A course of 25 lecture hours was given to over 50 participants from Chilean universities and utilities. The course was entitled "Curso de Perfeccionamiento 'Planificacion y Operacion Economica de Sistemas de Potencia'." The course was given during the mornings on the week of December 15-19 with lectures held from 8:30 - 13:30. The list of participants is given in Appendix B.

The course was divided into two principal sections (Operations and Planning) and was started with an overview of the PG and E system including a description of the resource mix, the transmission system, the distribution network, and the control center. Furthermore, outlines were given concerning the plans for the new PG and E Energy Management System (EMS) and the major features of the system. This lecture was concluded with a discussion of some of the major operational problems facing a major utility such as PG and E.

Next, the author presented the framework for the following five topics within the application software for modern control centers. The major components of the application software system and their inter-relationships were described. The five topics covered in lectures on operations are given below:

1. Short-Term Load Forecasting (STLF)

- . Definition
- . Role in the EMS Environment
- . Nature of System Load
- . Classification of STLF Procedures
- . Model Selection and Formulation
- . Forecasting Algorithms
- . Parameter Estimation
- . STLF Implementation Aspects

2. Unit Commitment

- . Problem Statement
- . Thermal System Description
- . Problem Formulation
- . Heuristic Approaches
- . Dynamic Programming Based Approaches
- . Mixed Integer Linear Programming Formulation
- . Lagrangean Relaxation

3. Hydro Scheduling

- . Problem Statement and Description
- . Hydro System Components
- . Hydro Scheduling Problem Formulation
- . Solution Approach
- . Major Applications
- . Literature Review

4. Hydro-Thermal Coordination

- . Problem Statement
- . Thermal System
- . Hydro System
- . Interchange Transactions
- . Energy Storage Plants
- . Classical Approach and Extensions

- . Integrated Approach
- . Lagrangean Relaxation

5. Optimization/Economic Dispatch/Optional Power Flow (OPF)

- . Optimization Problems
- . Linear Programming
- . Nonlinear Programming
- . Economic Dispatch
- . OPF Problem Formulation
- . OPF Solution Approaches
- . OPF Applications in the PMS

These five lectures and the introductory PGandE overview lecture were given on Monday, Tuesday, and Wednesday. On Thursday and Friday the lectures on Resource Planning were presented. The four topics covered and their contents were:

1. Reliability Evaluation

- . The Role of Reliability in Resource Planning
- . Reliability Indices: Loss of Load Expectation (LOLE), Loss of Load Probability (LOLP), Expected Unserved Energy
- . Reliability Criteria
- . Computational Methods
- . Interpretation of Results: Effect of Input Data Load

- . **Assessment of Demand Management Programs**

 - Load Carrying Capability and Equivalent Capacity Concepts**

- . **Reliability Economics**

 - Worth of Reliability**

 - Outage Costs**

2. Production Costing

- . **Deterministic Production Costing**

- . **Probabilistic Simulation for Production Costing**

 - System Load Representation**

 - Simplified Supply System Representation**

 - Evaluation of Expected Values of Energy and Cost; Reliability**

 - Indices**

 - Representation of Thermal Unit Operating Constraints**

 - Hydro and Energy Storage Units**

 - Nondispatchable Generation Sources**

 - Demand Management Programs**

 - Sample Calculations**

- . **Computational Techniques for Production Costing**

 - Piecewise Linear Approximation**

 - Method of Cumulants**

 - Mixture of Normals Approximation**

- . **Multi-Area Production Costing Software Packages for Mainframe and**

 - Desktop Computers**

3. Marginal Costing

- . Definitions of Marginal Costs for Energy and Capacity
- . Evaluation of Marginal Costs
- . Sample Calculations

4. Supply-Side Planning

- . Basic Principles
- . Characterization of Supply-Side Options
- . Optimal Resource Mix Determination: The Screening Curve Technique
- . Framework for the Evaluation of Supply-Side Alternatives
 - Generation Expansion Problem Formulation
 - Objectives and Constraints
 - Solution Methodologies: Assumptions, Computational Requirements, Limitations
- . Analytical Techniques: Linear-, Dynamic-, and Nonlinear-Programming Approaches
- . Software Packages for Mainframe and Desktop Computers

The material covered in the five days of lectures was collected by Professor H. Rudnick and published in a two-volume set. Each course participant was given a copy of the two-volume set. Additional copies may be obtained from Professor Rudnick. Appendix C reproduces the front pages of the 2-volume set.

The lectures provided ample opportunity for participants to ask questions. The large number of questions served to clarify several issues. The many good questions were instrumental in making the course useful to the participants.

5. FINDINGS

This technical visit afforded an opportunity to become acquainted with the key players and principal aspects of the UNIDO-sponsored Optimization of the Electric Power System Project. This ambitious undertaking is an important first project of this nature for Chile. This constitutes the first instance that the UN organization has sponsored a project which adopts a systems point of view. By focusing on the critically important area of system optimization, the Project is providing an appropriate framework for the study of the economic operation and effective planning of the Chilean electric energy system. UNIDO deserves congratulations for its farsightedness in supporting such a valuable undertaking.

Findings are grouped into the five areas below.

5.1 Project Benefits

The benefits of the Project are significant, particularly for a developing nation such as Chile. Overall, the Project delivers some useful tools for immediate application by the utility industry and builds up an important body of knowledge for the country. The Project has made valuable technology transfer to the utilities through two principal routes: the research results of

the university investigators and the visits of technical experts. The research activities within the Project framework have resulted in a number of applications that are beneficial for the utilities. These include a Short-Term Load Forecasting Methodology and a Loss Evaluation Program. Moreover, the Project engendered a healthy research atmosphere in several areas, all of potential usefulness to the utility. Particularly worthwhile are the research efforts on system security, economic dispatch, reactive power allocation, protective relaying, and identification. The collaborative efforts of the university-industry engineers throughout this project created considerably stronger university-utility ties in Chile. I believe this result is most important. The practical experience to which the university researchers were exposed will be passed on to the students at universities. The new ideas to which utility engineers were exposed should enhance their productivity. Through the improved relations better focused training for future utility engineers will result. Also, the framework for research that is practically oriented and useful has been established. For a technological industry which the electric energy industry is, it is of paramount importance to have strong university ties to ensure a continuous infusion of new ideas and fresh talent. Moreover, the existing personnel needs continuous updating of its technical knowledge. The strong university-utility ties established as part of the Project ensure that these objectives can be accomplished.

5.2 Project Assessment

The Project is a well thought-out undertaking. It is an imaginative collection of activities which support the central theme of economic operation of the Chilean utility system. The involvement of three principal sectors of the

energy area--utilities, universities, and the CNE--is a key ingredient for its success. Hugh Rudnick skillfully handled the challenging task of coordinating the various activities at the participating universities and utilities. Given the many pitfalls possible, when the multitude of activities and the large number of players are considered, Professor Rudnick was able to get the Project off the ground and steered its smooth operation without any problems - undoubtedly, a most impressive achievement.

5.3 Professionalism

A most interesting finding of the visit was the high respect and widespread use of operations research/management sciences/systems engineering methodologies and techniques throughout Chile. This fact ties in well with the general systems nature of the UNIDO Project. The prevalence of the systems approach in the university-utilities and as a basis for government policy is highly impressive. The author was surprised to find the strong consideration given to uncertainty in the analytic work of the utility engineers. The strong familiarity with probabilistic methodology and optimization techniques is very refreshing. In general, the author was deeply impressed by the Chilean engineers' technical competence and their high degree of professionalism. This must be the result of the strong engineering educational system in the nation's universities.

5.4 Timeliness

The Project is very timely in light of the new developments in Chile's economy. The research and training activities tie in well with the establishment of CDEC, the push toward privatization in the utility industry

by the government and the resulting environment of competition in energy markets. The current atmosphere has pointed out specific areas to which the universities can make useful contributions.

5.5 Technical Issues

From discussions at the various utilities, universities, and CNE, it became evident that there are several issues of a technical nature that require attention. In view of the establishment of CDEC, a principal activity of interest is wheeling. There is a need to establish a methodology for costing wheeling transactions on an equitable basis between participating utilities. The area of reactive power requires attention. Issues such as allocation of reactive sources, reactive dispatch, and capacitor placement must be investigated. The whole area of Control Center software applications must be revisited. The ENDESA Control Center has relatively limited applications software capabilities. For example, the feasibility of developing a hydro thermal coordination package operating in an on-line environment should be investigated. Such a tool would have many uses for off-line applications in operational planning. The utilities have no optimal power flows for either the planning or the operating environment. Such tools are important to evaluate losses, to study wheeling costs, and to securely operate the network.

6. RECOMMENDATIONS

The strong momentum for power system research and university-utility cooperation built up as a result of the UNIDO Project should be kept alive by ensuring that efforts in these directions will continue. Such future efforts

will ensure that the UNIDO Project is not an isolated initiative for fostering an atmosphere for imaginative energy system engineering work and close university-industry ties. The Chilean government, the utilities and the universities all have a role to play in ensuring that technological development can be facilitated, transfer of technology can be continued and postgraduate training of energy system engineers will be available. These players should seize the opportunity to embark on additional collaborative efforts which build on the strong ties established as a result of this UNIDO Project.

All the countries in the world, including developing nations such as Chile, must strive to improve productivity. One way to do that in the energy area could be to pursue aggressively interconnections with neighboring countries. While the political problems to be solved are rather monumental, the economic benefits of interchanges with systems in neighboring countries are very substantial. Such interchanges would take advantage of load diversity and improve reliable and economic operation. All efforts in support of interconnected operations deserve support.

Another area that should be studied is the possibility of pooling resources for establishing a South American or, somewhat less ambitiously, a multi-national South American energy research institute. This could allow the leveraging of each country's research money for an area of vital importance for its economic development. Each country would undertake research work in specific areas of expertise. As a result, such a multi-national institute would bring focus to the research activities of the Chilean universities and utilities in the energy area.

The South American market for utility activities is a relatively large one. There are some basic tools which all utilities require. Yet, so far there have been no major efforts aimed at tapping this market. The area of software development in which both the Chilean utilities and universities possess considerable expertise, is one which should be explored. Some generic energy system software can be developed and marketed on, practically, a continent-wide basis. This is particularly true if there are good manuals and user friendly instructions in Spanish.

A principal direction for future research at the university level should be one of focusing their strengths into a narrower scope of activities. It is understandable that the universities today must provide research activity in a very wide range of specialties because of the existing structure of the energy industry. However, it would be decidedly better if the universities would focus their efforts on a narrower range to become continent-wide experts in those areas.

Several topics may be recommended for further research to be undertaken as inter-university and utility-university collaborative efforts. For example, there are several topics which would benefit from a multi-disciplinary effort. The area of long-run marginal costs should be investigated in a joint engineering school-business administration/economics school effort. The entire area of privatization in the energy industry in general and wheeling issues in particular would also benefit from such efforts. In the more technical scheme of things, a multi-university-utility effort to look at distribution system planning, distribution automation, and improvement of distribution reliability is a project which could bring very substantial benefits. Other areas requir-

ing research include reactive power planning and operation, incorporation of uncertainty in mid-term planning models, hydro-thermal coordination and optimal power flows. There is also the need to bring into more widespread use the new technology in computing equipment. Universities and utilities should undertake a cooperative effort to investigate useful applications of microcomputer and mini-supercomputer technology.

To encourage closer university-utility ties, the institution of sabbatical leaves should be investigated. The internship of university faculty at utilities would bring about very substantial benefits. The faculty members would be exposed to real problems and would acquire valuable utility experience. The experience assimilated would be reflected in their teaching and research back at the university. This will result in enriching the education of future engineers. Similarly, utility engineers on leave to universities would refresh their technical skills and bring back the newest in technology to the utility. Such arrangements in North America have been very beneficial.

In summary, the substantial progress made so far through this UNIDO Project should be continued by undertaking additional projects of the nature described above. Such follow-on efforts will ensure that the stream of beneficial achievements to universities, utilities, and the nation will continue in the future.

Program for the Technical
Visit.

**UNIVERSIDAD CATOLICA DE CHILE
DEPARTAMENTO DE INGENIERIA ELECTRICA
ELECTRICAL POWER SYSTEMS GROUP**

**PROGRAM FOR THE VISIT OF DR. GEORGE GROSS
DECEMBER 1986
PROJECT UNIDO CHI/84/008**

**Visit Coordinators: Hugh Rudnick (telephone: office 5550058/4289,
home 2255207)
Sebastián Ríos (telephone: office 5550058/4288,
home 498108)**

**ACCOMMODATION: Avda. 11 de Septiembre 2211, Depto. 806,
Teléfono 2325656**

ACTIVITIES:

DATE	ACTIVITY
DEC 5	Arrival to Santiago. Flight Pan Am 209. Reception by H. Rudnick and S. Ríos. Transport to hotel. 20:00 Meeting at hotel with S. Ríos and H. Rudnick for program revision and general information. Invitation to dinner at a typical restaurant.
DEC 6	Tour of Santiago and surroundings with H. Rudnick
DEC 7	Tour to Viña del Mar and surroundings with S. Ríos
DEC 8	14:00 Meeting at U. Católica. Discussion on course structure and notes
DEC 9	10:00 Visit to UNIDO to collect money for local expenses Introduction to UNIDO project at Universidad Católica Lunch at U. Católica with lecturers of EE Dept. 14:00 Description of research activities at Universidad de Chile, Dr. Oscar Moya
DEC 10	09:00 Meeting at Endesa. Visit to National Control Center. Description of Endesa's activities. Description of PG&E activities. 14:00 Meeting at U. Católica. Lecture preparation.

- DEC 11** 9:00 Meeting with lecturers of Systems Dept. at U. Católica
15:00 Meeting at Chilectra Generación. Description of activities and problems of Operation's Department. Discussion on CDEC development
- DEC 12** 11:00 Meeting at Comisión Nacional de Energía. Discussion on CDEC developments.
16:00 Lecture at Universidad Técnica Federico Santa María, Valparaíso.
- DEC 13**
- DEC 14** 18:00 Meeting with Course Translators
- DEC 15** 08:30-13:00 Lectures at U. Católica
14:00-17:00 Lecture preparation at U. Católica
- DEC 16** 08:30-13:00 Lectures at U. Católica
14:00-17:00 Meeting at Endesa, Operations Department.
Lecture preparation.
- DEC 17** 08:30-13:00 Lectures at U. Católica
14:00-17:00 Description of research activities at U. Católica.
- DEC 18** 08:30-13:00 Lectures at U. Católica
14:00-17:00 Discussion of Chilectra Generación activities with U. Católica
18:00 Meeting with Dr. Bruno Philippi, Government Expert on Foreign Investments
- DEC 19** 08:30-13:00 Lectures at U. Católica
14:00-17:00 Meeting at U. Católica
19:00 Meeting with Chilectra Metropolitana engineers.
- DEC 20** 20:00 Invitation to dinner by the Rudnick family.
- DEC 21**
- DEC 22** 9:00-13:00 Meeting with researchers. Development of framework for additional research.
14:00-17:00 Development of framework for additional research.
- DEC 23** Preparation of final report. Review of dispatch algorithms.
Review of wheeling issues.
- DEC 24** Preparation of final report. Review of reactive power dispatch problem and placing of capacitors.
- DEC 25** -
- DEC 26** 9.00 - 13.00 Final meeting with researchers. Review of findings
Plans for future cooperation.



Pontificia Universidad Católica de Chile
Escuela de Ingeniería
Departamento de Ingeniería Eléctrica

List of Participants at the
Course.

PROYECTO PNUD/ONUDI/CHI/84/008

**CURSO DE PERFECCIONAMIENTO
"PLANIFICACION Y OPERACION ECONOMICA DE SISTEMAS DE
POTENCIA"**

**Dr. GEORGE GROSS
Pacific Gas & Electric Company
15-19 Diciembre 1986**

NOMINA ALUMNOS

Empresa: ENDESA

1. Esteban Skoknic C.
2. Pedro Gatica Kerr
3. Eduardo Calderón A.
4. Edgardo Fuchs
5. Miguel Vergara
6. Patricio Caro
7. Andrés Tirapegui
8. Rodrigo Chamorro
9. Julio Guzmán
10. Claudio Betti Pruzzo
11. Boris Muñoz Gebert
12. Eduardo Valenzuela Acuña
13. Vicente Villaseca Villalobos
15. Jaime Margarit Pineda
16. Luis Fredes Bastías

Empresa : CHILECTRA GENERACION

1. Juan Cembrano P.
2. Francisco Aedo M.
3. Alberto Ugalde A.
4. Juan Eduardo Vásquez M.
5. Ignacio Alarcón A.
6. Juan R. Inostroza López
7. Federico Sobarzo L.

Empresa: EDELNOR

1. Fernando Araya V.
2. Eduardo Villalobos Abad

Empresa: CODELCO - EL TENIENTE

1. Jorge Umaña Saavedra

Empresa: CHILECTRA METROPOLITANA

1. Hector Carrasco M.
2. Miguel del Valle B.
3. Victor Santis P.
4. Sergio Aguirre Ruiz
5. Guillermo Pérez del Río

Empresa: COLBUN MACHICURA

1. Alfredo Illanes Díaz
2. Juan C. Olmedo Hidalgo
3. José Rogers Squella
4. Eduardo Ricke Muñoz
5. Alejandro Artus Borquez

Universidad: U. DE ANTOFAGASTA

1. Victor Fuentes Morales

Universidad: U DE SANTIAGO

1. Juan zolezzi Cid

Universidad: UTFSM

1. Nelson Leiva
2. Julián Bustos
3. Luis Beltrán (alumno)
4. Claudio de la Jara (alumno)

Universidad: U DE CHILE

1. Luis Valenzuela
2. Luis Vargas
3. Alvaro Ferra (alumno)
4. Enzo Quezada (alumno)

Universidad: U. CATOLICA

- 1.-Sebastián Ríos
- 2.-Hugh Rudnick
- 3.-Arturo Bentjerodt
- 4.- Celso González (alumno)
- 5.-Fernando Urrutia (alumno)
- 6.-Marco Arróspide (alumno)
- 7.-Enrique Arenas (alumno)
- 8.-Francisco Ovalle (alumno)
- 9.-Alfonso Mejía (alumno)
- 10.-José Flores (alumno)



Pontificia Universidad Católica de Chile
Escuela de Ingeniería
Departamento de Ingeniería Eléctrica

Cover pages of the
Two-Volume Course
Publication

PLANIFICACION Y OPERACION ECONOMICA DE SISTEMAS DE POTENCIA

VOLUMEN I -OPERACION ECONOMICA

George Gross
PACIFIC GAS & ELECTRIC COMPANY

**Curso de Perfeccionamiento
Proyecto Optimización de los Sistemas de Energía Eléctrica
Programa de las Naciones Unidas para el Desarrollo
Organización de las Naciones Unidas para el Desarrollo Industrial**

DICIEMBRE 1986



Pontificia Universidad Católica de Chile
Escuela de Ingeniería
Departamento de Ingeniería Eléctrica

PLANIFICACION Y OPERACION ECONOMICA DE SISTEMAS DE POTENCIA

VOLUMEN II -PLANIFICACION ECONOMICA

George Gross
PACIFIC GAS & ELECTRIC COMPANY

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