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Ch. 13 - The Colombian Transmission Interconnection

1971

CHAPTER XIII - THE COLOMBIAN TRANSMISSION INTERCONNECTION

I. The Preliminary Phase (1962-67)

1.01 Interconnection among the major power markets in the heart of the country has been the keystone of the Bank's operations in the power sector of Colombia over the last decade. Back in 1950 the Bank-sponsored General Survey Mission had recommended preparation of plans for interconnecting the major sources and markets for power "as rapidly and economically as feasible, with the eventual goal of establishing a national grid." However, the idea of interconnection remained dormant until the early 1960s when it became apparent that the four main systems, which had received previous Bank assistance, were approaching a size which would make interconnection and integrated operation essential if an economic path of system expansion were to be followed. Most of the smaller economic generating sites had already been developed or were then being developed. Foreseeable future individual developments in each region were generally large in comparison to local market requirements and an obvious case seemed to exist for their cooperative exploitation in the context of a larger, interconnected market. The National Electrification Plan prepared by Electricite de France in 1964 strongly recommended the early interconnection of the main power markets of the country.

1.02 At the beginning of 1963, the Bank took three important decisions which were later to affect its policies vis-a-vis the entire power sector in Colombia: (a) the need and justification for interconnecting the principal systems in Colombia should be studied by Bank staff in connection with the appraisal of power projects to be financed by the Bank; (b) the

study of interconnection should be made an integral part of the appraisal of the Guatape project then under consideration; (c) if an interconnection would make the Calima II project of CVC superfluous, the Bank would not finance it.

1.03 As a result of the Bank's stand EEEB, EPM and CVC/CHIDRAL decided to call a meeting, which they duly held in March 1963. There they took the first steps toward interconnection by deciding to jointly employ the two leading Colombian engineering firms, Ingetec of Bogota and Integral from Medellin, to make a study of the technical and economic merits of interconnecting their systems. In a letter to the Bank dated May 1963, the General Managers of EEEB, EPM and CVC expressed "wholehearted" agreement on the principle of interconnecting their systems and indicated their willingness to take further steps in that direction if the conclusions reached by the consultants were favorable to the concept.

1.04 An important meeting of the group was held on September 19, 1963, which was attended by Bank staff members. During the meeting Ingetec and Integral presented the conclusions of their preliminary investigations, which indicated important economic advantages to interconnection; and they stressed the necessity of selecting a suitable program for the lay-out of the proposed system. With a view to providing an adequate institutional set-up for the formulation of such a program, EEEB, EPM, and CVC elected a "Comite de Interconexion". The Bank mission which participated in the meeting insisted that consulting firms more specialized than Ingetec and Integral should be hired to carry out the necessary studies. Although with some reluctance, the "Comite de Interconexion"

decided to recommend award of the contract for technical studies to the IIMA consulting group, a joint venture of Merz-McClellan from England with Ingetec and Integral; the firm of International Middle West Service of Chicago was offered that part of the feasibility study dealing with the organizational and administrative aspects of interconnection.

1.05 In February of 1964, the Bank extended a US$ 45 million loan to EPM for the construction of the Guatape hydroelectric project as discussed in Chapter XI. The project was considered justified on the basis of both the expected future power demand of the Medellin market alone and of the interconnected system as a whole. At that time, although the interconnection studies mentioned earlier had not yet been completed, there seemed little doubt that Guatape was probably the best project to meet the anticipated requirements for integrated operations.

1.06 In spite of the initial optimism expressed by the managers of the three main power companies, later divergences of views slowed down the work of International Middle West and would probably have brought to nought any agreement on interconnection had the Bank not repeatedly made clear the principal elements of its policy on the subject. During processing of the Guatape loan, the Bank indicated that, in view of the savings to be achieved through interconnection, it would not consider further lending to Colombia for electric power until satisfactory steps had been taken towards interconnecting the four principal systems. On this basis, the Bank deferred consideration of several power projects, (including Calima II), for which CVC had requested financial assistance.

1.07 While the benefits of interconnection were viewed by the Bank through the prism of Colombian national interest and within the broad

context of the power sector as a whole, the negotiators on behalf of the three major power companies had quite different interests which they sought to preserve and were strongly motivated by the regionalistic nature of their operations, by local political conditions and financial considerations. On the whole, EEEB displayed more good will than the other two partners; this is undoubtedly linked with the fact that Bogota has traditionally been more nationally oriented than any other city in Colombia; also, in view of the relative characteristics of the various systems, energy trade-offs between Bogota and the other two power markets were likely to balance out in case interconnection was to materialize.

1.08 At an early stage of negotiations, CVC had adopted a cautious position; its service area was bound to be the first to incur power shortages should Calima II be postponed in favor of early interconnection, and the Cauca Valley would always be on the receiving end of the line: a serious deficiency in CVC's power supply was expected to appear at the beginning of 1967 and the Company expressed doubts whether interconnection would be operative by 1967 as envisioned by the Bank. Furthermore, CVC pointed out that the postponement of Calima II would commit them to interconnection in advance of the organizational, financial and technical studies that were yet to be made, placing them in a weak bargaining position for negotiations with EEEB and EPM, neither of which would have any immediate problems in meeting their demand should interconnection be delayed. Although the Bank was generally sympathetic to the plight of CVC, it was of the opinion that acceptance of Calima II for immediate construction would cause interest in interconnection to wane[1]; the

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1/ Besides, the Bank did not view Calima II as the best plant in the context of interconnection.

strategy of the Bank was to act on the assumption that, without the threat of a power shortage, the companies involved in the negotiation would never reach an agreement.

1.09 Throughout the negotiation period, the position of EPM was very much parochial and regionalistic. EPM insisted that it had the best hydraulic resources in the country, and hence, the cheapest power. The idea of submitting these resources to the country through interconnection was popular neither among local politicians nor among the population itself, particularly in view of the fact that such a measure was likely to raise the cost of power to the consumer. Medellin also feared that exporting power might lead to industrialization of other regions at its expense and EPM was against an entity in Bogota over which the Central Government would have major influence. Yet, EPM decided to join the negotiations rather than risk the creation of an organization which it would be forced by events to join, and because the company hoped that the Bank would finance Guatape I. As pointed out, the Bank did agree in early 1964 to finance the project and it appears that, by doing so, the Bank may have lessened EPM's interest in interconnection as well as hardened CVC's position. If the Bank had not accepted the project so readily in 1964, progress on the interconnection negotiations would probably have been more rapid: it is quite unlikely that interconnection would have materialized by 1967, but it might at least have been realized by 1970[1/], or perhaps even somewhat earlier, in view of threatening power shortages.

1/ Instead of 1971 as actually occurred.

1.10 Electraguas had played little or no part in the early discussions. The first proposal for it to join the "Comite de Interconexion" came in late 1964 from a member of the Committee. As a result of the increased interest expressed by the Government for the idea of interconnection, Electraguas decided to join, through the participation of CHEC, as a fourth partner in the negotiations. The interconnection concept gained momentum when the general managers of the sponsoring power companies decided to take over the negotiations from their technical staff who had no authority to make decisions. An executive secretary was chosen for the "Comite de Interconexion" and information on interconnection was made public for the first time on November 24, 1964.

1.11 As a result of the increasing pressures exercised by the Government and the Bank as well as the submission in the summer of 1965 of the studies prepared by Middle West International and IIMA, negotiations on interconnection again started to move ahead. In August 1965, the four power companies involved agreed in substance to adopt the alternative recommended by Middle West, which called for the formation of a separate generation and transmission company to own and operate the proposed interconnecting transmission system as well as all new major power generating facilities. It was also decided that the four sponsors would share in the ownership of the new company in the proportion of 25 percent each. The pivotal issue was still the definition of a "new" plant, the case in point being the second stage of Guatape. EPM argued that the second stage of Guatape was physically inseparable from Guatape I and that it would be politically and emotionally impossible for the people of Medellin to consider outside control of part of the scheme. CVC,

adopting again a cautious position, insisted on common ownership of the new plants and expressed its apprehension that power supply contracts between parties involved in the interconnection would not be honored should energy available in the interconnected system become insufficient to meet aggregate demand.

1.12 There was still a latent feeling of distrust among the four sponsoring power companies, sharpened by the financial difficulties each of them had been experiencing. In view of the inability to reach an agreement three years after the start of the negotiations, and with a view to resolving the deadlock, the Bank sent a mission to Colombia in February 1966 and, in April of the same year, suggested that the Government should appoint a coordinator who could propose a solution acceptable to the parties. Actual resumption of negotiations was the result of the pressure exercised by the newly elected President; an agreement on principles was finally reached and the Interconnection Agreement was signed on November 8, 1966 in the presence of the President, who himself acted as a witness.

1.13 In spite of this important step forward, the creation of the institution that would embody the broad principles of the agreement was difficult. The main problems were the appointment of a general manager who would be acceptable to all partners, and still the exact meaning to be assigned to the expression "new plant". The Bank, for its part, indicated its willingness to consider financing the interconnection project provided that the company be legally constituted in accordance with Colombian law, a general manager appointed and a firm financial plan drawn up for each

sponsoring company. Without these demands being met, the Bank would not finance any project associated with interconnection, nor, indeed, with any of the sponsoring companies. It turned down requests from EEEB and CVC for plant financing.

1.14 For a number of reasons (such as the difficulty of reaching a final agreement on the appointment of a General Manager and the general unfamiliarity of the Committee with a type of concept they were facing for the first time), it was not until September 1967, that the new company was finally formed under the name of Interconexion Electrica S.A. (ISA).

II. Organization and Policies of ISA

2.01 ISA is a stock corporation under Colombian commercial law wholly owned by EEEB, EPM, CVC/CHIDRAL, ICEL, and CHEC. The authorized capital is represented by 2,000 shares with a nominal value of Ps. 100,000 each. The founding members have subscribed and paid for in Colombian currency 200 shares representing a total of Ps. 20 million, distributed as follows:

- EEEB: 50 shares
- EPM: 50 shares
- CVC: 49 shares
- CHIDRAL: 1 share
- ICEL: 49 shares
- CHEC: 1 share

Since CVC is the major owner of CHIDRAL and CHEC is a subsidiary of ICEL, it is considered that ISA's sponsors are EEEB, EPM, CVC/CHIDRAL and ICEL/CHEC, each being represented on ISA's four member Board of Directors.

2.02 ISA is administered by the General Assembly of Shareholders, the Board of Directors and the General Manager. The General Assembly elects for one year the Board's four members, who may be reelected. The chairmanship of the Board rotates among the members, thus emphasizing their equal status. The Board appoints for two years the General Manager and his two Deputies (Administrative and Technical) who may be reappointed indefinitely. The resolutions of the General Assembly or the Board are respectively adopted by the favorable vote of at least 75% of shares or 3 of its 4 members. The General Manager is ISA's legal representative for all the Company's commitments; all the employees of ISA are subordinate to him, except for the "Revisor Fiscal", an internal auditor elected by and responsible solely to the shareholders.

2.03 ISA's statutory purposes are the interconnection of the sponsors' electric systems and the planning, construction, ownership and operation of new power generating plants within the interconnected system. All major generation projects in the system were to be built by ISA, with the exception of the plants under construction or already at a stage of advanced planning in 1967, which were expected to be completed and wholly owned by the respective sponsors. These were:

Table 13.1: Central Interconnected System - Plants Under Construction or at a Stage of Advanced Planning in 1967

Company	Plant	Capacity (MW)[a/]
EEEB	El Colegio	300
EEEB	Canoas [b/]	50
EEEB	Alto Muna[b/]	n. a.
EPM	Guatape I, II	544
CVC/CHIDRAL	Calima I	120
CHEC	San Francisco	135

a/ Figures on installed capacity correspond to actual values and differ from values forecast in 1967.
b/ This plant never materialized.

CVC/CHIDRAL reserved the option to build and own Alto Anchicaya (340 MW) and has exercised it since.

2.04 ISA is endowed with broad corporate powers, including those of entering into contracts in general and contracting debts. The statutes outline the procedures for financing the Company's investments and guiding its operations, differentiating between the interconnection network and the generating plants; in both cases, it was contemplated that the foreign exchange component of the investments would be financed through external loans. It was established that, in return for ISA shares, the four sponsors would provide in equal parts the necessary local funds to finance the interconnection network and would be guarantors of credits and loans secured by ISA. The agreed upon procedure regarding the financing of ISA's generating plants is more complicated: 40% of the Peso expenditures are to be covered by the subscription of ISA stock in equal parts by the four sponsors and 60% by bond sales to the sponsors in the proportions necessary to have each sponsor's total contribution proportional to his agreed share of the output of the plant.

2.05 ISA was conceived as a company without profits at the transitional stage: it would buy the excess energy generated by some of the member companies and sell it to other member companies having excess demands by charging administrative and operating costs to the shareholders. Such costs, excluding those for depreciation, were to be shared by the co-sponsors in proportion to their relative annual contribution to total energy sales in the four interconnected markets together, exclusive of

energy sold through interconnection. Annual depreciation costs, on the other hand, were to be covered in equal parts by the four members. This transitional arrangement is expected to remain in force until the individual member companies have no more energy to spare and ISA has developed its own generation activities within the interconnected system. In other words, it was recognized that ISA's autonomy might be somewhat limited in the early years of operation and that its financial viability would depend upon the financial contributions of its sponsors; it would not achieve financial returns at levels normally considered satisfactory until after it owned generating facilities, but, from then on, its operations would be carried out on a conventional financial basis.

2.06 The Bank had a chance to review the statutes of ISA, and, save for a few suggestions which were accepted by the Colombians, the by-laws of the company remained basically unchanged. A very serious problem which still remains to be solved is the trading price of power and the levy ISA should charge for services it renders. ISA agreed, in connection with Loan 575-CO for Interconexion, that a methodology should be devised to determine tariffs for energy transfers, taking into account the lack of uniformity in accounting methods among the sponsors and the different values of the various classes of energy generated. The study, which is currently being carried out by the Swiss firm of Motor Columbus, with part of the proceeds of the first Bank loan to ISA, will make technical and financial recommendations regarding the manner in which to operate the system so as to assure a satisfactory rate of return to ISA. The study was scheduled for completion by the end of 1970, but was delayed because difficulties arose in connection with the valuation of the assets

of ICEL and CVC/CHIDRAL; the first part of the study (pricing of energy interchanges) has just been submitted to ISA's Board for consideration, in time for tariffs to be established and ISA's statutes amended accordingly before the interconnection network starts operation. The Bank will have an opportunity to approve the proposed revisions before these are adopted.

III. Bank Loans to ISA

Loan 575-CO - Interconnection Network

3.01 By the spring of 1968, the three main conditions to Bank lending to ISA had been fulfilled: a new company had been formed, a general manager had been appointed and a viable financial plan had been drawn up. Nomination of the General Manager proved to be an especially difficult issue which eventually led to several deadlocks in the negotiations between the shareholders; the Bank had to press for a decision before it could proceed with project appraisal. The shareholders finally reached a compromise: management would be composed of a general manager from the city of Bogota, a technical manager from the city of Medellin and an administrative manager from the city of Cali. For the new entity at this stage of its precarious existence, a Bank loan was, more than a simple loan, the very "raison d'etre" of the new enterprise, for it provided the means of constructing the interconnection network.

3.02 Loan negotiations did not pose any special problem and a loan for an amount of US$ 18 million was signed on December 2, 1968. The project consisted of: (a) three double-circuit 230 kv transmission lines, with a total length of 500 km, which would interconnect the four systems

by a "Tee" arrangement with the CHEC system as a focus (see map at the end of this chapter); and (b) four substations with autotransformers and appropriate switching equipment located at El Colegio hydroelectric plant in Bogota, Yumbo thermal plant in Cali, Guatape hydroelectric plant in Medellin and La Esmeralda hydroelectric plant in Manizales.

3.03 Total cost of the project was estimated at US$ 29.6 million equivalent, of which US$ 21.8 million was in foreign currency. The balance of the foreign exchange required for the project was to be provided by supplier countries under joint financing arrangements agreed upon with the Bank. As indicated earlier, the local currency costs of the project would be provided through common stock issued by ISA to the four sponsors, and also through contributions from the Central Government Budget if necessary. Given the tight financial situation of CVC/CHIDRAL, in particular, the loan agreement included a stipulation requiring that the Government provide the company at any time with the necessary funds so that it could live up to its commitments to ISA.

3.04 In spite of a few difficulties encountered in connection with securing the joint loans from Japan and Switzerland, general progress of the work has been **satisfactory;** the last interconnection tie between La Esmeralda and Guatape was completed in August 1971. Work related to load dispatching will be completed in time for the commissioning of the interconnected system. Due to higher than expected financing by supplier countries under the joint financing arrangement, total Bank loan disbursements are expected to fall short by about US$ 3.7 million. Actual project cost and disbursement schedules are shown on Table 13.4, appearing on page 481.

3.05 During loan negotiations, the Bank had been assured by the Government that adequate policies would be introduced to permit the establishment of timely tariff adjustments to earn an adequate rate of return. At present, no difficulty is foreseen regarding implementation of the recommendations to be made by the Motor Columbus study.

Loan 681-CO - Chivor Hydroelectric Plant

3.06 One of the fundamental purposes of Interconexion was to develop large scale generating plants and it had been agreed among the sponsors that the new capacity required at the beginning of 1976 would be constructed, owned and operated by ISA. Studies carried out by ISA, its consultants Ingetec-Integral and the National Planning Department (Planeacion) in 1968-69 showed that the existing generating plants and those under construction in the four sponsors' systems, including Alto Anchicaya, could meet forecast interconnected system demand up to 1975. The principal question to be resolved concerned the most economic sequence in which future plants should be constructed. An investigation carried out with the help of computer models identical to those used in the present study demonstrated that the construction of Chivor for initial operation in 1976 was the most attractive alternative to meet the interconnected demand until 1980, both from the economic and system operation viewpoints. The Bank agreed that Chivor was of highest priority and decided to support the project.

3.07 In 1969, however, at the time of project appraisal, difficulties arose because two of ISA's members, EEEB and ICEL, declared themselves

in favor of having EEEB construct and manage the project.[1/] The Bank appraisal mission which visited Colombia in August-September of 1969 insisted that ISA should assume full responsibility for Chivor and that lack of agreement on the matter would mean deferral of the appraisal; the point was made clear that, since ISA was the sole prospective borrower from the Bank and parallel financing countries, the objectives pursued at the time of ISA's creation should be respected, as the entity responsible for the coordination, construction and operation of the new major generating plants within the interconnected system. The mission further indicated its satisfaction with the current management of ISA and its feeling that, with the help of experienced specialists, it could successfully carry out the project. Under the pressure of Planeacion and the weight of the President's own intervention, a compromise was worked out with the help of the Bank, which allowed EEEB to be responsible to ISA for the engineering work carried out by Ingetec, as a continuation of this consultant's previous investigations, studies and design work on Chivor.

3.08 The Bank loan, to an amount of US$ 52.3 million equivalent, was finally signed on June 4, 1970. The signing of the loan under the agreed conditions bore with it a very beneficial institutional dimension: the shareholders, who would be the customers and, in some ways,

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1/ Preliminary investigations and engineering studies for Chivor had been started by EEEB before ISA had even been created.

the competitors of ISA, were now convinced that ISA as a power institution was a firm reality and that it was eventually bound to become the largest power generating entity in the country.

3.09 It had been agreed at an early stage of the negotiations that financing of the main equipment orders would be arranged directly by ISA with the supplier countries. Meetings to consider Bank-sponsored joint or parallel financing of the project were held in Paris in December 1969 and March 1970 with the principal supplier countries, but agreement could not be reached on either system of financing. ISA therefore undertook to resort to bilateral financing, a solution which also proved unattractive as further discussed later.

3.10 The Chivor project, as financed through the new loan, consists in the harnessing of the first part of a 1,000 MW hydroelectric site on the Bata River. The plant, which is currently under construction, will consist mainly of: (a) a rock fill type dam; (b) an open-channel gated spillway; (c) a 5,750 m long, 6 m equivalent diameter pressure tunnel followed by a 2,000 m long, 3.9 m diameter surface-mounted steel penstock; (d) a power house with four units, each one consisting of a 125 MW Pelton type turbine; (e) a 180 km 230 kv double-circuit transmission line and the necessary works and equipment to connect this line to EEEB's 115 kv system, at Suba, and to ISA's 230 kv network at La Mesa.

3.11 The estimated total cost of the project was equivalent to about US$ 114.2 million, of which the equivalent of about US$ 65.7 million would be in foreign exchange. The US$ 52.3 million Bank loan was to finance

the foreign exchange cost of the major and minor civil works contracts and minor equipment orders as well as the interest charges on the loan payable during construction; a proportionate amount of contingencies on the above items was also included. Foreign currency expenditures on main equipment orders, estimated at US$ 22.8 million, were to be financed by bilateral credits. It was also expected that local currency costs forecast at about US$ 48.5 million equivalent, and interest during construction on the anticipated bilateral credits, estimated at about US$ 2.7 million equivalent, would be financed by the four sponsors in proportion to their agreed share in the output of Chivor.

3.12 The Bank supervision mission which visited the site in April of 1971 reported that work on the project was proceeding on schedule. So far, geological conditions in the tunnel areas have been found better than expected. Road construction is proving difficult, however, and will cost more than originally anticipated due to changes in the layout and the necessity for additional tunneling. The cost of the main civil works contract (dam, spillway, tunnels, surge chamber, etc.) were significantly higher than expected, especially with respect to the foreign currency component. Other cost overruns are foreseen, as a result of changes to be introduced in the layout of the penstocks and the roads. Total project cost is currently estimated at US$ 126.5 million equivalent, or US$ 12.3 million above the original forecast amount. The overrun, as estimated by the supervision mission, will be entirely on the foreign exchange component, while the revised local currency component is now lower than the original value; this feature is due to the different currency composition of the main civil works contract. As a result of

this, disbursements on the Bank Loan are currently ahead of schedule.

Table 13.2: ISA - Loan 681-CO - Original and Revised Cost Estimates for the Chivor Hydroelectric Project[a/]

	Appraisal Report May 1970 (US $ million)	Revised Estimate March 1971 (US $ million)	Difference US $ million	Difference % of original forecast
Foreign Currency	65.7	79.3	+13.6	+20.8%
Local Currency	48.5	47.2	- 1.3	- 2.7%
Total	114.2	126.5	+12.3	+10.8%

Source: Bank Supervision Report (April 9, 1971).

a/ Figures are exclusive of interest during construction.

For the time being, ISA is planning to finance the anticipated increase on local costs through additional share and bond subscriptions by the sponsors.

3.13 As indicated earlier on, bilateral financing, as conceived at the time of project appraisal, proved impractical due to the unfavorable terms proposed: 10-15% down payment and 10 year repayment period. Instead, ISA obtained, with Bank concurrence, a US$ 34 million loan from the IDB to be repaid over a twenty year period.

IV. Future Development of the Interconnected System

4.01 Several recent developments, which had not been foreseen or explicitly taken into account at the time of the appraisal of Chivor, have substantially modified the features of the interconnected system. These are:

(1) The 230 kv transmission line currently under construction between Paipa and Bucaramanga, which,

upon completion by mid-1973, will be the first interconnection of ISA's system with the Northeast through the existing 115 kv line which already links Bogota to Paipa.

(2) The 230 kv transmission line Guatape-Barrancabermeja to be completed by the end of 1973.[1/]

(3) The 230 kv transmission line Bucaramanga-Cucuta planned for commissioning by the beginning of July 1974, which will complete the interconnection with the Northeast.

(4) The development of the nickel mine and processing plant at Cerromatoso, 180 km north of Medellin, which will probably be connected to ISA's system through a 230 kv line[2/] by mid-1974 and contribute 65 MW to system demand.

(5) The 51 MW Rio Prado hydroelectric plant currently under construction by ICEL. Work on the project was initiated in early 1967 and completion is expected for the end of 1972, by which time the plant will be interconnected with ISA's system through the 115 kv Prado-Flandes transmission line also under construction.

1/ The Northeastern loop will be completed by July 1974 once the Guatape-Barrancabermeja transmission line has been extended to Bucaramanga (see map at the end of the chapter).

2/ This will represent the first step toward the interconnection of the Northern region.

(6) The third thermal unit (66 MW) at Zipaquira which has already been started by EEEB and is planned for commissioning by the middle of 1973.

(7) The new 66 MW thermal plant in Barrancabermeja (Termobarranca) to be commissioned around mid-1974.

(8) The 33 MW thermal unit currently planned for Paipa, to be operational by mid-1974.

(9) The additional energy generation expected from the Chingaza water project in Bogotą as a result of the increased flow rate in the Rio Bogota; project completion is scheduled for the beginning of 1977.

4.02 Generating plants currently under construction are expected to meet the demand of the interconnected system until 1977. Consequently, considering normal construction periods for hydro projects, ISA will probably decide on the next expansion in the course of 1971. Guatape II (280 MW) and Chivor II (500 MW) are the plants for which sufficiently advanced feasibility studies are available. The studies for the development of the Nare-Guatape-Samana system are also almost completed and include the projects of San Lorenzo (100 MW), Playas (250 MW), and Samana (two plants of 520 MW each). In a much more preliminary stage, but being pressed by EEEB, is the study of the Mesitas scheme on the Bogota River (first stage: 500-600 MW). It can be expected that one of the major projects will be submitted for Bank consideration in the near future.

4.03 Engineering studies are also currently being carried out by Ingetec/Integral on the development of the Cauca and Guavio[1/] river basins. About eight sites in the Cauca river basin, which would be suitable for future hydroelectric plants and could play an important role in the long term development of the interconnected system, have also been identified on a preliminary basis. Regarding the Guavio river basin, preliminary investigations have indicated that reasonable alternatives of reservoirs and diversions could be envisaged, either for independent development on the Guavio River or for a diversion towards the Chivor plant on Rio Bata. ISA is now preparing a contract on this subject which will be submitted to the Bank for approval as soon as possible in order that work on feasibility studies may start in the first half of 1971.

4.04 In view of these various developments, load forecasts are being thoroughly revised and the level and timing of new investments will largely be dependent upon the results of the investigation. As a result of such changes, a new allocation of ISA's shareholders' contributions towards the local financing of Chivor has been approved by ISA's Board in accordance with the statutes of the company. To date the reallocation has led to a considerable increase in the share to be provided by ICEL. An understanding is currently being sought with the Government that it

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1/ Rio Bata on which the Chivor hydroelectric plant will be located is a tributary of Rio Guavio, itself a tributary of Rio Upia, itself a tributary of Rio Meta, itself a tributary of Rio Orinoco.

will provide the additional funds required by ICEL for this purpose.

4.05 ISA has recently sought the Bank's agreement for utilization of the expected savings of US$ 3.7 million on loan 575-CO to finance the foreign component[1/] of the 230 kv line Guatape-Barrancabermeja. The line will permit postponing installation of 130 MW of capacity which would otherwise be required to meet the demand expected to emerge in the Northeast in 1973-77. ISA's request was approved by the Board of the Bank and this will involve an extension of the closing date of the loan by about three years to December 31, 1974. Furthermore, ISA is planning to ask Motor Columbus to incorporate the implications of the interconnection with the Northeast into its study, which would mean an expansion of the consultants' present contract.

4.06 The various plans currently under consideration, as discussed above, demonstrate that the electrification program of Colombia is proceeding towards progressive interconnection on the national level. The electrical integration of the Northeastern region can now be considered a forthcoming reality, while the integration of the North is becoming a crystallized concept.

V. Basic Technical and Financial Data

5.01 This section presents a certain amount of technical and financial background information on the interconnection network. The voltage of

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1/ Estimated at US$ 3.5 million.

the Tee system now being complete is 230 kv and its maximum carrying capacity is 180 MW.

5.02 The length and resistance of each of the three lines in the Tee are as follows:

	Length (km)	Resistance (Ohm)
- La Esmeralda - Yumbo	194.1	6.26
- La Esmeralda - Guatape	169.2	5.32
- La Esmeralda - La Mesa	174.2	5.54

5.03 Expected transmission losses are shown below in Table 13.3.

Table 13.3: Expected Transmission Losses on Central Interconnected System

Power Transferred	La Esmeralda-Yumbo		La Esmeralda - Guatape		La Esmeralda - La Mesa	
(MW)	(MW)	(%)	(MW)	(%)	(MW)	(%)
180	3.82	2.12	3.24	1.80	3.38	1.88
150	2.63	1.75	2.23	1.49	2.33	1.55
120	1.69	1.41	1.44	1.20	1.50	1.25
90	0.94	1.04	0.80	.89	0.83	.92
60	0.44	.73	0.37	.62	0.39	.65
30	0.10	.33	0.09	.30	0.09	.30

5.04 Table 13.4 shows the original forecast of construction costs for the whole Tee system, actual expenditures to date and the current estimate of requirements for completion.

Table 13.4: Forecast and Actual Investment Costs of Transmission Network and Substations
(US$ Million Equivalent)

	1968	1969	1970	1971	1972	Total
Forecast[a/]						
Local Currency	0.77	3.56	2.45	1.03		7.81
Foreign Exchange	1.64	5.75	9.53	2.48		19.40
Total	2.41	9.31	11.98	3.51		27.21
Actual[b/]						
Local Currency		1.61	2.85	1.33	0.14	5.93
Foreign Exchange		3.37	6.17	6.36	0.82	16.72
Total		4.98	9.02	7.69	0.96	22.65
Cost Overrun						
Local Currency						(1.88)
Foreign Currency						(2.68)
Total						(4.56)

a/ Source: IBRD Appraisal Report; figures include engineering costs and contingency allowances ($0.7 million on local component and $2.3 million on foreign component).

b/ Source: ISA; figures include engineering costs.

5.05 Table 13.5 shows the latest forecasts of annual costs for the system.

Table 13.5: Forecast Annual Costs 1971-75
(US$ Million Equivalent)

	1971	1972	1973	1974	1975
Administration	0.80	0.76	0.72	0.68	0.65
Operation and Maintenance	0.16	0.31	0.28	0.26	0.24
Depreciation	0.29	0.54	0.50	0.46	0.42
Interest	0.18	0.66	0.85	0.74	0.65
Total	1.43	2.27	2.35	2.14	1.96

Source: ISA

VI. The Benefits of Interconnection

6.01 The several benefits to be derived from interconnecting independent electric systems have been referred to in previous sections and are summarized below.

(a) Utilization of larger and more economical plants - Integrated development allows important economies of scale through earlier utilization of large generating plants with low unit capital costs. Larger and more economical units are also justified within the expanded system.

(b) Pooling of reserves - The independent systems each require a reserve capacity equal to at least the value of their largest generating unit. However, reserve requirements for the interconnected system are less than the arithmetic sum of independent reserves, being

commonly accepted as 10% of total capacity or the capacity of the largest unit, whichever is greater.

(c) Load diversity - Since peak demands on the individual systems do not occur simultaneously, the aggregate system coincident demand is less than the arithmetic sum of individual demands. In the case of the central interconnected system of Colombia, such diversity was estimated at 5% of the aggregate peak loads of the individual systems; the largest generating unit currently available in the system[1/] has a capacity representing only about 4% of such cumulative demand.

(d) Hydrological diversity - The integration of several systems allows better use of the seasonal variations in rainfall and river flows between different areas. Excess water flows occurring periodically within any given system can be utilized by other systems, thus enabling the latter to store hydroelectric energy. This is especially valuable in the case of the central interconnected system of Colombia, since the individual systems are predominantly hydraulic.

(e) Better utilization of thermal and hydro plants - The integration of mixed systems can yield important savings on fuel consumption through a more intensive use of hydraulic energy. In periods of high water flows, the integrated system provides the opportunity to use excess flows, thus reducing thermal generation and, consequently, fuel expenditures; if the systems were isolated, such water would have to be spilled because of insufficient market demand and lack of storage capacity.

1/ 66 MW at Guatape.

(f) Firming of capacity - It follows from the foregoing that, with integrated operation, water can be stored at certain times and places in a manner which would be impossible on an individual system basis, thus providing the possibility of increasing the proportion of firming capacity throughout the system.

(g) More economical utilization of the various generating units - The pooling of resources makes it possible to reduce operation and maintenance expenditures through a more intensive use of the units which have relatively lower operating costs, the more expensive units being kept as reserve capacity or operated for peaking purposes only.

(h) Other Benefits - Intangible benefits will result from integrated operations such as greater service reliability, better frequency and voltage control and more flexibility in scheduling maintenance.

6.02 Although the interconnected system has not yet started operation, a number of comments based on recent developments can be made regarding the validity of some of the assumptions made at the time Interconexion was still at the planning stage. The quick review carried out below follows the order adopted in the previous section and is partly based on a computer simulation of the interconnected system analyzing an early interconnection (in 1967) as an alternative to what has actually occurred.

6.03 The estimated cost of the Chivor I project, the first plant to be undertaken strictly within the context of interconnection, is relatively low, at about US$ 228 per installed KW[1/]; the scheme appears

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1/ Includes engineering and transmission costs.

even more attractive if one takes account of the fact that the present investment for 500 MW includes an important component (the dam in particular) common to this phase and the future expansion also of 500 MW. It is estimated that the cost of the completed plant will be equivalent to about US$ 150 per installed KW, one of the lowest unit costs ever experienced in Colombia.[1/]

6.04 Rough estimates have shown that, with interconnection, the Chivor I hydroelectric plant can be developed to its full capability in about one-third the time that would occur without it: if the plant were to supply the Bogota market alone, saturation would be reached about six years after the commissioning, whereas a period of only about two years will be necessary in the context of the interconnected market. A rather oversimplified calculation has shown that the benefits to the economy of accelerating the saturation process of a large generating capacity can be substantial; the calculation was made in the case of Chivor I, assuming different saturation periods, as shown in Table 13.6. Annual benefits have been expressed in terms of actual discounted investment expenditures on the additional capacity saturated over the year under investigation; such an approach is equivalent to considering that the capital cost of the additional annual generation capacity saturated is paid off over the first year of saturation, which is obviously unrealistic but useful for illustrative purposes.

1/ To date, only the Guadalupe III and the San Francisco hydroelectric plants, respectively in EPM's and CHEC's systems had forecast and actual unit costs lower than US$ 150.

Table 13.6: Economic Benefits Resulting from an Accelerated Saturation of a Large Generating Capacity (Example of Chivor I)[a/]

Period of Saturation	Year when Additional Capacity Becomes Operational	1	2	3	4	5	6	Total
2 years	capacity (MW)	250	250					500
	benefits ($min)	57.0	48.0					105.0
3 years	capacity (MW)	166.7	166.7	166.7				500
	benefits ($min)	38.0	34.5	31.4				103.9
4 years	capacity (MW)	125	125	125	125			500
	benefits ($min)	28.5	25.9	23.5	21.4			99.3
5 years	capacity (MW)	100	100	100	100	100		500
	benefits ($min)	22.8	20.7	18.0	17.1	15.6		95.0
6 years	capacity (MW)	83.3	83.3	83.3	83.3	83.3	83.3	500
	benefits ($min)	19.0	17.3	15.7	14.3	13.0	11.8	91.1

a/ With a unit cost of $228 per KW installed and a 10% discount rate.

6.05 The table shows that developing Chivor I to its full capacity in two years instead of six years would yield "benefits" to the economy, defined in the manner mentioned, of about $13.9 million, or about 12% of project total capital cost.

6.06 As regards economies in reserve generating capacity, it can be seen from Table 13.7 that, with the reserve criteria adopted, a capacity of about 50 MW could be spared between 1970 and 1978 with pooling; this corresponds to capital cost savings of some $10 million equivalent.

Table 13.7: Central Interconnected System - Reserve Capacity Requirements in 1970, 1974 and 1978 (MW)

Individual Markets (largest unit)	1970	1974*	1978*
EEEB	50	66[a/]	125[d/]
EPM	45	66[b/]	66
CVC/CHIDRAL	33	85[c/]	85
CHEC	45	45	45
Total	173	262	321
Interconnected System			
- largest unit	50	85	125
- 10% of total capacity	118	219	269
Redundant Reserve Capacity with Interconexion	55	43	52

* Based on system development as assumed in economic evaluation (See Table 13.16).

a/ Zipaquira 3
b/ Guatape I
c/ Alto Anchicaya
d/ Chivor

6.07 The experience of the last few years has shown that peak load diversity among the four central markets will probaly be less than the 5% originally anticipated. The main reason for this is a recent shift in the daily peak demand of the Medellin power market from the morning to the evening, which will make the individual peak demands of the four markets

closer to coincident in the future.[1/] ISA is now assuming 3% diversity for planning purposes.

6.08 In order to assess the contribution of interconnection toward greater efficiency in the use of installed generating capacity and particularly hydroelectric capacity (points d, e and f above), two sets of computer simulation models were run, respectively for:

(i) the four systems considered independently

(ii) the interconnected system, assuming interconnection in 1967.

The basic model was one taking as given actual river flows in each month and consequently, the amount of energy that could be produced by each plant, and analyzing the allocation of generation among plants with optimal utilization of system capacity for meeting actual loads. The results are presented in detail in Table 13.8 and they are summarized in Table 13.9, which shows monthly averages for each year.

6.09 The tables show that aggregate excess capacity within the interconnected system is generally larger than the sum of individual excess capacities appearing in the various isolated markets. Over the last two quarters of 1970, for instance, the differential spare capacity remained close to 70 MW in favor of the interconnected system. Of the 48 months covered in the investigation, however, 19 months witnessed aggregate

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1/ A humorous and perhaps realistic sociologist would probably assert that the shift observed in Medellin was due to a change in the habits of the Antioquenian population, traditionally a major consumer of beans: beans are generally cooked in the morning for consumption throughout the day.

excess capacities larger in the case of the individual systems than in the case of the interconnected system. This was especially true in the first half of 1967. This phenomenon appears to result from two considerations: (a) system conditions at the beginning of the study period (January 1967) were assumed to be identical to those generated by the individual market models run over the previous years and (b) the reservoir operation policy adopted in the case of the interconnected market model was more stringent in terms of storage requirements than in the analysis of the various markets independently. In general, it is clear from the tables that interconnection would have permitted more efficient capacity utilization: excess hydrocapacity is generally smaller with interconnection than without, and thermal capacity is used less extensively, the difference in excess thermal capacities often reaching up to 100 MW.

6.10 System simulation thus shows that a more efficient use of hydroelectric resources can be achieved through interconnection. Conclusions regarding the share of excess hydrocapacity that may be unusable (due to inadequate water flows) were impossible to draw, for the model does not relate excess hydroenergy available at one plant (or even in one subsystem) to excess hydrocapacity available at the same plant (or subsystem); only aggregate values are provided for the overall interconnected system. An attempt has been made, however, in Table 13.10, to relate unusable excess hydrocapacity in the various isolated systems to total excess hydrocapacity in the interconnected system. The table shows that, over the period investigated, excess hydrocapacity with interconnection would have been much larger than aggregate unusable excess hydrocapacity appearing on the systems when in isolation. The frequently high values of the theoretical potential utilization factor for such excess capacity,

as given in the last column of the table, suggests that usable excess hydrocapacity would probably still have been important had the four markets been interconnected. This result is not surprising in view of the fact that the model also indicates that, in the case of an early interconnection, thermal generation would have been very small and, in several months, even non-existent. The limited amount of thermal generation taking place would actually have been the result of the reservoir operation policy adopted, which attempts to maintain water storage at acceptable pre-established levels.

6.11 Table 13.11 shows that, if interconnection had taken place in 1967, the system would have had large excesses of usable energy. However, it should be noted that the same model also indicates a very low utilization of the thermal plants when applied to the case with the markets isolated from one another. The comparison can be more easily made in terms of the relative expenditures on fuel in the different alternatives, as summarized below.

Table 13.12: Central Interconnected System - Actual and Potential Expenditures on Fuel Over the Period 1962-1970 With and Without Interconnection in 1967 (Amount in present values of 1968, using 10% discount rate)

	Expenditures on Fuel (equivalent US $000)	Retrospective Potential Savings on Fuel (equivalent US $000)
Simulation of historical behavior[a/]	7,819	-
Simulation of potential behavior		
- Independent systems	5,386	2,433
- Systems interconnected in 1967	5,256	2,563

a/ Actual expenditures.

Source: Power Simulation Model - Computer Output of Economic Routine.

6.12 The table indicates that the potential savings on fuel to be obtained by interconnecting the systems in 1968 would have been relatively small (in terms of present worth in 1968, US $130,000 equivalent over four years). In practice, however, separate operation of the individual systems would probably necessitate more extensive use of thermal capacity than implied. The thermal plants typically have to be kept in operation over longer periods of time and more intensively than would be strictly necessary to meet peak demand. If the systems were to be interconnected, on the other hand, some of the thermal plants would become completely redundant (such as the three CVC/CHIDRAL units at Yumbo, as indicated in Table 13.11) and there would be no necessity to maintain the minimum base load in such plants. In other words, the amount of $130,000 on fuel cost savings is likely to be an underestimation of the savings which would have actually occurred in practice.

6.13 The other benefits of interconnection previously listed under items (g) and (h) are obviously impossible to discuss in the light of past developments within the interconnected system.

VII. Interconnection and the Timing of Guatape

7.01 It was suggested earlier that the Bank's agreement in February 1964, to make a loan for the Guatape project may have slackened EPM's interest in interconnection at that time and eventually have caused the link to be achieved a year or more later than might otherwise have occurred. This section attempts to determine whether, from a strictly technical viewpoint, the construction of Guatape was premature or adequately timed.

7.02 The argumentation is based on the information provided by the computer simulation models run in the case of both the interconnected system (with interconnection in 1967) and the independent systems. The precision of the analysis is unfortunately limited by the following two shortcomings:

- System simulation was restricted to the 1962-70 period, although Guatape was not commissioned until late in 1971.
- The model simulating the behavior of the interconnected system does not relate excess available hydroenergy to excess available hydrocapacity, thus making it impossible to determine whether such excess hydrocapacity is actually usable.

7.03 Prima facie, there would clearly appear to have been considerable excess generating capacity on the system in 1970, had it been interconnected. Chart 13.1 at the end of the chapter shows the aggregate peak load in 1970 for the combined four systems,(without any allowance for diversity), of 1114 MW against combined capacity of some 1461 MW, equivalent to a reserve ratio of nearly 350 MW or more than 30% of peak load. This corresponds approximately to the figures shown in the last columns of Table 13.8 above. This reserve ratio will probably have been higher by the end of 1971 as a result of greater increase in combined system capacity (Guatape first two units and Canoas) than in peak load; it would probably be in the neighborhood of 35%. But the question is how much of this capacity was actually usable and how much could have been expected to be

usable, from a hydrological standpoint.

7.04 Table 13.13 gives the detail of the monthly aggregate excess capacity and energy available in the four systems considered independently. As explained before, interconnecting the system means using available capacity more efficiently. In other words, if the systems had been interconnected earlier, aggregate system excess capacity would have been larger, but adequate information is not available to indicate how much of this capacity would have been usable. Comparison between tables 13.8, 13.10 and 13.13 suggests that available excess energy (as opposed to capacity) would not have been substantially greater with interconnection under the hydrological conditions experienced in 1970. Table 13.13 indicates that, without interconnection, aggregate excess energy availability in 1970 has ranged between 10% and 35% of aggregate energy consumption. In the first three quarters of 1970, excess energy available in the overall system was generally limited, amounting to only about 10% of aggregate energy consumption in the same months. The recovery which has taken place since is mainly due to the intense rainfalls which have prevailed over the last 15 months.

7.05 From past trends in peak demand and energy consumption, it appears that excess capacity and energy as prevalent in December 1970, would have been absorbed by growing demand within about two years. Table 13.14 shows the pattern for energy, based on the figure for excess energy given (for December 1970) in Table 13.13 and assuming 12% annual growth in energy consumption.

Table 13.14: Gradual Absorption of Excess Energy Available on Hypothetical Interconnected System, December 1970

	Gwh	
	Aggregate Energy Consumption	Total Excess Energy a/
Dec. 1970 b/	487.6	128.6
Dec. 1971 c/	546.1	70.1
Dec. 1972 c/	611.6	4.6

a/ Assuming an 80% potential utilization factor of excess thermal capacity.
b/ Actual
c/ Forecast - energy consumption forecasts based on 12% annual growth rate.

7.06 Table 13.13 has shown that excess energy in July and August of 1970 was only about 50 Gwh, that is, less than the expected increase in monthly energy consumption during 1971, estimated at approximately 60 Gwh. In other words, if the hydrological conditions had not been as favorable as actually occurred over the last 15 months, the central interconnected power market would probably have faced power shortages in the second half of 1971. The increased efficiency in system utilization resulting from interconnection would probably have extended somewhat (perhaps by about 6 months) the period over which the system became saturated. Assuming system conditions to have remained what they were in December 1970 (an optimistic assumption), the saturation period would have been at the most one and a half years. Taking into account the need to provide for an adequate reserve capacity, one can assert that additional capacity was necessary within the interconnected system by the end of 1971. As will be recalled, Guatape I has started operation recently (September 1971) and Canoas is expected to be commissioned by the end of 1971; it therefore appears that

the actual timing for the introduction of the new capacity was about right in retrospect. One should bear in mind, however, that the first unit of Guatape was initially planned for commissioning by December 1968; if the schedule had been met, other things being equal, both the isolated power system of Medellin and the interconnected system[1/] would have experienced high excess capacities over the last three years. This is again a typical case where delays in construction more or less compensated for excessive demand forecasts.

VIII. Evaluation of Economic Benefits of Interconnection

8.01 The several benefits of interconnection listed in the preceding sections are difficult to quantify individually, but resulting savings on capital and operating costs can be more easily estimated. Such savings provide an approximate measure of the economic attractiveness of interconnection. Hence, with a view to determining the extent of such savings, calculations were made of the capital and operating costs which each individual system would have had to incur to meet its own market requirements; these costs were then compared to the corresponding capital and operating costs involved by integrated system operation, including the costs of the interconnecting network. The analysis was carried out for both an interconnection completed in 1967 (as planned in 1964) and an interconnection completed in 1971 (as actually occurred).

8.02 As pointed out in the historical section of this chapter, the first study of the benefits of interconnection was carried out in 1963 by

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1/ Assuming an early interconnection.

Ingetec/Integral and updated in 1968 by the same consultants; the 1968 analysis was restricted to the four central systems and reposed on the assumption of interconnection becoming effective by the end of 1971. Table 13.15 gives the load growth between 1968 and 1980 assumed by the consultants and Table 13.16 shows the corresponding alternative power expansion programs selected for comparison.

Table 13.15: Central Interconnected System - Demand Forecasts Prepared by Ingetec/Integral in 1968 a/

	Without Interconnection Aggregate Demand of Individual Power Markets (MW)	With Interconnection in 1971 (MW) b/
1968	997	997
1969	1109	1109
1970	1230	1230
1971	1357	1289
1972	1500	1425
1973	1644	1562
1974	1804	1714
1975	1979	1880
1976	2171	2062
1977	2359	2241
1978	2564	2436
1979	2787	2648
1980	3037	2879

a/ Values are as of December of each year.
b/ Allowing for a 5% diversity factor from 1971 on.

8.03 As Table 13.16 shows, integration of the system was expected to provide the possibility of (a) eliminating the various thermal plants which would be necessary should the four systems remain independent; and (b) postponing the construction of the various hydroplants. The elimination of the thermal plants obviously carries with it related savings on fuel consumption. Table 13.17 gives the details of the savings expected

from interconnection, expressed by their present value in 1968 for different discount rates.

Table 13.17: Central Interconnected System - Benefits of Interconnection for the 1969-80 Period, As Calculated by Ingetec/Integral in 1968
(Present Worth in 1968 expressed in US$ Million Equivalent)

	Foreign Exchange	Local Currency	Total
8% Discount rate			
Savings in construction costs	15.53	10.36	25.89
Savings in operating costs	-	30.67	30.67
Total	15.53	41.03	56.56
15% Discount rate			
Savings in construction costs	15.28	10.18	25.46
Savings in operating costs	-	13.37	13.37
Total	15.28	23.55	38.83

Source: Ingetec/Integral.

The table shows that the potential savings resulting from the interconnection of the four central systems, as assessed in 1968, are quite substantial. Savings on fuel represent a large proportion of total savings and it is interesting to note that savings on capital, unlike savings on operating costs, remain virtually unaffected by variations in the discount rate. This tends to demonstrate the economic attractiveness of early interconnection in terms of capital investment.

8.04 The evaluation of interconnection benefits as made by Bank staff in the 1968 appraisal report differs quite substantially from the evaluation of Ingetec/Integral. The two sets of figures relative to the stream of benefits are given in Table 13.18. The main difference between the two sets of figures apparently stems from the fact that the Bank forecast included the second stage of Chivor to be built between 1976 and 1978, whereas only the first stage appeared in the consultants' forecast. It was unfortunately impossible to obtain the details of the assumptions adopted by the Bank in its evaluation, in particular with regard to the demand projections used. It is therefore difficult to assess the accuracy of the analysis, but the various calculations appearing in later sections tend to demonstrate that Bank estimates of interconnection benefits were probably on the high side.

8.05 Since 1968, the various power systems which now compose the central interconnected system, have evolved in a way which differs substantially from what had been forecast at the time. Undoubtedly, the most important change is the forthcoming interconnection with the Northeast, which will introduce major modifications into the composition of the load and installed capacity of the interconnected system. Also, some plants which, at the time, had not been taken into consideration, or were considered redundant in the context of interconnection, are now being built, particularly Zipaquira 3. Furthermore, estimated costs and disbursement patterns on various plants appearing in the 1968 evaluation are now more accurate, for such plants have been appraised in the meantime.

8.06 In a first stage of study, interconnection with the Northeast was set aside, restricting the analysis to the capital savings yielded by interconnecting the four main markets of the Central region. In this regard, two sets of calculations were made, involving interconnection in 1967 and 1971, respectively.

8.07 Tables 13.19 and 13.20 give the details of system annual peak loads used in the analysis for 1967-71 and of the composition over time of the power expansion program, both as actually occurred and as could have occurred had interconnection been implemented by 1967. The various plants were taken identical in both cases and the only variation introduced in the case of the interconnection alternative were the construction of the interconnection network and the postponement of the various generating plants. The investment program for the interconnected system was established on the basis of actual demand in the four individual markets, assuming a reserve capacity of about 10% of aggregate peak load.

Table 13.19: Central Interconnected System - Actual Annual Aggregate System Peak Loads and Estimated Peak Loads Assuming Interconnection in 1967
(1967-71)

	Without Interconnection Aggregate Demand of Individual Power Markets (MW)[a]	With Interconnection in 1967 (MW)[b]
1967	848.3	822.8
1968	928.2	900.4
1969	1044.7	1013.4
1970	1160.7	1125.9
1971	12964.2	1255.4

a/ Actual values up to 1971; mission estimate for 1971.

b/ Allowing for a 3% diversity factor.

8.08 From Table 13.20, it can be seen that, if interconnection had become effective in 1967, the possible postponements in the commissioning of the various generating units would have been as follows:

Calima 3, 4:	1 year
El Colegio 1, 2, 3:	2 years
El Colegio 4, 5, 6:	2 months
San Francisco:	2 years
Guatape I:	1 year
Canoas:	4 months

Table 13.21 gives the investment pattern for both alternatives. Investments on generating plants are given in detail in the case of the individual markets and, as previously pointed out, the stream of investments in this case corresponds to actual historical values.

8.09 The net savings resulting from the interconnection of the four markets have been calculated on a discounted cash-flow basis for various discount rates (8%, 10% and 12%) and two values of the foreign exchange rate, one the official rate and the other twice that. The results are summarized below.

Table 13.22: Central Interconnected System - Interconnection in 1967 a/
Savings on Capital Expenditures Necessary to Meet System Load Growth 1967-71
(Present Worth in 1968 expressed in US$ Million Equivalent)

S.f.e.r. \ i	8%	10%	12%
1	(8.12)	(4.98)	(1.59)
2	(21.03)	(17.54)	(11.62)

Legend: i = discount rate
S.f.e.r. = Shadow Foreign Exchange Rate

a/ Based on cash flow appearing in Table 13.21.

The table shows that, with the discount rates used and considering capital costs only, the investment in the interconnection transmission line cannot be amortized within the investigated 4-year period. However, the break-even point would be reached at the official foreign exchange rate for a slight increase in the discount rate (to about 13%). The somewhat original trend followed by the value of net savings, which tend to go up with the discount rate, is due to the postponement of the heavy investments in generating plants made possible as a result of the early interconnection. In brief, the economic features of interconnection appear favorable even in the medium-run perspective.

8.10 The next step was to evaluate the cost savings that interconnection makes possible in meeting future load growth. The following evaluation rests on a demand forecast, shown in Table 13.23, based on extrapolating the recent past growth of the four individual systems. An allowance of about 10% of forecast load was made for reserve generating capacity. The system expansion plan for the interconnection case was kept as close as possible to present plans for future developments (including Zipaquira 3). Table 13.24 gives the detail of the alternative expansion programs between 1971 and 1980, as currently envisaged and as might have prevailed had the four markets remained independent.

Table 13.23: Central Interconnected System - Forecast Aggregate Peak Loads of Individual Systems and Forecast Peak Load of Interconnected System Assuming Interconnection in 1971 (1971-80)

	Without Interconnection Aggregate Demand of Individual Power Markets (MW)[a/]	With Interconnection in 1971 (MW)[b/]
1971	1286.3	1247.7
1972	1402.1	1360.0
1973	1544.6	1498.3
1974	1700.8	1649.8
1975	1868.5	1812.5
1976	2058.9	1997.1
1977	2269.4	2201.3
1978	2502.4	2427.3
1979	2760.1	2677.3
1980	3045.4	2954.0

a/ Average annual growth rate assumed over 1971-80 period:

Bogota: 11%
Medellin: 7%
Cali: 12%
CHEC: 12%
Total Central Interconnected System: 10%

b/ Allowing for a 3% diversity factor.

8.11 The table shows that interconnection will make possible omission or major postponements of several plants in accordance with the following pattern:

- Yumbo 4: omitted
- Alto Anchicaya 1, 2: 2 years
- Chivor 1, 2: 8 months
- CHEC thermal plant: omitted
- Guatape II 1, 2: 2 years

Table 13.25 gives the future yearly investments on the various units for the two alternative expansion programs presented in Table 13.24.

8.12 The results of the discounted cash flow analysis are presented below.

Table 13.26: Central Interconnected System - Interconnection in 1971 - Savings on Capital Expenditures Required to Meet Load Growth through about 1980
(Present Worth in 1968 expressed in $ Million Equivalent)

S.f.e.r. \ i	8%	10%	12%
1	12.81	14.42	15.67
2	17.79	20.52	22.53

Legend: i = discount rate
S.f.e.r. = shadow foreign exchange rate

8.13 The combined results of the various analyses with regard to savings in capital expenditures occasioned by a joint operation of the four central systems are summarized in Table 13.27. As can be seen from the table, interconnection will permit major savings on generating plants in the future. Over the 1971-80 period then savings, expressed in terms of present worth in 1968 would amount to some $15 million, approximately 8% of the aggregate investments that would be necessary for expansion of generation facilities within the four systems taken individually. Such savings would have been much larger, representing a total of about $28 million, if the four systems had been interconnected in 1967.

8.14 If the four major power companies had planned their investments during the 1960s in the perspective of an early interconnection (in 1967), major savings to the economy would have resulted, amounting to some $14 million equivalent in 1968 present worth (see Table 13.27). This, added to the fact that the present worth of the benefits of interconnection increases with the discount rate, tends to demonstrate that the interconnection of the four central markets has been an economic priority for a number of years. It therefore appears that the strong position adopted by the Bank with respect to interconnection was highly justified.

8.15 The calculations presented above did not take into account operating cost savings occasioned by interconnection. A rough estimate of such savings over the 1971-81 period is given in Table 13.28. These correspond to the savings on fuel expenditures resulting from omission of Yumbo 4 and CHEC thermal plants.

Table 13.28: Central Interconnected System - Savings on Operating Costs Yielded by Interconnection
(Present Worth in 1968 Expressed in $ Thousand Equivalent)

	Discount Rate		
	8%	10%	12%
Interconnection in 1967			
Savings over 1967-71 Period[a/]	217.5	162.5	100.0
Savings over 1967-81 Period[a/b/]	5378.1	4552.8	3853.5
Interconnection in 1971			
Savings over 1971-81 Period[b/]	5160.6	4390.3	3753.5

a/ Based on computer simulation with actual fuel prices.

b/ Assuming a 50% utilization factor of the Yumbo 4 and CHEC thermal plants; fuel prices were taken as US¢60 per million BTU or 0.72¢ per kwh (assuming 12,000 BTU per kwh generated).

The table also shows the savings on fuel expenditures which would have occurred had the four systems been interconnected in 1967. These figures are based on the values provided by the computer simulation models run in the case of both the independent systems and the interconnected system.[1/]

8.16 Table 13.29 summarizes the savings on both capital and operating costs to be obtained through interconnection of the four central systems. As can be seen by comparing Tables 13.17 and 13.28, the forecasts prepared by Ingetec/Integral provide for much higher savings on fuel expenditures than those calculated here. This is due partly to the fact that the estimates given here do not allow for the fuel cost savings in coming years on the already existing thermal plants and partly to the fact that the consultants assumed deletion of Zipaquira 3 in their interconnection case. Although the total revised estimates presented here are somewhat different from the 1968 forecasts and are on the low side, there is no doubt that the economic evaluation made at the time adequately foresaw the overall economic attractiveness of interconnection.

The Link with the Northeast

8.17 As pointed out earlier the 230 kv line Guatape-Barrancabermeja should be completed by the end of 1973, thus connecting the Northeast (Bucaramanga-Barrancabermeja) to the central interconnected system. Detailed

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1/ A slight correction has been made to the figures provided by the computer, so as to take account of the savings on fuel which would have occurred in 1971, a year not covered by the simulation.

information is not presently available, but it is expected that construction of the line would permit postponement of installation of 130 MW of thermal capacity which would otherwise have been required to meet the demand emerging in the Northeast in 1973-77. Hence, two alternatives were considered for purposes of the present analysis.

A. Connection of the Northeast effective at the end of 1973; 130 MW thermal capacity commissioned by the end of 1977.

B. 130 MW thermal capacity commissioned at the end of 1973; connection of the Northeast effective at the end of 1977.

The two development programs envisaged will obviously leave the system with exactly the same features by the end of 1977. Comparison between the two alternatives gives an indication of the savings realized by interconnecting the Northeast in 1973 instead of 1977. The calculation was made with the following assumptions:

- Capital cost of transmission:

Foreign Currency:	US$3.5 million
Local Currency:	US$1.2 million
Total	US$4.7 million

- Capital cost of the 130 MW thermal capacity:

Foreign Currency:	US$13 million
Local Currency:	US$13 million
Total	US$26 million

- Construction period of both the transmission line and the 130 MW capacity: 3 years.

8.18 The results of the comparison are shown in Table 13.30. No allowance is made for fuel costs or for any extra capital or operating costs that might be incurred on the central interconnected system itself to generate the energy required for the Northeast between 1973 and 1977, because too little is known about energy requirements or the type of thermal plant that might be installed in the region in the absence of interconnection. Consequently, given the relative capital costs of the transmission and Northeast generation capacity involved and the relative timing of the two schemes, the program including early interconnection naturally appears much the more economic.

Table 13.30: Interconnection with the Northeast - Savings on Capital Expenditures Resulting From an Early Interconnection (Present Worth in 1968 Expressed in US $ Million Equivalent)

	S.f.e.r. = 1			S.f.e.r. = 2		
i	8%	10%	12%	8%	10%	12%
A. Interconnection in 1977	21.69	19.99	18.48	32.47	30.54	28.20
B. Interconnection in 1973	17.52	15.37	13.54	27.12	23.86	21.04
Savings (A - B)	4.17	4.62	4.94	5.35	6.68	7.16

Legend: i = discount rate
S.f.e.r.= Shadow Foreign Exchange Rate

The actual advantages of the early interconnection alternative would depend on the costs of energy generation under the two alternative schemes, relative to the capital cost savings shown above. Presumably, generation costs would be less on the central interconnected system, which would tend to favor the proposal for an early link.

IX. Conclusions

9.01 Among the many facets of the Bank's operations in Colombia, the establishment of Interconexion Electrica S.A. stands out as a very interesting example of economic diplomacy, an instance in which twin instruments of incentives and pressures were sometimes delicately, sometimes forcefully employed to achieve an important objective. The contribution of the Bank toward institution-building in Interconexion presents the original characteristic of having been central rather than peripheral to the lending operation as such. The Bank played a catalytic role in translating into reality an idea which the Colombian authorities had recognized to be important, but which they were unwilling or unable to adopt on their own. At an early stage, the Colombian Government had provided the Bank with its support, for it felt that interconnection could promote national unity, but progress on the matter was curbed by the reluctance of the power companies involved to reach an agreement which would infringe upon their independence and autonomy.

9.02 At the time when the Bank started to promote interconnection strongly, it had no clear vision on the final set-up for the emerging entity; this was due both to the Bank's lack of experience in that kind of enterprise and to its reluctance to force the hands of the Colombians before broad consensus had been reached. By leaving the responsibility of organizational planning to the companies and their consultants, the Bank continued to maintain its catalytic role in the protracted process of negotiation. The keynote of the Bank's approach was to raise questions and suggest alternatives, but never to espouse strongly any one solution to the technical and organizational problems involved, until that solution

had been adopted by the companies themselves. This, on the other hand, was backed by firm adherence to the principle of not financing any power plants which an interconnection would make superfluous; this principle developed later, when the Colombians delayed action, into a refusal to provide any further financing for power plants until agreed steps had been taken.

9.03 The financing of Guatape I, however, appears to have been contrary to such declared policy. By agreeing to finance the plant in 1964, the Bank, in fact, caused the interest of EPM in interconnection to fade temporarily and the position of CVC to harden, especially in view of the fact that financing of Calima II had been denied at about the same time. The analysis has shown that there was a need for additional capacity within the interconnected system by the end of 1971 and that the actual timing of Guatape would probably have been about right in retrospect had hydrological conditions not been abnormally favorable over the past year. Moving interconnection ahead by one year, other things remaining equal, would not have substantially affected the timing of investments on generating capacity and no major capital saving would have resulted. If the construction schedule of Guatape I originally anticipated had actually been met, however, both the isolated power system of Medellin and the interconnected system would have experienced high excess capacities over the last three years, implying an important overinvestment. There may be a case for the argument according to which the character of non-urgency presented by Guatape I, conferred by load growth lower than anticipated, may have slowed down the pace of construction, thereby unnecessarily

expanding the period of project implementation. If this were to be true, a more rigid attitude by the Bank with respect to Guatape could have entailed earlier completion of both interconnection and Guatape, possibly leading to a postponement of the second stage of El Colegio.

9.04 System simulation has indicated that the interconnection of the four central systems will effectively provide a more efficient utilization of hydroelectric resources and a less extensive use of thermal capacity. The economic analysis has shown that the interconnection of the four central systems should permit important savings on capital investments and operating costs. The present value in 1968 of savings on the capital investments necessary to meet system load growth from 1971 to 1980 has been found to be about $15 million,[1/] or 8% of the total aggregate investments in the four power systems considered individually. If interconnection had taken place in 1967, as originally anticipated by the Bank, and plans had been properly adjusted to this expectation, total capital savings would have amounted to approximately twice this amount (in 1968 present worth terms). Anticipated reductions on fuel expenditures are also important, representing an estimated $4.4[1/] million over the forthcoming decade. This, added to the fact that the present worth of the capital savings occasioned by interconnection tends to increase with the discount rate, demonstrates that the interconnection of the four central markets has been an economic priority for a number of years. It therefore appears that the strong position adopted by the Bank on Interconexion was highly justified in retrospect.

1/ With a 10% discount rate.

9.05 The evaluation of capital savings as carried out here provides results comparable to the forecasts prepared by Ingetec/Integral in 1968. Bank forecasts, on the other hand, appear to have been on the high side with an estimated saving of about US$ 132 million on capital expenditures; part of the difference can be attributed to the fact that the Bank took into consideration capital savings occurring beyond the planning horizon of 1979/80 adopted here. In any case, there is no doubt that the economic evaluation made at the time adequately foresaw the overall economic attractiveness of interconnection.

9.06 The benefits of Interconexion reach far beyond the mere savings realized by the four central power markets. The central interconnected system in fact represents the core of the national electric network which appears to be a forthcoming reality. The interconnection of the Northeast with the central interconnected system will probably have been completed by 1973 and serious consideration is currently being given to the subsequent connection of the expanded central system with CORELCA's network in the North. This national network will provide for efficient and flexible transfer of large amounts of energy from the large hydroelectric plants to be developed in the central region toward all the major power markets of the country, thereby permitting important economies of scale. The completion of the national electric backbone will also ultimately allow a more economical connection of the as yet isolated rural areas. Finally, ISA's increasing responsibilities in power generation will gradually allow the individual power companies to devote more of their attention and resources to the modernization and expansion of their subtransmission and

distribution systems, which have generally been lagging in the past, at least relatively to generation facilities.

9.07 There is little evidence that the Bank had originally envisaged the interconnection of the four central markets in the perspective of a broader power grid to be gradually expanded to other areas of the country. The Bank seemed in fact mainly concerned with an increased efficiency in the operations of the four power companies with which it had been heavily involved over the preceding years. The Bank also probably felt that involving a large number of partners in the negotiations over interconnection would only delay actual action on the matter; the Bank never really encouraged ICEL's participation in the venture, in spite of the favorable features offered by CHEC's system for an integrated operation. Equally, the positive implications of interconnection for the expansion of distribution systems and for the possible development of rural electrification does not seem to have drawn the attention of the Bank in any respect.

9.08 The responsibilities of ISA appear to be bound for a dramatic expansion in the future, shifting from the regional level to the national level. It seems, however, that system expansion planning might be hampered in the forthcoming years by the conflicting aspirations of ISA and its shareholders on the subject of plant ownership. In particular, as the electric systems now under the jurisdiction of ICEL gradually become part of the interconnected network, the relative weight of ICEL among the shareholders of ISA is likely to become increasingly large, thus reducing the relative authority of the three other shareholders who still attempt to maintain their status as the three strongest power companies in the country.

9.09 As interconnection of the various regional power systems with the central system proceeds, there will be an increasing need in the future for a strong power entity in Colombia with broad responsibilities on the national level. It appears that such responsibilities, which would include system planning, program implementation and integrated system operation, should be borne by either of the two existing power institutions whose current functions extend beyond the regional level, that is ICEL and ISA. The respective roles to be played by the two entities in the future should be clearly redefined in the perspective of a centralized power system efficiently serving the whole national territory.