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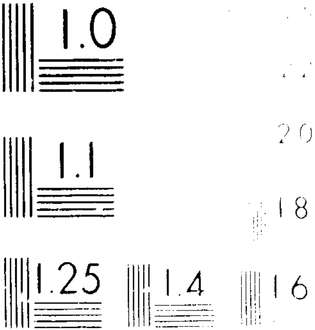
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ELECTRICAL INDUSTRY

DP/MEX/78/003

MEXICO

Terminal report *

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

Based on the work of Dr. F.A.M. Rizk, Team Leader, Dr. R. Malewski,
Mr. David Train and Dr. P.S. Maruvada

United Nations Industrial Development Organization

Vienna

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ABSTRACT

Consultation services were offered by four experts from the Institut de Recherche d'Hydro-Québec to the Instituto de Investigaciones Electricas (IIE) extended over the period of 11 November 1980 to 24 January 1981, within UNIDO Contract No. 80/132.

This report comprises a summary of the technical subjects discussed and the recommendations formulated by IREQ experts in the areas of high voltage measuring techniques, dielectric testing, corona effects and contaminated insulators.

The report points to the necessity of extensive research work related to the performance of high voltage networks under the particular atmospheric conditions of Mexico, including reduced air density and severe pollution. Close collaboration between IIE and the Comision Federal de Electricidad (CFE) is found indispensable for the success of this research and possibilities of foreign participation in this work are outlined.

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1. INTRODUCTION

The objectives of this project have been defined in the UNIDO contract No. 30/132 signed between UNIDO and IREQ as follows:

a) advise and report on special measuring techniques for High Voltage and High Power laboratories, for a period of two (2) months;

b) advise and report on development of research programs in dielectric test techniques and impulse testing, for a period of three (3) weeks;

c) advise and report on development of research programs on corona effects, for a period of three (3) weeks;

d) advise and report on development of research programs on insulator contamination and training of research personnel, for a period of three (3) weeks.

The work started at the Instituto de Investigaciones Electricas (IIE) in Mexico on November 11, 1980 and ended on January 24, 1981.

The present report is subdivided into 4 parts covering each of the above items with the exception of the problems of training of resear . personnel which is dealt with in a separate chapter.

2. SPECIAL MEASURING TECHNIQUES

(DR. R. MALEWSKI)

2.1 Identification of the Available Resources and Prospective Customers

The assignment has consisted in initiating research projects for a small team specializing in HV technique and specifically in HV measurements and testing.

The structure of the department concerned in IIE is as follows:

Mr. Eduardo Lobaton	Director of the Equipment Department
Mr. Rogerio Covarrubias	Assistant Director
Mr. Ramon de la Rosa	Group Leader
Mr. Salvador Portillo	
Mr. Joachim Ruiz	
Mr. Maurillo Ramirez	

An analysis of the IIE structure, objectives and resources has revealed that the CFE (Comision Federal de Electricidad) had been the main customer for the IIE services and that this situation will most probably continue in the foreseable future.

At present, the energy transmission system of Mexico is based on a 400 kV grid but it is expected that a higher voltage (800 kV or 500 kV DC) system will be installed in the future.

Considering specific geographic conditions of Mexico, (a main load center of high altitude around Mexico City) an experimental study of transmission line insulation is needed for optimization of the existing 400 kV system and for planning of the future EHV lines.

Since no data are available on the dielectric strength of HV line and apparatus insulation at 3000 m altitude, a testing laboratory will have to be established to provide the necessary information for CFE and local manufacturers' personnel.

An investigation of the IIE installations has indicated that the IIE has actually an appropriate experimental station at 3000 m. This site called Salazar is located off the main highway some 40 km south from Mexico and was established some 15 years ago for corona studies. Presently the station is not active but a necessary infrastructure is there (fenced lot, building power, water, watchman, access road, free adjacent land).

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2.2 Proposed Research on Dielectric Strength of Line Insulation at High Altitude

The final result of these preliminary contacts and investigations was formulated in a proposal of a research study on the performance of line and apparatus insulation installed at high altitude.

The proposed research project consists of a series of experiments to be performed on HV line tower models installed at the 3000 m altitude site (Salazar) and also close to sea level (IREQ). The real scale 400 kV and 800 kV tower models will be tested with switching and lightning impulses in order to determine their 50% flashover voltage (FOV) and its standard deviation. This will allow for derivation of the altitude coefficients of the line dielectric strength. A low probability FOV will be determined experimentally using the modified alpha and beta method in order to provide CFE with design data for the new 400 kV line and future 800 kV line clearances.

The experimental equipment needed consists of an outdoor type impulse generator for installation at the high altitude site, voltage divider, recording equipment and the tower model. For studies of 400 kV line insulation an impulse generator of 2,8 MV will be sufficient; a larger 4,4 MV generator will be needed for investigation of the 800 kV system insulation.

A complementary study performed at low altitude will provide reference data on the dielectric strength of tower models of the same geometry as tested at 3000 m. Since the general data on dielectric strength of air at low altitude are available, the measurements performed at IREQ HV laboratory will consist only in checking a few selected tower clearances. The test program of the high altitude site will be more complete, covering tower clearances corresponding to a few overvoltage levels of the transmission system.

The study of dielectric strength of large gap at high altitude is of a unique character and it is desirable to collect additional physical data on mechanism of discharge during these tests. A necessary equipment for this purpose is a streak camera with image intensifier and a quartz lens.

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Such a camera would allow for a study of influence of air density on the discharge mechanism. Results of this work would permit for a generalization of the FOV data obtained during the impulse test.

In order to familiarize the IIE personnel with the experimental techniques as well as to provide reference data at sea level, it has been proposed that some experiments will be performed by the IIE engineers at the HV laboratory of IREQ.

The development of an outdoor HV laboratory at the Salazar site will also be performed in collaboration with the IREQ personnel on contract basis.

2.3 Additional Projects

Apart from this main project, some smaller projects have been proposed on the area of HV measurements. These are listed as follows:

- Development of auxiliary HV impulse dividers
- Measurements and perfectioning of shielding efficiency of HV test bays and instruments
- Development of impulse current shunts
- Techniques of partial discharge measurements on HV apparatus

2.4 Conclusions

1. An in-depth investigation was performed in order to identify the prospective customers of the IIE and their needs.
2. A major research project on the dielectric strength of HV line towers at high altitudes has been proposed, initiated and brought to the level of acceptance by the IIE and CFE top management.
3. Further collaboration on this project has been arranged between IIE and IREQ.
4. Several smaller research projects were initiated and consultations offered to the IIE personnel.

3. DIELECTRIC TEST TECHNIQUES AND IMPULSE TESTING
(MR. DAVID TRAIN)

A preliminary analysis of the IIE customers has indicated that apart from the Comision Federal de Electricidad (CFE) there is a number of local manufacturers of HV equipment and the Instituto may render them services in form of research contracts and consultations.

A review of the possible areas of collaboration with the Mexican industry of HV equipment is presented below. These suggestions are based on present and anticipated needs of CFE who is the principal user of HV equipment in Mexico.

3.1 Electrical Porcelains

Most items of high voltage equipment utilize high voltage porcelains in their construction. For example, high voltage circuit-breakers, disconnect switches, insulators, lightning arresters, bushings, etc. For those items listed above which are manufactured in Mexico, the required porcelains are imported into the country because there are no Mexican manufacturers of high voltage porcelains. Consequently, the manufacture of many items is to a considerable extent an assembly of pre-manufacturer parts which have been made elsewhere.

A detailed study of the present and future markets for electrical porcelains is recommended. Such a study could be performed by the IIE and, if found to be economically justifiable, the IIE in association with a national manufacturer and possibly with government support could try and develop the technology required to manufacture high voltage porcelains or persuade a foreign manufacture to establish a manufacturing plant in Mexico.

3.2 Transformer Bushings

At the present time, there are no manufacturers of high voltage transformer bushings in Mexico although there are several manufacturers of high voltage transformers.

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Part of the reason may be due to the lack of a porcelain manufacturer in Mexico. The other part may be due to the relatively small market. Table I shows the CFE forecasts for major equipments up until 1989. If the statistics for Table I transformers are multiplied by 3 (because the majority are 1ϕ transformers) and by 2 or 3 again because most transformers are 2 or 3 winding units then the number of bushings required becomes interesting.

The IIE in association with a national manufacturer (who might welcome the opportunity to diversify) could develop the technology required to manufacture transformer bushings using either porcelain, "polysil" or cycloaliphatic resin for the envelope.

3.3 Transformers

The IIE has already embarked on the development of a new type of distribution transformer. A natural extension of this activity would be the development of dry-type transformers for indoor operation where the use of oil is prohibited because of fire hazard (indoor substations in buildings for example). Such transformers usually have their windings encapsulated in epoxy resin which insulated them and at the same time physically held them in position. The usual power rating for such transformers is in the 200 kVA → 5000 kVA range.

3.4 Insulators

At the present time, conventional cap-and-pin porcelain or glass insulators are used by the CFE for transmission lines. Such insulators are heavy, awkward to transport and time consuming to install. The above disadvantages will be overcomed by using synthetic insulators which are currently under development by various manufacturers. The IIE should initiate a research project to evaluate synthetic insulators made by different manufacturers. The IIE could collaborate with IREQ where considerable experience in this field has already been accumulated.

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T A B L E   I

CFE FORECAST FOR NEEDED MAJOR EQUIPMENT

Equipment	Year 1981	82	83	84	85	86	87	88	89	90
Transfos. 400 kV 1φ	15	29	8	15	20	15	22	23	11	
--- 3φ	0	0	0	0	1	0	0	1	0	
230 kV 1φ	22	32	43	38	51	21	20	29	20	
--- 3φ	3	6	10	3	1	6	4	4	5	
Disconnects 400 kV	45	75	54	21	120	42	90	99	68	
230 kV	208	352	424	348	368	220	220	212	172	
Circuit breakers 400 kV	23	38	27	11	60	21	45	50	35	
230 kV	52	88	106	87	92	55	55	53	43	
Arrestors 400 kV	45	75	54	21	120	42	90	99	69	
230 kV	156	264	318	261	276	165	165	159	129	
C.T.'s 400 kV	135	225	162	63	360	126	270	297	207	
230 kV	156	264	318	261	276	165	165	159	129	
P.T.'s 400 kV	45	75	54	21	120	42	90	99	69	
230 kV	78	132	160	131	139	83	83	80	65	

Preliminary tests could be performed in the High Voltage Laboratory at IREQ and participating IIE personnel would be able to transfer the testing techniques and expertise to the Irapuato laboratory when it goes into operation.

3.5 Power Transformers

The CFE is experiencing an increased rate of failure of power transformers. This is particularly the case for core-type transformers which have been subjected to high fault currents following short-circuits on the system or accidental out-of-phase switching during synchronization. The development of a diagnostic technique to detect the physical displacement of transformer windings following short-circuit would provide the CFE with a useful diagnostic tool. Such a technique will be required in any case when the Irapuato High Power Laboratory becomes operational since transformer manufacturers will be requested to submit prototype transformers for short-circuit tests before acceptance.

A detection technique which has been described in the literature consists of the injection of short-duration current impulses into the winding and measuring any change in the waveshape of the corresponding voltage developed across the winding.

By performing such measurements on all new transformers and then repeating them at regular intervals, it is possible to detect if serious changes have occurred in the windings.

3.6 Lightning Arresters

The failures of high voltage lightning arresters in service is causing concern to the Operations Department of the CFE. Although such arresters are not manufactured in Mexico, the IIE could initiate a research project to evaluate arresters made by different manufacturers.

The arresters should be subjected to repeated duty cycle and di-

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electric tests in order to check for deterioration in operating characteristics. IREQ has developed a method of performing duty cycle tests by using the synthetic test plant. If the initial testing required by this project was performed at IREQ, in collaboration with IIE personnel, the technology learned by the IIE group would be transferred to Irapuato when the CFE laboratories there go into operation.

3.7 <u>Partial Discharge Detection in Service</u>

The catastrophic failure of energized substation equipment (for example potential transformers) may cause severe damage and even destruction of surrounding equipment. In addition to causing a system outage, such incidents pose a safety hazard for the operating personnel. A method of detecting incipient faults is desirable and would permit the removal of defective apparatus before it becomes dangerous.

Most failures in internal electrical insulation are preceded by partial discharges and the detection of partial discharges in equipment while it is energized by the system would permit an evaluation to be made regarding its condition. Unfortunately, the performing of sensitive partial discharge measurements in a substation environment is extremely difficult due to high levels of external interference. However, ultrasonic signals produced by the P.D.'s can be detected by special transducers and these are immuned from external interference caused by corona on overhead lines, etc. The transducers would be attached on the outsides of the tanks of P.T.'s and C.T.'s and could be monitored at regular intervals. The development of suitable transducers could be done at Cuernavaca.

3.8 <u>Application of New Materials to an External Insulation of Such Apparatus as Measuring Transformers</u>

Existing and future resources of the IIE are such that a substantial amount of research will be performed for Mexican industries on a contractual basis. As an example, preliminary discussions with the Balteau Co. indicated a need for long term research into properties of cycloaliphatic resin which is used as the weather-shield material for instru-

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ment transformers manufactured by the company. Such research would be beneficial to Balteau who would like to export instrument transformers to South American countries where experience with this type of material is non-existent. Research performed by an independent and serious organization such as the IIE would help Balteau establish credibility for their products in new markets.

3.9 Testing

Many manufacturers of distribution equipment (such as transformers, switchgear cubicles, insulators, etc.) do not have the necessary equipment to perform dielectric tests. The IIE with its existing high voltage facilities in Cuernavaca will be able to provide a much needed service to Mexican manufacturers of distribution class equipment by performing such tests as:

- lightning impulses
- 60 Hz withstand tests: dry and wet
- partial discharge measurements
- RIV measurements
- tan δ and capacitance measurements

3.10 Additional Services to Industry

Although some of the following items are not research activities as such, they are nevertheless required in order to provide necessary services to Mexican industry.

3.10.1 National Calibration Services

At the present time, most Mexican manufacturers have their own "in-house" standards which are used for the testing or calibration of their products. However, none of these "in-house" standards is traceable to Mexican National Standards since in many instances such National Standards do not exist. This is particularly the case for high voltage measuring equipment. The IIE should endeavour to provide a calibration service which is accredited by the Mexican Standards Association.

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4. CORONA EFFECTS

(DR. P.S. MARUVADA)

The main purpose of this part of the visit has been to propose some research projects in the area of corona and electric field effects from high voltage transmission lines. Since the Comision Federal de Electricitad (CFE) is responsible for the design, construction and operation of the high voltage transmission network in Mexico, they will be the principal customers of IIE in any research effort related to high voltage transmission lines. Personnel of both IIE and CFE has therefore been consulted before making any concrete proposals for research projects.

4.1 Need for Studies at Present and Future Transmission Voltages

The highest transmission voltage presently used in Mexico is 400 kV ac. The transmission lines traverse regions at different altitudes, from sea level to more than 3000 m above sea level. The insulation strength of air is decreased at higher altitudes, because of the reduced air density, and consequently, larger air-gap clearances as well as bigger conductor bundles will be needed at high altitudes. Although 400 kV ac seems adequate to meet the present transmission requirements in Mexico, there are indications, based on a study of the existing growth patterns, that a higher transmission voltage, such as 800 kV ac or ±500 kV dc, will be needed before 1990. The design of these higher-voltage lines should also take into account the influence of high altitudes.

For the existing 400 kV transmission lines in Mexico, it may still be possible to optimize the line design, taking into account the different altitudes traversed by the lines. For example, a line designed for operation at 3000 m would be completely overdesigned for operation at sea level. However, a more important aspect of the existing 400 kV lines which needs to be studied immediately is the influence of corona-generated interference on carrier current communication and protection. Some of the unexplained outages of the existing 400 kV lines may probably be attributed to the failure of the carrier current protection scheme due to corona-generated interference.

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For the higher voltage transmission lines, namely 800 kV ac and ±500 kV dc, foreseen in the near future, it is absolutely necessary to conduct corona studies at high altitudes in order to obtain appropriate design data for the choice of conductor bundles. Studies at these high voltages should include corona effects such as power loss, radio interference and audible noise as well as electric field effects. Due to random variation of the parameters influencing corona generation on conductor bundles, a statistical approach is generally used to characterize the corona performance of transmission lines and, consequently, a sufficiently long period of testing (at least one year) is needed for these studies.

4.2 Existing Facilities and Infrastructure

A high-altitude corona test site, presently under the control of IIE, already exists at Salazar, about 40 km from Mexico City and at an altitude of 3000 m above sea level. The test site at Salazar comprises a test line about 400 m long, a single phase transformer and associated control and protection equipment for energizing the line up to 400 kV ac, some rudimentary measuring equipment and a control room. The two dead-end towers of the test line are designed to carry three different conductor bundles simultaneously, such that the single phase transformer may be used to energize any one of them as required. By switching the transformer (under unenergized conditions) from one bundle to the other according to a predetermined schedule, the corona performance characteristics of all the three bundles may be obtained during a test period of about one year.

A group of researchers, headed by Mr. José A. Tovar Martinez, at IIE, have already undertaken three research projects for CFE, dealing with the influence corona and other types of interference on carrier current communication. Discussions with the group of Mr. Martinez, as well as with CFE personnel responsible for transmission line communications, revealed considerable interest by both groups to expand the research program to include tests at the Salazar station, measurements on the operating 400 kV lines and studies on the influence of the corona-generated interference on carrier current communications and protection.

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4.3 Proposed Studies

Following several discussions with the IIE and CFE personnel, two comprehensive research proposals have been prepared for studies on corona and interference aspects of transmission lines at 400 kV and above. the first proposal ("Propuesta de proyecto para estudiar el efecto corona en sistemas electricos de 400 kV y 800 kV, utilizando la estacion experimental de Salazar" por P. Sarma Maruvada, IIE Report, January 15, 1981) deals with corona studies at 400 kV and 800 kV at the Salazar test station, and 400 kV corona studies on the operating 400 kV lines of CFE. For studies at 800 kV, the existing test transformer at Salazar will not be adequate. A single-phase transformer rated at 600 kV, 1A, will be necessary for tests at the higher transmission voltage. It has been found that the IMEX company, located at Queretaro, has ordered a 700 kV, 1A test transformer for their own testing purposes. However, since they may not need the full capability of this transformer for at least two years, the possibility of a short-term exchange with the Salazar 400 kV transformer has been discussed. Mr. P. Maigler of IMEX agreed on the technical feasibility of such an exchange. However, the managements of IIE and IMEX should solve the administrative problems involved. In the event that an exchange with the IMEX transformer is not possible, IIE should then be prepared to buy a new transformer.

The second proposal ("Estudio del Fenomena corona en lineas de 400 kV y su interferencia en canales de proteccion y datos de los sistemas onda portadora por linea de alta tension en la instalacion experimental de Salazar" por M.C. José A. Toval Martinez, IIE, Dr. P. Sarma Maruvada, IREQ; IIE Report, January 29, 1981) deals exclusively with studies at 400 kV. Studies at this voltage do not require any major additional equipment at Salazar. The only equipment required in this case is for purposes of interference measurements on operating 400 kV lines as well as at the Salazar station. This project would meet the immediate needs of CFE, while at the same time providing an opportunity for training the personnel.

The two proposals have been discussed with CFE personnel and have received their general approval. It was felt particularly that the second project may be started as soon as it is practically feasible. The delay

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involved to start this project would be mainly for purchasing the necessary instrumentation and putting the Salazar station back in operation.

4.4 Conclusions

1) The need for corona studies at the transmission voltage of 400 kV ac, presently the highest voltage used in Mexico, as well as at higher voltages, such as 800 kV and ±500 kV dc, has been established.

2) A research proposal has been prepared for the revival of the high-altitude (3000 m) Salazar test station, which belongs to IIE, for purposes of corona studies at 400 kV ac, 800 kV and ±500 kV dc.

3) A proposal is made for the immediate start of corona studies at 400 kV ac on the operating lines of CFE as well as at the Salazar test site, with particular emphasis on the effect of corona-generated interference on carrier current communications and protection.

5. INSULATOR CONTAMINATION

(DR. F.A.M. RIZK)

5.1 General Characteristics of the Mexican Transmission System

5.1.1 Transmission Regions

The main transmission system consists of a vast network of 230 kV and 400 kV with lengths in 1978 amounting to 8084 km and 4737 km respectively. The backbone of the sub-transmission system is an extensive 115 kV network whose length amounted to 11380 km in 1978.

The geographic location of the different transmission regions is shown in Fig. 5.1, while the distribution of transmission line mileage for different voltage levels from 69 kV to 400 kV is presented in Fig. 5.2.

5.1.2 Climatic Conditions

The climatic conditions which are decisive as far as insulator contamination is concerned vary widely across the country and represent in some cases severe combinations of adverse conditions.

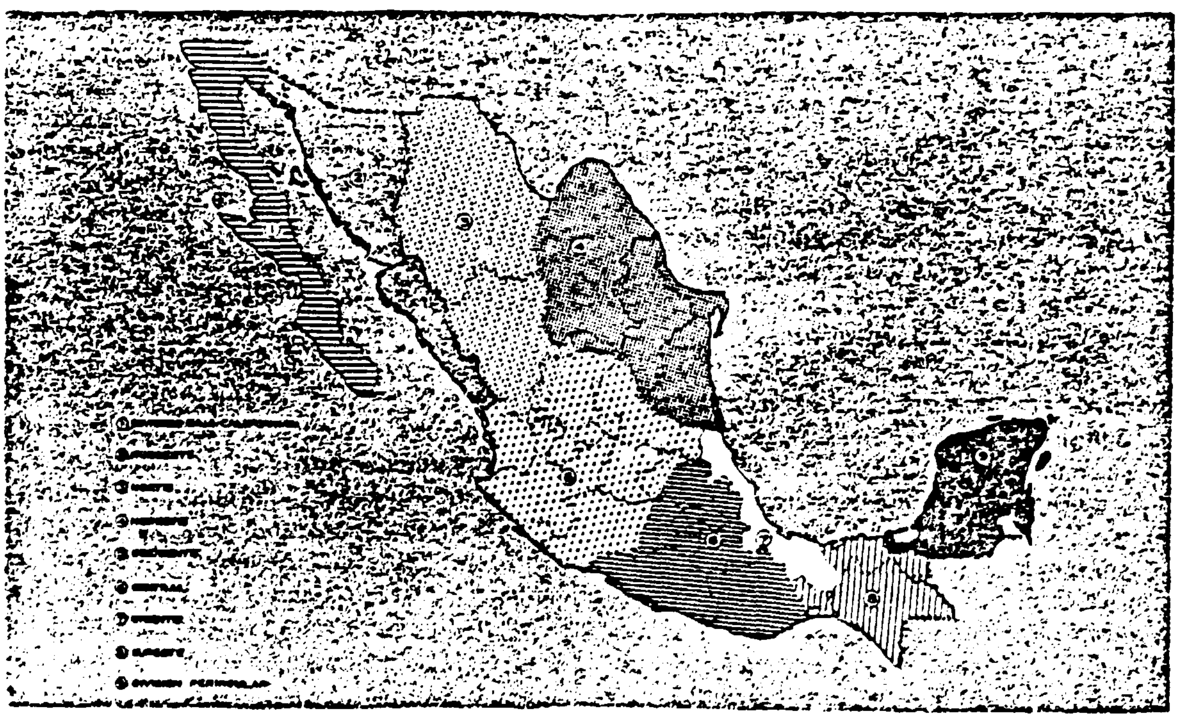

Fig. 5.1 Geographic Location of Different Transmission Regions of Mexico

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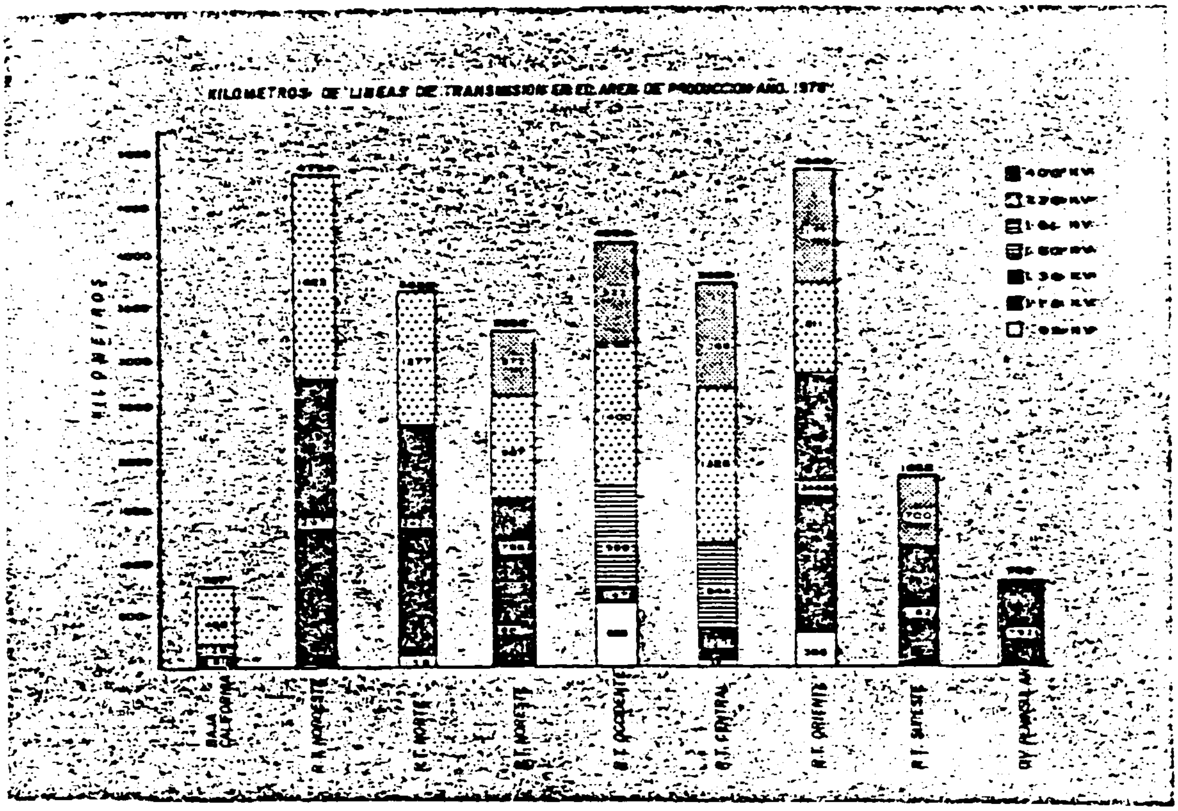

Fig. 5.2 Transmission Line Lenghts in the Different Regions of Mexico

The California Bay and North regions represent mainly arid desert regions. The North East region can be characterized as arid-industrial climate. The Central region around Mexico City combines industrial pollution and high altitude. The Eastern region near Veracruz presents a combination of marine and petro-chemical pollution.

5.1.3 <u>Insulation Levels</u>

Cap and pin insulators, some of which are locally manufactured, corresponding to Ohio Brass Catalog numbers 32440, 40640 and 32449 are used for 115, 230 and 400 kV lines. The 32440 insulators have a combined mechanical and electrical strength of 15000 lb,a working length of 5"$\frac{3}{4}$ and a leakage path length of 11"$\frac{1}{2}$. The 40640 insulator has a combined mechanical and electrical strength of 25000 lb, a working length of 5"$\frac{3}{4}$ and a leakage parth of 11"$\frac{1}{2}$. The 32449 insulator has a combined mechanical and electrical strength of 36000 lb, a working length of 7" and a leakage path length of 12"$\frac{1}{2}$.

The initial design of the 400 kV transmission lines forsaw 19 insulators (No. 32449) per string but due to unfavorable service experience was increased to 24 units for suspension strings and 25 units for tension

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strings. In very heavily polluted areas,up to 27 insulators units per string are used. The initial design, therefore, corresponds to a specific leakage path of 2.61 cm/kV phase-ground, i.e. 1.51 cm/kV phase-phase. The 27 insulators in heavily polluted areas, on the other hand, correspond to a specific leakage path of 3.7 cm/kV phase-ground or 2.14 cm/kV phase-phase.

The 230 kV lines use 16 insulators discs in suspension and 17 insulators discs in tension strings. The 16 discs per string correspond to a specific leakage path of 3.52 cm/kV phase-ground or 2.03 cm/kV phase-phase.

The 115 kV lines use 7 insulators in suspension strings and 8 in tension. The 7 insulator string corresponds to a specific leakage path of 3.08 cm/kV phase-ground or 1.78 cm/kV phase-phase.

5.2 Transmission Line Reliability

Based on available service statistics of the Federal Electricity Commission (CFE) in 1978, the major causes of faults in the transmission system comprises sugar cane fires, lightning and contamination. The importance of each varies with the region as well as with the system voltage as it will be explained below.

In the 400 kV system the major causes of faults are the sugar cane fires and lightning which were responsible for 2.93 Faults/100 km. year and 1.1 Faults/100 km. year on the average respectively. Most of sugar cane fire faults take place in the eastern region (Oriente) with an excessive fault rate of 10.2 Faults/100 km. year. On the other hand, the average interruption time due to this type fault amounts to approximately 5 minutes per fault indicating a transient nature. On the contrary, one conductor breakage in the 400 kV system caused a 175 hours interruption of the line concerned, which is typical for conductor and structural faults. In the 230 kV system lightning, sugar cane fires and contamination constitute the major causes of faults and in the order given. On the average,lightning

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resulted in 0.62 Faults/100 km.year while sugar cane fires caused 0.21 Faults/100 km.year. As for the contamination flashovers in the 230 kV system the specific outage rates are given below for the different regions concerned:

California Bay	0.66	Faults/100 km.year
North East	0.22	Faults/100 km.year
West	0.21	Faults/100 km.year

Except for the California Bay region these figures do not appear excessive. It should be noted however that there is a large number of faults for which a reason could not be found (53 Faults) which correspond to an additional 0.66 Faults/100 km.year, some of which might have been caused by pollution.

In the 115 kV system the major cause of outages are: lightning, strong winds, contamination and sugar cane fires in the order of importance. Lightning contributes 3.43 Faults/100 km.year on the average but the Western region (Occidente) suffers an excessive specific fault rate of 10.2 Faults/100 km.year. The specific outage rates attributed to contamination are given below:

California Bay:	3.87	Faults/100 km.year
North East	1.58	Faults/100 km.year
North	0.25	Faults/100 km.year
Peninsular	0.25	Faults/100 km.year

As much as 96 faults have not been accounted for, representing an additional 0.84 Faults/100 km.year, some of which might have been caused by contamination. It should be noted that insulator breakage in the 115 kV system caused an interruption time of 226 hours of the lines concerned and points out to the necessity of studying the problems of insulator puncture due to steep lightning impulses and insulator breakage due to power arcs.

In the 69 kV system, lightning constitutes the main outage cause with an average of 3.59 Faults/100 km.year. The Central region suffers as high as 6.2 Faults/100 km.year.

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5.3 Contamination in Distribution Systems

Contamination appears to constitute a major cause of outage in the Mexican distribution network. A detailed study was carried out by IIE for the distribution system around Mexico City where a combination of industrial pollution and high altitude prevails. Equivalent salt deposit densities of up to 0.18 mg/cm^2 were found. Considering the utility revenue losses, leakage current losses, consumer losses and maintenance cost, the IIE study recommended to overinsulate the 23 kV distribution feeder to 34 kV. The success of this study points out to the necessity of extending these studies to cover the different regions of Mexico since anticipated technical solutions will differ from one location to another depending on climatic conditions and system voltage.

5.4 Proposed Contamination Studies

From the above, it is clear that there is a real need for a detailed study of the insulator contamination problem in Mexico. The purpose of this study should be to establish a guide for selection of types, profiles and numbers of insulators to be used in each region and every voltage class extending from distribution to high voltage transmission. The solution recommended should be economical and lead simultaneously to acceptable reliability of the lines concerned.

Following several discussions with the IIE researchers and CFE engineers, it is now foreseen that 15 contamination test stations will be constructed covering the different regions of the CFE network. Among these it has been suggested that 12 stations will be designed to study the contamination layer build-up and carry out leakage current measurements. The 3 other stations will moreover be equipped with test transformers permitting flashover studies. The exact location of these stations will take into account service experience and insulation levels of existing transmission and distribution lines, general atmospheric conditions as well as the presence of concentrated sources of contamination such as cement factories, chemical industry, etc.

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General discussions were held to cover the following points concerning the design of the measuring stations:

Characteristics of necessary test supplies

Types of leakage current detectors

Test Voltage levels

Numbers of insulators in test strings

Types of strings (suspension, tension, double strings, I-strings, V-strings, etc.)

Our discussion with the Mexican engineers also covered matters related to exposure periods, field analysis and supplementary laboratory tests. It is realized however that at a more advanced stage of the project, more detailed exchanges have to take place and that external expertise, possibly from IREQ, could be beneficial during the course of the measurements as well as during the formulation of preliminary and final recommendations.

One problem of both scientific and practical interest is the study of the mechanism of flashover of contaminated insulators at high altitude (reduced air density) Part of this study can be carried in a controlled chamber in the laboratory but must be supplemented by field tests and line experience in Mexico. This problem is expected to be the subject of a joint research project between IREQ and IIE in which the facilities and expertise of both parties could be put into use.

6. TRAINING OF RESEARCH PERSONNEL

(DR. F.A.M. RIZK)

The training of research personnel has been discussed with both IIE and CFE management. It was agreed that the best kind of training that could be offered abroad, possibly at IREQ, or in Mexico with participation of foreign experts, is through participation in well defined research and testing programs serving actual present and future needs. The high altitude test station, the corona research and the insulator contamination work offer such opportunity. It is clear from the discussions and the review of some ongoing projects that local expertise is quite satisfactory in computer applications, electronics, communications and control. What is lacking is expertise in the handling of heavy high voltage equipment particularly in their transient behaviour under adverse conditions (climatic, grounding, shielding, etc.).

It was agreed that the manager of CFE High Voltage and High Power laboratories will come to IREQ in March 1981 to work out a more specific program of training within the projects described above. For the time being, we can foresee the possibility of training of the following personnel from IIE at IREQ:

1 Engineer for a period of six months on High Voltage impulse testing and measuring

1 Engineer for a period of six months on testing techniques for contaminated insulators

1 Engineer for a period of six months on the High Voltage experimental lines available at IREQ

This can be modified according to the needs of CFE and IIE within the proposed research projects.

7. CONCLUSIONS

1. Investigation of switching impulse sparkover characteristics of tower-clearance gaps at high altitude is essential for optimization of the existing 400 kV level and for obtaining the design data for future higher voltage systems. The Salazar site can be equiped to produce the necessary data.

2. IIE can offer existing electrical industries essential testing services and can also act as catalyst for the establishment of other electrical manufacturers in Mexico.

3. Insulator contamination presents a severe problem that influences considerably the reliability of distribution as well as transmission system. Outlines of necessary research have been described in the report.

4. Corona effects particularly with view of interference with the carrier protection system merit close investigation. The Salazar site, if completed with appropriate equipement, offers good facilities for corona investigation.

5. Training of IIE and CFE personnel at IREQ will be quite beneficial and can best be ensured within joint research projects that remain to be formulated.