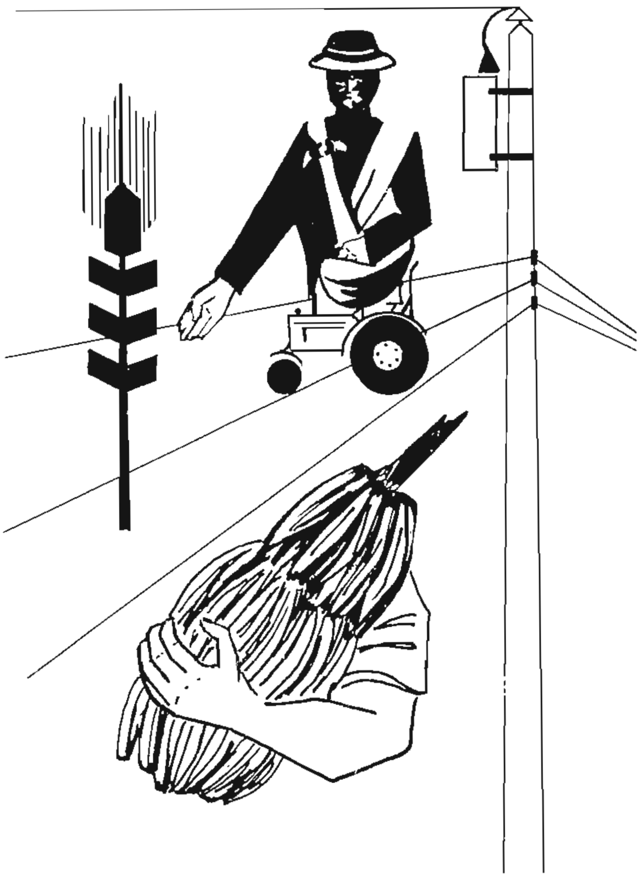
REPUBLICA DEL ECUADOR

MINISTERIO DE RECURSOS NATURALES Y ENERGETICOS
INSTITUTO ECUATORIANO DE ELECTRIFICACION

I N E C E L

INECEL

PLAN NACIONAL DE ELECTRIFICACION RURAL



DIVISION DE PLANIFICACION

ESCUELA POLITECNICA NACIONAL

QUITO – ECUADOR

FINAL REPORT OF TECHNICAL ASSITANT

FOR

RURAL ELECTRIFICATION IN ECUADOR

March, 1977   Everett C. Bristol

NRECA

FINAL REPORT OF TECHNICAL ASSISTANCE PROJECT

FOR

RURAL ELECTRIFICATION IN ECUADOR

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NRECA SPECIALIST

C O N T E N T S :

I. PURPOSE AND SCOPE OF STUDY :-

The purpose of the study was to provide technical assistance for the rural electrification program of Ecuador .

The scope of the study included :

1. Review of work already accomplished in the analysis of the existing systems .

2. Review and suggestions regarding additional data required .

3. Evaluation of progress in system planning and recommendations for consideration .

4. Review and recommendations on design criterio for rural electric systems .

5. Recommendations for selecting pilot project areas essential conditions and desirable conditions .

6. Considerations for methodology for projecting load growth .

7. Recommendations for cost reductions and for improvement in the quality and continuity of rural electric service .

II. ACTIVITIES AND INSPECTION TRIPS

To afford a perspective of the personal observations and validation of the material in this report, the following list of specific activities is provided :

1. Auto trip to Santo Domingo de los Colorados (two days). Discussions were held with the General Manager, the President of the Board of Directors, Chief of Distribution and a peace corps volunteer (8 years experience with a major USA manufacturer) . We inspected the generating plant and substation, about 30 miles of distribution lines, a plywood mill, palm oil processing plant and a fiber plant (Vía Quevedo and Vía Chone) .

2. One day trip by auto to the Otavalo-Ibarra region with observation of the distribution lines, electric services and general economic conditions and productivity of the area .

3. Traveled by auto to Ambato (Pelileo, Huambaló, Cotaló), Baños, and Socio-Economic Groups about various aspects of system design and the methodology for making load forecasts .

   Made a detailed inspection of the region to observe the system capacity and to visit some areas being considered for rural electrification (One day) .

4. Traveled by auto from Ambato to Riobamba to Guayaquil (one day) and observed the state of the rural areas enroute .

5. Visited areas generally north from Guayaquil to see distribution and transmission lines built and under construction. Inspected

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rice mills, irrigarion pump, and various residential areas at Flor de María, El Mate, Pedro Carbo, Daule, Palestina, Vinces, and Babahoyo. Inspected lines 4-8 years old, tranformers, services, etc. Visited the generating station at Babahoyo and talked with a peace corps volunteer with many years of experience as a diesel mechanic.

6. Presented conference papers to INECEL and Politécnica personnel at Quito and Guayaquil on rural electrification .

7. Held informal discussions with the Technical .

III. OBSERVATIONS AND COMMENTS

The Appendix and the parts of this report contain observations and recommendations about the rural electrification program in Ecuador. This section contains additional miscellaneous comments about the standards for construction and some suggestions regarding operations and maintenance .

System Expansion

Which portions of the existing systems can be modified and integrated into the long range plan ? Which parts should be abandoned and replaced with new facilities? Most of the lower voltages (below 13.2 KV), particularly old lines of small conductor size should be replaced . Most of these that were observed are in poor condition and could not be rehabilitated at a reasonable cost .
What is the optimum relation between transmission lines, substations and distribution lines? What voltage levels are preferable? There is likely more than one acceptable solution. However, it appears that a good system has already been started that will serve the long range

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loads very well. That system is to build 69 KV transmission lines from bulk terminals of 138 KV and 230 KV of the interconnected - system. The 69 KV lines can adequately supply the stepdown distribution substations located at the major load centers throughout the regions. From the distribution centers, 13.2 or 13.8 KV lines should be constructed along the main routes. Radial taps should be single phase to the small villages, unless there are likely to be large motors requiring three phase power .

It may be desirable at a future date to loop the 69 KV transmission line if possible, so that all main distribution substations will have an alternate source of power. This is not necessary, however, and radial lines can operate satisfactorily if properly constructed and good maintenance practices are followed .

Additional 69/13.2 or 13.8 KV substations can be added along the 69 KV lines as loads increase in the future. In the early stages it appears that both the primary lines and the secondary voltage lines will have to be extended further than normal, to serve the large number of very small loads .

Substation Design Practices

My experience has been to design substations as simple as possible to facilitate construction, operation and maintenance .

In the early years of REA it was common practice to specify three single phase transformers plus a spare. However, performance of the transformers was so reliable that it is now common to specify one three phase transformers for most rural distribution substations .

It is desirable, when there are many substations of similar voltage characteristics, to have a mobile sub available for emergencies, and also for routine maintenance of the substations periodically .

For protection of substation transformers on rural electric systems up through 7500 KVA, high side fuses should be adequate , if proper time-current characteristics are selected. For 10 MVA and above, - consideration should be given to relayed circuit switchers with - differential protection. My experience has been to use high quality station type lightnings arresters on both the incoming high voltage lines and all outgoing distribution circuits .

I recommend consideration of step voltage regulators for the low vol tage bus of all distribution substations, unless it is a power bank for just one large industrial consumer. The ± 10% voltage regulators at substations are a standard REA practice.

For protection of the distribution circuits, my experience has been very good with hydraulic oil circuit reclosers, with two fost and two slow, time-current curves. These devices are simple and reliable and are easy to coordinate with sectionalizers and fused cutouts on branch taps. A number of good vacuum reclosers with solid state electronic - controls are now available at a somewhat higher cost. For heavy duty circuit loading above 4 MVA, it would be good to considerate these .

It is recommended that all larger stations have certain basic instrumentation, which is not very expensive, but provides the measurements necessary for good operation and maintenance - KWH and KW (with a time reference) and KVARH metering for the total substation. Maximum current in each phase and substation voltage should be measured at time of - system peak by using portable instruments. These can be used at other substation and at points along main lines .

Supervisory control, telemetering, etc. in my opinion are not necessary and is too expensive for rural distribution stations and lines .

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Lightning Protection

It seems that thunderstorm days in Ecuador vary from 10 to 50 days per year. So the application of arresters will depend upon local conditions. On my system we have an isokeraunic level of 40+ days per year. It has been our practice to install arresters on all transformers, regulators, reclosers, etc., but not on lines otherwise. Records should be maintained of lightning damage over a period of time to evaluate the expenditures for such protection.

I have observed that shield wires are sometimes used on 69 lines and sometimes not. Experience is being gained. However, I would recommend that shield wires be used at least on the transmission lines in close proximity to substations. It is also important to apply lightning arresters according to whether the system is effectively grounded, or is ungrounded, in order to get the maximum protection.

Poles

Most of the poles in use are concrete, but some experiments are being made with wood poles. The cost of the concrete poles seems to be 2 to 2 1/2 times the cost of wood. The concrete poles are doing a fine job, have a good appearance but are heavy to transport and set.

For rural areas it seems highly desirable to use wood poles if adequate treatment can be achieved to assure long life. In either event, concrete or wood quality control is very important. There are reports of some concrete poles that have seriously deteriorated in areas near the ocean. Is it possible some of these poles were poorly manufactured, using bad water or some other deficiency ?.

Adequate treating facilities for wood poles should receive a high priority in order to extend service in rural areas at a reasonable cost.

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Arounding and Neutral Conductors

There are different philosophies about installing neutral conductors and where they should be framed.

Apparently, some single phase lines are operating satisfactorily with out a neutral conductor. This is contrary to my experience. It would seem to offer some problems in safety from broken ground wires, as well as in getting proper operation of protective devices under fault condi tions. I would also think there could be some regulation problems in the future .

My experience is to ground according to REA standards of grounding about every 1500' with a driven ground rod, including all equipment installa tions. An multiphase lines I recommend a pole protection ground on every pole .

We generally install the neutral below the cross area. I think it affords greater safety and is also easier to connect transformers .

I recommend an effectively grounded system with a grounded neutral conductor on both single phase and three phase lines .

Computers

Most of the rural electric systems in the USA do not use computers for system design purposes. However, many are adopting central computer services for various operation and maintenance programs. The most common are for consumer billing and accounting and for other related programs utilizing the KWH and financial data obtained through the bill ing process .

My rural electric system is presently using a central computer service

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for transformer loading, substation and line losses, and for load factor and power factor information .

Although, computers are useful tools, particularly for analysis of complex integrated systems, there are others satisfactory and simplified methods of accomplishing the necessary results. Undue reliance should not be placed on computers as a means of solving all - problems. There is no substitute for good experience and judgment.

Construction Standards

I reviewed the standard drawings and specifications for distribution construction. They look good to me and are quite similar to the REA standards with which I am familiar. I inspected many miles of lines in service and under construction and the design and construction seems to be working well. There were a few minor differences, but apparently of no significance in operating problems .:

- double pins for leadends, rather than using suspension type insulators .
- guip leads seemed short in some cases, permitting the poles to lean .
- midspon service taps for residences and businesses is a good idea because of the short service drops and small conductors. However, I could anticipate some problems with the wrapped connections as loads increase. Perhaps, connectors should be used; I have found the best experience with compression type, but the tools are expensive and may not be readily available .
- both steel and wood cross arms are being used satisfactorily. However, I observed a number of wood crossarms, installed from 4-8 years that were badly warped or deteriorated. Some study should be made

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of the quality control on treatment of the crossarms, the degree of preservative penetration and retention .

- the distribution transformers have taps permitting use on either 13.2 or 13.8 KV systems. It could be desirable, but perhaps not possible to standardize on one voltage. I believe about 10% could be saved on the cost of transformers by eleminating the taps. I have found it is difficult to use taps on distribution transformers for voltage regulation too difficult to maintain records and to keep up with system voltage levels. I recommend generally that taps be specified only on substation transformers or large power banks .
- care should be taken in using hot line clamps on conductors under tension. Artnor rod or a stirrup should be used; otherwise, the conductor under tension can be damaged by arcing and eventually fail .
- I prefer the distribution design using the pole top pin because it provides better separation for long span rural construction .

Operations and Maintenance

This is a serious problem facing many rural electric systems in the USA, as well as Ecuador. It is very important to establish and carry out a regular maintenance program :

- Substations should be inspected at least monthly, if not semi - monthly, for broken insulators, loose connections, transformer temperature, etc. Annually, the oil in the all transformers, regu lators and breakers should be tested for dielectric strength. Acidity of the oil should be checked in the larger transformers also .
- A line maintenance program should be undertaken for clearing away

trees and other hazards such as TV antennas. I saw many problems of TV antennas very near the high voltage lines. Then, should be a planned program for identification and replacement of bad cross arms before they fail and cause an interruption of service.

Service Interruptions

It is my understanding that the entire country is quite free of loading problems due to natural causes such as wind or snow, etc. The major causes of outages seem to be :

1. Inadequate generation and substation capacity .
2. Lack of maintenance programs for certain equipment .
3. Some cases of inadequate records and load management to anticipate overloading and ,
4. Protection is not available or is not properly coordinated to isolate faulted equipment and lines to sectionalize the system, and to minimize the area out of service .

   It is recommended that records of service interruptions be kept analyzed monthly, and that attention be given to further sectionalizing and protective coordination studies .

Consumer and Community Relations

If the local people have a good understanding of INECEL's interests and concern in the economic development and improvement of their rural areas, they will be interested in using electricity and the loads will grow. Local newspapers and radio stations can be used, community meetings can be held and good relations established with local leadership .

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Power Use

The power use advisors will need to learn the conditions and problems of each area, how people think about rural electric service, and how they can utilize electricity for better productivity and greater benefits. The power use personnel will have to develop demonstration programs and can perhaps work with local dealers and merchants for consumer education programs .

Goals for Improvement

Some recommendations have been included for pursuing goals in the following areas :

- System losses are in the range of 18-25%; these need to be reduced to approximately 12% over a period of time.
- Load factors are 28-40% at present; load management methods should be considered to increase to 50% if possible.
- Power factors range from 75-85% shunt capacitors should be considered to rain the systems power factor to at least 90%. This could be done by requiring large consummers to install shunt capacitors as well as the power companies adding capacitors on selected 13.2 or 13.8 KV lines .

IV. CONCLUSIONS

1. The work in progress in planning and designing the rural electrification program in Ecuador is very good. Excellent basic data about the existing systems has been prepared for all the regional systems.

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2. The personnel of the rural electrification group are very well educated, but are quite young ingeneral, and therefore, have not had a great deal of experience .

3. There are certain priority areas under consideration for the first phase of the long range national rural electrification program. They are being selected to assure a successful beginning for the long range national program .

4. The priority areas have been tentatively selected and will be confirmed on the basis of certain essential conditions as listed in the Appendix B, section N° 1 .

5. These identified priority areas have already some "Backbone" distribution lines of good quality and capacity from which lateral extensions can be made to expand the rural electrification program .

6. Power requirements studies of these selected areas are underway and these will be followed by a detailed feasibility study to support a loan application .

7. My further conclusions are that attention must be given to consumer power use programs, to improved quality of service and to redution in costs where possible. Comments and suggestions have been included about these matters in this report .

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V. RECOMMENDATIONS

1. The Power Requirements Study for the target areas should be completed as quickly as possible with the forecast of the - loads for the next ten years.

2. The essential conditions as outlined in Appendix B, Section Nº 1, should be resolved and accepted.

3. Programs should be undertaken to improve the quality of service by establishing maintenance programs as suggested in this study.

4. A feasibility study should be prepared to support a loan application for the necessary funds to construct the facilities in the pro ect areas .

5. Adequate provision must be made for the development of additional human resources. There are skilled personnel at present, but many more will be needed for the rural electrification program . Training programs should be undertaken in the areas of management and administrativa practices, organization and employer relations and consumer education and power use .

APPENDIX A

March 11, 1977

Everett C. Bristol

NRECA SPECIALIST

"PLANNING & DESIGN FOR RURAL ÉLECTRIC DISTRIBUTION SYSTEMS"

I Introduction and Background

-General Remarks
-Experience in a typical rural electric system-USA
-Experiences in Brazil and Panama

II General Comments - System Planning and Design

-Objectives
-Analysis of existing system
-Forecast of power requirements
-Factors and criterion for consideration
-Communications among departments

III Specific Comments - System Planning and Design

-Availability of electric service
-Power supply
-Relationship of Transmission lines, substations and distribution Lines

-Quality of service

-continuity
-voltage regulation
-consumer relations

-Cost Control

-simplified design techniques
-simplified field engineering
-standardization
-losses
-load factor
-power factor

IV Measurement and Evaluation

-Records
-Standards of performance
- Modification of planning and design

"PLANNING AND DESIGN FOR RURAL ELECTRIC DISTRIBUTION SYSTEMS"

I Introduction and Background

-General Remarks

I am happy to be in Ecuador and it is a pleasure to work with the highly educated and competent people in INECEL and the EEPN and ESPOL groups. There are many degrees here but my background is more in experience than formal education.

My purpose is to share some typical examples of rural electrification and describe some methods that you may find interesting and helpful and that you may want to adapt to your needs. An the other hand you may determine that what you are doing now is already a better method.

My stay has been very short so it is impossible to know all the conditions, all the work that has been done and how the systems operate, so I may make some mistakes about your electric programs.

I have had the opportunity to visit several areas. Ecuador is a very beautiful country and has many different cultures and climates. In my travels I have noticed that many people are without electric service. I understand also, that there are times of shortages, mostly because there is not enough generation and transmission capacity. It is my understanding that these problems are being corrected by facilities planned and under construction.

-Experience in a typical rural electric system - USA

In my opinion the R.E. Program in the USA is one of our very best programs, not only in the improvements in living conditions for our rural inhabitants, but also in the benefits to the nation as a whole. The increased productivity of agriculture, processing of food and fiber, and the related economic development of commerce and industry helps the entire country.

I have been working in rural electrification for 30 years, much of the time with the same rural electric system - it has grown in those years from 300 consumers, 112 miles of line, one 300 KVA sub., an organization of 4 employees, to 10.000 consumers, 1800 miles of lines, 80.000 KVA in 17 subs. and an organization of 67 employees.

Peak demand for the system 50.000 Kw ±

Annual load factor 55%, AWG, monthly L.F. 70%

Systems losses 9%

Power factor - in excess of 95%

My R.E. system is only one of several hundred similar systems. There are some differences in the methods of operation, and widely different climates and terrain, but the same basic patterns have been used, and have been tested by many years - since the beginning of REA in 1936.

Most of the R.E. systems in the USA do not have generation plants; they purchase electric power from large generating and transmission networks at scattered bulk power delivery points. From these points the R.E. distribution systems transmit and distribute power to the towns, villages and scattered consumers in their regions. If I understand correctly, this is similar to the plan for Ecuador.

-Experiences in Brazil and Panama

In 1965 , I spent 5 months working with rural electric projects in - (Belo Horizonte) Minas Gerais, Brazil Later , in 1967, I had the - opportunity to be in Panama for 3 months to prepare a feasibility study for a project in the Province of Los Santos.

There are some different philosophies about the financing the ownerships and the operation and control of electric systems, and also about the priorities for social - economic development, I believe R.E. deserves a high priority, with the important goals of providing good electric service, at a reasonable cost to as many consumers as possible.

I have a firm belief in the values and benefits of rural electrification (You see, I grew up on a far in Colorado and we did not have electricity we used wood /coal for fuel and kerosene for lighting).

It has been my experience that there are some differences, of course, but many of the problems of planning and design,construction and operation and maintenance are similar in Brazil, Panama, USA, and perhaps in Ecuador.

II <u>General Discussion - System Planning and Design</u>

-Objectives

At this time, long range plans are being formulated for a national rural electrification program. But, of course, the actual construction and extension of service can only be accomplished over a period of several years. It is a tremendous undertaking.

At the same time that long range plans are being developed, intense efforts are underway for the first phase of the project. It will be important to select priority areas with the density and the characteristics to assure success of the pilot projects. Thus a successfull pattern for rural electrification can be established for the entire country in the future.

- System Analysis

Excellent work has been accomplished in the preparation of the basic data, the mapping of existing lines, substation and generation, and one line schematic diagrams of the existing systems with the electrical characteristics. Graphs have been prepared showing the relation of generating capacity to peak demands. Detailed maps are being prepared of the locations and KVA sizes of distribution transformers.

One problem has been the determination of the power flows, bus voltage regulation and fault current calculations on the systems with several interconnected sources of small generation. Computer programs for these specific situations have not been acquired and may not be readily available.

Perhaps adequate field measurements could be made under various generating conditions to form a judgement of the probable voltage levels and power flow.

Future plans may provide for relocation of some smaller thermal and diesel generation to isolated areas to reinforce power supply in those systems.

Most of the rural electric projects, with which I am familiar, do not have generation and do not operate interconnected. They prefer to operate either radial or with loop feeds and alternate supplies, but with an open point.

Other information that is important in the analysis of the present system includes:

1) Actual loading of substations and distribution lines and phase balance.

2) Voltage conditions at consumer utilization points as well as at substation buses.

3) System energy losses

4) Service reliability and the adequacy of the sectionalizing plan.

5) The physical condition of the electric facilities, and the adequacy of the maintenance program.

6) Load factor and power factor of the system.

-Factors and Criterio for consideration

A number of factors are inter related and tend to make the system planning and design somewhat complex:

1) Bulk power costs from the generation and transmission grid. What will the long range costs be?

2) Costs of construction of lines and substations the initial investment depending upon the electric capacity, safety factors, mechanical strength, and redundancy built into the system .

3) Anticipated operating and maintenance costs?

4) Cost of energy losses?

5) Rate of inflation?

6) Rate of load growth? Early obsolescence and the need for line changes and conversions should hopefully he avoided.

-Power Requirements Forecast

The design of the rural electric system must be adequate to supply all existing consumers and the potential consumers that are likely to be connected by the time the system attains the long range loading The long range load level is the estimated peak month average use in KWH/ consumer for all consumers except for large power loads which are treated individually. This average is generally 4 to 6 times the highest load levels to date. Tables are available which facilitate the estimation of demands based on average consumption.

Consideration must be given to the kind of education and power use assistance program that will be implemented. This will affect the power requirements, as will the level of tariffs. The tariffs must be high enough to return revenues which will maintain the integrity of the system and support future capital needs.

A survey must be made of the target areas to determine the attitude of the people toward rural electrification and their willingness and ability to use and pay for electric energy.

In a recent trip to Santo Domingo we observed several instances of, opportunitties for beneficial use of electric energy to expand production of food and fiber to introduce additional processing of raw materials, as well as improve the living conditions in the residences.

Skill and good judgement will be required of the socio - economic group to forecast the power requirements. Excellent base data from the 1974 Census is available and only the field work is required to determine the power requirements.

-Organization and Communications

The design of the rural electric systems must be more than technical calculations. It must include the practical factors and the experience of construction and operations and maintenance. So, there must be good cooperation and sharing of ideas throughout the organizations of INECEL and the Regional Systems. In this way, we can achieve a system that not only has adequate capacity but will also be economical to construct and easier to operate and mainten over many years at a low cost.

III <u>Specific Comments - System Planning and Design</u>

Availability of an adequate source of power is, of course, the first consideration. The generation and transmission grid and interconnected system should provide a good source of power for the regional distribution systems in the future.

The terms and conditions and particularly the cost, are very important The cost of the electric service to the ultimate consumer is largely determined by the wholesale power cost. In the USA now, the cost of the wholesale power represents about 60% of the cost of electric service to the consumer.

Relationship of transmission lines- number and location of substations- length of distribution lines. What is the optimum relationship among these components of the electric system?

It is desirable to keep the distribution feeders as short and direct as possible, within the economic restrictions. In the early stages of developing a rural electric system it will be necessary to extend the distribution lines for perhaps 100 Kms to serve isolated communities and to reach the greatest number of people. Should the new lines be 1 or 3 phase? Our experience has been that the main, principal lines should be 3 phase in each direction and the lateral tap lines should be 1 phase. Also, 1 phase transformers would be installed along the main lines, balanced among the three phases.

Of course, the routing and direction of the lines should be along the roads to facilitate construction and maintenance and to supply the maximum number of consumers.

At Santo Domingo and near Guayaquil we saw good examples of these principles.

A common experience in the USA would be similar to same possibilities here. That is, to utilize 69 KV transmission lines from the bulk terminals of 138 KV and 230 KV. The 69 KV lines are not so expensive to build and can easily be done, by the Regional Systems to supply load center distribution substations. From these distribution substations 13.2 or 13.8 KV feeders can be extended to serve the consumers.

It is desirable, but not necessary to have a looped 69 KV transmission system. In my experience we prefer to operate as simple as possible with the loop open at same point. This may not be the optimum for load flow, but we find that on rural systems, it is not so complex, and the reliability is improved.

One experience we have had in system planning on two ocassions was to build a 69 KV line, but operate it initially as an express distribution feeder at distribution voltage. Then at a future time when the load requires we build a substation and change operation to 69 KV.

-Quality of service

There are different opinions as to standards for the continuity of service. REA suggests a standard of 5 horus per year per consumer. In my system we have a standard of 2 hours per year, however, our actual experience in this year is 4 hpurs average per consumer. (We have had some problems with our underground circuits).

Our records of service interruption are in three categorities:

1) Power supply from the G and T grid.

2) Planned outages for replacement of equipment , etc.

3) Emergency - due to ice and snow, trees, wind, bird (eagles), vehicles, ligthning, equipment, failure, etc.

Records - Number of interruptions, location, consumers, and cause.

An analysis of records each month will show whether the problems are from inadequate design, bad construction or lack of maintenance.

Voltage Regulation

Voltage provided to consumers must be within certain limits for the proper utilization of equipment.

The system should be designed so that the voltage drop profile allows for a primary V.D., drop through the transformer and service and a drop in the consumers internal wiring. An a 120 volt. base these values could be 8 Volts, 6 Volts and 3 Volts. We attempt to maintain voltage at the consumers meter between 126 and 114 Volts.

In most of the systems in my experience we use voltage regulators in all distribution substations to regulate the bus voltage and these are part of the system design. However, we do not include line voltage regulators in our system design. They are added, if necessary, as the loals increase for voltage regulation until such time as it is economically feasible to make other system changes - such as, conversion to three phase, install larger conductors, or adding another substation to shorten the length of distribution lines.

-Consumer Relations

Perhaps this is more an operating problem, rather than a criterion for system design. But we must be concerned about customer satisfaction with the service we are providing, and also concerned about public relations and a good image. These factors will influence the utilization of electricity and also the support we need for the expansion of rural electrification.

For example, we must design for adequate safety, to protect both the public and the linemen working on the lines and in the substations. We need to consider proper separations, clearances from buildings and above the ground, according to a National Electric Safety Code.

Another example of consumer relations is to assure accurate registration of the meters. The requirements for my rural electric system in Colorado are to test each meter at least every 8 years and to guarantee accuracy limits of ± 2%. Consumers will be more willing to pay their electric bills if they have confidence in the meter registration.

-Cost Control

We must always be concerned about costs. How can we control costs? How can we reduce costs?.

-Simplified Design Techniques

It is most important to master the basic knowledge and principles of technical education. However, it is possible to utilize some simplified techniques and some short cut methods to reduce the time and the cost of designing, for example, substations, transmission lines and transformer and regulator installations. REA, for example, has developed streamlined methods for making voltage drop studies and sectionalizing studies. Although it is possible to use computer programs for these purposes, it is not necessary for most rural electric systems. Good technical knowledge is still required to judge the reality of the results, but there is a cost savings in the time required to design the various elements of the system.

-Simplified Field Engineering

We have found advantages in field engineering by utilizing precalculated staking tables for staking the location of poles and anchors in the field. These tables are available form conductor manufacturers for various conductor sizes, design tensions, and ruling spans.

Sagging tables are also available to match the staking tables, so that the conductor can be installed with the proper sag and tension.

It is our experience that a three man crew can field stake, and prepare the staking sheets for construction, of one to two miles per day.

- Standardization

I have not yet had the opportunity to learn fully about National Standards in Ecuador. There are obviously some great differences between the Costa and Sierra zones. However, there must be some advantages in developing some standards on a national basis, such as: standard voltages, safety standards, service standards - perhaps similar to NESC and NEC.

One example, I believe, are system voltages of 13.2 and 13.8 KV, which require transformers with taps for use on either system. Our experience has been to eliminate taps, except in susbstation transformers, and thus reduce transformers costs by 10%.

I believe that standardization contributed a great deal to rural electrification in the USA. Excellent work has done by REA in setting standards, in developing standar construction drawings and in preparing approved material lists for use on rural electric systems. The NEMA standards, and the REA approved list of materials and equipment,greatly facilitate the preparation of plans and specifications for construction. Much time is saved in detailed design calculations. Also, the equipment suppliers and contractors can become more proficient and competitive in bidding on projects. They can do a better job at lower cost.

Another example of standardization is to select the least number and types of materials and equipment that will satisfy the needs for - equipment that will satisfy the needs for system design. For instance to select as few as 3 or 4 sizes of conductor would keep inventories at a minimum and would minimize the stocks of connectors, armar rods, dead end clamp and other accessories.

- Losses

Energy losses cost money and are directly related to the costs of - generation. It is important to reach a balance between the annual cost of energy losses and the annual fixed costs on the investments in the electric system.

For instance, an evaluation can be made in selecting conductor size for given conditions is that the cost of losses plus the annual fixed costs will be the least.

- Load Factor

It is important to achieve efficient utilization of the electric system, otherwise we have annual fixed costs on equipment that is not productive. I understand that some of the operating electric companies here hace a rather low load factor, perhaps 35% in some cases.

In my electric system in Colorado we are now understanding load - management programs of incentive tariffs and load controls to shift certain loads from peak to off-peak periods. This is extremely important because our demand cost has recently doubled. Perhaps load management is being considered here, because of the shortage of generation.

-Power Factor

It is necessary to assume a value of power factor is designing a rural electric system. Unless, there is evidence to the contrary we assume a system power factor of 90% for most designs.

Obviously, it is desirable to achieve a power factor higher than this value for the better utilization of system capacity, voltage regulation and reduction of losses.

In our application of shunt capacitors, we generally consider them a solution to operating problems, rather than a part of system design. On my system, our power factor is above 95% so we do not have to install many shunt capacitors. However, this is because our tariffa have a penalty for consumers with a power factor less than 90%.

IV Measurement and Evaluation

In order to make improvements, we need to know what results are achieving. It is necessary to measure, to maintain records and to evaluate.

-Records

It is important to measure operating conditions and to keep adequate records of the critical areas (we call "key performance areas") on a regular and consistent basis. Among others, these could include:

1) Voltage conditions - at least one continuos chart at a typical location on the system to indicate the average voltage conditions, level and fluctuations.

   - annual voltage measurements on each main line, with simultaneous charts at time of system peak, on the substation bus and at the end of the line. This would give a profile of the primary line voltage.

2) Load Measurements

   Substation - Load balance between phases
   - KW peak demand and KWH
   - KVARH
   - With this data we can determine and record monthly, the load factor, power factor and the losses perhaps on an annual basis by comparing with the KWH's billed to consumers.

Lines - Annual measurement on main lines, perhaps using thermal ammeters, to measure load flow at the time of system peak load- particularly at locations where reclosers or fuses are installed.

3) Interruptions of service - these records are often maintained in three categories of :

a) Power supply from the G and T grid,

b) Planned interruptions for scheduled maintenance and replacement, and

c) emergency interruptions. The records should show the location, length of time, number of consumers and the cause of the interruption.

-Standards of performance

In order to evaluate the results, it is desirable to establish standards for comparison. These should not be rigid, but should he guidelines for good management based on the conditions and what it is reasonable to except. Examples for a rural electric system:

Voltage - maintain the voltage at the consumers meter between 127 - 110 Volts.

Service interruptions- Interconnected system, hours/Cons./Mo - 0.1
- Planned interruptions, hours/Cons./Mo - 0.2
- Emergency interruptions hours/Cons/Mo - 1.0

Losses - 12%
Load factor- 50%
Power factor-90%

There are many similar standards that can be developed for construction costs, operation and maintenance, and other indicators of system efficiency and productivity.

- Modification of Planning and Design

On the basis of the experience we gain and an evaluation of such experience on a systematic basis, - good records and standards of performance, we can make new system designs and other changes for improvement.

A simple formula I use for system planning , is:

Where am I?
Where do I want to go ?
How will I get there?
And how will I Know?

APPENDIX B

March 10, 1977

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CONSIDERATIONS FOR SELECTION OF RURAL ELECTRIFICATION PROJECT AREAS AND FORECASTING THE POWER REQUIREMENTS :

It is very important to choose the initial project areas carefully in order to be certain of a successful pattern of rural electrification. It is also important to prepare evidence of cost/benefit ratios and feasibility of the projects, that will gain the acceptance of the funding institutions.

A most important step is the power requirements study which estimates :

- types and size of loads .
- future number of consumers by classification, their future KWH consumption and the total requirements.
- the peak KW demand and season of the year .
- consideration of improvement in losses, power factor and load factor.

The power requirements study is the basis for :

- planning and engineering studies for the future generation and transmission system.
- planning and design of the future distribution systems and the preparation of construction plans.
- analysis of tariffs for financial planning and loan feasibility studies.

This is most difficult, because only the future experience will prove that our projections were right or wrong. However, there are several factors that we can explore that will support and validate our projections .

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1. Essential Conditions For Priority Areas

- Availability of good bulk power supply of reliable generation and adequate substation capacity. These must be existing or under construction with completion dates in advance of the rural electrification construction .
- Agreement and common understanding with the Electric Companies as to the purpose, objetives and scope of the rural electrification program. Cooperation and good working relationships are necessary.
- Adequate density and income levels to assure economic feasibility under the established criteria .
- Interest among the people of the area in getting electric service and an attitude of working together to jointly accomplish goals of mutual benefit .

2. Available Information

There is excellent demographic data from the 1974 census for each community indicating the population, number and type of dwellings occupations, land ownership, present energy, sources and the number with electricity .

Data has been gathered from the electric companies showing the trend for the past 5 years in the number of consumers and the KWH consumption by the various classifications .

3. Additional Data Needed for Analysis of Growth Patterns

- Income levels and amount that could be used for purchase of energy.
- Cost of present forms of energy in comparison to the cost of electricity .
- Has the growth in electric energy use been restrained by lack of

generation, overloaded substations, by poor service, by cost, or other possible factors ?

(There are some graphs that plot generating capacity and demand. It is interesting to note the sharp upturn in electric usage when generating capacity is added) .

4. Factor that Will Influence Future Load Growth Negative Factors

- High cost of getting electric service and high cost of energy used Some data indicates a range up to 2,500 (sucres) for initial cost of service in some parts of the country. Energy costs per KWH range from 1.0 - 1.2 (sucres). At one fiber plant the operator had not changed to electric motors because there was a concessionaire charg ing high rates to his tenant operators .
- Lack of interest and commitment on the part of the Electric Companies to the rural electrification program .
- Poor quality of service. I encountered lack of trust and confidence in the continuity of service in several places visited on our field trips. This has discouraged conversion to the use of electricity .

Positive Factors

- Positive enthusiastic dedicated attitude on the part of the Electric Companies .
- Good, reliable service .
- Reasonable cost of getting service and for energy used .
- Assistance and advise in how to use electricity efficiently and beneficially; perhaps financial assistance in the form of loans for wiring and for the purchase of appliances and equipment. (The availability of good electric service in itself will not suffice) .

.../.

- Establishment of demonstration projects, both for homes and for agro-industry, to illustrate how electricity can be used. " Seeing is believing" .
- Develop joint effort programs in cooperation with various governmental institutions - education, health, recreation, development of local community leadership, etc. Coordinate the priorities and goals for maximum benefits .

5. <u>Survey Methodology</u>

It is not possible for the limited forces of the socio-economic groups to survey all the rural areas of Ecuador, or even to interview all the potential consumers in the target areas. It will be necessary to do some randoms sample surveys and apply these to the census data for the target areas in order to make load projections .

It appears that the socio-economic task force personnel should make the survey related to agro-industry load growth. But could they select and train local leaders in the priority communities to conduct the survey regarding residential use of rural electrification ? (Just in order to save time) .

An example of some survey questions is attached :

EXAMPLE OF SURVEY QUESTIONS

Survey of communities where rural electrification has been introduced to determine the changes that have taken place, and also, survey of prospective communities to obtain a judgment from the people about the probable changes when rural electrification is introduced. The following sample questions could be included in the survey :

1. With proper education and assistance in acquisition and use, what uses have been made or could be made in the residences? Lighting ____ Iron____?Small single burner hot plate______?Small electric pot for soup or heating water______?Small fan _______?Potable water pump - (perhaps for a group of people_____?washing machine______? small refrigerator______? radio/ TV_______?

2. What uses have been made or could be made in agro-industry? How many? Rice mills______? Cotton gins______? Lumber mills______?Irrigation pumps______? Processing sugar carre______?Palm oil processing______? Fiber processing______?Grain/rice drying______? Processing and storage of livestock feed for the dry season______?

   - Increase in annual production per hectare __________?
   - Reduction in production costs per unit __________?
   - Improvement in marketability with less waste and spoilage __________?

3. What other small industries have been or could be started with the availability of reliable electric service? Cement block or brick manufacturing _______? Ice cream or soft drink plants______? Central refigeration or cold storage plants______? Cottage industries using sewing machines, electric drills, saws, etc._______?

.../.

4. What community problems have been solved and what improvements could be made with good electric service ?

- Community lighting for security and evening recreational activities _______?
- Lighting for schools and the use of movies and other audio-visual aids_______? What change in the average level of years of education _______?
- Health centers with small hot water heater and with refrigeration for drugs, medicines, etc._______?
- Community potable water supply _______?
- Improved housing because of local saw mills or cement block mfg___? Number of new houses per year_______?
- Increase in business of local merchants because of the stimulated economy_______? % increase_______?

5. General Statements

A. Comments by local community leaders as to changes and as to the desirability and feasibility : ____________________________________

B. Statements from appropriate governmental officials about their interest in joint programs and cooperation in the priority areas for rural electrification : ____________________________________

6. Other Supporting Data

To the extend applicable, some comments should be included of the probabilities of load growth based on similar rural electrification programs in other Latin and Central American countries ____________________________________