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Zaire

Design, construction, and management recommendations for the Koda Falls electric power system

NRECA Small Decentralized Hydropower (SDH) Program

ZAIRE

Design, construction, and management recommendations for the Koda Falls electric power system

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SUMMARY

In January 1985, NRECA sent a two-person team to Zaire to assist with the Koda Falls mini-hydroelectric project. The 300 kW installation is being funded by USAID/Kinshasa to provide electric service to the missionary facilities at Rethy and the commercial center at Kwandruma. In addition, AID wants to test the institutional structure as a model for a national small hydropower program. AID/Kinshasa contracted with the Organization for Rehabilitation through Training (ORT) to administer the project. The turbine has been ordered and a Project Engineer/Contractor has begun detail design work. The NRECA team provided ORT with criteria and recommendations for the distribution system design, construction, management, rate structure, operations and maintenance.

Power requirements

In order to determine who would be offered electric service the following consumer classifications and priorities were established:

- Large public service loads
- Large commercial loads
- Small public service loads
- Small commercial loads
- Residences

Four types of service were defined for appropriate consumers:

Large public service	-	12 kV and transformer
Large commercial	-	Transformer; 3-phase secondary
Small public service	-	Transformer; 1-phase secondary
Small commercial and residential	-	1-phase secondary to those within 0.5 km of a transformer or 0.2 km of 3-phase service

Using these restrictions the service area was defined and the power and energy requirements estimated. It is anticipated that with modest load growth this system will approach its low-flow capacity limits in two years and design flow limits in ten years by which time the system will use approximately one million kilowatt hours of energy annually.

Electric system

Major recommendations reached during the study period were to use:

- a 500 kVA step-up station located adjacent to the powerhouse
- three single-phase 167 kVA transformers with a fourth spare at the step-up stations
- underground rather than overhead distribution lines
- an un-grounded, delta, 12 kV cable system
- three-phase step-down transformers at the load centers
- 231/400 volt secondary system

- phase load unbalances to be under 20%
- voltage drops on the 400 volt feeders and service drops kept under 5%

Detailed design standards were discussed and left with the Contractor.

The Contractor will make economic evaluations to determine the following unresolved issues:

- use of a three-conductor 12 kV cable vs. three single conductor cables
- use of circuit breakers vs. fuses at service entrances.
- proposal for crossing the swamp area
- use of insulated vs. bare secondary conductors

It was agreed that the Contractor will prepare and send to the Mission and ORT for approval:

- detailed drawings and construction plans for all the major components;
- protective coordination curves;
- load schedules including initial transformer tap settings and phase loadings.

Construction

The Evangelical Community in Central Africa (CECA) should conduct engineering inspections to ensure that the Contractor is following the approved construction and materials specifications.

A list of performance and acceptance tests for equipment and materials should be developed for approval. The turbine-generator should be tested at no-load and full-load, the cable tested at high voltage, and the 231/400 lines should be sequentially tested for proper operations.

Complete "as-built" drawings should be left with CECA at the end of the construction phase.

Rates

Rates were designed to recover full operating costs plus contributions to a depreciation fund and a development fund. These funds could be viewed as equivalent to paying a pseudo debt service. The anticipated ten-year load requirements were used to determine unit cost.

A two-tier rate schedule is recommended; large consumers to be metered and billed at $0.11/ kWh; and a monthly fixed-rate for small consumers billed at $4.51 per month. Small consumers would be wired with two light bulbs, one standard receptacle, with current-limited 4 ampere service.

Management

It is recommended that ownership and financial stewardship of the system remain under the control of CECA. However, it may be in CECA's interest to establish a separate legal entity to limit their liability. ORT's lawyer was apprised of the issue and he will advise CECA accordingly.

To obtain local input, a corporate management structure based on a Board of Directors is recommended. The Board would be responsible for the long-term viability of the system and would hire a manager to conduct the day-to-day operations. CECA should appoint an interim manager while they begin recruiting a permanent manager.

Operations

For operating the proposed system it is recommended that:

- a headquarters office, shop, and warehouse space be established;
- a communication system between the powerhouse, transformer locations, and headquarters office be provided;
- two utility operators and two powerplant caretakers be hired and trained;
- accounting training be given to the book keeper and manager;
- a household wiring program be instituted;
- the existing diesel units be used to provide "backup" supply for priority loads although they are not to be paralleled with the hydro unit;
- load management policies be adopted.

All personnel must be hired and trained to take over the system at the end of the construction period.

Progress

The Contractor must begin an intense effort to complete the designs, specifications, and construction work plans promptly if the project is to remain on schedule.

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INTRODUCTION

In June 1981 the Evangelical Community in Central Africa (CECA) submitted a proposal to USAID for the construction of a 300 kW hydroelectric plant. The plant would serve the power needs of their missionary facilities in Rethy and the neighboring town of Kwandruma. In June 1983 the proposal was revised and updated by AID/Kinshasa for submission to AID/Washington for an Operational Program Grant (OPG) and was approved soon thereafter.

In December 1983, AID/Kinshasa contracted with a local firm, American Organization for Rehabilitation through Training Federation (ORT) to administer the project. ORT and CECA have contracted for the turbine, generator, and penstock with the German firm Ossberger. They also awarded the design and construction contract to a local consortium of ACEC, Dumo Van, Dervin (DVD) and Bureau d'Etudes Techniques de Construction (BETC). The Engineer/Contractors (hereafter referred to as the Contractor) has prepared basic layouts and collected design data, but at the time of this visit, had not begun the detail designs.

Rethy

Rethy is located in Haut Zaire 20 kilometers west of Lake Mobutu (see Figs. 1 and 2). There CECA operates a 100-bed rural hospital, a private 60-student academy, an optical and printing shop, and various support services. Several villages have grown up in and about the Rethy area. About 2 km south of Rethy sits Kwandruma, a small commercial community of about 1,400 residents and 22 shops. The region produces cattle and vegetables which are sold in Bunia (100 km away) and Kisangani (700 km away).

Approximately 10 km southwest of Rethy lies the Koda River Falls; site of the proposed hydroelectric scheme. Here, the river flows over a steep 900 meter escarpment. A small flat area some 260 m down the slope was selected for the powerhouse location.

Mini-hydroelectric project

AID has two primary reasons for sponsoring this project. The first is to provide an adequate supply of electrical power to meet present domestic, industrial, commercial and health needs as well as encourage growth in the commercial and industrial sectors in Rethy, Kwandruma, and neighboring villages through the construction of a 300kW hydroelectric plant, a 11.9 km, 12,000 volt cable system and a limited amount of secondary lines. Second, the project is to test the economic and technical feasibility of the chosen mode of implementation for use in future design and planning. Rather than use a "self-help" approach with PVO's, AID chose to test the efficiency and cost-effectiveness of using professional contractors in the design and construction. Also, AID is using this project to test whether it is feasible to establish a fund for the collection of user fees which will generate sufficient income to cover the costs of operation and amortization.

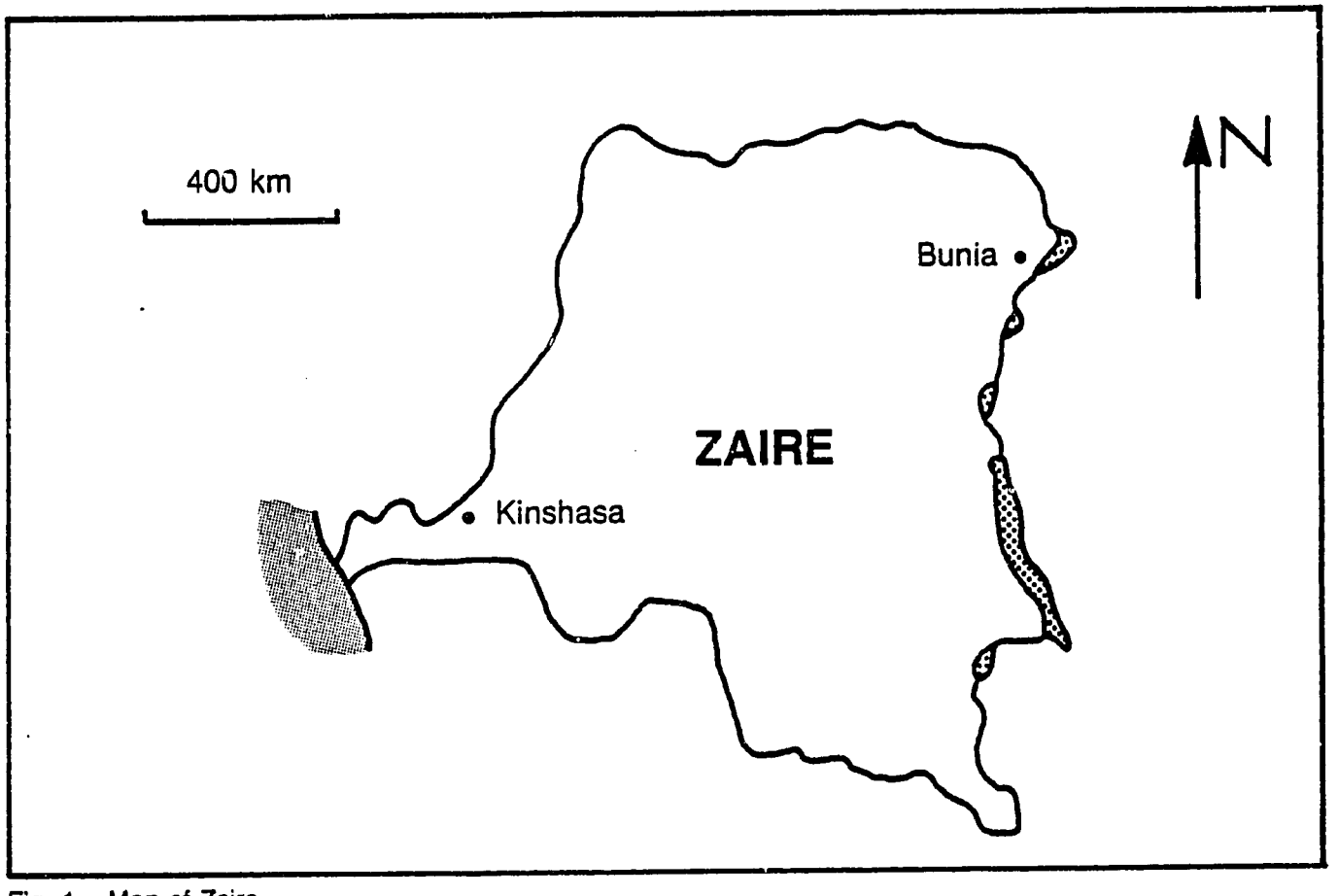

Fig. 1. Map of Zaire

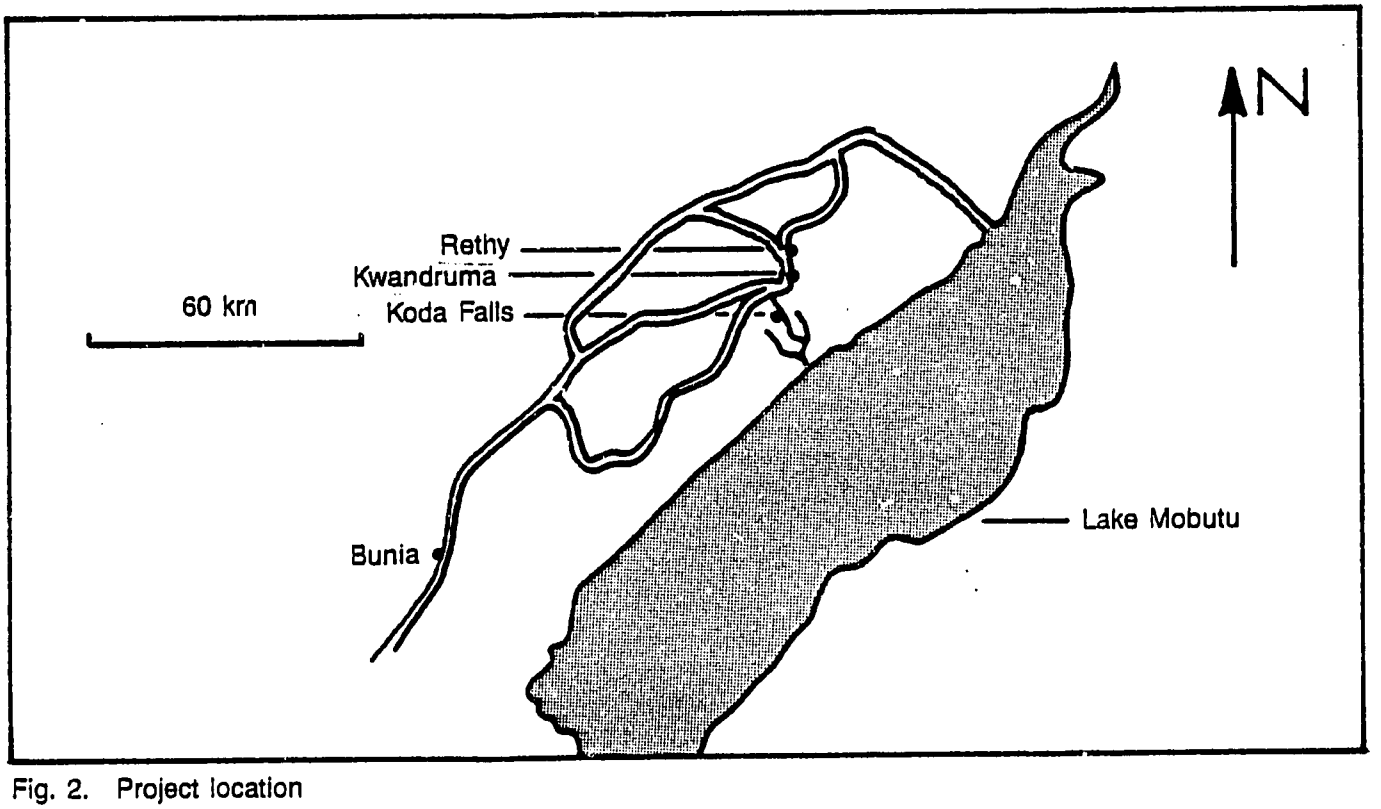

Fig. 2. Project location

Scope-of-work

The original scope-of-work outlined in AID/Kinshasa cable number 87824, May 1984, was to:

- Design an overall management system for the sub-project including a financial system for recuperation of the cost (i.e., user fees);
- Determine the overall training needs for the Koda sub-project;
- Design a base line survey that can be used to gain a socio-economic profile of the sub-project area. This will assist in the project design as well as serve as a basis for measuring future project impact.

In August 1984 the DH Program Manager, Dr. David Zoellner, visited Kinshasa to refine this scope-of-work. In November 1984 the AID Science and Technology Office agreed to provide assistance to AID/Kinshasa. Because of the Christmas holiday schedule, it was agreed to send a two-person team in January 1985.

Meanwhile, during the period from May 1984 to January 1985, the Contractor was to have completed his detailed distribution designs and to have submitted them for approval before February 1985. The Contractor was unable to do this since the project managers were waiting for an independent, unbiased consultant to determine who should receive power and how much. They were also looking for guidance on design criteria and standards. In discussions with AID/Kinshasa, ORT, CECA, and the Contractor, the team's objective was shifted to:

- assessing the priority needs in the project area and recommending a distribution system to deliver the energy;
- recommending institutional policies necessary to serve the need with hydroelectric generation;
- recommending a socially acceptable pricing policy which satisfied the financial goals.

In response, NRECA dispatched an experienced electric utility consultant and the DH Principal Engineer to Zaire for a three-week assignment.

POWER REQUIREMENTS

Service Area

In the project area there are more potential consumers than can be served by the planned Koda generator or by the amount of distribution line funded. Hence, it is necessary to establish a policy for deciding who will be offered electric service and who will not. This policy will define a service area from which loads can be estimated, operation and maintenance budgets formulated, a rate structure proposed, and a management entity developed. Other policies are recommended that will extend the benefits of the mini-hydro project to the entire target population.

Consumer Classifications

One of the goals of the mini-hydro project is to improve the quality-of-life in the target area. Hence, loads which benefit the greatest numbers in the community should have priority in obtaining service.

Public. The first priority will be extended to those loads which provide service for the entire community. These "public" consumers are the Rethy Hospital, dispensaries, optical shop, and public schools.

Commercial. The second group of consumers which provides benefits to the community are the commercial enterprises. They provide employment, generate income, and improve the economic status and infrastructure of the community.

Residential The final classification is residential or domestic consumers of electricity.

Within each group there are both large and small consumers. The following matrix shows the consumer classifications and the priority for extending them service.

GROUP	PRIORITY	
	LARGE	SMALL
PUBLIC	1	3
COMMERCIAL	2	4
RESIDENTIAL	5	5

Service Classification

For planning purposes the project will offer four types of services for the consumer groups. The first, and most reliable service is high voltage (12kV) feeder and transformer service. This would be extended to large public loads and those commercial enterprises willing to pay for the cost of additional 12 kV line.

The second (II) type of service would include a transformer and high capacity (3 phase) secondary service. This service would be extended to large commercial consumers located within 500 meters of the main 12 kV feeders.

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The third (III) type of service is a high capacity line extended to loads located within 500 meters of a transformer. This service would be offered to small commercial operations and residents.

The fourth (IV) type of service is a low capacity secondary service for small loads located within 200 meters of a type I, II or III consumer service. The following matrix summarizes the types of service for consumer groups.

GROUP	TYPE OF SERVICE	
	LARGE	SMALL
PUBLIC	I	II
COMMERCIAL	II	III
RESIDENTIAL	III, IV	IV

Applying this criteria to loads in the project area yields the system sketched in Fig. 3. The shaded portion represents the project service area. Residences in this area can be offered electrical power service. The recommended distribution system is described in detail in the technical sections of this report. Note in Figure 1 the two diesel generators. CECA presently has two small diesels rated at 39 and 26 kW. It is recommended that all three units (Koda hydro and the two diesels) be operated as one system. Then, when there is a shortage of capacity, the diesels will be called on to independently serve part of the demand (not parallel operations). The projected fuel usage would be added into the system's rate base and all consumers would share the cost of both the diesel and hydro units. The diesels would also act as emergency power supplies for the Rethy hospital and academy. Diesel generation energy cost peaked at about $0.60/kWh and is presently running about $0.50/kWh.

Energy and demand projections

Load projections for Kwandruma and Rethy were previously prepared by an AID staff economist and are presented in the Project Paper. Businessmen in Kwandruma were interviewed and asked to submit a written request for the amount of electricity they wanted. The NRECA team used these statements as the basis for the demand projections for the Kwandruma area.

For Rethy, the NRECA used figures in the Project Paper plus estimates of demand for the public, commercial, and large residential users. These loads are listed in Appendix A. Additional loads were assumed for the number of small residential consumers, and a diversity factor applied to obtain the projected station demand. The diversity factor is based upon the ratio of the installed capacity to peak load on the existing diesel units. The present or "suppressed" load (i.e. the load that will develop within two years after construction) is estimated at 191 kW. This load can be expected to grow, after the initial two year period at a minimum rate of 5% - equivalent to the Rethy load growth in the period 1980-1983. The projected demand will approach the 300 kW available (during most of the year) by 1997. Energy and load projections are shown in Tables 1 and 2. If the load does not grow at the expected rate, then CECA can extend the service area to more consumers or implement marketing "sales promotion" practices to develop the load. However, it will be much easier to extend the service in later years than to curtail service for lack of capacity.

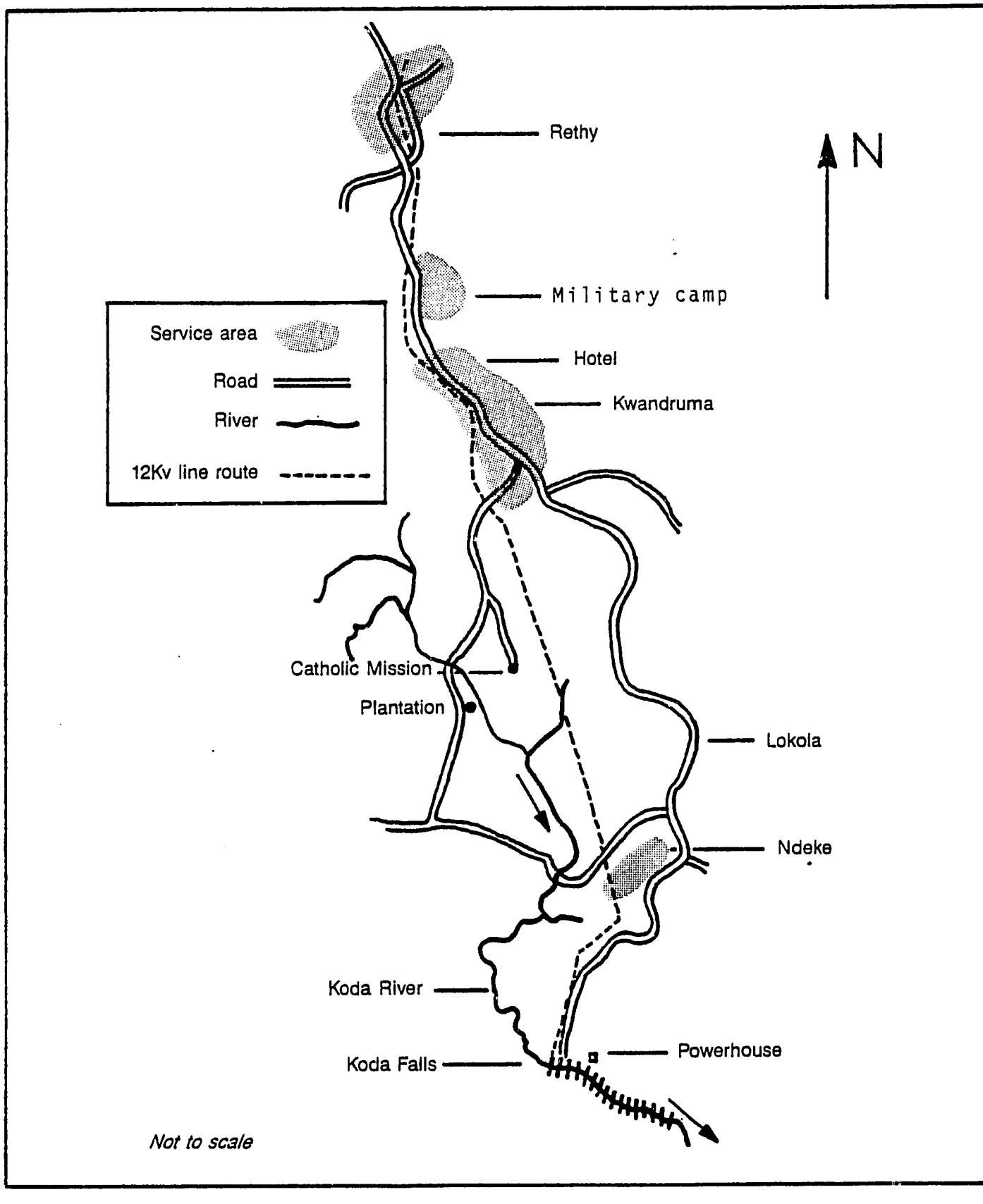

Fig. 3. Location of 12 kV line and service area.

Table 1. 1997 Energy (kWh) requirements.

Location	ANNUAL KWH USAGE Commercial	Public	Residential	Total
Rethy	281,200	90,500	226,300	598,000
Uguru Village	6,500	-	5,000	11,500
Taiya Village	6,500	-	4,500	11,000
Military Post	-	2,600	5,000	7,600
Hotel & Vicinity	29,500	-	10,000	39,500
Kwandruma No. 1	65,700	-	30,000	95,700
Kwandruma No. 2	65,700	18,000(*)	30,000	113,700
Kwandruma No. 3	28,100	1,000(**)	15,000	44,100
Ndeke (Dispensary)	-	1,000	4,000	5,000
Totals	483,200	113,100	329,800	

Total kWh usage.....926,100

Plus overall system losses (5%)
to power plant.....46,300

Total kWh requirements at power plant.....972,400

(*) Pump load for Water Supply
(**) Dispensary

Another reason for not extending the service area further in the initial years is to give the management time to mature and adopt policies for curtailing service during low flow periods. According to the Project Paper, full power output can be expected for 7 months of the year, at least 207 kW for 11 months, and over 166 kW for 12 months a year.

Table 2. 1997 Power (kW) requirements

Transformer Location	Number	Size (kVA)	Demand (kW)
Rethy: Academy, dorm, dining & kitchen, shop and vicinity, Uguru village	T1	167	110
Hospital area, prim. school, technical school and vicinity, Taiya village	T2	167	127
Military Post	T3	10	4
Hotel Vicinity	T4	25	16
Kwandruma No. 1	T5	50	34
Kwandruma No. 2	T6	50	37
Kwandruma No. 3	T7	25	16
Ndeke	T8	10	3
Total			347

Total demand at power plant assuming a diversity factor of 1.25 = 277 kW

Total kWh to be fed from Powerhouse: 972,400

Estimated Load Factor for the Overall Operation = $\frac{972,400}{8760 \times 277} \times 100 = 40\%$

This assumes 8760 hours per year of operations. However, there may be low-water days when generation is not possible.

POWER STATION

At the time of the site visit the electrical system designs were under 15% complete. In fact, the basic decisions such as:

- whether to use overhead or underground distribution
- size and location of transformers
- the type of secondary service to be offered

had not been finalized. Hence, the NRECA Team concentrated its efforts on finalizing the basic system configuration and giving the Contractor design criteria to ensure a safe and reliable system. This information was explained in detail to the Contractor and sample specifications, construction standards, and applicable codes were provide to him. The following sections summarize the configuration and design criteria agreed upon.

Turbine-generator

Ossberger is supplying the turbine, generator, control package, and steel penstock for the powerplant.

The Ossberger crossflow turbine is rated at 312 kW at 96 m head and 425 l/sec flow with 78% turbine efficiency. Assuming a generator efficiency of 96%, the maximum expected output of the generator is about 300 kW. The supplier is providing a generator nominally rated at 360 kVA at 0.8 power factor. Since it was decided to use an underground distribution system the power factor will be higher than 0.8, probably around 0.95. Hence, the maximum kW output of the generator will be slightly higher than anticipated.

The generator is 3-phase, 231/400 volts, 50 Hz.

In order to insure personnel safety and proper operation of protective relays, the powerhouse, penstock, turbine, generator, switchgear cabinets, security fence, and step-up station must be properly grounded. A grounding mat needs to be embedded in the powerhouse foundation with sufficient grounding rods to obtain a low ground resistance. The Contractor has agreed to specify the grounding resistance standard and submit a grounding mat design for CECA aprroval.

The Contractor should obtain a complete wiring diagram for the powerhouse equipment from the turbine manufacturer.

The Contractor should develop a station-service wiring diagram that will provide the powerhouse, walkway, and intake structure locations with adequate lightning and power receptacles.

Detailed structural and foundation designs should be prepared and submitted to CECA and ORT for approval.

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Step-up transformer

Two alternative locations were considered for the step-up transformers; adjacent to the powerhouse, and at the top of the hill near the intake structure. After considering the size and cost of cables required to locate the station at the top, and the voltage drop in the 260 meter cables, it was agreed to keep the station adjacent to the powerhouse. This will also increase the system reliability by decreasing the number of components.

The advantages and disadvantages of a 3-phase transformer versus three single-phase transformers were discussed with the contractor. It was agreed that three single-phase transformers, with a fourth for a spare, would add reliablity to the system and would be easier to install without increasing the cost significantly.

The step-up transformers are to be:

- 167 kVa each
- wired in a wye low-side, delta high-side configuration
- 231/400 to 12,000 V step-up rating
- have 4 taps, two up and two down, with 2.5% steps each

Simplified diagrams of the step-up station are given in Figs. 4 and 5. The station is "outdoor type" with all transformers mounted on a concrete pad. The switches on the high and low sides are to be 3-phase group-operated with arc suppressor.

Using the ungrounded delta configuration on the high voltage side follows normal European standards and is generally more expensive for rural electrification than the grounded wye system used in the U.S. This configuration is preferred by the Contractor and acceptable for the Koda Falls project since:

- this configuration is the most common one in Zaire;
- the Contractor is familiar with these standards;
- the system will be capacity constrained hence serving small distant loads with single-phase taps is not encouraged;
- all locally-made transformers are three-phase units;
- most locally-available motors are three-phase.

The Contractor was urged to promptly complete the design and construction work plans for the step-up station and submit them to ORT and CECA for approval.

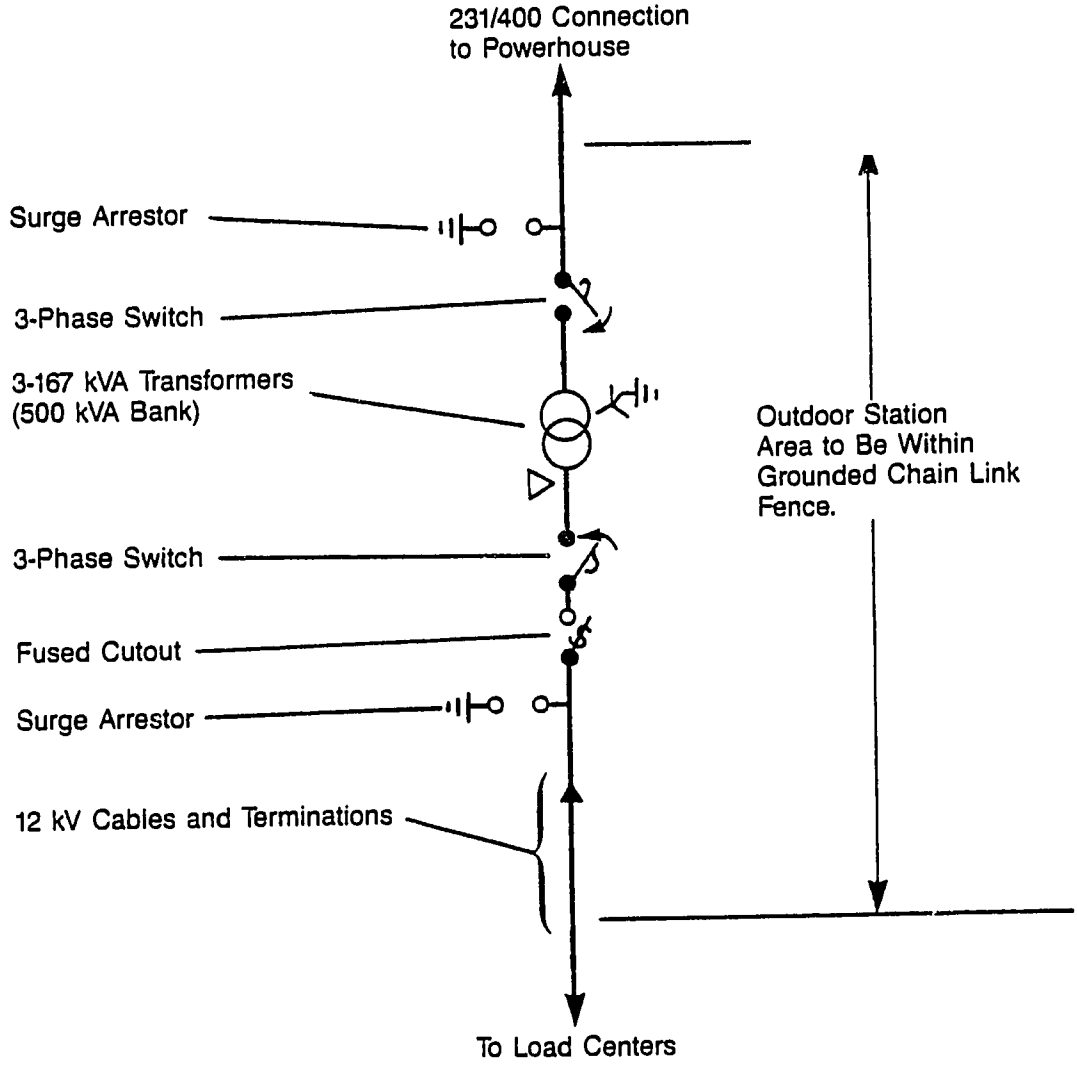
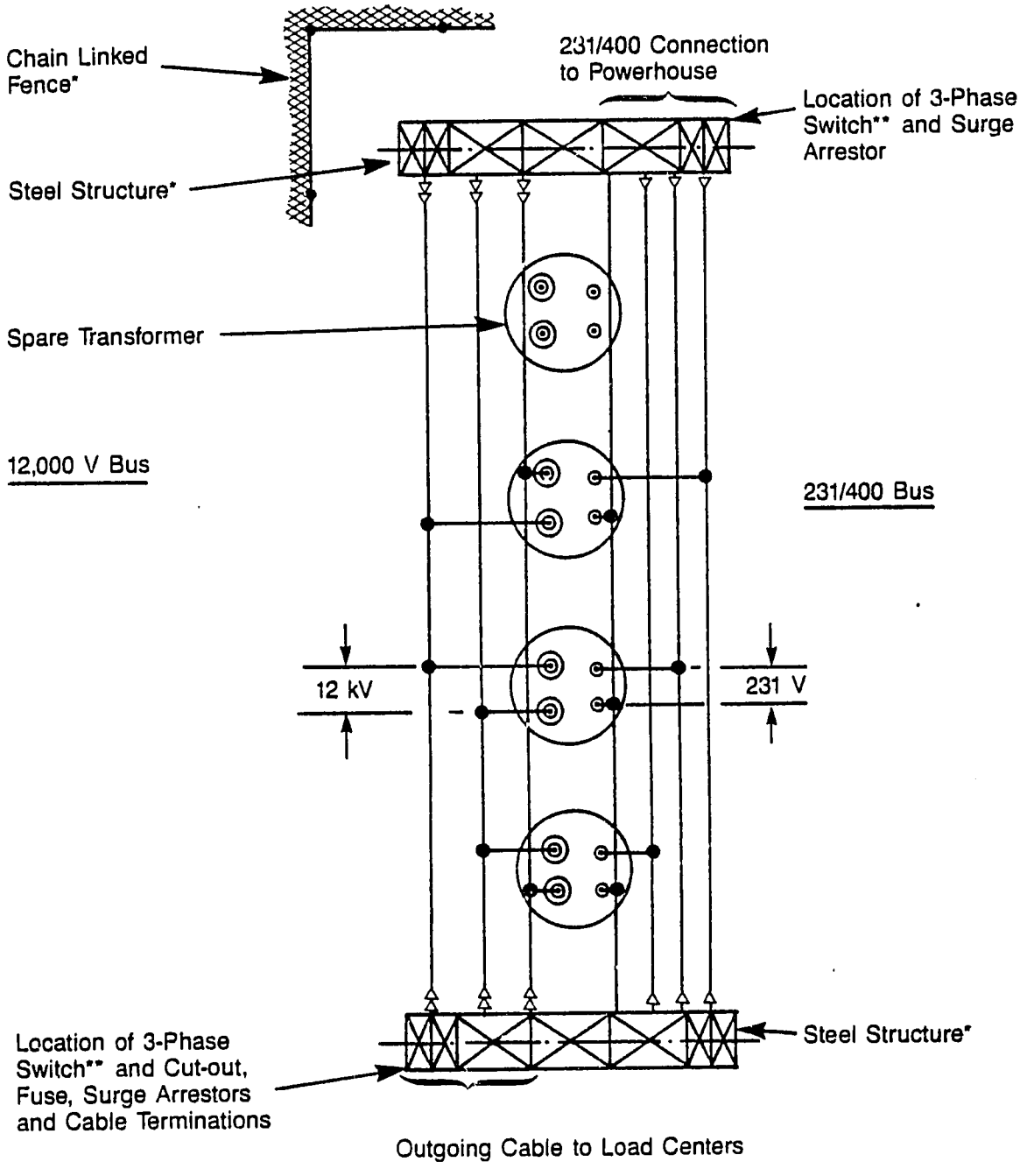


Fig. 4. One-line Diagram of the Step-up Station.



*Grounded. Grounding and/or Ground-Mat Resistance Will Not Exceed 5 Ohms. Bonding To Plumbing Will Not Exceed 2 Ohms.
**Group Operated Switch.

Fig. 5. Step-up Station Arrangement, Plan View. For Illustration Only, Not for Construction.

DISTRIBUTION FACILITIES

12 kV Cable system

Nominal 12 kV operation of the distribution line was selected in previous engineering activities. The preference for underground rather than overhead construction was also expressed but a final decision depended upon the Team's recommendations.

There are several advantages and disadvantages of underground vs. overhead construction. The disadvantages of underground construction are:

- proper equipment selection is much more critical;
- conductor costs are more expensive;
- line faults are difficult to locate;
- splices must be expertly made;
- taps for new loads are difficult to install.

The advantages of underground construction are:

- there is less exposure to lightning and other weather conditions;
- quality wood poles are difficult to locate and ship
- steel or concrete poles are expensive
- local labor can dig the trench

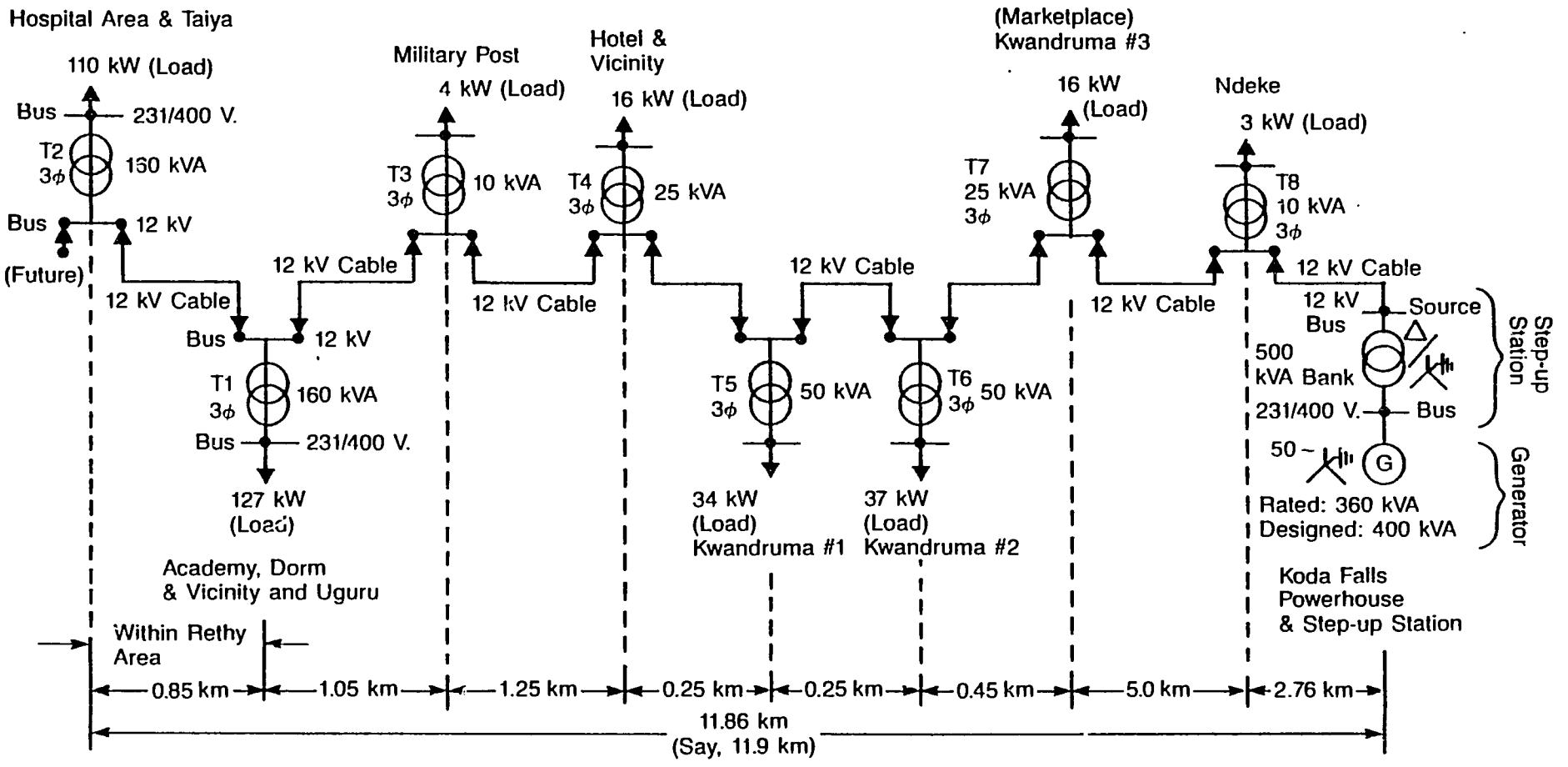
Considering the above factors, the use of underground construction is acceptable to the NRECA Team provided that it is expertly designed, protected and installed.

The size of the cable, especially close to the powerhouse, should be based upon the short-circuit capabilities of the installation. A short circuit in one phase will probably cause damage to all three phases of a three-conductor cable. Hence, the Contractor will investigate the economics of installing three single-phase cables rather than one three-phase cable.

The Contractor will also develop and submit for approval a trench specification which will indicate the cable depth, cable bed, backfill material, bending radius, and markings. He will also provide drawings and specifications for crossing the swamp areas and the cable terminations.

Step-down transformer stations

The step-down transformers locations and sizes are indicated in Table 2 and Fig. 6. Each transformer will be three-phase type with delta connected primary and wye connected secondary having the nominal voltages 12 kV and 231/400 V respectively. All transformers will have $\pm$ 5% taps with respect to the center-line (nominal) 12 kV system; with 2 taps up and 2 taps down each of 2.5% The taps will be adjusted to provide 231/400 V at the transformer under full load operation.



NOTES:

1. General Locations of All Stations Are Determined by NRECA Team. However, Actual Sites of the Stations and the Exact Length(s) of the 12 kV Cable(s) Will Be Determined by the Contractor.
2. Voltage Regulation of 12 kV System (From 12 kV Source at Koda Falls to the 12 kV Bus of Station #T2) Will Not Exceed 4.0%.
3. Grounding of Neutral and/or Ground-Mat Resistance Will Not Exceed 5Ω. Contractors Will Follow USA (REA), German or French Codes as Required.

Fig. 6. Diagram of Transformer Station Locations.

The Contractor should submit a transformer specification that indicates the:

- basic insulation level (BIL)
- short-time overload capability
- temperature ratings
- coolant
- maintenance requirements
- short-circuit capability

Secondary system

Secondary distribution will be at 231/400 V using overhead construction and European standards. These lines will be fed from the step-down transformer through the low-voltage compartments. Transformer stations No. 1 and No. 2 will have three active bays and one spare bay in the low-voltage compartment. The other stations will have one active bay and one spare bay for future expansion (see Fig. 7).

The following are recommended design criteria for the secondary distribution system:

- nominal voltage at the secondary side of the distribution transformer would be 231/400 V under full load condition,

- main feeders would be sized and circuits arranged such that the voltage drops under full load would not exceed 5% (220/380) at the far-ends of the lines and at the location of meters. The voltage drops on the service wires from the meter to the service entrance would not be included in this 5% when the meter is located away from the building.

- motor loads and their starting requirements will be incorporated into the design so that intolerable voltage flickers will not occur. On this basis, the maximum allowable single-phase and three-phase motor sizes would be specified as well as the transformer performance requirements.

- connection of services will be carried out such that the load unbalance between phases will not exceed 20%.

To comply with the voltage drop criteria recommended, voltage drop profiles should be calculated for each feeder starting from the source voltage at the step-down station to the far end of the distribution line. An example for Transformer station No. 2 is given in Fig. 8. Since there is no voltage regulator on the 12 kV system, there will be considerable spread between the minimum and maximum voltage levels as the load changes. Therefore all light bulbs and sensitive devices should be rated to operate at 230 V.

Main three-phase feeders should be bare conductor because of its lower cost. Single-phase extensions may be bare conductor or insulated suspended cable depending upon the recommendation of the Contractor.

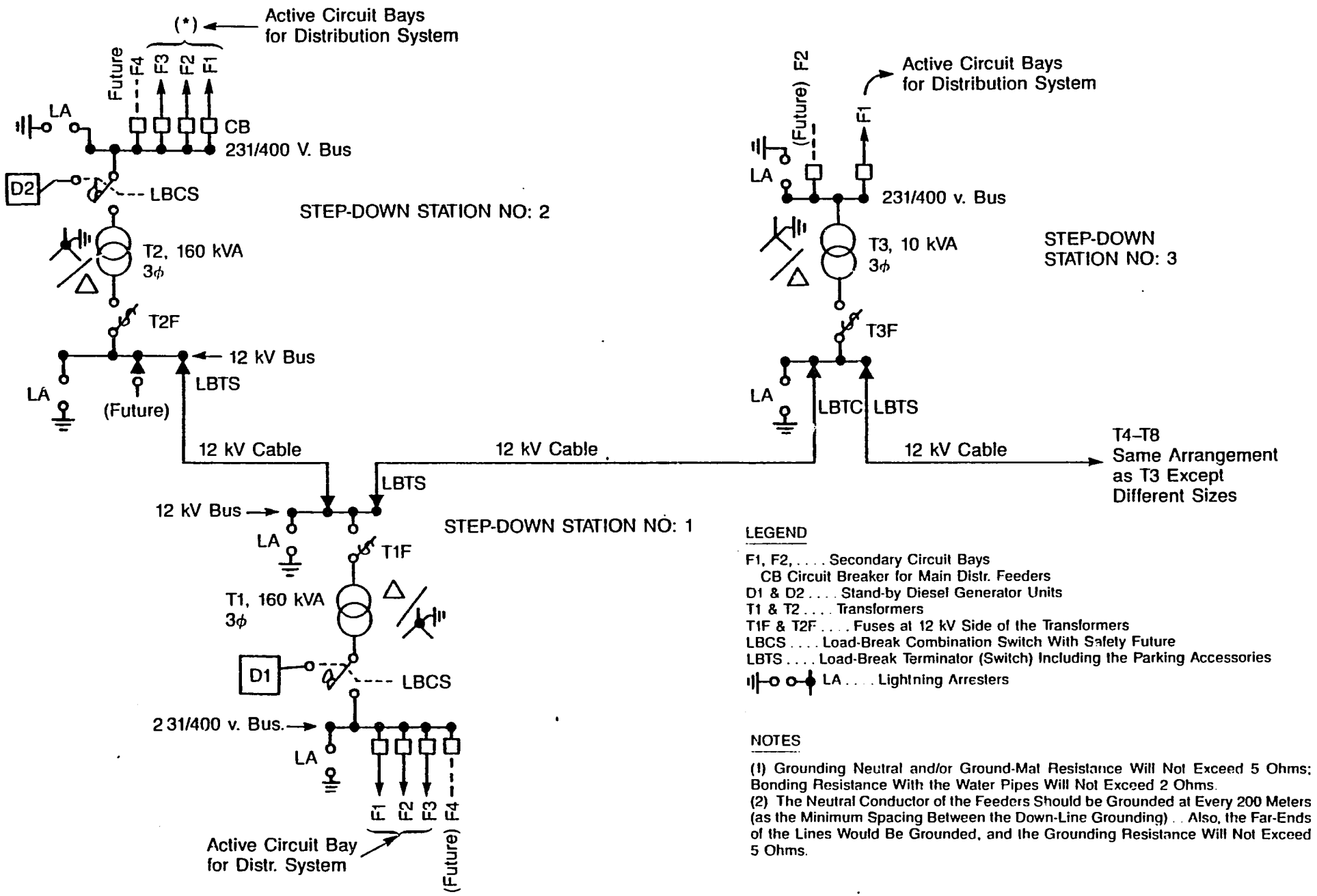
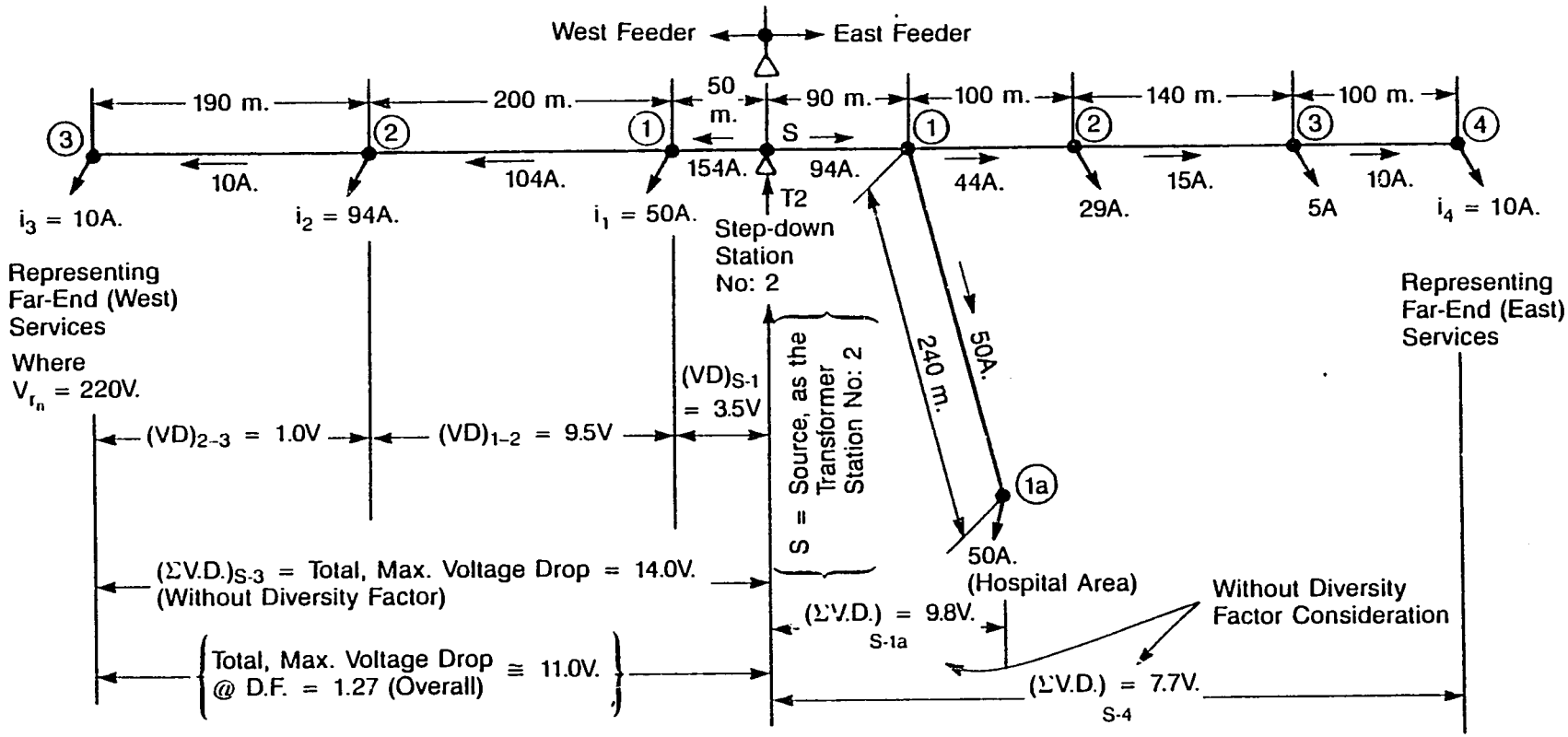


Fig. 7. Design Criteria for the Step-Down Stations. Actual Design Will Be Done by the Contractor.



Required Line-to-Ground Voltage at the Source Would Be, V_{S_n} = 220+ $(\Sigma V.D.)_{max}$
$(\Sigma V.D.)_{max}$ on West Feeder = 11.0V.

Therefore, the Supply Voltage at T2 Would Be (220 + 11) = 231 V

Calculations Are Based on:

(a) P.F. = 0.95 With the Loads Concentrated at Numbered Locations
(b) Distances Are Estimated (Actual Distances Will Be Determined by the Contractor
(c) Calculated Ampere-Loads Are per Phase @ 220 V. (220/380 V.)
(d) 3/0 ACSR Is Considered (Approx. 85 Sq. mm of Al. Wire)
(e) Section Voltage Drop = (i) [R cosθ + X Sinθ] Where i = Ampere Load

Fig. 8. Format for Voltage Drop Calculations. Design Data To Be Provided by the Contractor.

Meters Meters should be installed on all large consumer loads, large consumers being defined as those that want more than two bulbs and one receptacle, 4 amp. service. Smaller meters can be 240 volt, 2 wire, 10 amp. service with 60 amp. overload capacity with bottem connections to avoid the cost of sockets. If purchased in quantities over 100, these can be obtained for about $25 each. Larger, three-phase consumers should have accurate 3-phase metering. A policy should be implemented to standardize and limit the number of single-phase and three-phase services and corresponding meters.

PROTECTIVE COORDINATION

There will be various types of protective devices on the system including:

- main circuit breaker on the generator in the powerhouse
- fuses on the 12 kV side of the step-down stations
- feeder circuit breakers at the low-voltage compartments of the step-down stations,
- occasional fuses for the branch circuits,
- service circuit breakers or fuses.

Proper coordination of the protection devices is necessary for reliable, quality service and safe utilization and operation of the system. Coordination provides selective and safe protection between all devices and is clearly shown when comparing time and current characteristics (TCC) curves. The Contractor should prepare TCC curves for their protective scheme coordination to support design data on the overall project. The short-circuit capability curves for the transformers and cable must be coordinated with the TCC curves. The curves shown in Fig. 9. illustrate proper coordination between the various devices and should be prepared for this project by the Contractor.

Main line fusing is not recommended except in special cases such as where there may be tree problems. Excessive fusing can cause more harm than good. Eliminating danger trees and properly clearing right-of-ways and installing protective devices at service entrances are more effective measures than additional branch fuses. This is especially true at Koda where the feeders are less than 0.5 km.

Service beyond the meter should be protected by either a fuse or a circuit breaker. A circuit breaker is safer and requires less maintenance than fuses. However, local cost and standard sizes should be further investigated by the Contractor before an installation standard is adopted.

Surge (lightning) arrestors should be installed to protect the system against line surges, especially lightning strokes. Proper selection of arrestors is critically important for all equipment , particularly for the major apparatus and cable system and should be done by an experienced engineer. Arrestors should be installed at the low and high voltage sides of all transformer stations. Installation of a few extra arrestors at important locations on the 231/400 lines would be a worthwhile expenditure due to the low cost of arrestors relative to the extra security gained.

The distribution system design and performance requirements as outlined above have been discussed with the Contractor and he has been urged to promptly complete the overall design and related construction plans for submission to ORT and CECA for approval.

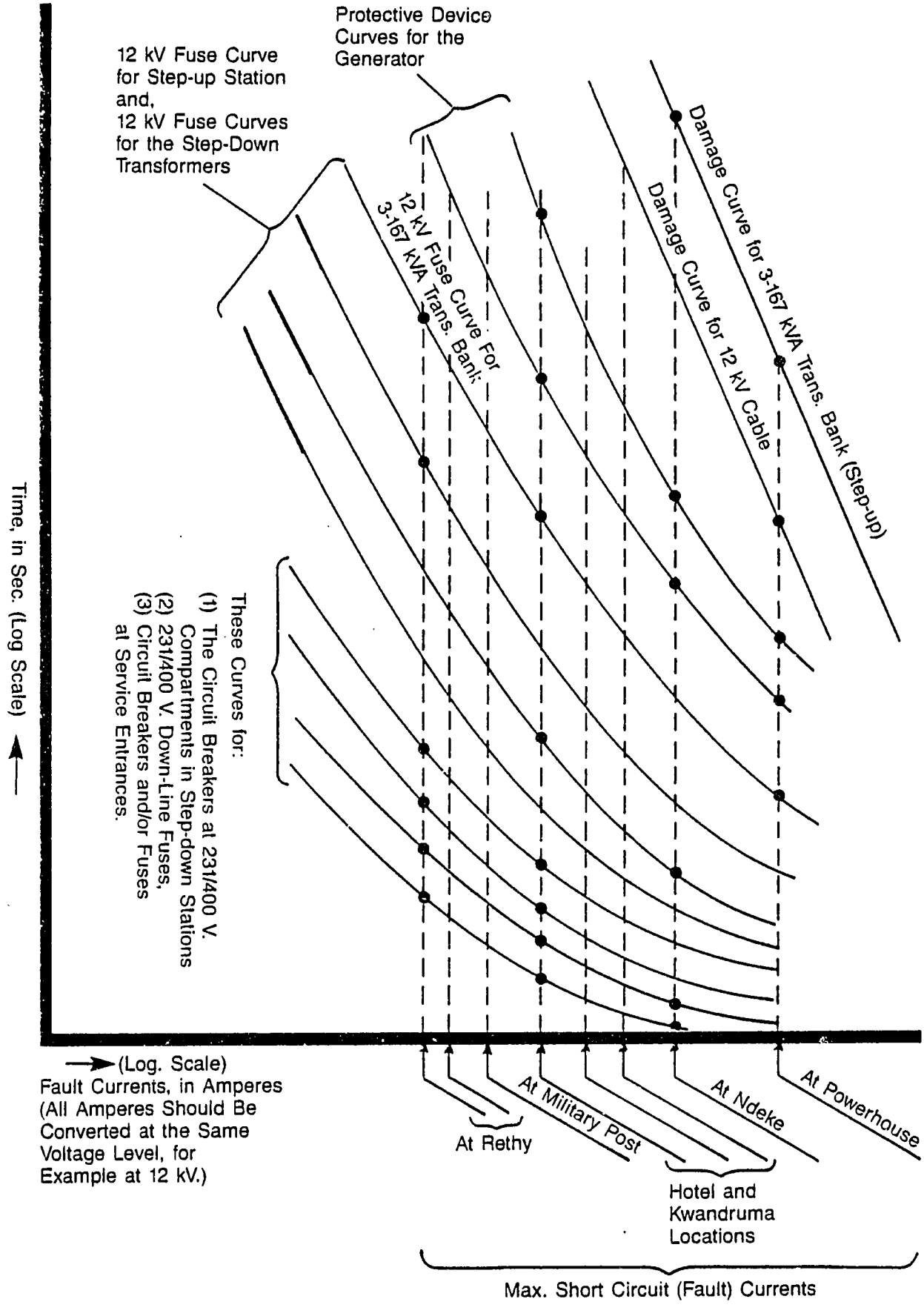


Fig. 9. Time-Current Characteristic Curves. (For Illustration Only.)
Actual TCC-Coordination Curves Will Be Prepared by the Contractor To Support the Overall Design and Equipment Selection.

CONSTRUCTION PHASE

Construction management activities required to monitor and coordinate the Contractor's work may be divided into two main activities; engineering inspection and testing conducted by professionals, and non-technical activities such as coordination of the labor force, warehousing materials, etc.

Inspection

Construction inspection will be one of the most important factors for the successful completion of the construction and the reliable operation of the system. Equipment and construction specifications, based on sound designs, do little good if they are not enforced. The one-year guarantee on the system by the Contractor will not assure long-term operational capability. Therefore, engineering inspection activities must be carried out by CECA during various phases of the construction and at the end of the construction period.

Cable installation

To obtain the advantages of the underground cable scheme vs. overhead construction the cable must be properly installed. This will require skilled, experienced cable splicers, minimum splices, and careful engineering inspection.

Cables can be damaged during their transport and installation. Hence, the cables should be visually inspected during unreeling and again before they are covered with back-fill.

Test

Powerplant

A 300 kW mini-hydroelectric unit should not be expected to go through all the acceptance tests generally performed for a large turbine-generator. However, a few tests are necessary to insure that the plant will perform as guaranteed. A full power test, no-load and load regulation tests are particularly important. Since the connected load will not reach the full power output, additional ballast loads will be necessary. Preferably, the test will be conducted when there is sufficient flow in the river for 100% output.

Cable

Damage to the cable during installations may not be evident under normal inspection and operating conditions but would cause cable failure during a system surge. Hence, it is important to conduct a high voltage test of the cable. REA standards for cable voltage tests were left with the Contractor. The Contractor is searching for high voltage test equipment and will notify CECA of their proposed test procedure.

Overall energization tests, in an orderly manner, from the generating plant to the load center, should be conducted before connecting the facilities to any consumers.

231/400 V Lines

When a line is ready to be energized, the Contractor should notify the Manager. The Manager should be satisfied that the line has been constructed in accordance with the plans and specifications. He will insure that the consumers on the line are ready to be energized. Meters should be set and installed and the household wiring scheme inspected. The Manager should be certain that all men are clear of the lines. Then they can;

- o test the transformer and related equipment at no load,
- o test the main feeder (no load) with all branches disconnected,
- o connect each branch to the main feeder separately,
- o test the service and check the meter at each consume
- o repeat for each branch

Should defects be noted which the Contractor must correct, the line will be deenergized and the switch locked open. Phase conductors should be grounded before any correction work is performed.

The Contractor will up-date his construction plans as the construction activities progress. At the end of the construction phase the Contractor should turn over to CECA the "as-built" drawings and system maps.

MANAGEMENT

Legal status

Ideally, CECA could form a separate, limited liability, non-profit corporation for operating the system. This would protect the CECA organization from being liable for a major accident caused by electricity. Then, in the event of a legal suit, the assets exposed would be limited to the electrical power facilities. The limited corporation could be called the "Koda Falls Electric Power Corp." However, to establish a non-profit corporation in Zaire requires a Presidential decree which is very difficult, costly and time-consuming to obtain. To establish a profit-making corporation in Zaire requires 40% Zairian participation which makes it an unacceptable structure. These matters were discussed with ORT's legal consul. He will investigate the legal status of CECA and advise CECA accordingly.

Consumers should be required to sign a statement indicating they recognize the dangers of electricity and they understand that CECA is not liable for possible accidents in the consumers buildings. This was also discussed with ORT's lawyer and he will determine how the national electricity association, SNEL, handles this and will advise CECA accordingly. CECA should also carry liability insurance if it is available.

Board of Directors

If a separate corporation is established, a Board of Directors can be developed to accept responsibility for the long-term viability of the power system. One alternative would be to establish an 11-member Board which would represent the total community; yet CECA would remain in control. Two members could be non-voting members to represent the interest of groups outside the defined service area. One of these directors should be from the Lokola area. Members could be;

1. CECA Management representative (President)
2. CECA Treasurer (Treasurer)
3. CECA Legal representative (Secretary)
4. Rethy hospital representative
5. Rethy academy representative
6. Manager
7. Rethy total service area representative
8. Kwandruma service area representative
9. At-large director
10. Non-service area representative
11. Non-service area representative

Directors numbered 10 and 11 would be non-voting members and the Manager would vote only in the event of a tie. Directors numbered 1, 2, 3, and 6 would be officers. Directors numbered 7, 8, 9, 10, and 11 could be elected by the consumers. If Directors are elected, it is recommended that a "one consumer-one vote" policy be adopted.

The Board would be legally liable for the long-term sound operations of the system and would have four major responsibilities,

1. Legal/financial
2. Planning
3. Manager evaluation and control
4. Policy

The Board would establish the appropriate committees, composed of Board members only, to carry out the assigned responsibilities. They are not to be involved in the day-to-day operations of the system which is the responsibility of the Manager.

Committees

The Manager will need policy guidance on several matters throughout the growth and operations of the plant. It is recommended that the Board form committees as follows:

Planning committee. This committee will keep abreast of the amount of energy and power being used, current consumer's future requirements, and consider changes to the service area. They will also be responsible for recommending adjustments to the rate schedule for Board approval.

Operating committee. This committee will manage the Consumer Loan Fund, select and evaluate the Manager, set personnel policy, salaries, etc.

Financial committee. The Treasurer will be the permanent chairman of the financial committee which will be responsible for preparing monthly budget reports, future year budgets, and annual financial statements. All reports will require Board approval.

Another possible committee is discussed later in the report.

Manager

The system Manager will be responsible for the day-to-day operations and would report to the Board of Directors. The Manager must be intelligent, be able to read, write, and know basic electrical theory and accounting. Qualified candidates must be completely trustworthy and a sincere effort should be made to determine the candidate's honesty. He must have the stature to demand payment from every consumer connected including local chiefs and CECA managers. He should be old enough to command respect, yet dynamic with new ideas. He should be able to communicate well with the various consumers in the service area and committed to remain in the community.

CECA should select an Interim Manager during the present construction phase and begin a search for a permanent manager.

Duties

Upon completion of construction, the operation of the system becomes the responsibility of the Manager. His duties consist primarily of seeing that the project is operated safely and economically and that continuous service is provided on the lines. He:

- shall immediately become familiar with all lines and equipment
- shall give prompt attention to the restoration of service in the case of interruption. This means that he will be available 24 hours a day.
- is responsible for all work done on the lines, for tools and their condition, and shall reguarly inspect all tools used,
- shall make certain that each employee has read and understands the safety rules,
- shall make certain that each employee is fit and competent to do the work required of him.
- shall schedule periodic line inspections, insure that meters are read, and other duties as required to conduct the day-to-day operations of the system.

RATES

Self-financing

As stated earlier, one of AID's purposes in sponsoring this project is to test to see if schemes similar to Koda Falls can be "self-financing" meaning that the scheme should be able to set rates which can cover operating and "amortization" costs. However, the Project Paper is unclear as to what is meant by amortization cost. It states, in the financial analysis, that interest payments are not included in the cost estimates since the project "is a grant rather than a loan." The Project Paper proposes an amortization amount based on 35-year period or 3% of the capital cost per year. This could either be thought of as: a depreciation allowance for future replacements and system improvements; an equivalent debt service fee for a very soft loan; or only principal payments on a soft loan. In the cooperative agreement with ORT the term "self-financing" was re-phrased as "self-sustaining" implying that the system was to establish a sinking fund for major system replacements and system improvement and expansion.

Cost of service

Total cost of service includes the operating cost plus the aforementioned amortization cost. In this report all costs are presented in equivalent U.S. dollars since the current inflation rate in Zaire is so high. This was specifically requested by members of the Koda Falls Local Technical Committee.

Operation cost

The monthly cost of operating the proposed system is estimated to be:

Personnel	Cost
Manager	150
Book keeper	50
Operators (2x100)	200
Collector	40
Laborers/guards (3x 50)	150
	$590
Operations	
Normal repairs	75
Transportation	90
Diesel fuel	50
General funds (admin.)	75
Insurance	75
Total monthly operating cost	$1455

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Amortization cost

The project cost estimates were developed in the AID Project Paper and include hard currency requirements plus the US dollar equivalent to the local currency requirements. Since the equipment, design, and construction contracts have been issued on a fixed-price basis and fall within the budget, the Project Paper funding amount of $1,417,000 is used as the total capital cost of the project.

Two options are offered for addressing the self-financing requirements: a depreciation fund and an equivalent debt service. Assuming a 3% overall system depreciation rate, and a capital cost of $1,417,000, the monthly depreciation expense would be;

(3% x $1,417,000)/12 = $3,542

Assuming a soft loan at 6%, repayable over 50 years, the monthly debt service is approximately;

(0.063 x $1,417,000)/12 = $7,439

<u>These amounts also reflect the fact that this project is a prototype and may cost significantly more than follow-up schemes</u>.

Unit cost

Unit costs are calculated by dividing the total costs by the expected power and energy usage. Since the system will grow considerably in the first few years, there are several possible values of power and energy usage that could be used. As the system grows, the kWh sales will increase and the general unit cost will decrease. If a very early year usage rate is used for unit cost tariffs, then the cost will appear very high, consumers will not connect, and the load will not grow.

The following data look at unit costs for the third year, when most of the suppressed load should be connected, and the tenth year when the system's peak load should approach the system capacity. In the third year the demand is estimated to be 191 kW and the energy usage 670,000 kWh. For the depreciation rate, the unit costs are:

($4997 x 12) / 670,000 = $0.089/kWh

The "debt-service" unit cost would be:

($8894 x 12) / 670,000 = $0.159/kWh

It is assumed that by the tenth year the operating cost would increase by $500 per month. The unit cost in the tenth year for the depreciation rate is:

($5497 x 12)/ 926,000 = $0.071 /kWh

For the "debt-service" unit:

($9394 x 12) / 926,000 = $0.121/kWh

The need to stimulate growth with low rates in the first years must be balanced against the need to recover actual operating costs. It is felt that a rate as high as $0.16 per kWh will discourage many potential users. A rate of $0.07 is too low to demonstrate "self-financing" capability. As a compromise, a rate of $0.11 is recommended. This rate can be viewed as demonstrating either:

- o self-financing capability for repaying a soft loan at 6% using the tenth year expected sales and a slighty lower capital cost in recognition of the fact that this project is a prototype; or

- o self-sufficiency by paying into a depreciation fund at 3% of the capitalized cost plus paying 3% into a development fund.

This rate would also allow the system to just meet its expected operating cost in the first two years, but not enough to begin the depreciation or development funds.

Development fund

It is proposed to add a "Development Fund" surcharge on metered loads only. The fund would be used to finance development projects which would benefit the entire community, but especially those that are outside of the project service area. This would then have the impact of spreading the project benefits to the entire target population. Roads, water supply, and rural health would be appropriate undertakings. Another Board committee should be organized to manage this fund and should include the two non-voting members representing populations outside of the service area.

Another means of extending the availability of electric service to those outside the service area would be to install battery chargers. A villager could purchase a lead-acid battery, install a 12 volt lighting system in his hut, and carry his battery to the charger when it needed re-charging. The batteries could be carried on bicycles or small carts. The chargers could be purchased by the development fund, or individuals could operate them as a cottage business and charge people a small amount.

Rate schedules

Since there is only one electric service entity in the project area it is essentially a business monopoly. This puts the responsibility on CECA to deal with every individual consumer and all classes of consumers on a fair and equitable basis. For sound business operation, consumer rates should reflect the true cost of service. It is recognized that some adjustments are necessary to promote social service, assist the poor, etc. However, these adjustments must be held to a minimun to ensure viable operations.

It is recommended that two rates be used: a fixed monthly rate for small consumers and metered kWh rate for large consumers. The development fund surcharge would be added to the large metered consumers only. Only one type of installation should be offered to the small, fixed rate consumers, although this may be changed as the system develops experience in dealing with small consumers.

Fixed rate service

It is recommended that the fixed rate service serve small, poorer consumers with two 60 W light bulbs and one receptacle. The demand would be limited by placing a 4 ampere fuse or circuit breaker in a locked box at the service entrance. Only the system employees would have keys to the boxes and anyone caught tampering with the lock would be disconnected. These consumers would pay a fixed monthly fee equivalent to their expected contribution to the peak load but would not pay into the development fund. Assuming that the 4 amp. fuse will limit the maximum demand per small consumer to 1 kW, and with the diversity factor for the average small consumer approximately 4.0, the monthly rate would be:

($4997 / 277 kW) / 4.0 = $4.51 per month

At the current exchange rate of 42 Zaires per dollar, this is equivalent to 190 Zaires per month. A survey of small consumers showed that they spend an average of 100 Zaires per month for kerosene. Considering the additional advantages of electricity, this appears to be a reasonable rate.

OPERATIONS AND MAINTENANCE

General plant

Capital equipment needed for the operation of the electric plant including the buildings, vehicles, tools and communications equipment is referred to as the "general plant".

Headquarters facilities

The system will need a headquarters administrative office for the manager and the book keeper. The office will need the appropriate number of desks, file cabinets, lamps, etc. In addition to the office furniture, office machines will be needed for billing, typing, mimeographing, etc. Shop space should be available for the operators. Warehouse space will be required for spare conductors, fuse boxes, fuses, etc. Access to a light pick-up truck will be necessary for ordinary maintenance.

Tools

In order to perform operations and maintenance and make line extensions in a safe and efficient manner good tools are necessary. The utility operators will need an initial outlay for tools to include electrician belts, tool kit, megger, ohm meter, cable repair kit, etc. If good electric service is to be delivered to the consumers, voltage must be checked and loads measured and balanced. Power delivered must be measured by precise voltage and clamp-on ampere meters. First aid kits must be available for the system employees.

A means of transporting equipment to and from the powerhouse during construction needs to be proposed and approved by CECA and ORT. This transportation system should stay in place for use in powerplant maintenance.

Communications

The operating personnel must be able to communicate from points in the service area to the powerhouse and the headquarters office. Normally, the best communications system is small radios. Radios can also be mounted on repair vehicles and offer the most flexibility. Prior to the team's visit, CECA tried using a small radio and could not obtain satisfactory operation, apparently due to the mountainous terrain. Since the powerhouse is located on the opposite side of the mountain ridge from Rethy, a repeater station would probably be required to operate a low-powered radio system. Repeater stations require monthly checks and can not be repaired locally. Alternatively, CECA can consider a battery-powered telephone system. The telephone cable could be buried in the same trench as the power cable but there should be at least 30 cm spacing between the two sets of cables to limit telephone interference. Telephone jacks could be placed in each transformer station low-voltage compartment and in the system headquarters office.

Maintenance personnel

Competent and dedicated people must be hired for every position on the electric system staff and they should be given training in program requirements, policies and objectives in addition to their own specific trade training.

Since the powerhouse will operate automatically, except for re-start, two well-trained utility operators should be able to operate and maintain the proposed system. The turbine requires little maintenance and a utility operator could easily perform the routine mechanical maintenance. Guards or caretakers could be hired to watch over the powerhouse if needed for security reasons. They could also clean the trashracks, adjust the flow control, and take periodic readings. Routine maintenance procedures should be written down, explained, and given to the operators.

Duties

The utility operators will install the service drops, build minor extensions, repair minor damage, and inspect household wiring. As the load grows they will adjust phase loadings and transformer taps. As the system grows older they should be able to inspect and change poles on the secondary system. They should record all changes on the system maps and records. They will perform hydropower and diesel powerplant start-up, shut-down and routine maintenance procedures. The operators should be able to read blueprints, make out individual reports, be familar with storing materials, and able to instruct trainees and part-time employees during emergency work.

Trainees/laborers The utility operators should have assistants to perform unskilled tasks. Preferably they should have an aptitude that would allow them to advance to electrician someday. In addition to assisting the electricians they could trim trees, clear right-of-ways, replace fuses, notify consumers of scheduled outages, haul materials, and identify dangerous conditions.

Training

Skilled manpower in management and diverse technical areas is a prerequisite to the successful establishment and operation of the system. Anyone working with high voltage must know the dangers and be trained to follow safe procedures. Where skilled manpower is not available training is required. priorties are:

Personnel	Subject
• Manager	Electric distribution and utility accounting
• Utility operators	Practical electrical theory, basic wiring, powerplant operations, safety.
• Bookkeeper	Basic accounting
• Consumers	Electrical safety

Correspondence courses on accounting and the distribution system were sent to Mr. Paul Brown of CECA. SNEL, the national electric authority, provides electrical training in Kinshasa. The Engineer/Contractor is arranging turbine-generator operations training at a nearby Ossberger site in Zaire.

Connection Fee

A connection fee helps ensure that every consumer connected really wants electricity and has thought about how he will use and pay for electrical service. The connection fee should be geared to the ability to pay and the cost to connect. For large users, it should cover the cost of the meter. The connection fee may be waived where a meter presently exists. A recommended connection fee schedule is:

GROUP	CONNECTION FEE	
	LARGE	SMALL
PUBLIC	0	0
COMMERCIAL	$60	$20
RESIDENTIAL	$60	$10

Connection fees should be placed in a fund used to purchase meters and service drops. All meters should be owned by the system to help establish the right-of-access to the meters.

Household wiring program.

Many poorer households may fail to sign up for service if they do not have cash savings on hand to pay the connection fee and the cost of wiring their premises. They will need financial assistance if they are to prepare their houses with a safety switch, wiring, bulb sockets, and outlets for using electricity. Three activities will assist in obtaining a large sign-up when the electric system is getting underway;

- o keep the cost of household wiring as low as possible by purchasing in bulk quantities,
- o train local electricians to individually contract for installing household wiring for a fixed price,
- o adopt standard housewiring specifications.

To insure that all wiring installations are safe, an inspection and certification must be made before the system connects the service. This is an absolute requirement to prevent fires and the loss-of-life.

A program could be offered to provide loans for housewiring which the system could extend to the prospective consumers. Loans would be made for repayment within 5 years and monthly charges incorporated in the system billings. The loans should only be made to those consumers who demonstrate a need for such assistance and it would only cover the basic installation.

Load management

Project viability depends on a high usage rate of the limited capacity. The expected demand in the third year will be 191 kW, slightly more than the output during low-flow periods. This estimate assumes that all hot water heaters are on timers that will keep their usage off-peak. For load growth beyond the third year the system must be able to curtail the peak demand during the low-flow periods. Hence, for the third to tenth years, load growth should be coupled with a seasonal load management strategy. After year ten (assuming a 5.2% growth rate) the load management scheme must focus more on daily peak "shaving" and valley "filling" strategies.

FUTURE OPERATIONS AND EXPANSION

Facilities

As the load develops the 231/400 V facilities may need to be expanded. This can be economically done by using the spare bays provided in the low-voltage compartments. The increased load will effect the voltage profile and the appropriate taps on the step-up and step-down transformers will have to be adjusted accordingly.

If greater reliability is needed in Rethy a loop-feed arrangement at transformer station No. 2 is possible.

CECA may want to expand the system capacity for the tenth year operations. Additional capacity could be generated by either extending further down-stream from the present powerhouse location, or by building storage up-stream from the forebay location.

Financial

First year operation. It is recommended that the CECA seek a $5,000 short-term loan to establish a service connection fund and a consumer equipment loan fund to promote load development. About $3,500 could be used to purchase materials and equipment and approximately $1,500 used to help repay the loan during the first few years.

Fifth year operation. By the fifth year the organization should be generating sufficient funds to undertake some development projects. At this time they should also consider establishing an "insurance fund" and becoming self-insured.

Appendix A - Rethy projected connected load

Building	Total Connected Load (kW) Present	Future	Total
(1) Specman home	2.2	5.3	7.5
(2) Clement home	2.8	5.0	7.8
(3) Moffet home	1.5	1.5	3.0
(4) Guest house	1.0	1.5	2.5
(5) Bigge dorm	3.3	3.0	6.3
(6) Family apt.	1.5	3.0	4.5
(7) Intermediate dorm	0.9	3.0	3.9
(8) Family apt.	1.5	3.0	4.5
(9) Family apt. (Browns)	2.5	5.0	7.5
(10) Dining hall & kitchen	4.3	10.0	14.3
(11) Woodwork shop	4.7	0.3	5.0
(12) Shop	7.6	1.4	9.0
(13) Titchie dorm	0.9	3.0	3.9
(14) Family apt.	1.5	3.0	4.5
(15) Barn	1.2	0.3	1.5
(16) Laundry	5.6	9.0	14.6
(17) Pump (main pump)	3.0	1.5	4.5
(18) Auditorium(Music Bldg)	2.0	0.5	2.5
(19) School	2.2	-	2.2
(20) Science bldg.	1.0	0.2	1.2
(21) Earnst home	1.5	1.8	3.3
(22) Hosie home	1.9	1.5	3.4
(23) Armstrong home	2.5	4.0	6.5
(24) Post Office	0.3	0.2	0.5
(25) Guest house (CECA)	0.8	0.2	1.0
(26) Balonge home	0.3	-	0.3
(27) Gokpa home	0 3	-	0.3
(28) Old Church	0.8	-	0.8
(29) New Church	0.9	-	0.9
(30) Doctor's house	3.3	11.3	14.6
(31) Ganda home	0.9	1.5	2.4
(32) Lalem home	1.5	0.5	2.0
(33) Mullen home	3.4	6.0	9.4
(35) Main Guest house	0.8	2.0	2.8
(36) Buyes home	2.5	5.0	7.5
(37) Optical Office	3.1	-	3.1
(38) Burgess home	1.8	1.5	3.3
(39) Press bldg.	9.8	-	9.8
(40) Duplex residence	6.3	3.0	9.3
(41) Bello home	-	0.8	0.8
(42) Technical school	-	0.9	0.9

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Building (Cont'd)	Total Connected Load (kW) Present	Future	Total
(43) Primary School (2-rm.)	-	0.5	1.2
(44) Primary School (main bldg)	-	1.2	1.2
(45) Primary School additions		0.5	0.5
(46) Bookstore	0.3	-	0.3
(47) Mission shop	19.9	-	19.9
(48) Stand-by diesel bldg.	0.2	-	0.2
(49) CECA Office	0.1	0.2	0.3
(50) Doctor's guest house	0.7	-	0.7
(51) Maternity Waiting room (private ward)	0.4	-	0.4
(52) Hospital shop	0.3	-	0.3
(53) Stand-by generator rm.(Hosp.)	0.2	-	0.2
(54) Salterbuner home	1.7	4.0	5.7
(55) Nurses School	-	0.3	0.3
(56) Maternity bldg.	0.6	1.0	1.6
(57) Main Hospital bldg.	3.1	15.0	18.1
(58) Dispensary	0.4	0.2	0.6
(59) Patient Ward bldgs.	-	0.9	0.9
(60) Nurses dwellings	0.8	1.5	2.3
(61) Hospital pump	2.1	-	2.1
(62) Director's home (Sec.Sch.)	-	0.8	0.8
(63) Secondary school	-	1.0	1.0
(64) Airport guard house	-	0.1	0.1
Total	124.8	127.8	252.6