Table 8.3.1 Power System Expansion Plan and Calculation Items

Year	Expansion of Power Source	Expansion of Power System	Calculation
1987	No change	-	Power flow
1991	Kikuletwa No.1 0.5 MW to 1.5 MW	-	Power flow
1992	Pangani Falls 17.5 MW to 60 MW	Hale-Pangani Falls 132 kV line	-
1994	Kikuletwa No.2 11 MW	Kikuletwa No.2 to Kiyungi 33 kV, 2 cct	Power flow Short circuit capacity
	(Arusha diesel station retired)	(66 kV Arusha-Kiyungi line abolished)	

8.4 RESULTS OF SYSTEM ANALYSIS

The results of power flow and voltage calculations for 1987 to 1994 are given in Table 8.4.1. Power flows are shown in Figs. 8.4.1 to 8.4.10, and the short-circuit currents in Fig. 8.4.11.

(1) Present State of System (1987)

The 1987 power flow is shown in Fig. 8.4.1. According to the operation records obtained in field investigations, voltage drop is on the whole quite large, with drops in excess of 15% of rated voltage at the buses of some substations. In the calculations, voltage fluctuations are maintained in the range of $\pm 5\%$ of rated values.

The reason that the voltage fluctuation differs greatly from the actual operation state is thought to be due to the fact that at the time of the field investigations some of the generators were out of service for repair, and also to the method of voltage regulation.

If the generators are operated normally the system voltage can be appreciably improved by voltage regulation through coordination of transformer top voltage and generator operating power factor.

(2) Effect of Rehabilitation on Kikuletwa No. 1 Power Station

The power flow diagram for the present Kikuletwa No. 1 Power Station, at an output of 0.5 MW is shown in Fig. 8.4.2. The diagram for the rehabilitated station with an output of 1.5 MW, is shown in Fig. 8.4.4. Rehabilitation of the power station would improve the capability of maintaining system voltage, and reduce transmission losses.

(i) Before Rehabilitation

If the 33 kV bus voltage of Njiro Substation drops 25% below the rated level, the generator cannot operate at the allowable voltage range 100 $\pm$ 5% of the rating. As a result, most generator voltages will drop below 95% of the rating.

To maintain normal system voltage, it would be necessary to install, on the Njiro Substation's 33 kV bus, a static condenser of capacity larger than 3 MVA, or else to perform load shedding. Fig. 8.4.2 shows the power flow diagram that applies when a static condenser is not used; Fig. 8.4.3 shows the power flow diagram that applies when a static condenser of 3.1 MVA is installed.

With no static condenser, the transmission loss is 8.75 MW. The loss decreases to 7.44 MW if a static condenser is installed.

(ii) After Rehabilitation

The 33 kV bus voltage drops 10% from the rated level, but generator voltage can be maintained above 95% of the rating. The power system can, therefore, be operated normally. To stabilize the voltage, however, it remains preferable to install a static condenser, in this case with a capacity greater than 2.5 MVA, at the 33 kV bus of the Njiro Substation.

Fig. 8.4.4 shows the power flow diagram that applies when a static condenser is not used. The power flow diagram that applies when a static condenser of 2.5 MVA is installed, is shown in Fig. 8.4.5.

Without the static condenser, the transmission loss is 7.41 MW. The loss decreases to 6.99 MW if a static condenser is installed.

(iii) Comparison

The effects of rehabilitation of Kikuletwa No. 1 Power Station, when no static condenser is installed are itemized below.

Before Rehabilitation:
- The system voltage is not maintained at the normal level. It is necessary either to install a static condenser or to perform load shedding.
- Transmission loss increases to 9.95 MW.

After Rehabilitation:
- The system voltage is maintained.
- Transmission losses decrease to 7.41 MW.

Reduced losses through the rehabilitation are 2.54 MW, which corresponds to about 11,000 MWh annually.

Note, however, that the power consumed in this region is transmitted from Kidatu Power Station. If the transmission losses beyond the Chalinze Substation are also considered, the above-mentioned losses would be greater.

(3) Effect of Developing the Kikuletwa No. 2 Power Station

The power flow diagram for the situation before development of Kikuletwa No. 2 Power Station is shown in Fig. 8.4.6; the diagram for the situation after development is shown in Fig. 8.4.8. Development of the power station improves the power system characteristics by: improving the capability of maintaining system voltage, reducing the transmission losses, and improving the reliability of power supply in the region.

(i) Before Development

The 33 kV bus voltage drops 35% from the rated level and generator cannot be operated at the allowable voltage fluctuation range 100 $\pm$ 5% of the rating. To maintain the system voltage at the normal level, it would be necessary to install a static condenser larger than 9 MVA at the 33 kV bus of the Arusha Substation. Fig. 8.4.7 shows the power flow when a static condenser of 9 MVA is installed at the Njiro Substation.

Transmission losses are 7.59 MW if a 9-MVA static condenser is installed at the Njiro Substation. Without the static condenser, the losses are 14 MW, and it is impossible to maintain the function of the power system.

Plans call for the capacity of the Pangani Falls Power Station to be increased from its present 17.5 MW to 60 MW in 1992. Voltage improvements at the Kiyungi and Njiro Substations, however, can not be expected.

As these substations are more than 300 km distant from the power station, it is impossible for them to receive reactive power to maintain the system voltage.

(ii) After Development

The 33 kV bus voltage is maintained above 95% of the rated level and the power system can be operated normally (Fig. 8.4.8). No static condenser is necessary. Transmission losses are 4.89 MW.

(iii) Comparison

The effects of developing Kikuletwa No. 2 Power Station are listed below.

Before Development:

- The system voltage is not maintained at the normal level. It is necessary either to install a static condenser or to perform load shedding.
- Transmission losses are 7.59 MW if a static condenser of 9 MVA is installed.

After Development:

- The system voltage is maintained.
- Transmission losses are decreased to 4.89 MW.

Development of the power station thus removes the need for the 9 MVA static condenser, and decreases transmission losses by 2.7 MW. The losses saved correspond to about 12,000 MWh annually.

(4) Power Transmission Method for Kikuletwa No. 2 Power Station

(i) Selection of Transmission Voltage

The transmission voltages presently used in the Kikuletwa No. 2 project area are 132 kV, 66 kV, and 33 kV, and the transmission voltage for the No. 2 Power Station must be chosen from among these values. TANESCO's policy, however, is to discontinue use of 66 kV, and the intention is to eventually abolish the existing 66 kV transmission lines. Therefore, only the 132 kV and 33 kV values were compared.

Comparisons were made based on the transmission methods of the two cases below (Fig. 8.4.12).

Case 1: Connection with Kiyungi Substation with 33 kV line (1 Circuit)

Case 2: Connection with the Same-Kiyungi Line with 132 kV line

The power flow diagram for Case 1 is shown in Fig. 8.4.9, and that for Case 2 in Fig. 8.4.10. There are practically no differences in voltage drop and transmission losses. This is because the 132 kV lines would be about 10 km longer (5 km incoming and 5 km outgoing). Increased line length would cause increased voltage drop at the Kiyungi and Arusha substations.

It was, therefore, decided to employ a 33 kV line, as this is less expensive than a 132 kV line.

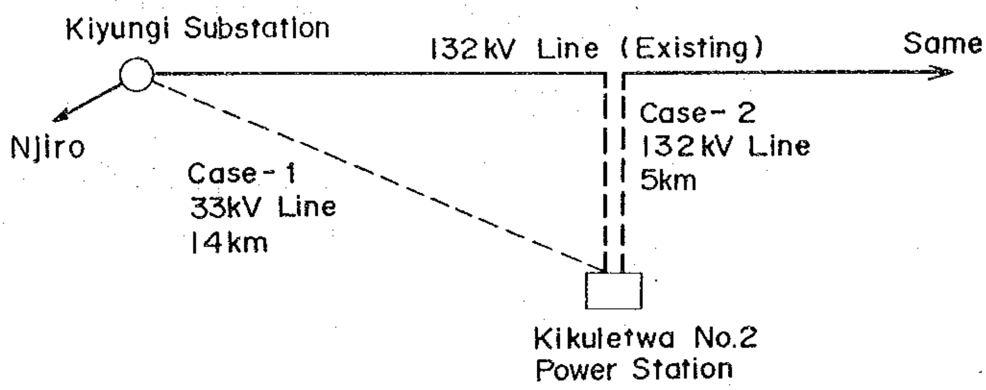


Fig. 8.4.12 TRANSMISSION ROUTES FOR KIKULETWA No.2 PROJECT

(ii) Determination of the Number of Circuits

If a 33 kV line is used, the 14-km distance between the Kikuletwa No. 2 Power Station and the Kiyungi Substation is sufficient to cause a relatively large voltage drop. To reduce this drop, either a single circuit with a large size conductor, or a double circuit with TANESCO's standard conductor, must be used.

A Comparison study was, therefore, made for the following two cases:

Case 1: Single circuit, ACSR 240 mm^2
Case 2: Double circuit, ACSR 160 mm^2

The power flow diagram for Case 1 is shown in Fig. 8.4.9, and that for Case 2 in Fig. 8.4.8. Voltage drops and transmission losses for the two cases are as follows:

	Voltage Drop (%)	Transmission Losses (MW)
Case 1	3.7	0.21
Case 2	2.4	0.17

(Note) These values are calculated for the 14-km section between the Kikuletwa No. 2 Power Station and the Kiyungi Substation.

Although the construction cost for the double-circuit line is about 30% more than that for the single-circuit line, it was decided to adopt the former, in order to help ameliorate the following conditions.

- The Kiyungi and Arusha substations are located at terminals of the interconnected system. The ability to maintain the voltage level is low because of the remoteness from major power station.

- As these substations are tied to the interconnected system by a 132 kV long-distance line, their power supply reliabilities are low.

(5) Short-circuit Current

The short-circuit current on the buses, and current flow, are shown in Fig. 8.4.10. The maximum values of short-circuit currents calculated by voltage class in selected sections of the system, are shown below.

132-kV bus (Chalinze SS)	607 MVA (2.65 kA)
66-kV bus (Kiyungi SS)	121 MVA (1.06 kA)
33-kV bus (Tanga SS)	130 MVA (2.88 kA)

Table 8.4.1 Results of Power Flow and Voltage Calculations

Power development scheme (power system condition)	Max. power demand (MW)	Njiro, 33 kV bus voltage (%)	Kiyungi, 33 kV bus voltage (%)	Transmission losses (MW)	Annual energy losses (MWh)	Static condenser (MVA)	No. of figures
Present state (1987)	54.4	101.7	102.8	2.22	9,500	-	Fig. 8.4.1
Kikuletwa No. 1 0.5 MW, before rehabil. (1991)	74.2	75.2	88.3	9.95	42,700	-	Fig. 8.4.2
Kikuletwa No. 1 0.5 MW, before rehabil. (1991)	74.2	95.0	104.0	7.44	32,000	3.1	Fig. 8.4.3
Kikuletwa No. 1 1.5 MW, after rehabil. (1991)	74.2	89.4	103.5	7.41	31,800	-	Fig. 8.4.4
Kikuletwa No. 1 1.5 MW, after rehabil. (1991)	74.2	95.0	104.4	6.99	30,000	2.5	Fig. 8.4.5
Kikuletwa No. 2 before develop. (1994)	85.1	64.2	86.0	14.07	60,400	-	Fig. 8.4.6
Kikuletwa No. 2 before develop. (1994)	85.1	95.3	102.0	7.59	32,600	9.0	Fig. 8.4.7
Kikuletwa No. 2, 11 MW after develop. (1994) 33 kV double circuit	85.1	95.4	101.8	4.89	21,000	-	Fig. 8.4.8
Comparison of transmission lines							
Kikuletwa No. 2 11 MW, 33 kV single circuit	85.1	95.1	101.2	4.98	21,400	-	Fig. 8.4.9
Kikuletwa No. 2 11 MW, 132 kV line	85.1	95.3	101.4	4.95	21,200	-	Fig. 8.4.10
Short-circuit current, after develop. of Kikuletwa No. 2 11 MW (1994)	-	-	-	-	-	-	Fig. 8.4.11

Note: The scope of the calculation is the 132 kV, 66 kV and 33 kV systems from Chalinze Substation to Njiro Substation of the interconnected system.

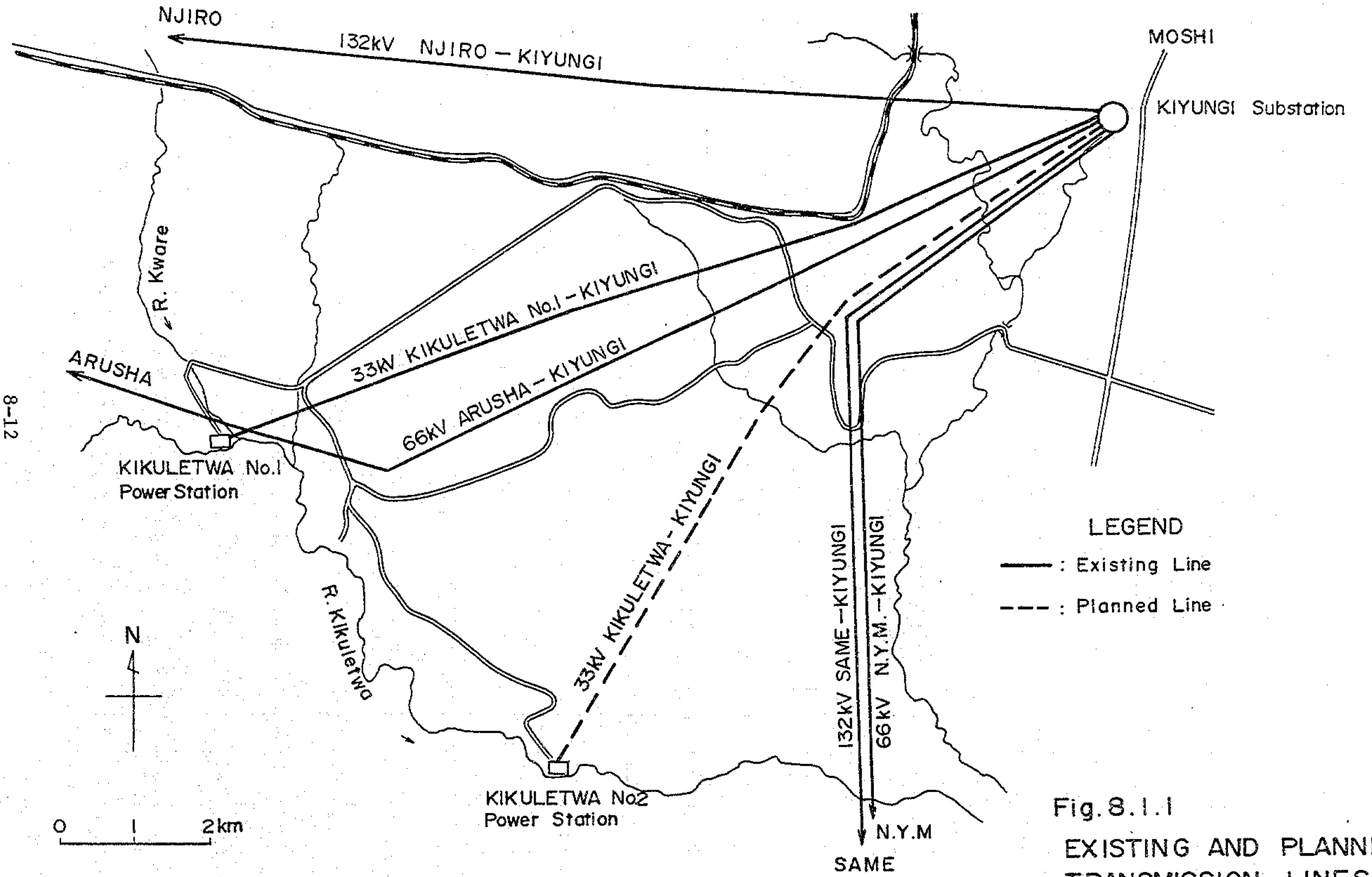


Fig. 8.1.1
EXISTING AND PLANNED TRANSMISSION LINES

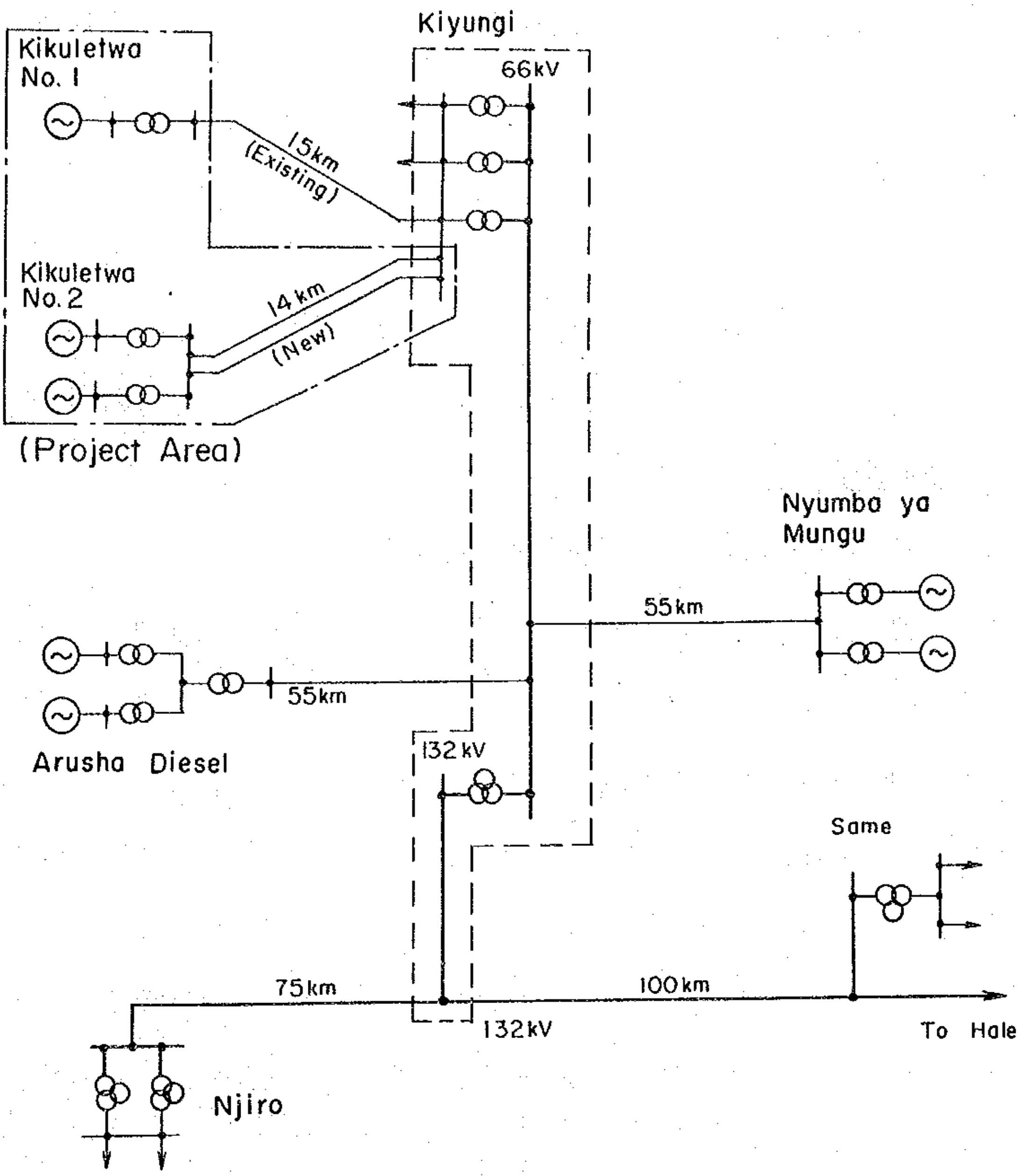


Fig. 8.1.2 TRANSMISSION LINE SCHEME

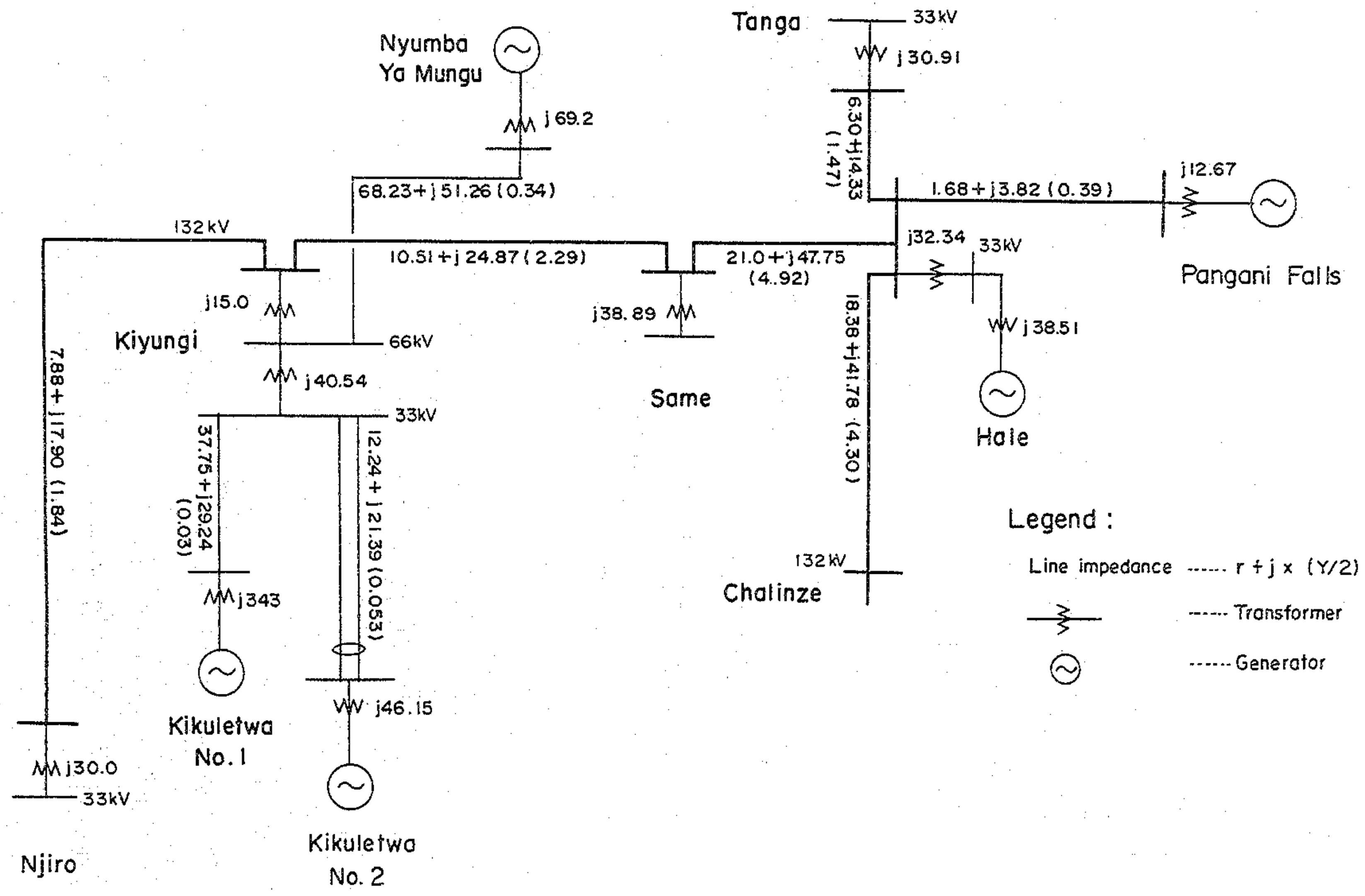


Fig. 8.3.1 IMPEDANCE MAP IN 1994
(Positive phase sequence, % at 100MVA base)

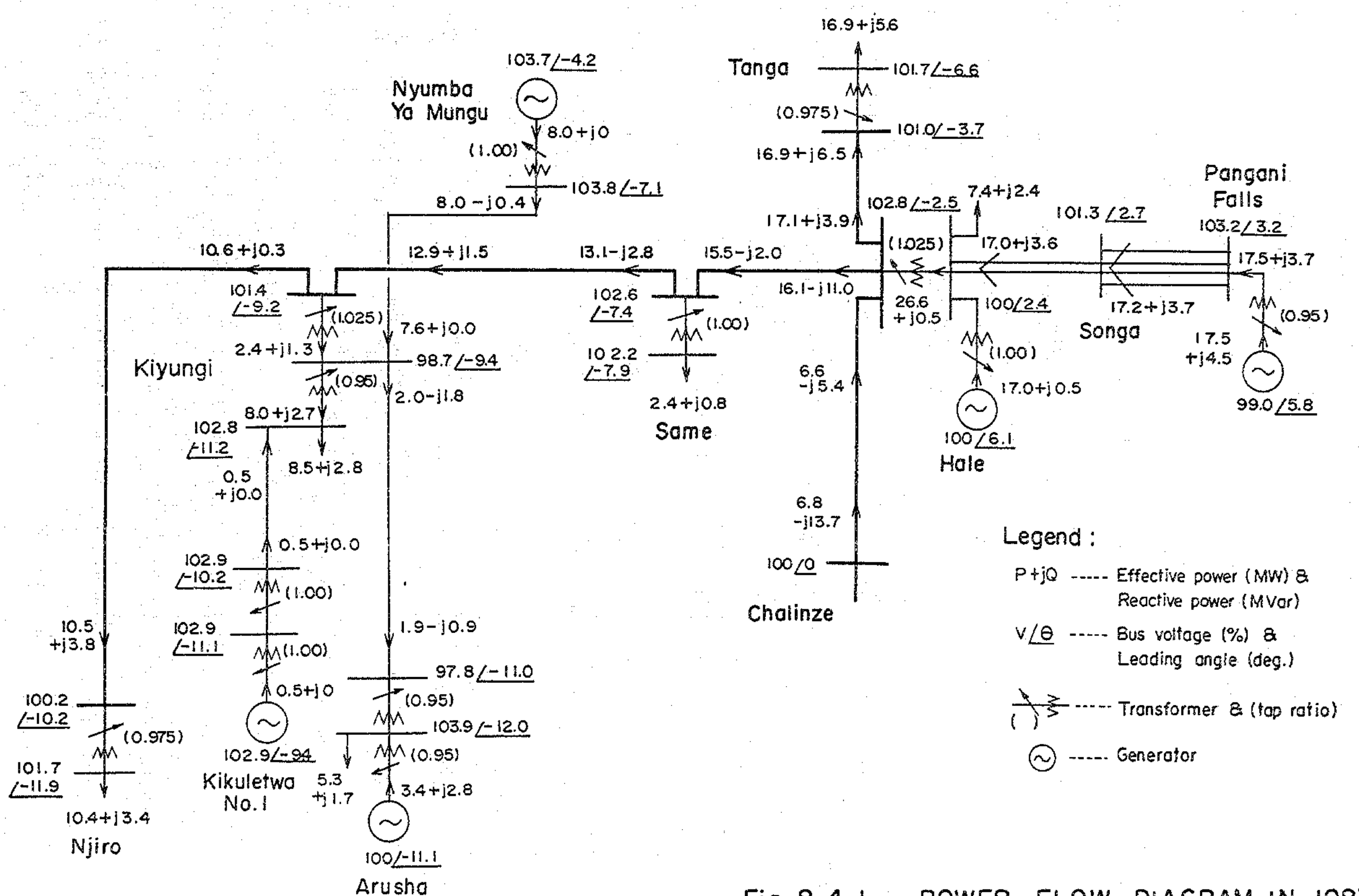


Fig. 8.4.1 POWER FLOW DIAGRAM IN 1987

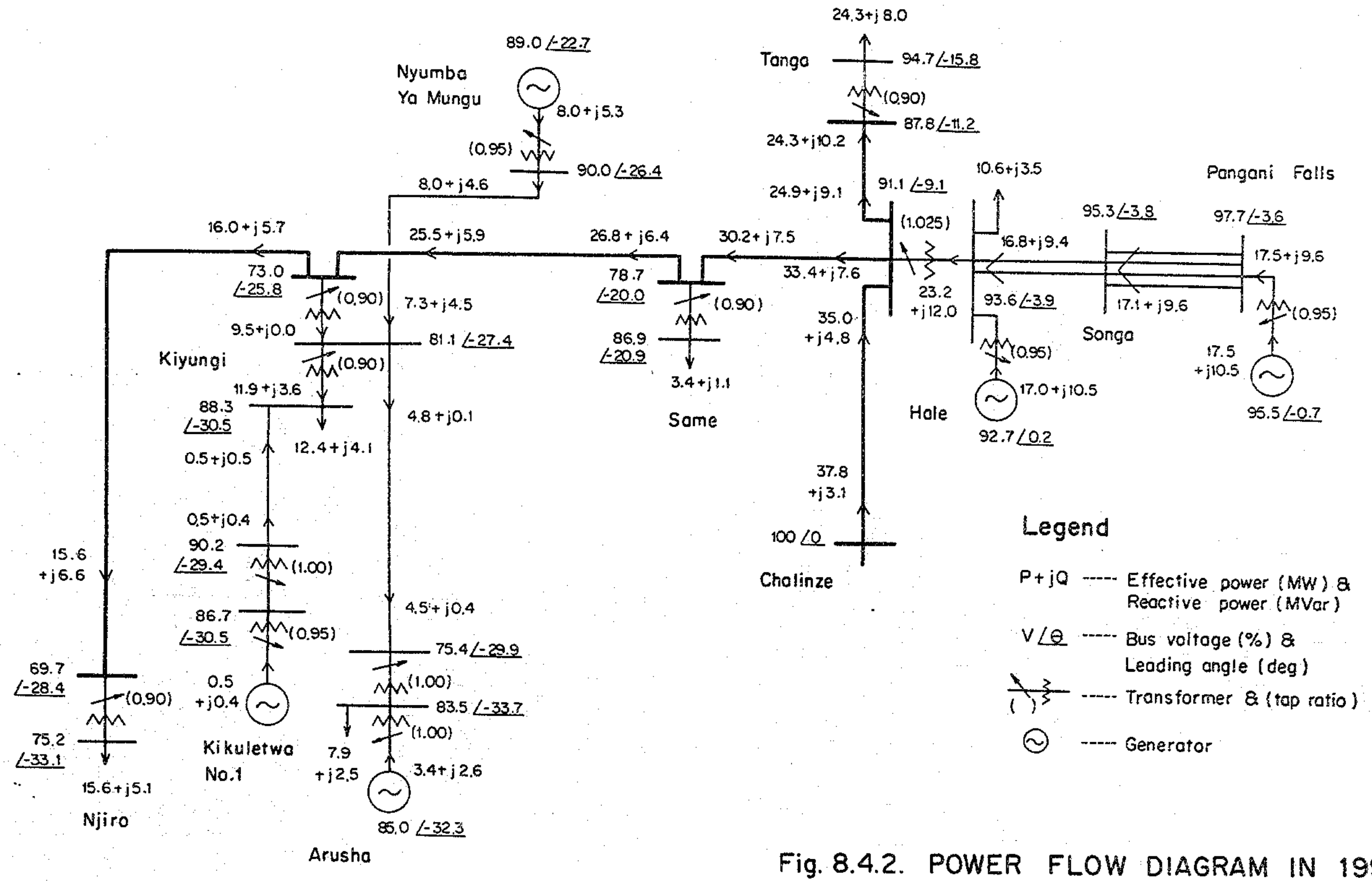


Fig. 8.4.2. POWER FLOW DIAGRAM IN 1991

(Before Rehabilitation of Kikuletwa No.1 Project, without Static Condenser)

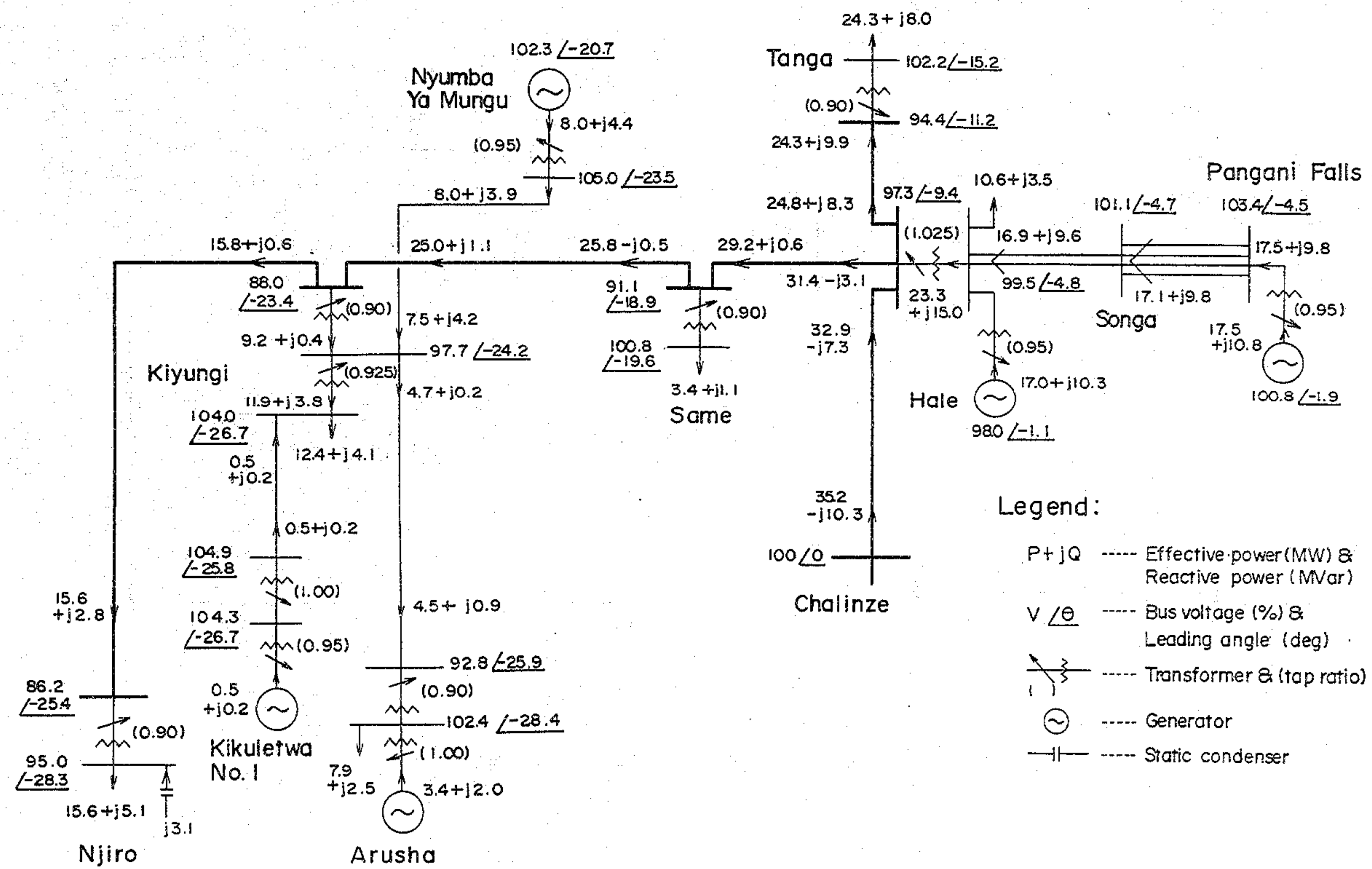


Fig. 8.4.3 POWER FLOW DIAGRAM IN 1991
(Before Rehabilitation of Kikuletwa No.1 Project, with Static Condenser at Njiro)

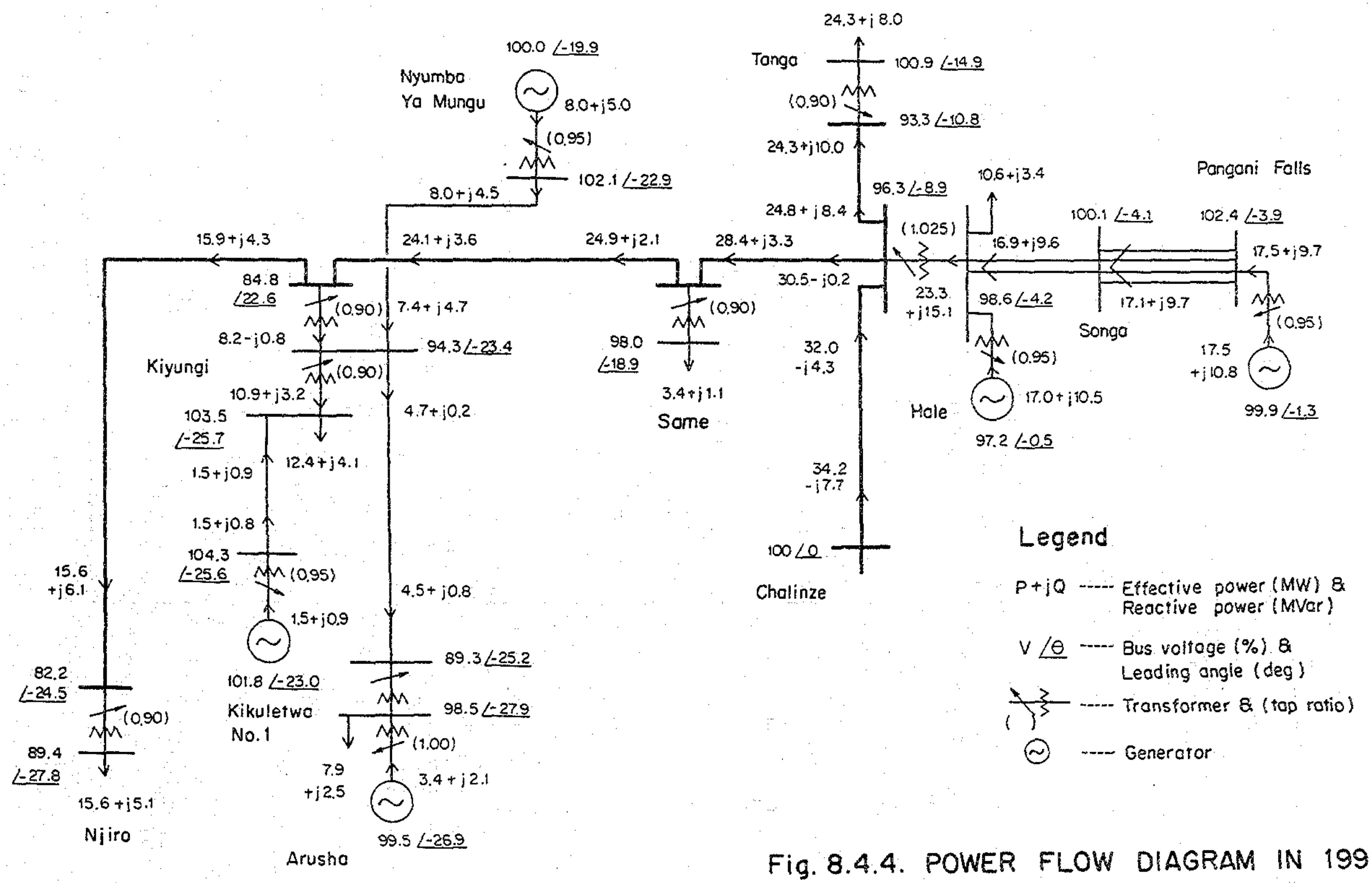


Fig. 8.4.4. POWER FLOW DIAGRAM IN 1991

(After Rehabilitation of Kikuletwa No.1 Project, without Static Condenser)

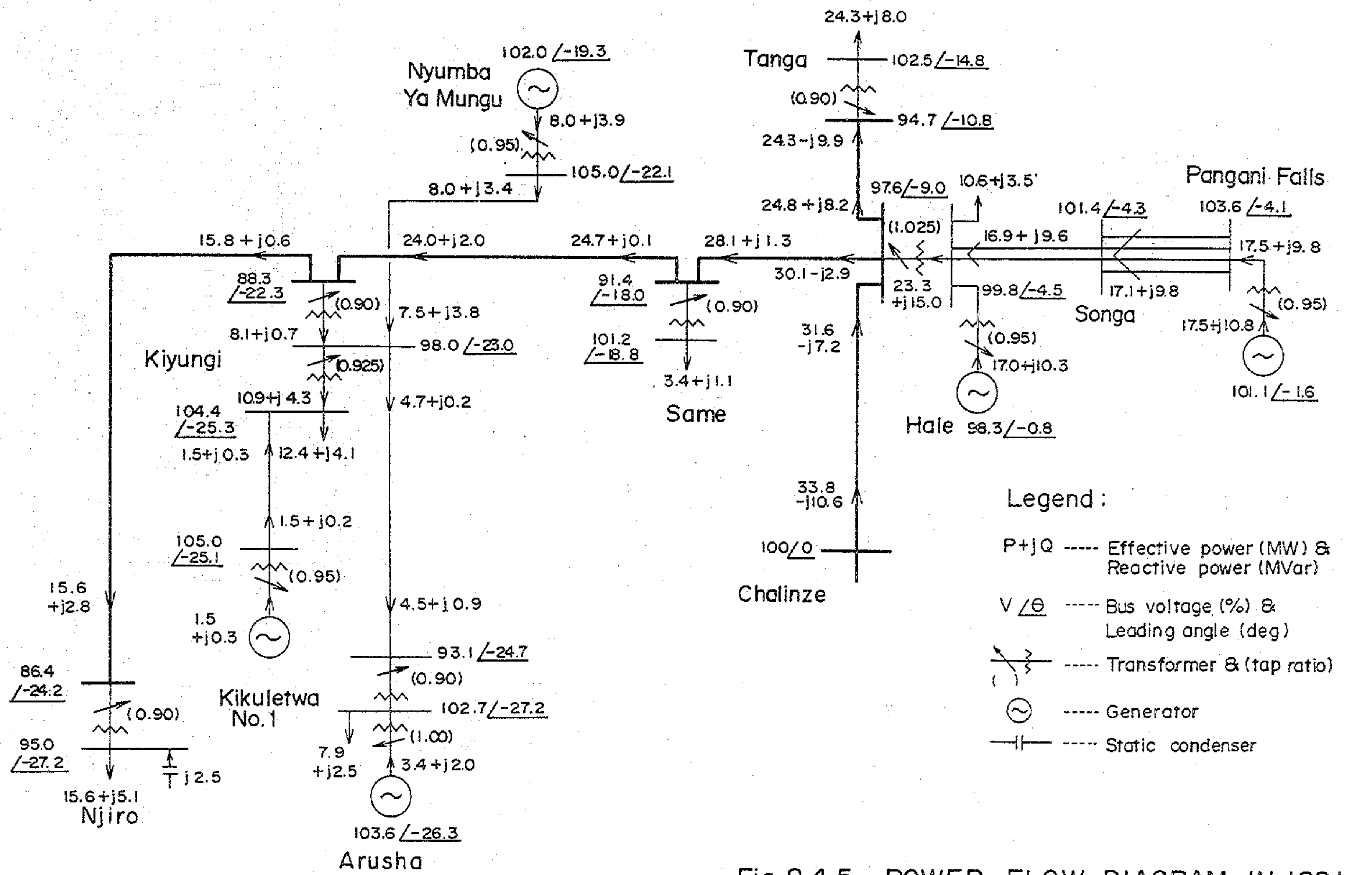


Fig.8.4.5 POWER FLOW DIAGRAM IN 1991
(After Rehabilitation of Kikuletwa No.1 Project, with Static Condenser at Njiro)

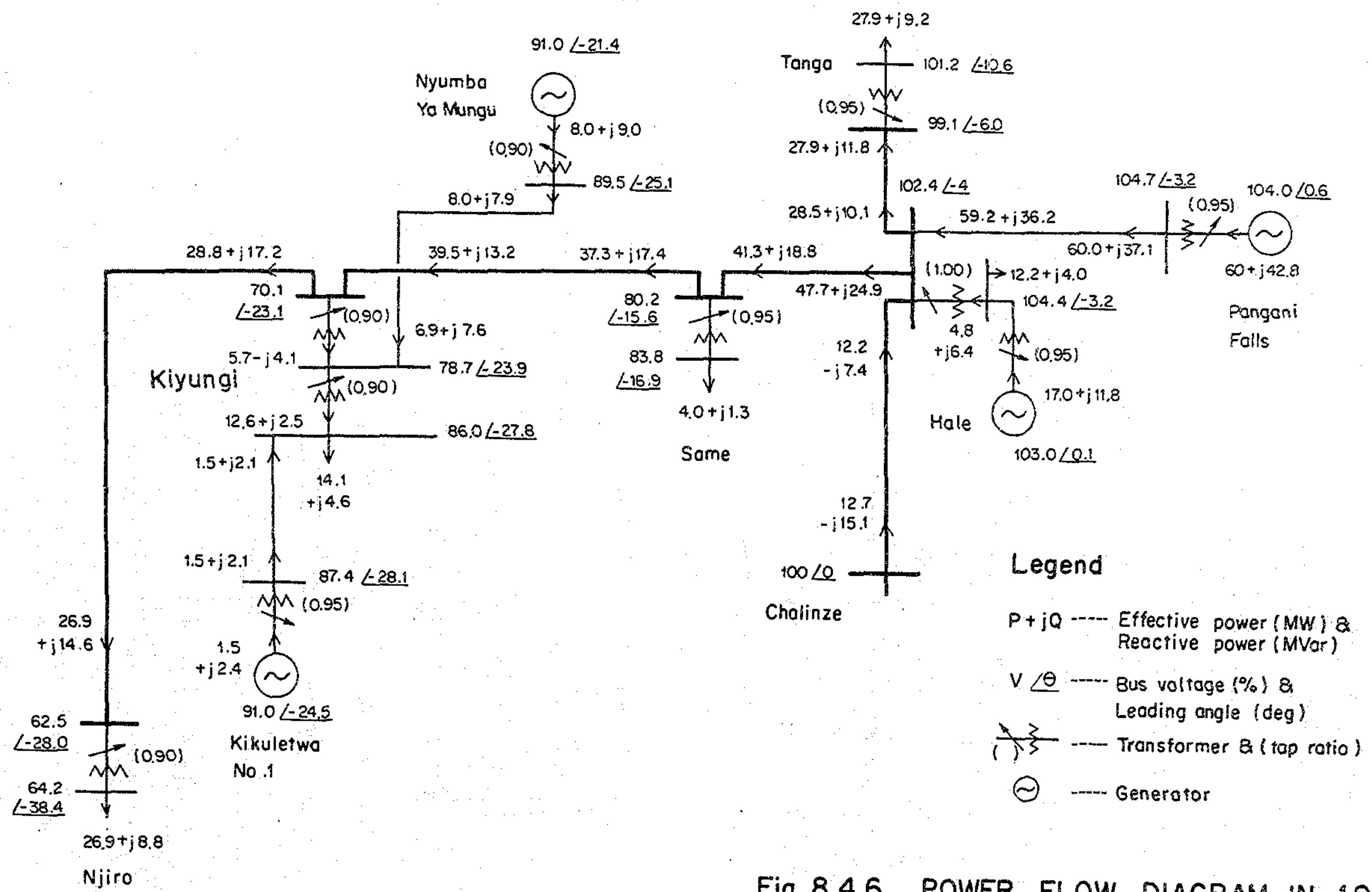


Fig. 8.4.6. POWER FLOW DIAGRAM IN 1994

(Before Kikuletwa No.2 Project, without Static Condenser)

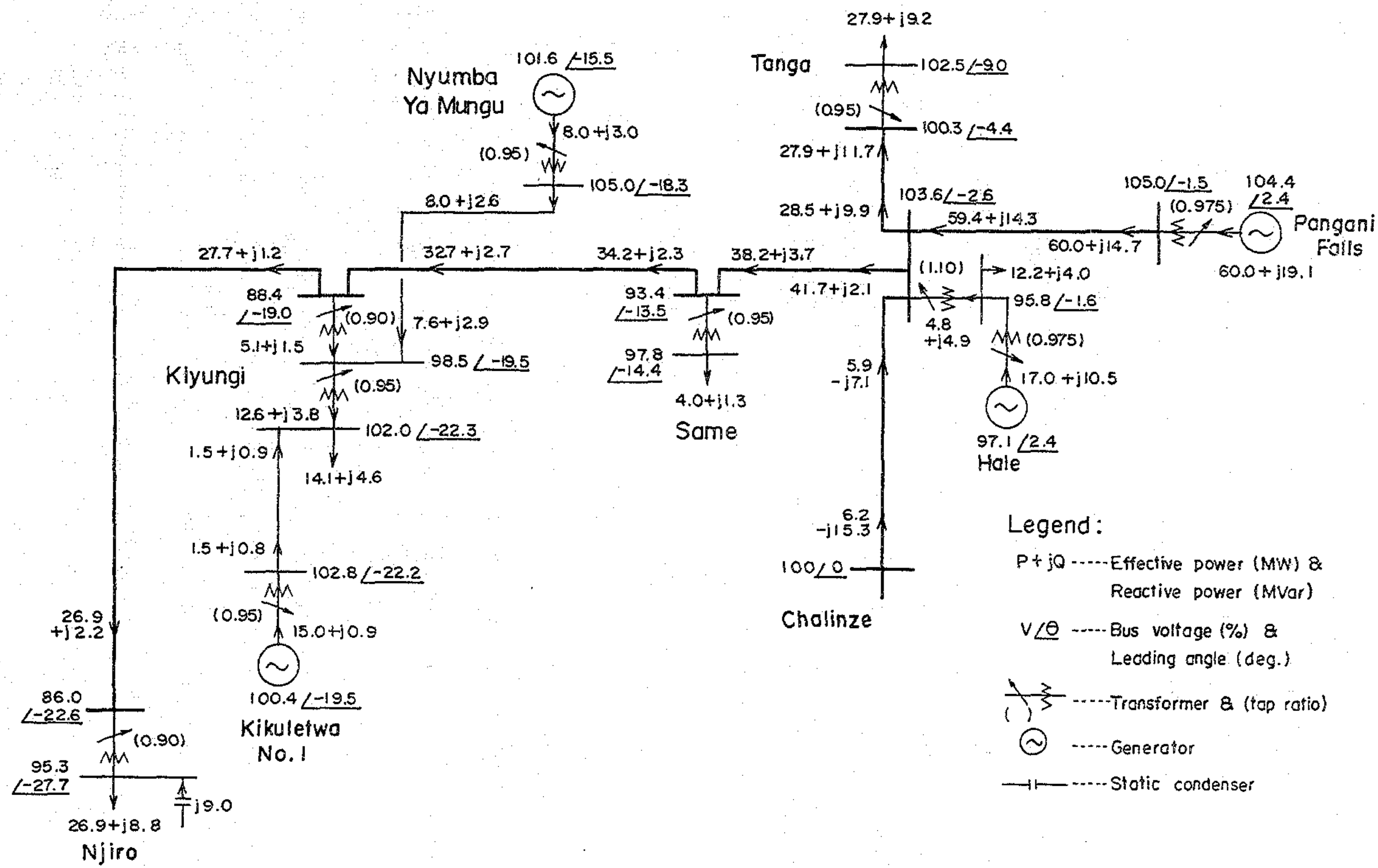


Fig.8.4.7 POWER FLOW DIAGRAM IN 1994
(Before Kikuletwa No.2 Project, with Static Condenser at Njiro)

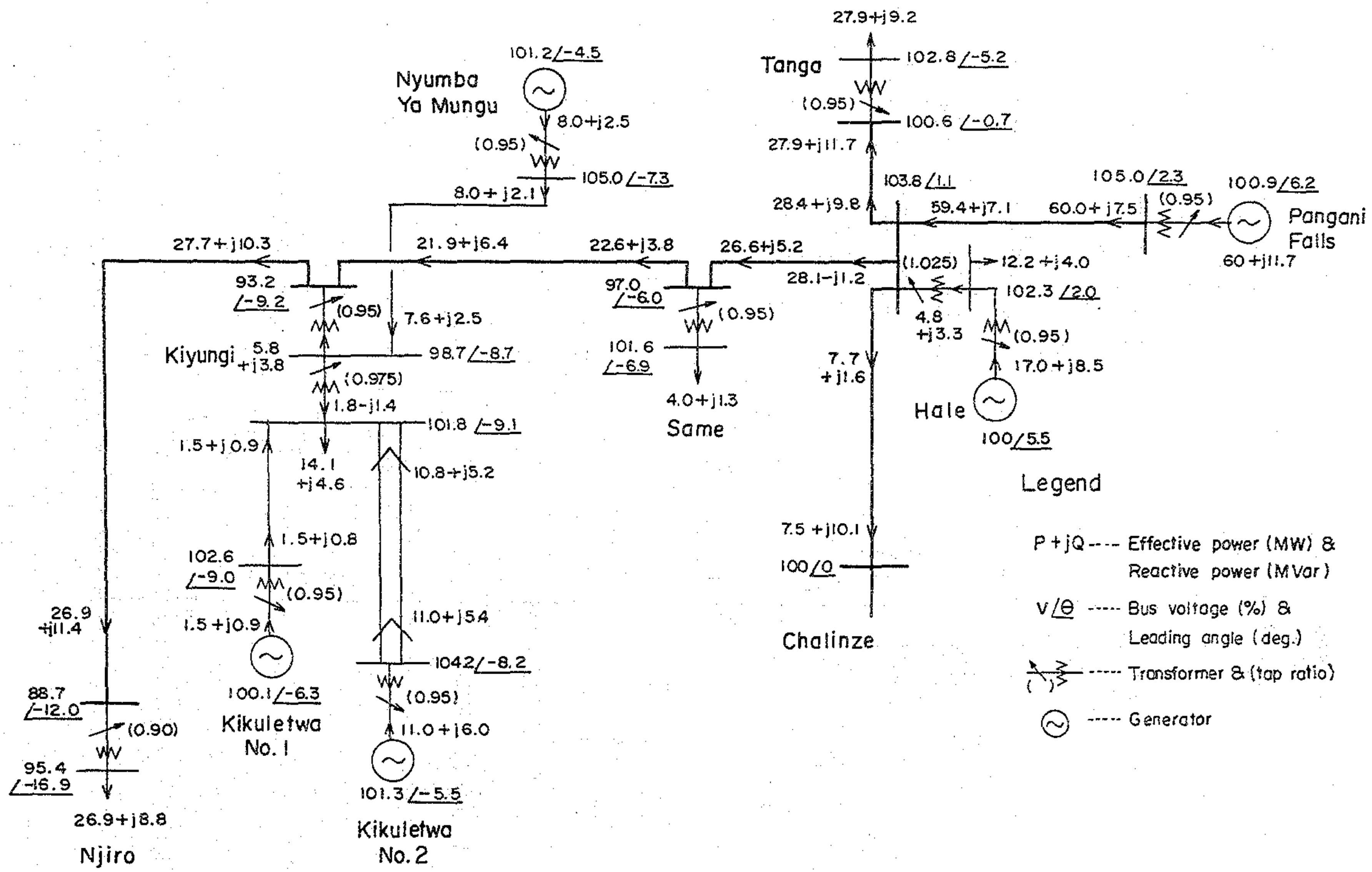


Fig. 8.4.8 POWER FLOW DIAGRAM IN 1994
(33kV Double Circuit for Kikuletwa No.2 Project)

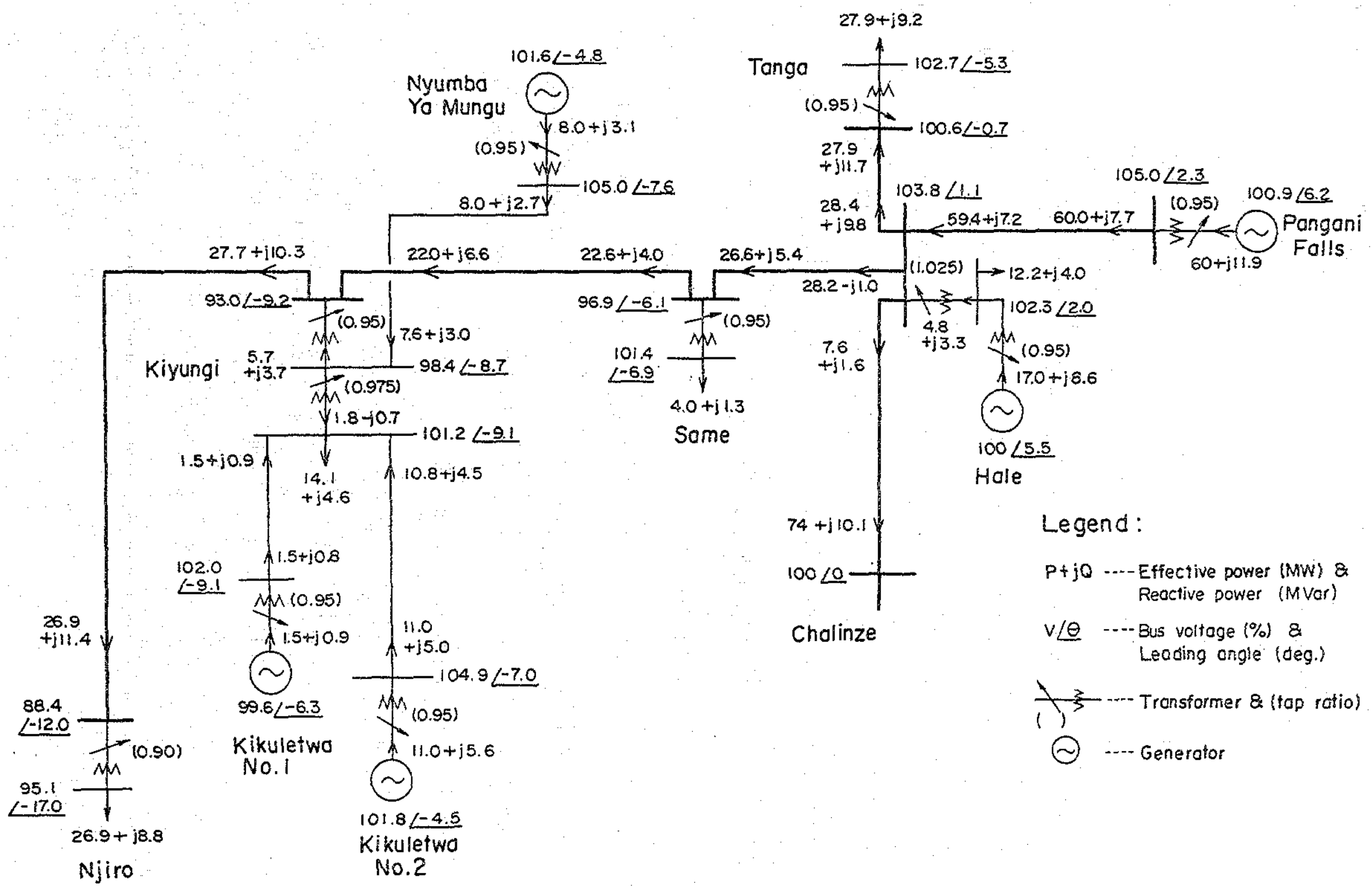


Fig. 8.4.9 POWER FLOW DIAGRAM IN 1994
(33kV Single Circuit for Kikuletwa No.2 Project)

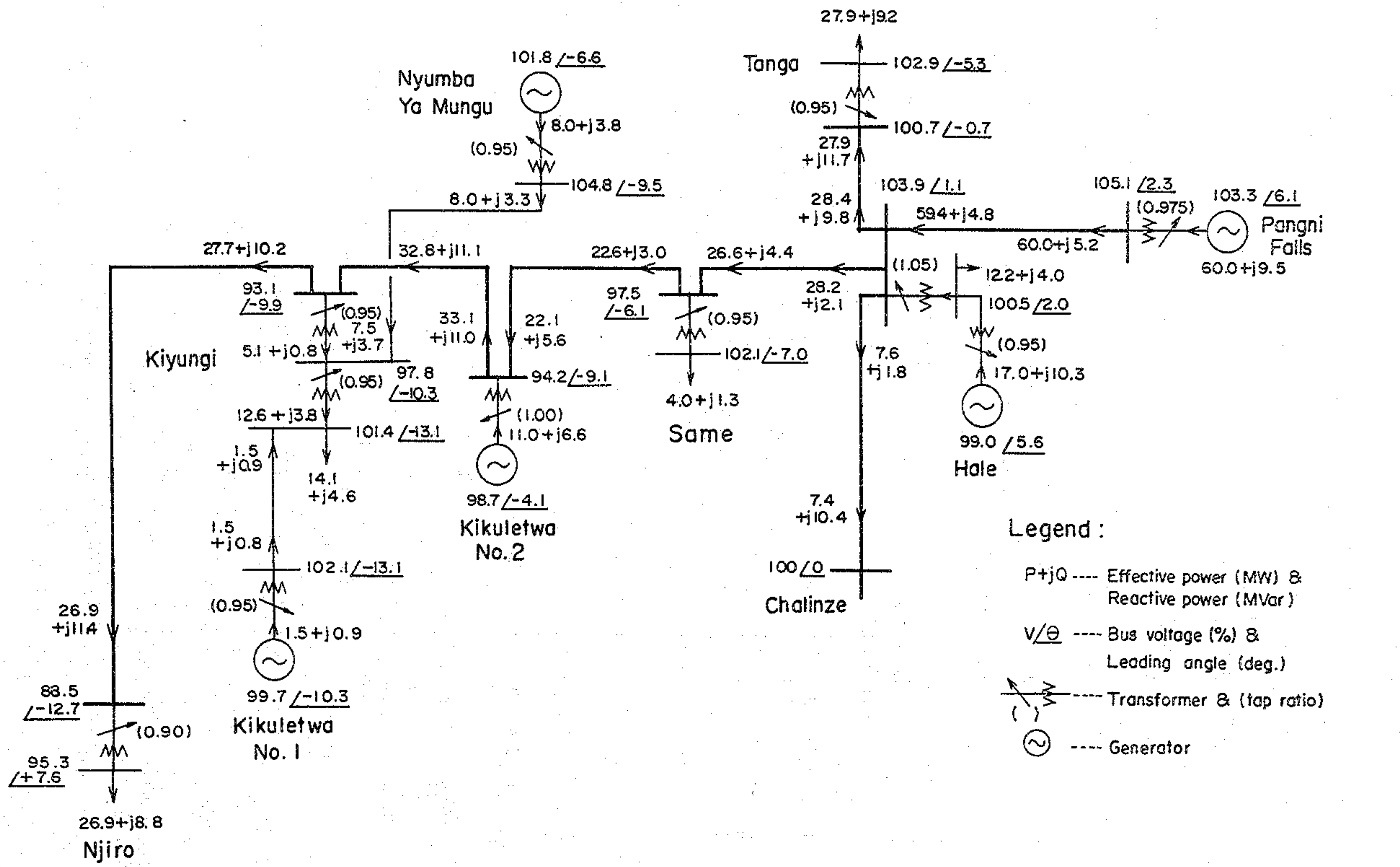


Fig. 8.4.10 POWER FLOW DIAGRAM IN 1994
(132kV Line for Kikuletwa No.2 Project)

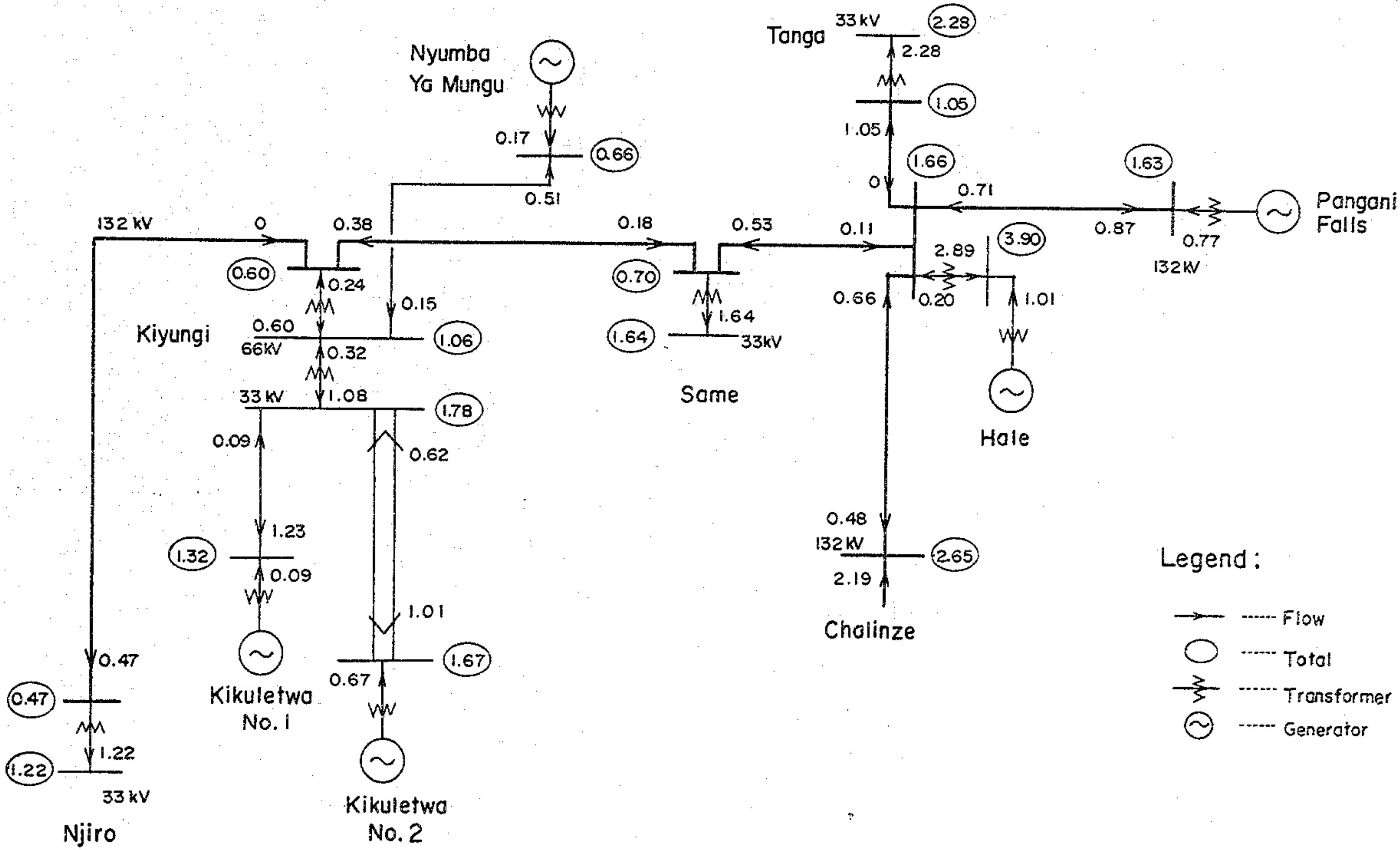


Fig. 8.4.11 SHORT CIRCUIT CURRENT
(3ø - fault in 1994, kA)

CHAPTER 9
PRELIMINARY DESIGN

CHAPTER 9 PRELIMINARY DESIGN

Page

9.1 KIKULETWA NO.1 HYDROPOWER DEVELOPMENT PROJECT (REHABILITATION PLAN)

The focus of this Rehabilitation Plan is to utilize, as far as possible, the existing facilities, while increasing energy production to as high a level as possible.

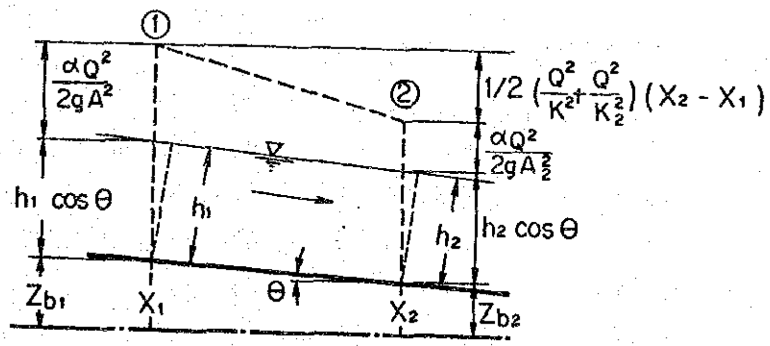
The present power station was constructed about 50 years ago, and particulars and drawings for most of the structures and equipment do not exist. The JICA team, therefore, carried out a field survey and other studies in order to gain an understanding of the existing principal facilities, so that an optimum improvement plan could be formulated.

9.1.1 Study on Water Level of Head Tank

Water is conducted to the head tank from the Kikuletwa and Kware rivers by means of two canals.

The Kikuletwa Canal is the main waterway (see the canal profile in Fig. 9.1.1), while the Kware Canal serves as an auxiliary waterway. Because the Kikuletwa Canal is influenced more by the head tank water level, head tank and intake water levels were analyzed using step-by-step calculation method, for that canal.

$$h = h_2 - h_1 = Z_{b1} + Z_{b2} + \frac{Q^2}{2g}\left(\frac{1}{A_1^2} - \frac{1}{A_2^2}\right) - \frac{Q}{2}\left(\frac{1}{K_1^2} + \frac{1}{K_2^2}\right)(X_2 - X_1)$$



(1) Calculation Conditions

(i) Using the above equation, the head tank water level and intake water levels for the Kikuletwa Canal were considered in relation to the canal's discharge capacity.

(ii) Roughness coefficient (n)
Shotcrete lining : 0.016
Concrete lining : 0.013

(iii) Cases examined:

Case	Discharge Capacity (cu.m/sec)	Head Tank Water Level (m)
1	8.9	830.30
2	8.9	830.40
3	15.4	830.00
4	15.4	830.10
5	15.4	830.20
6	15.4	830.30

(2) Case Studies

The results of calculations on the conditions given above are as follows:

Case	Q (cu.m/sec)	Head Tank Water Level (m)	Intake EL. (m)	Av. Water Surface Gradient
1	8.9	830.30	830.351	1/11,935
2	8.9	830.40	830.428	1/13,214
3	15.4	830.00	830.188	1/1,968
4	15.4	830.10	830.256	1/2,371
5	15.4	830.20	830.23	1/2,846
6	15.4	830.30	830.412	1/3,304

(3) Results

For a head tank water level elevation of 830.30 m, the intake water level necessary to draw the maximum power discharge (Q_{max} = 15.4 cu.m/sec) will be 830.412 m. The crest elevation (830.46 m) of the existing intake dam is, therefore, sufficient to draw the maximum power discharge.

The standard cross sections of the Kikuletwa and Kware Canals are trapezoidal, with bottom widths of approximately 4.00 m. The respective canal bed gradients are 1/450 and 1/800, and the ratio of intake capacity is 1:0.74. Maximum power discharge (15.4 cu.m/sec) will, therefore, be supplied when the canal rates are as follows:

Kikuletwa Canal : 8.9 cu.m/sec
Kware Canal : 6.5 cu.m/sec

9.1.2 Reinforcement of Canal Cross Section

Although some sections of canals are presently lined with concrete block, most sections remain unlined. As a result, there are many places where the side walls have been damaged by water flow and, leakages are occurring. The side walls will, therefore, be repaired at the damaged areas, following which shotcrete protection will be provided.

The canal floors will be cleaned of deposited material, treated to obtain the designated gradient, and then lined with concrete.

Following reinforcement and repair, the existing canals will be sufficient to convey the maximum power discharge of 15.4 cu.m/sec.

9.1.3 Head Tank

The existing head tank is to be extended on the east side. Appurtenant facilities, such as screen and sand flush gate, are to be installed at the front of the penstock inlet.

The head tank will be repaired by placing concrete in the deteriorated portions of side walls, and laying bedrock on the tank floor. This will help to prevent water leakage.

A side-overflow spillway will also be provided so that surplus water can be safely released at load rejection. The present waterway connecting to the spillway will be partially repaired, and will continue to be used.

9.1.4 Penstock and Powerhouse

The penstock will be one line (inside diameter: 2.5 m; length: 19.7 m) connecting to the powerhouse. The penstock will be installed underground and protected by concrete. The concrete will also prevent corrosion.

A semi-underground powerhouse is to be installed at the left bank of the Kikuletwa River. The location was selected to ensure sufficient distance from existing structures, so as to protect them from damage during excavation blasting. In addition, the location reduces the length of the penstock.

9.1.5 Electro-mechanical Equipment

(1) Number of Main Equipment

Kikuletwa No. 1 Power Station (Rehabilitation Plan) will utilize a normal effective head of 12.70 m, and a maximum power discharge of 15.40 cu.m/sec.

The runoff characteristics at this site, are such that the difference between the runoff in the dry season and the average runoff (maximum efficiency point of turbine: weighted average power discharge) is less than 20 percent. There is therefore no concern regarding the possibility of a large efficiency drop during the dry season. Furthermore, the proposed output represents only a small part of TANESCO's overall electric power system in the Kilimanjaro region, so that an outage at this site would have little influence on the overall power system. For these two reasons, a single turbine of 1,600 kW rated capacity was chosen as the main equipment.

(2) Selection of Main Equipment

A propeller-type turbine is most suited to satisfying the basic specifications described above. Such turbines may be classified, according to their mechanical aspects, as tubular turbines or Kaplan turbines. Tubular turbines may be further divided into S-type and valve-type. For reasons of economy and ease of operation and maintenance, a horizontal-shaft S-type tubular turbine with fixed-blade runners has been selected for this site.

The specifications of the main electro-mechanical equipment are as follows:

(i) Turbine

Type	: Horizontal-shaft, cylindrical propeller, S-type tubular turbine
Number of units	: 1 unit
Normal effective head	: 12.7 m
Maximum discharge	: 15.4 cu.m/sec
Rated capacity	: 1,600 kW
Speed	: 375 rpm

(ii) Generator

Type	: 3-phase, AC, synchronized generator
Number of units	: 1 unit
Capacity	: 1,750 kVA
Frequency	: 50 Hz

(iii) Main transformer

Type	: Outdoor, 3-phase, self-cooled
Number of units	: 1 unit
Rated capacity	: 1,750 kVA
Voltage	: 11/33 kV

(3) Powerhouse

The powerhouse is to be a semi-underground structure. Its planned location is immediately downstream of the existing powerhouse. An overhead travelling crane will be put in place to enable erection, and one (1) unit of main equipment, as well as auxiliary equipment will be installed.

(4) Connection of Main Circuit

The main circuit, as shown in Fig. 9.1.2, will have an 11 kV bus connected to the circuit breaker for the generator, and utilize a station service transformer. Connection between the 11 kV bus and the outdoor main transformer will be by 11 kV CV cable, approximately 100 m in length. From the standpoint of receiving an emergency power supply, it will be necessary to consider means for receiving power from an existing distribution line.

9.1.6 Outdoor Switchyard

A new switchyard is to be constructed adjacent to and on the upstream side of the existing switchyard.

A Dead-end steel structure for the 33 kV transmission line, a 33 kV circuit breaker and disconnecting switch, lightning arresters, protection devices, an instrument transformer, and a main transformer are to be installed.

The connection to the existing 33 kV transmission line is to be by an 11 kV CV cable of about 100 m in length.

9.2 KIKULETWA NO.2 HYDROPOWER DEVELOPMENT PROJECT

9.2.1 Intake Dam

(1) Selection of the Dam Site

The dam site will be approximately 2.2 km downstream of the existing Kikuletwa No. 1 Hydropower Station. This site, which includes the area of the regulating pond area, is optimum site from the standpoint of the geological structure (as described in Chapter 4). The slope of the right bank is comparatively steep, while left bank slopes gently, at about 1/7.

In order to maintain the function of the regulating pond, a sand flush gate will be installed to remove suspended loads which flow in during floods. The inflow at the intake dam site (described in Chapter 5) exceeds the 17.9 cu.m/sec maximum power discharge for about 45 days in an average year. The surplus water will be discharged downstream by the sand flush gate. This operation will enable the release of sediment deposited in the regulating pond.

(2) Annual Sedimentation in Regulating Pond

Methods for predicting sediment inflow and deposition amounts in a regulating pond are as follows:

(i) Prediction of an annual average sedimentation using an empirical formula based on surveys of existing reservoirs and regulating ponds.

This method cannot be applied in this case, as there are no records of sedimentation measurements at the Nyumba ya Mungu Reservoir, which is downstream of the proposed site of the Kikuletwa No. 2 Hydropower Development Project. Nor are there any sedimentation measurement records for the intake dam of the existing Kikuletwa No. 1 Hydropower Station, which is immediately upstream.

(ii) Method of comparison with known annual average sedimentation in similar river basin

This method is also inapplicable, as no measurement records are available on annual average sedimentation at other river basins with similar geology, topography, vegetation, and precipitation. However, a group of U.S. geologists (Witzig, Brune-Allen, Brown-Jarvis, Churchill, and Borland) have derived the following general equation from sedimentation data of storage reservoirs where there is a mixture of bed load and suspended load.

$$q_s = K \cdot (C/F)^{0.569}$$

where, qs: average annual sedimentation ratio (cu.m/sq.km/yr)
C : storage capacity (cu.m)
F : catchment area (sq.km)
K : 0.501 as average value

Applying this equation to the present site results in the following estimate:

$$q_s = 0.501 \times (\frac{208,875}{2.280})^{0.569}$$

$$= 6.55 \text{ cu.m/sq.km/yr}$$

$$Q_s = 6.55 \times 2,280 = 14,934 \text{ cu.m/yr}$$

(iii) Estimation of annual sedimentation using measurement data of suspended loads and daily average discharges at gauging stations near dams of storage reservoirs and regulating ponds.

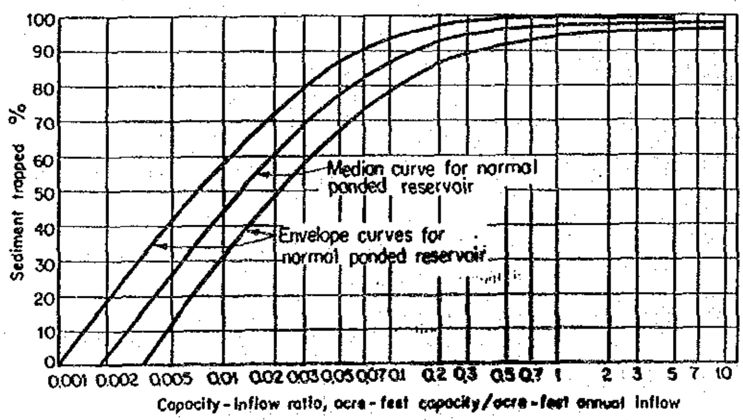
As described in Chapter 5, the suspended load of the Kikuletwa River in the average year of 1970 was estimated, based on the relation between discharge and suspended load at the Weru-weru River Gauging Station (No. IDD 5A), at 24,505 cu.m. This corresponds to 11.04 cu.m per square kilometer annually.

The average sedimentation rates of (ii) and (iii) are fairly close.

(3) Trap Efficiency

Trap efficiency refers to the settling of sediment flowing into a regulating pond. The relationship of trap efficiency and total storage capacity/total annual inflow has been expressed by Brune as shown in Fig. 9.2.1

Fig. 9.2.1. TRAP EFFICIENCY AS RELATED TO CAPACITY-INFLOW RATIO



Source : From Ven Te Chow, "Handbook of Applied Hydrology," pp. 17-23, Mc Graw-Hill Book Company. New York, 1964

The trap efficiency of the regulating pond of the Kikuletwa No. 2 Hydropower Development Project, based on Brune's relationship diagram, gives

$$\text{Capacity-inflow ratio} = \frac{208{,}875 \text{ cu.m}}{410{,}587{,}700 \text{ cu.m.}} = 0.0005,$$

indicating that the value of storage capacity/total annual inflow is very small. Sediment volume is very small on the upstream of the intake dam of the existing Kikuletwa No. 1 Power Station (which has been in operation for 50 years), which is located upstream. Based on these considerations and on the actual conditions, it is estimated that the amount of settlement in the regulating pond will be small.

This estimate is further supported by the fact that, although the station has been operating for about 50 years, the sediment-induced abrasion of the turbine runners is very small. This seems to indicate that the sediment amount is also very small.

(4) Results of Examination

It is assumed that the flow of sediment into the regulating pond occurs mainly during the flood season.

In the rainy seasons, and especially when the inflow exceeds the maximum discharge, the sand flush gate adjacent to the intake structure will be opened so that floods will be discharged to the downstream of the intake dam. This operation will flush away the sediment deposited in front of the intake dam, so that, the effective storage capacity of the regulating pond will not be impaired.

(5) Height of Non-overflow Section of Dam

The height of the non-overflow section of the dam is obtained by the following equation:

Design water level is normal high water level

$$h_f = h_w + h_e + h_a$$

Design water level is design flood water level

$$h_f = h_w$$

The larger of the two values above is to be adopted,

where,

h_f: addition to required water level (m)
h_e: wave height due to earthquake (m)
h_w: wave height due to wind (m)
h_a: addition depending on existence or non-existence of spillway (0.5 m)

a) Wave Height due to Earthquake

$$h_e = 1/2 \frac{k\tau}{\pi} \sqrt{gH_o}$$

where,

k : horizontal seismic coefficient (0.12)
τ : period of seismic wave (1.0 sec)
H_o: water depth of regulating pond from normal high water level (8 m)

$$h_e = 1/2 \times \frac{0.12 \times 1.0}{\pi} \times \sqrt{9.8 \times 8} = 0.17 \text{ m}$$

b) Wave Height due to Wind

$$H_w = 0.0086\ V^{1.1} F^{0.45}$$

where,

F: fetch (= 50 m)
V: 10-minute average wind speed (30 m/sec)
$H_w = 0.0086 \times 30^{1.1} \times 50^{0.45} = 0.021$ m

c) Height of Non-overflow Section

Where design water level is normal high water level

$$h_f = h_w + h_e + h_a$$
$$h_f = 0.21 + 0.17 + 0.50 = 0.88 \text{ m}$$

Elevation of non-overflow section = 821.00 + 0.88
= 821.88

Therefore, the height of the non-overflow section is 822.00 m.

(6) Overflow Section

The discharge formula for crest configuration of standard shape is as follows:

$$Q = CBH^{3/2}$$

$$c_d = 2.20 - 0.0416 \left(\frac{H_d}{W}\right)^{0.990}$$

where,

Q: design flood discharge (300 cu.m/sec)
C: discharge coefficient
B: length of overflow crest (28 m)
H: overflow head
H_d: design head (m)
W: height of dam (6 m)
C_d: discharge coefficient at $H = H_d$

Assuming a discharge coefficient of C = 2.20,

$$H_{d_1} = \left(\frac{Q}{C.B}\right)^{2/3} = 2.87 \text{ m}$$

$$C_{d_1} = 2.20 - 0.0416 \left(\frac{H_d}{W}\right)^{0.99} = 2.181$$

$$H_d = \left(\frac{Q}{C_d \cdot B}\right)^{2/3} = 2.89\ (m)$$

$$C_d = 2.20 - 0.0416\ \left(\frac{H_d}{W}\right)^{0.99} = 2.181$$

Therefore, the discharge coefficient at design head H_d = 2.89 m will be C_d = 2.181. Consequently, the overflow water depth is H = 2.90 m. Hence, the elevation at time of flood is 818.00 + 2.90 = 820.90 ≒ 821.00 m.

(7) Diversion Scheme During Construction

During construction, the Kikuletwa River runoff is to be released through a diversion channel in the riverbed.

The most economical diversion scheme would be to release water through the sand flush section located at the left abutment.

The flood discharge during construction will be for the 3-year return period flood of 65 cu.m/sec. The height of the upstream cofferdam will be EL. 814.00 m.

The relationship between the volume of discharge through the sand flush gate and the regulating pond water level is shown in Fig. 9.2.2.

9.2.2 Intake

The intake is designed in a direction perpendicular to the dam axis. In other words, the direct inflow of sediment from the regulating pond that would occur if water intake were parallel to the river will be avoided.

Since the water is to be conducted by a non-pressurized waterway, as described in the following section, the inflow will be regulated using the intake gate. If continuous inflow exceeds the maximum power discharge during the rainy season, however, the flood water will be discharged downstream through operation of the sand flush gate.

The bed elevation of the intake is to be such that the maximum discharge of 17.9 cu.m/sec can be drawn even when the regulating pond water level is at its minimum of EL. 816.00 m. In order to enable drawing of the headrace is designed to assure a water depth of 2.80 m, so that the headrace bed elevation will be 813.20 m :

Bed elevation of headrace = 816.00 - 2.80 = 813.20 m

9.2.3 Headrace

The headrace route will be through the comparatively flat tableland on the left bank of the Kikuletwa River.

As described in Chapter 4, the geology in this vicinity consists of thin talus deposits (not more than 1 m) and basement rock of hard tuff breccia.

A 1/5,000-scale aerial photographic map was used to select the headrace route with the least risk of sliding. The longitudinal profile of the selected headrace route shows that the rock cover from the headrace bed to the ground surface for a section of about 2.2 km from the intake will be 10 to 18 m. Drilling at this section revealed that the groundwater table is high, so that the headrace must pass through a zone below it (see Fig. 4.3.2).

The use of a tunnel for this section was considered, but tunnel construction could face unforeseen difficulties connected with the handling of the ground water during tunnel excavation, and because of the thin rock cover. To enable safe construction within the scheduled period, therefore, open excavation will be applied to this section, and the headrace will be a culvert. The 1,050 m long section having a rock cover of less than 10 m, will be an open canal. The hydraulic characteristic curves for open canal and culvert are shown in Figs. 9.2.3 and 9.2.4.

9.2.4 Head Tank

The configuration of the head tank was planned for a flow velocity of $V_{max} \leq 1.0$ cu.m/sec inside the tank.

To achieve a smooth transition to the penstock, the 3-meter section prior to the penstock will be tapered, as seen from above. A control gate will be installed at the penstock entrance to enable inspection inside the penstock.

The longitudinal configuration is based on the fact that the head tank's bed elevation, gradient, and other features have been planned, with consideration to the inflow velocity, the effective water depth at the penstock entrance, and the hydraulic conditions.

A 16-m long side-overflow spillway is planned for the left side of the head tank, so that the maximum power discharge of 17.9 cu.m/sec can be released at load rejection of the power station. The overflow water depth will be 0.70 m. The spillway cross section will be 2.4 m, and the gradient 1/10.

9.2.5 Penstock

To facilitate its construction and maintenance, the penstock will be installed on the ground surface. The penstock is to be of welded steel pipe. The upper part will be one line with an inside diameter of 2.6 m; the line will bifurcate immediately before entering the powerhouse. The pipe shell material will be SM 41 (JIS) or equivalent.

Both sides of the penstock will be excavated to a slope of 1:0.5 and protected with shotcrete. At the connection of powerhouse and penstock, the pipes will be embedded in concrete and backfilled with earth.

9.2.6 Powerhouse

A surface powerhouse will be constructed on the left bank of the Kikuletwa River. The powerhouse will hold two units of turbines and generators, with total output of 11,000 kW at the maximum discharge of 17.9 cu.m/sec. The elevation of the turbine center will be EL. 729.40 m, a value determined in consideration of the tailrace water level (EL. 730.90 m) and the draft head. The elevation of the erection bay will be EL. 736.00 m determined in consideration of the flood water level (EL. 735.00 m).

The access road to the powerhouse, and the erection bay, will be at EL. 736.00 m.

9.2.7 Electro-mechanical Equipment

(1) Selection of the Number of Main Units

The Kikuletwa No. 2 Hydropower Development Project is expected to be an important power supply source for the Arusha-Kilimanjaro Region. In consideration of the river runoff conditions at the site, it has been decided that two (2) units will be used, so that maximum energy can be produced.

(2) Selection of Main Equipment

The specific speed of a turbine is expressed by the following equation:

$$n_s = n \times p^{1/2}/H^{5/4}$$

where,

n_s: specific speed (m-kW)
H: effective head (m)
n: rotating speed (rpm)
p: maximum output (kw) at effective head H (m)

$$p = 9.8 \times 8.95 \times 78.2 \times 0.84 = 5{,}761 \text{ kW}$$

The applicable maximum specific speed of a Francis turbine is:

$$N_{smax} \leq \frac{20{,}000}{H + 20} + 30$$

$$= 234 \text{ (m-kW)}$$

The rotating speed of the turbine at this time is:

$$n_s = \frac{N_{smax} \cdot H^{5/4}}{p^{1/2}} = \frac{54,415.7}{75.9} = 716.9 \text{ (rpm)}$$

The turbine's rotating speed should therefore not exceed 716.9 rpm.

The synchronized rotating speed of the generator directly coupled to the turbine is 600 rpm, the standard applicable rotating speed at 50 Hz. The specific speed (N_s) of the turbine under such conditions will be as follows:

$$N_s = N \times \frac{p^{1/2}}{78.2^{5/4}} = 196 \text{ (m-kW)}$$

As Fig. 9.2.5 indicates, a Francis type best complies with this specific speed.

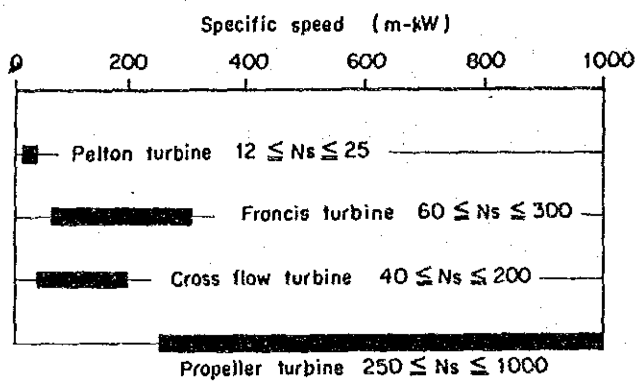


Fig. 9.2.5 Range of Specific Speed by Turbine Type

The specifications of the main electro-mechanical equipment for the Kikuletwa No. 2 project site are as follows:

(i) Turbine

Type	:	Vertical-shaft Francis
Number of Units	:	2
Normal effective head	:	78.2 m

Maximum discharge	:	8.95 cu.m/sec per unit
Rated capacity	:	5,800 kW per unit
Speed	:	600 rpm

(ii) Generator

Type	:	3-phase, AC, synchronous generator
Number of units	:	2
Rated capacity	:	6,500 kVA per unit
Frequency	:	50 Hz

(iii) Main Transformer

Type	:	Outdoor, 3-phase, air-cooled
Number of units	:	2
Rated capacity	:	6,500 kVA per unit
Voltage	:	11/33 kV

(3) Powerhouse

The powerhouse building, as shown on Dwg. No. 9, is to be aligned in parallel to the Kikuletwa River. The building will be 37.50 m long and 11.00 m wide. Space will be provided for a control room, two units of main equipment, an erection bay and overhead travelling crane, 11 kV switching equipment and auxiliary equipment.

(4) Main Circuit

The main circuit is shown in Fig. 9.2.6. A low-voltage synchronized system for parallel-in of the generator is to be adopted to ensure supply of station service power.

The main transformer will be of an outdoor type and will be installed in the outdoor switchyard near the head tank.

The powerhouse and switchyard are to be connected by two circuits of 11 kV overhead line.

9.2.8 Outdoor Switchyard

The outdoor switchyard is to be constructed at a flat space close to the head tank. The main transformer, 33 kV switching equipment, protection devices, and instrument transformers are to be installed in the switchyard. (See Fig. 9.2.7.)

Operation and monitoring of the switchyard will be performed at the control board in the powerhouse.

9.2.9 Transmission Line

The 33 kV transmission line facilities to be newly constructed are outlined below:

Line Voltage:	33 kV
Electrical System:	3-phase 3-wire
Frequency:	50 Hz
Conductor:	Wolf (Corresponding to ACSR 160 mm^2)
Shield Wire:	GSW 30 mm^2
Insulator:	33 kV pin type insulator (for the tangent type support, and for the jumper wire on the angle/dead-end support) Diameter 250 mm Suspension type insulator, 3 pcs per one string (for the angle and dead-end support)
Line length:	14 km
Support:	Wooden pole, double-circuit vertical arrangement

Fig. 9.2.8 shows typical 33 kV transmission line structures for double-circuit arrangement.

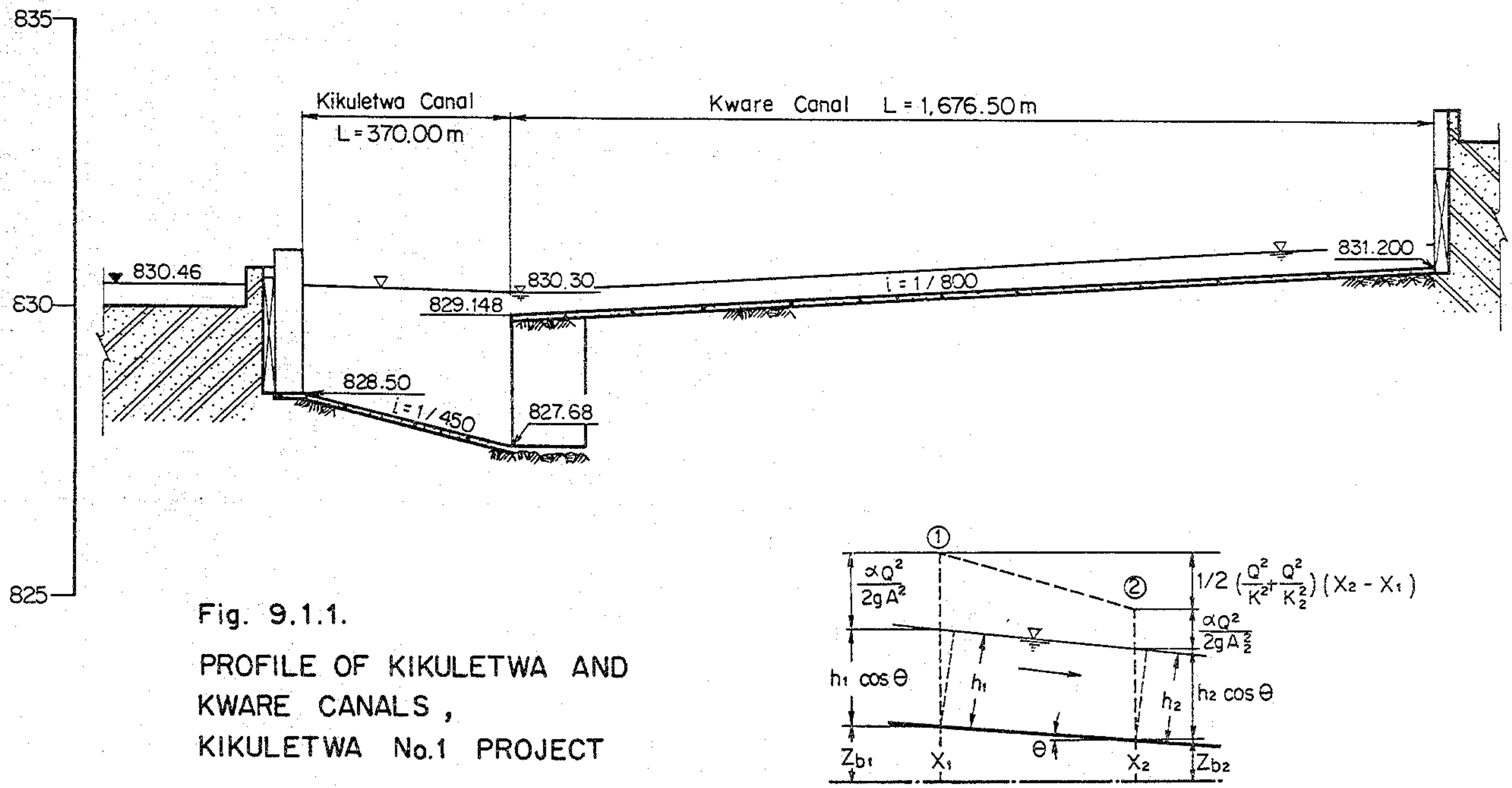


Fig. 9.1.1.

PROFILE OF KIKULETWA AND KWARE CANALS, KIKULETWA No.1 PROJECT

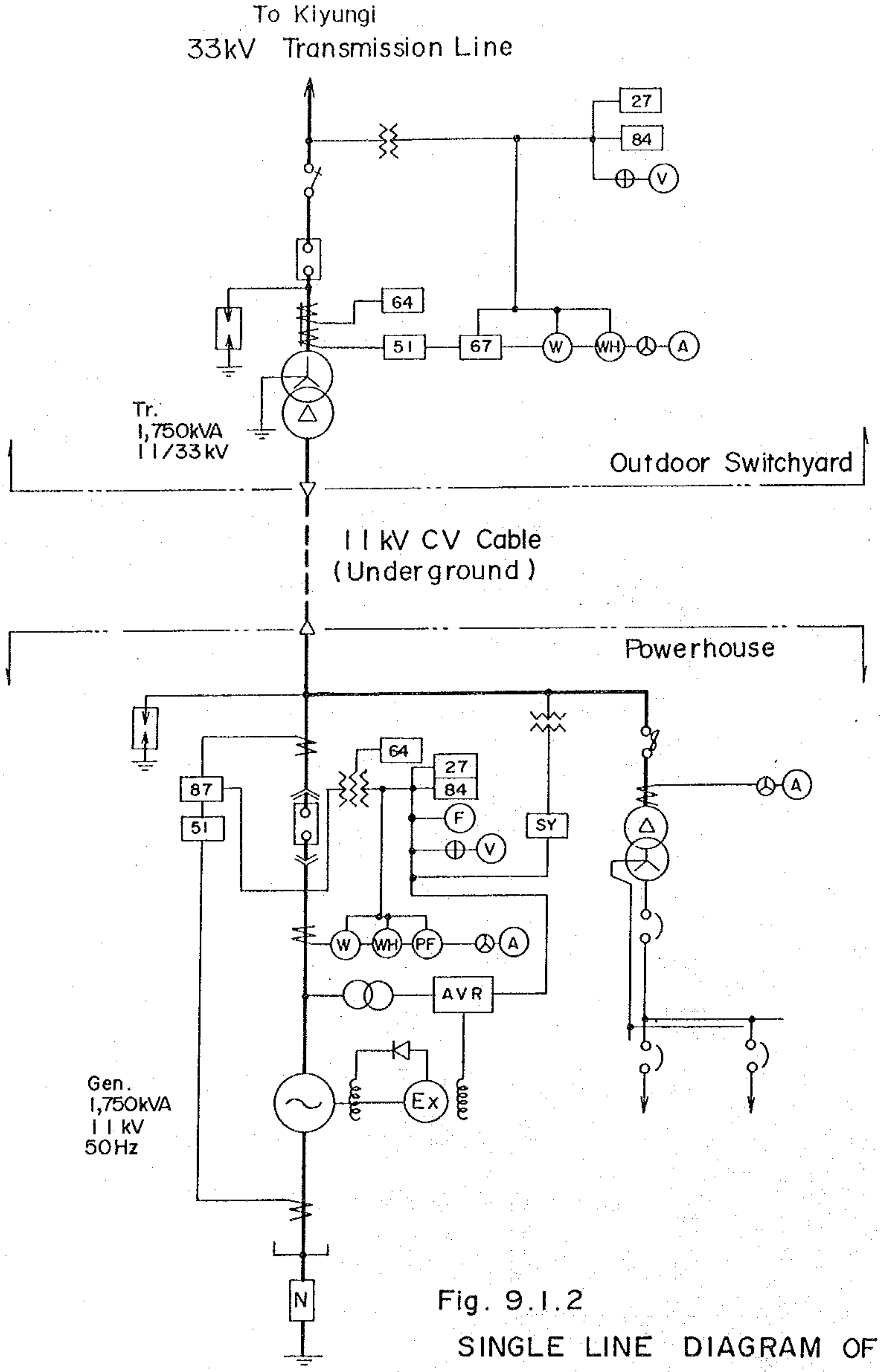
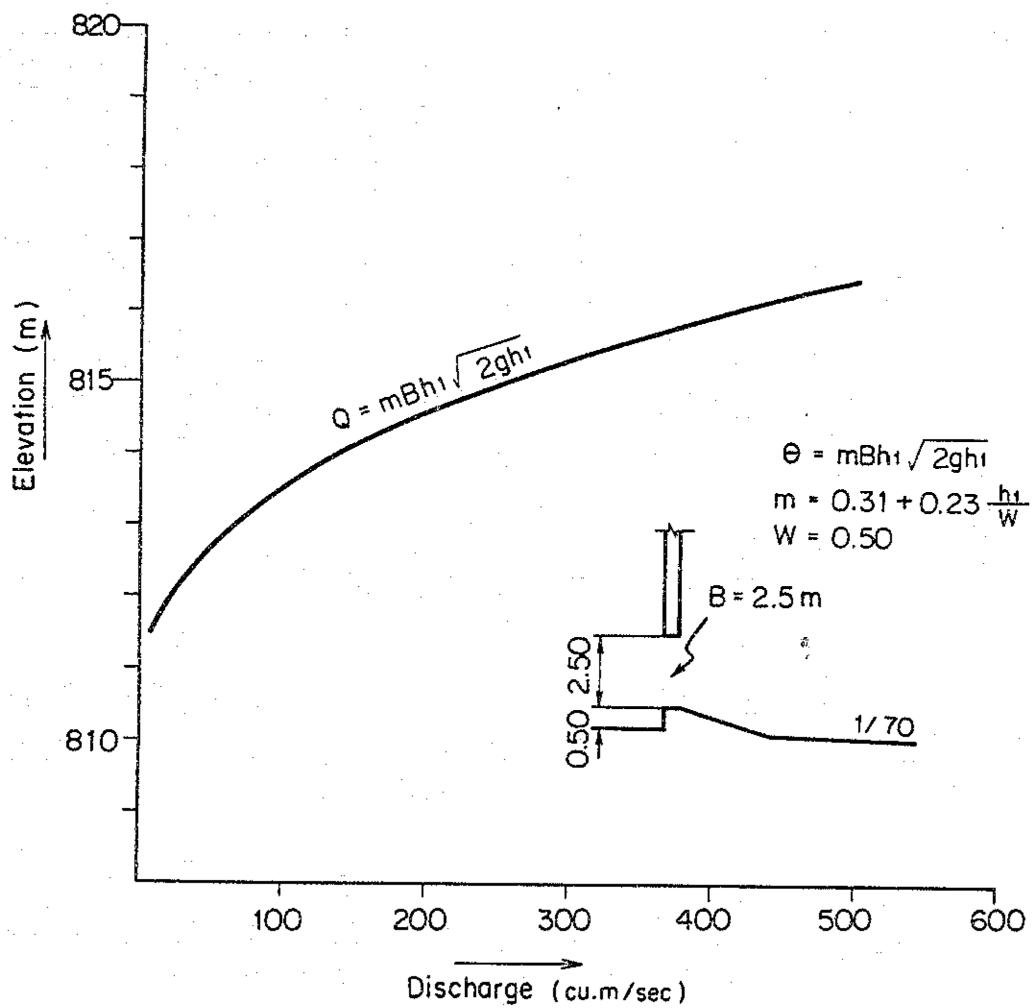


Fig. 9.1.2

SINGLE LINE DIAGRAM OF KIKULETWA No.1 PROJECT

Fig. 9.2.2. DISCHARGE FROM FLASH GATE



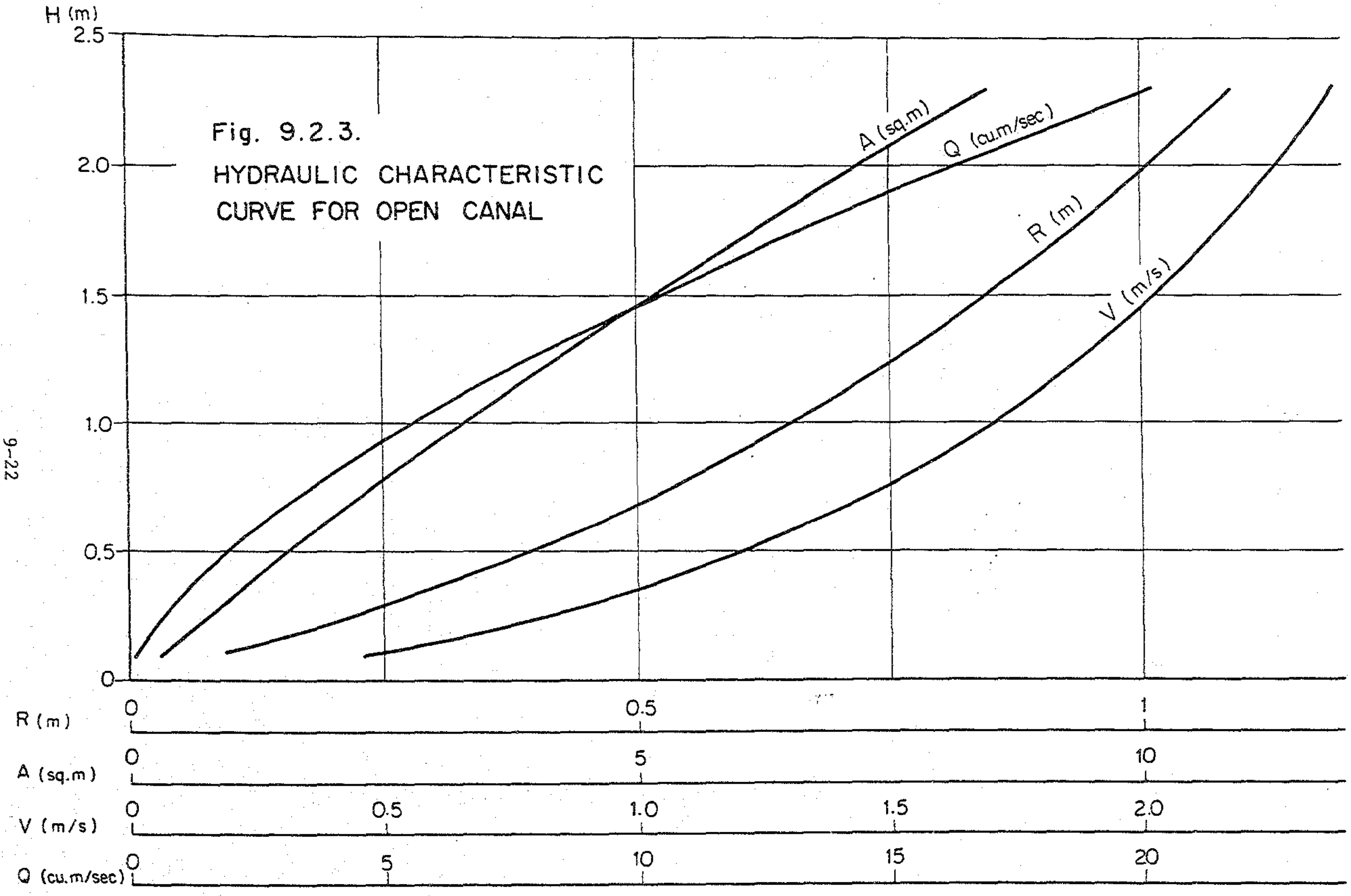


Fig. 9.2.3.
HYDRAULIC CHARACTERISTIC
CURVE FOR OPEN CANAL

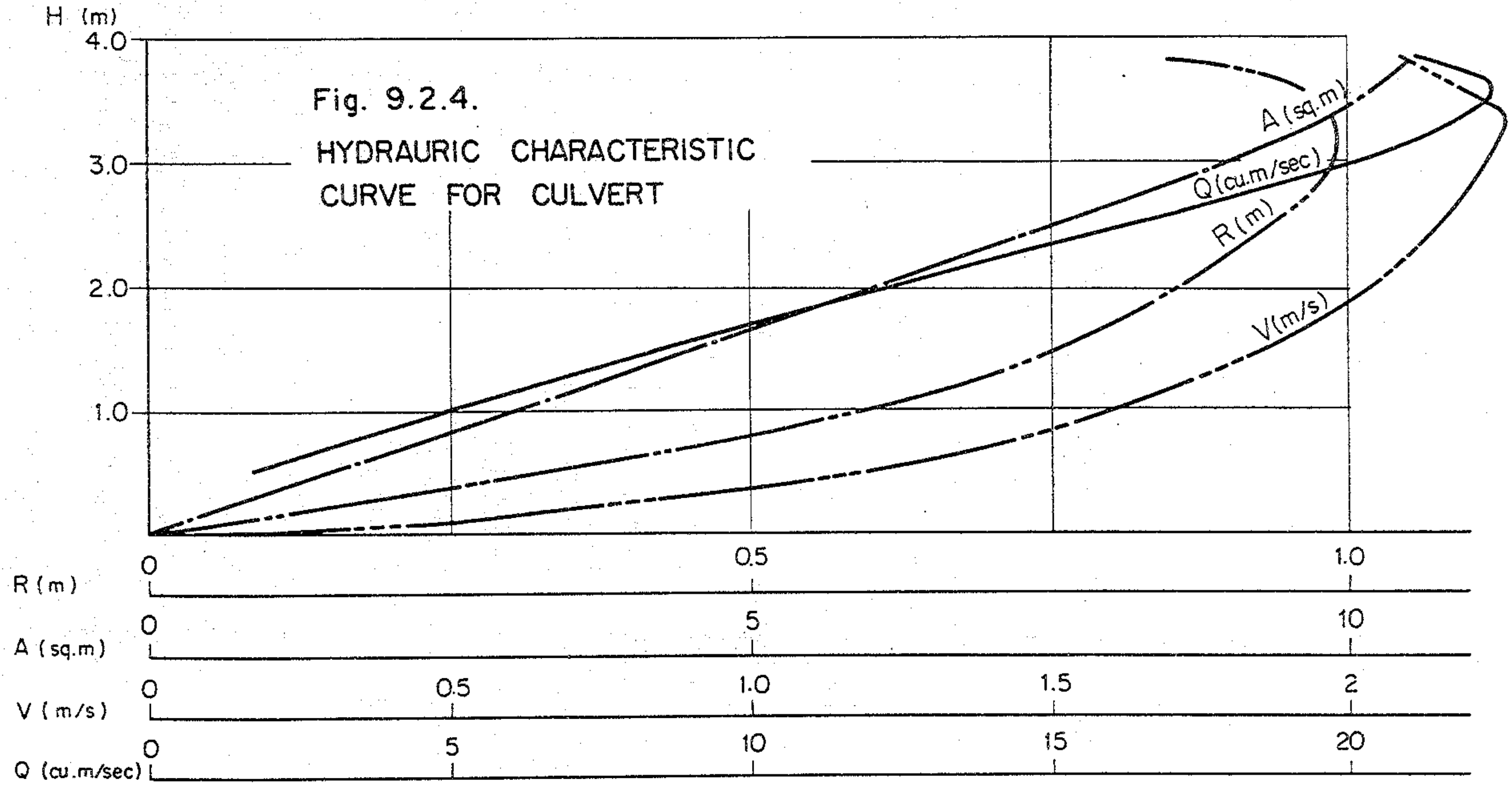


Fig. 9.2.4.
HYDRAURIC CHARACTERISTIC CURVE FOR CULVERT

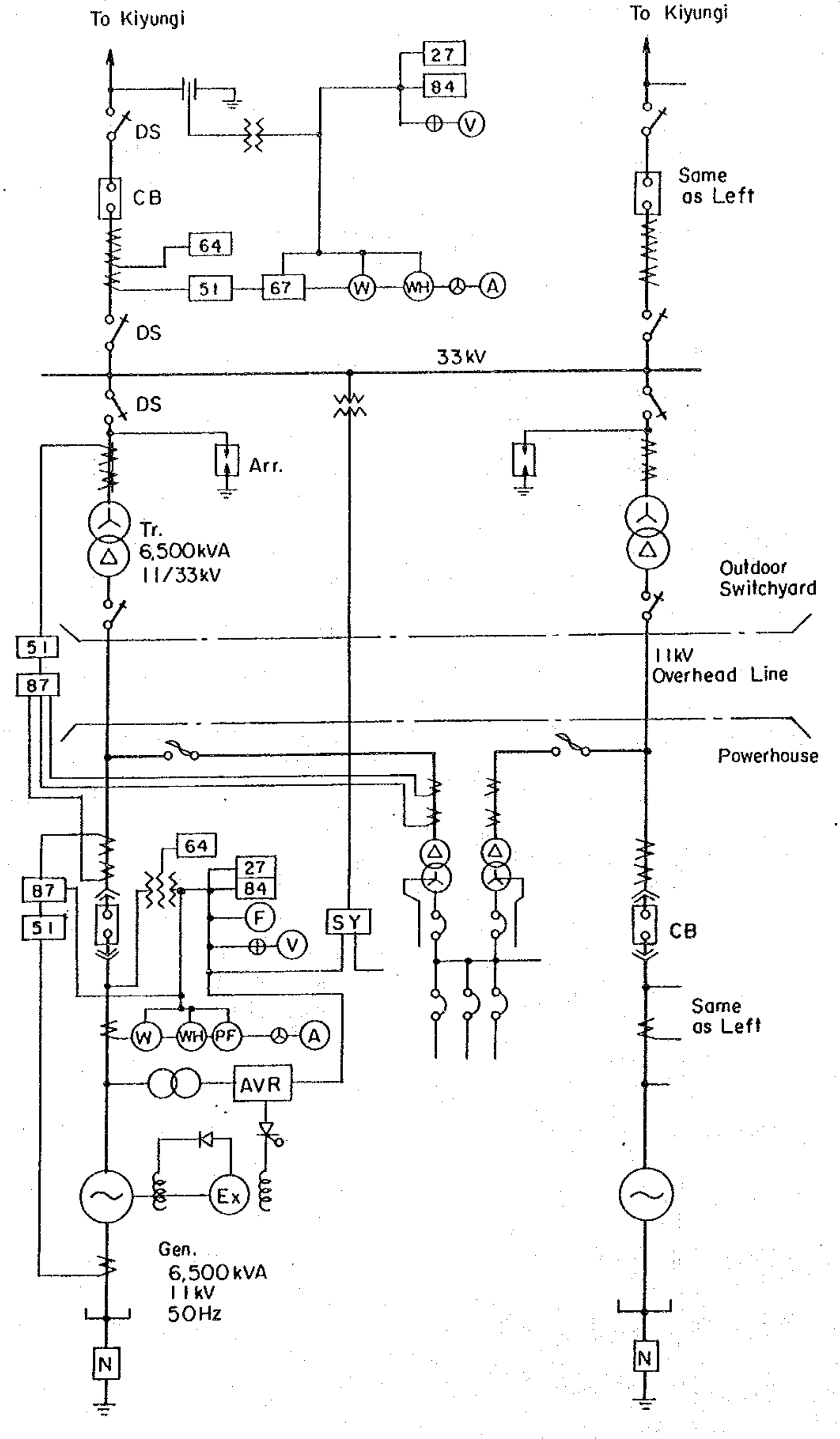


Fig. 9.2.6 SINGLE LINE DIAGRAM OF KIKULETWA No.2 PROJECT

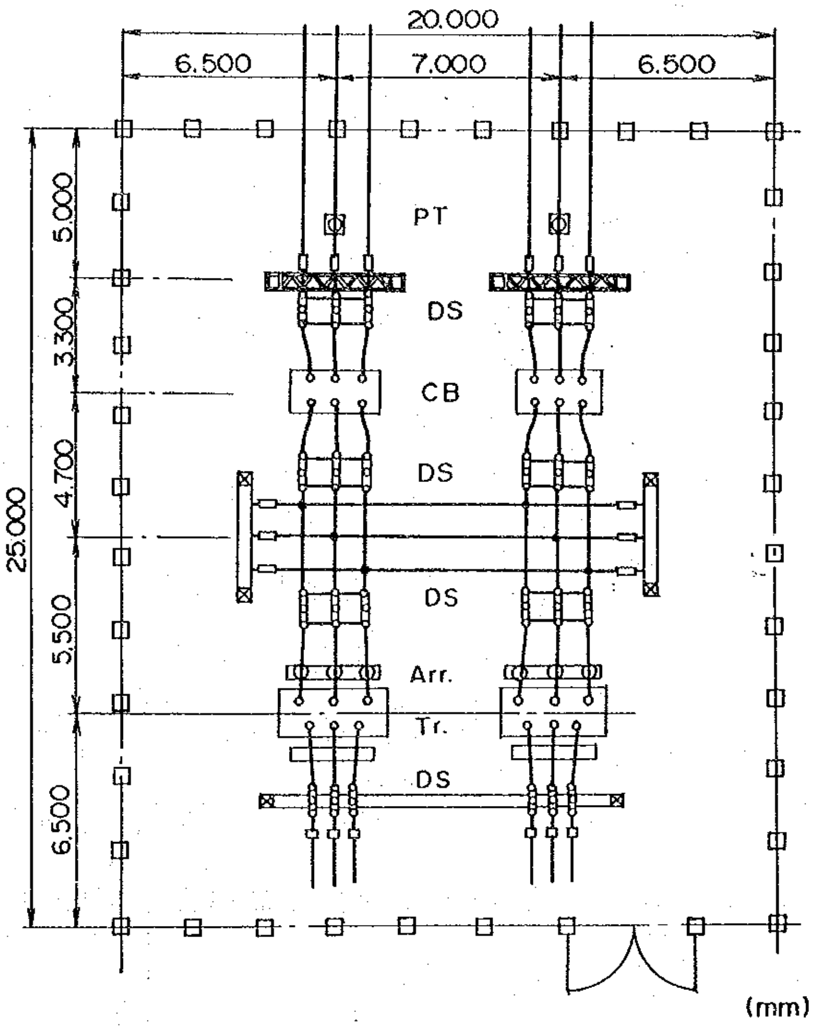
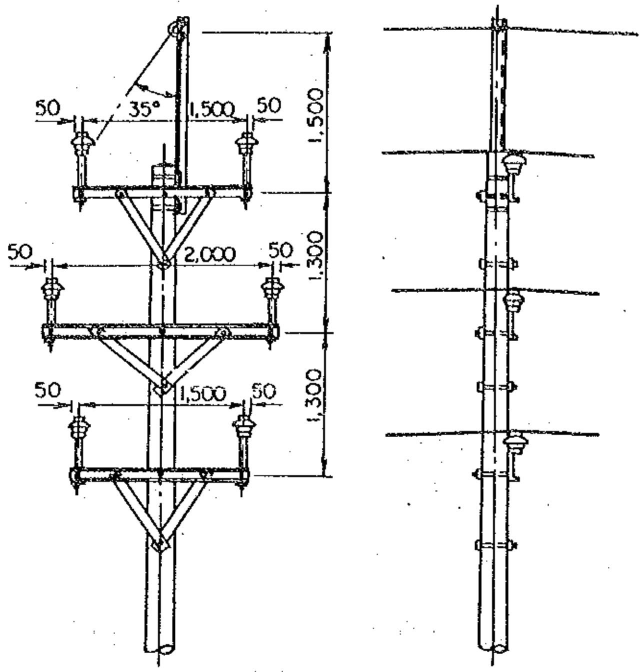
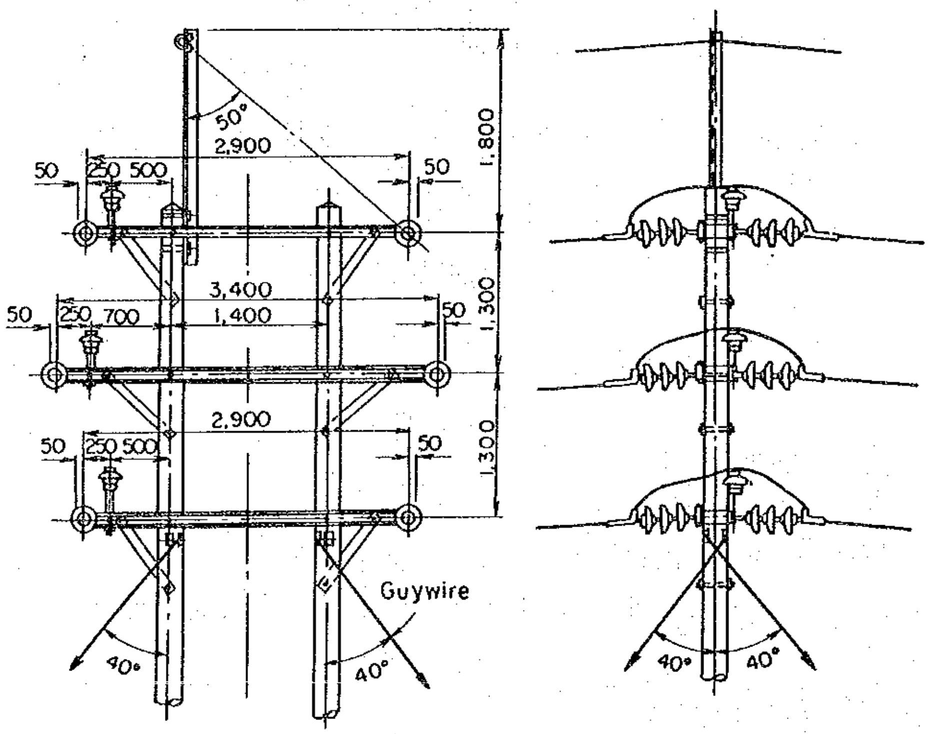


Fig. 9.2.7 GENERAL ARRANGEMENT OF OUTDOOR SWITCHYARD FOR KIKULETWA NO. 2 PROJECT



(a) Tangent Type Support



(b) Angle Type Support

Fig. 9.2.8 33kV TRANSMISSION LINE TYPICAL SUPPORTS(Double Circuit)

CHAPTER 10
CONSTRUCTION PLAN

CHAPTER 10 CONSTRUCTION PLAN

Page

CHAPTER 10 CONSTRUCTION PLAN

10.1 GENERAL

The installed capacities of the Kikuletwa No. 1 and No. 2 hydropower development projects will be 1.5 MW and 11.0 MW, for a total of 12.5 MW. The electric power generated at the two sites will be supplied to meet the demand in the Kilimanjaro and Arusha regions. The targeted commissioning times are as follows:

Kikuletwa No. 1 commissioning: 1991
Kikuletwa No. 2 commissioning: 1994

The construction plan is scheduled so as to meet these targets.

10.2 TRANSPORTATION ROUTE AND METHOD OF HAULING

10.2.1 Transportation Route

(1) Existing Roads

The Kikuletwa No. 2 Hydropower Development Project calls for the construction of an intake dam 2.2 km downstream of the existing TANESCO Kikuletwa Power Station, and for construction of a powerhouse 6 km downstream.

A 350-km trunk highway runs from the port of Tanga to Moshi, via Hale and Same; a 40-km road runs between Moshi and the existing Kikuletwa Power Station, via the village of Kifura. The road surfaces, however, have not been adequately maintained. In particularly, it will be necessary, before the start of construction, to repair the road base of the road running from Moshi to the existing Kikuletwa Power Station. The road condition will be an important factor in the overall work schedule, so that repair should be performed as quickly as practicable.

(2) New Road

At present, there is no road between the existing Kikuletwa Power Station and Kikuletwa No. 2 Project site. A new road of about 6 km in length will therefore have to be built.

10.2.2 Method of Hauling

The construction of the Kikuletwa No. 1 and No. 2 power stations, and related transmission and transformation facilities will require the hauling in of construction materials and equipment, hydraulic equipment (gates, penstocks, etc.), and electro-mechanical equipment (turbines, generators, etc.).

The longest and heaviest construction items are assumed to be the following:

	Heaviest Article	Longest Article
Kikuletwa No. 1 Project	During Construction Breaker Approx. 15 tons	
	Generating equipment Generator rotor Approx. 8 tons	Penstock pipe Approx. 6 m
Kikuletwa No. 2 Project	During construction Bulldozer Approx. 20 tons	
	Generating equipment Generator rotor Approx. 18 tons	Travelling crane Approx. 9 m

The transport plans are described below:

(1) Imported Heavy Articles

Most of the imported materials and equipment, including the construction machinery, will be landed at Tanga Port, on the Indian Ocean. Trucks and trailers will be used for transport from the port to the site.

(2) Imported Light Articles

Lightweight equipment and components will be flown to Kilimanjaro Airport, and then transported by road.

(3) Domestically Procured Materials

Materials and equipment which can be obtained domestically will be procured at Arusha and other cities, and transported to the site.

10.3 ELECTRIC POWER FOR CONSTRUCTION

(1) Kikuletwa No. 1 Hydropower Development Project (Rehabilitation Plan)

The power required for project construction is estimated at about 1,000 kW. This power could be taken from the existing switchyard, or else diesel generators could be installed. The former method would be cheaper - but because of the instability of the region's power supply, it is not dependable. Diesel generators should therefore be used, to assure adequate supply.

Installation of four portable diesel generator units with capacities of 250 kVA is considered the best plan.

(2) Kikuletwa No. 2 Hydropower Development Project

The maximum power supply capacity required for construction is estimated to be about 4,000 kW. To obtain this electric power, the 33 kV transmission line and switchyard can be constructed in advance of the main work and can then be used as temporary facilities. The transmission line must therefore to be completed before the main construction work starts.

10.4 CONSTRUCTION METHODS FOR VARIOUS FACILITIES

10.4.1 Kikuletwa No. 1 Hydropower Development Project (Rehabilitation Plan)

(1) Preparatory Work

In addition to road construction and repair (see Section 10.2.1), it will be necessary to build a TANESCO field office, accessory buildings, materials warehouses, repair shops, etc. Plans call for constructing these facilities either at the same time or immediately following the carrying out of the necessary road work.

(2) Concrete Plant

About 4,000 cu.m of concrete will be required for the canals, and about 3,000 cu.m for the head tank and powerhouse. Because it has been determined that the material excavated at the site will contain very little material suitable for concrete aggregates, a suitable quarry will be selected in the vicinity of the project site.

An aggregate plant will be located on the right bank of Kware Canal.

Based on the concrete placing schedule, the economically preferred capacities of the aggregate plant and the concrete plant are 10 ton/hr and 10 cu.m/hr, respectively.

(3) Air Compressor

Both stationary and portable compressors will be used to supply the compressed air required for the construction. The stationary compressors will be of capacities suitable for the head tank and powerhouse sites; the portable compressors will be used for the other work.

(4) Water Supply Facilities

Water for construction use is to be pumped in from both the Kikuletwa and Kware rivers, and held in storage tanks. The stored water will be supplied to the canal, head tank, penstock, and powerhouse construction sites, and also to the aggregate and the concrete plants.

(5) Other Facilities

A field shop for the penstock, and other facilities, will be provided in the project area.

(6) Canal

Before the beginning of canal repair work, repair will be made to the existing intake gates at the Kikuletwa and Kware canals, and to the sand flush gates at the intake dam. Water will be removed from the canals, the side slopes which have slided will be repaired and reinforced with shotcrete, and the canal bottoms will then be excavated.

The excavation volume will be about 4,500 cu.m, and excavation is to be completed within about 5 months. The heavy equipment necessary for this work will consist of breakers, small size bulldozers, shovels, and dump trucks.

Invert concrete will be placed as soon as the bottom excavation is completed. Concrete work is to be completed within approximately 3 months.

Concrete will be placed in blocks of 15 m.

(7) Head Tank

The excavation volume for the head tank will be approximately 2,000 cu.m, and excavation is to be completed within about 2.5 months. In order to protect existing structures close to the work site from damage, equipment such as breakers will be used for rock excavation. Deteriorated concrete in the existing structure is to be removed and repaired by shotcrete, followed by concreting of the invert.

(8) Penstock and Powerhouse

Since the penstock and powerhouse are located close to each other, excavation for the penstock is to be performed from the top towards the powerhouse. Excavated rock is to be hauled to a spoil bank on the right side of Kware Canal. The powerhouse foundation will be excavated to a depth lower than the river bed. It will be necessary to construct a cofferdam about 3-m high at the tailrace prior to starting excavation.

Foundation concrete and side-wall concrete will be placed first. Obstacles around the powerhouse will be removed to permit the hauling of generating equipment.

The tailrace is to be constructed together with the powerhouse.

10.4.2 Kikuletwa No. 2 Hydropower Development Project

(1) Preparatory Work

As mentioned in Section 10.2.1, preparatory work will include construction of a 6-km access road to the No. 2 powerhouse, which will connect to the end (Kawaya Dispensary site) of the road that runs between Moshi and the Kikuletwa No. 1 Project site. Maintenance and repair of the existing roads will also be carried of during this construction period. In addition, TANESCO, site offices and accessory buildings, warehouses, repair shops, etc., will be necessary, at both dam sites and powerhouse sites.

(2) Concrete Plant

Plans are for concrete aggregates to be manufactured at an aggregate plant to be placed about 1 km downstream of the powerhouse site. Rock excavated at the canal will be used as the raw material for the aggregates.

The concrete plant will be placed near the aggregate plant. Concrete will be supplied to the various work sites using transit mixers of 3 to 4.5 cu.m. in capacity.

Based on the concrete placement schedules, the required capacities for the aggregate and concrete plants will be 50 ton/hr and 25 cu.m/hr, respectively.

(3) Air Compressor

Both stationary and portable compressors will be used to supply the compressed air required for construction. Stationary compressors will be installed at the intake dam, head tank, penstock, and powerhouse sites. Portable types will be used at the other work sites.

(4) Water Supply Facilities

Water for construction is to be pumped in from the Kikuletwa River and held in storage tanks.

Water for the aggregate and concrete plants is to be pumped in directly from the Kikuletwa River.

(5) Other Facilities

Other facilities, such as a motor pool and a penstock field shop, will be provided on tableland near the project site.

(6) Intake Dam

The intake and sand flush structures on the left bank will be constructed first. After embankment of a cofferdam, the sand flush structure will be utilized as the diversion channel. Once the river flow is directed through this channel, the foundation for the overflow section will be excavated, followed by concrete placement of the dam.

Excavation for the dam foundation will be total of 7,500 cu.m and will be completed within 6 months. The concrete volume to be placed is 4,100 cu.m; concrete placement is also scheduled to take about 6 months.

(7) Headrace

The headrace construction will govern the construction schedule for the entire project. Excavation will be divided into open canal and culvert sections, and work at both will commence simultaneously. Because some of the excavated rocks are to be utilized as concrete aggregate, the excavated material will be hauled to the aggregate plant.

The excavation volume is 323,500 cu.m, and the excavation is to be completed within 2 years. The heavy equipment required consists of 15-ton class breakers, shovels with bucket capacities of 1.5 to 3.0 cu.m, 18-ton class dump trucks, and 15-ton to 20-ton class bulldozers.

Roads of sufficient width and gentle gradient should be constructed along the canal to permit trucks to pass.

When excavation is completed, concrete will be placed. Steel slipforms will be used for conducting placement.

(8) Head Tank

Excavation for the head tank will be performed following the completion of excavation for the open canal. The excavation volume, including the spillway, will be 7,500 cu.m. The excavation work is to be completed within about 5 months. Concrete will be placed as soon as excavation is completed.

(9) Penstock

As the bottom portion of the penstock is a steep slope, it will be impossible to perform work at the powerhouse below the penstock during this excavation. Excavation is therefore to be divided into two parts - that for the gentler sloped area and that for the steeper area - with consideration to the schedule for installing the penstock pipes.

(10) Powerhouse

Excavation for the foundation is to be started as soon as excavation of the steeply-sloped portion of the penstock is complete. Concrete placement will then commence.

Before the starting of excavation, it will be necessary to construct a cofferdam on the left bank of the Kikuletwa River.

No special problems are anticipated during the powerhouse construction.

10.5 CONSTRUCTION SCHEDULE

Construction times for the Kikuletwa No. 1 Hydropower Station (Rehabilitation Plan) and the Kikuletwa No. 2 Hydropower Station are anticipated to be 15 months and 48 months, respectively. The construction work schedules are shown in Tables 10.5.1 and 10.5.2.

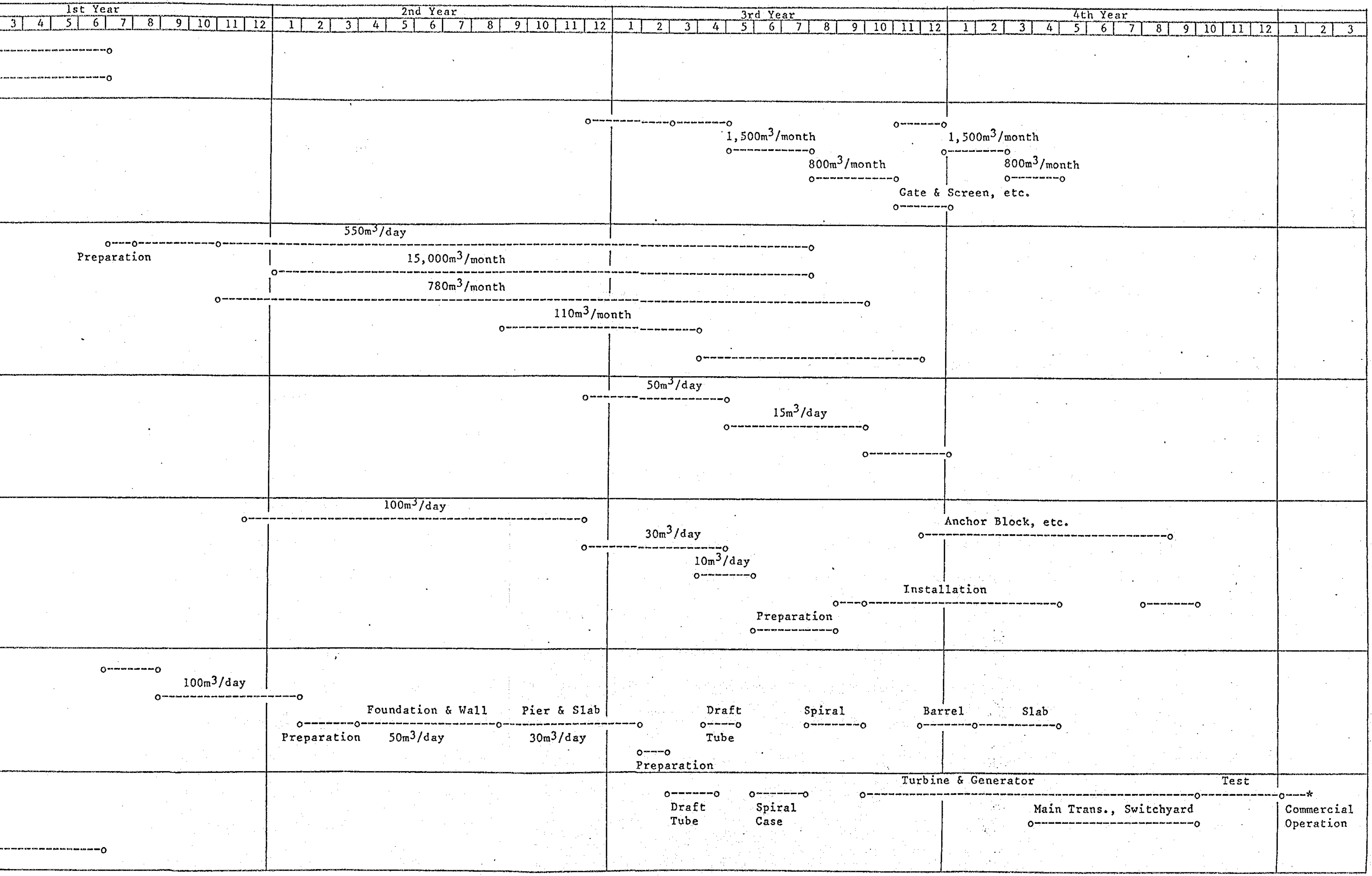
Table 10.5.1 CONSTRUCTION SCHEDULE OF KIKULETWA NO.1 HYDROPOWER PROJECT (REHABILITATION)

Item		Quantity	1st Year (1–12)	2nd Year (1–12)
Preparatory Works	Access Road	L.S	o-------o	
	Camp and Others	L.S	o--o--------o	
Headrace	Excavation Com.	$3,530m^3$	Preparation o-----o------------o $50m^3/day$	
	" Rock	$920m^3$	$20m^3/day$ o--------o	
	Concrete	$3,100m^3$	$50m^3/day$ o---------o	
	Shotcrete	$800m^3$	$10m^3/day$ o-----------o	
	Others	L.S		
Head Tank	Excavation Com.	$400m^3$	o---o	
	" Rock	$1,320m^3$	$40m^3/day$ o-----o	
	Concrete	$1,100m^3$	$20m^3/day$ o---------o	
	Hydraulic Equipment	L.S	o---o	
	Others	L.S	o-----------o	
Powerhouse, Penstock and Tailrace	Excavation Com.	$500m^3$	o---o	
	" Rock	$4,400m^3$	$1,100m^3/month$ o---------------o	
	Backfill	$1,800m^3$		
	Concrete	$1,660m^3$	Foundation o---------------o	
	Penstock Liner	L.S	$20m^3/day$ o---o	
	Hydraulic Equipment	L.S	o---o	
	Others	L.S	Preparation o-------o---o coffer dam	
Electro-Mechanical Equipment	Turbine, Generator	L.S	Turbine & Generator, Test o-------------------*	* Commerical Operation
	Trans, Switchyard	L.S	Main Trans., Switchyard o---o	
	Others			

Table 10.5.2 CONSTRUCTION SCHEDULE OF KIKULETWA NO.2 HYDROPOWER PROJECT

Item		Quantity	1st Year, 2nd Year, 3rd Year; 1–12
Preparatory Works	Access Road	L.S	
	Camp and Others	L.S	
Diversion Wier	Coffer Dam	L.S	
	Dam Excavation	$7,500m^3$	$1,500m^3$/month
	" Concrete	$4,100m^3$	$800m^3$/month
	Hydraulic Equipment	L.S	Gate &
Headrace	Open Excavation	$323,500m^3$	Preparation; $550m^3$/day
	Backfill	$282,300m^3$	$15,000m^3$/month
	Concrete	$17,980m^3$	$780m^3$/month
	Shotcrete	$750m^3$	$110m^3$/month
	Others	L.S	
Head Tank	Open Excavation	$7,500m^3$	$50m^3$/day
	Concrete	$2,300m^3$	$15m^3$/day
	Hydraulic Equipment	L.S	
	Others	L.S	
Penstock	Open Excavation	$28,400m^3$	$100m^3$/day
	Concrete	$4,200m^3$	$30m^3$/day
	Shortcrete	$500m^3$	$10m^3$/day
	Penstock Liner	L.S	Instal
	Others	L.S	Preparation
Powerhouse and Tailrace	Coffer Dam	L.S	
	Open Excavation	$11,600m^3$	$100m^3$/day
	Concrete	$4,600m^3$	Preparation; Foundation & Wall $50m^3$/day; Pier & Slab $30m^3$/day; Draft Tube; Spiral; Bar
	Others	L.S	Preparation
Electro-Mechanical Equipment	Turbine, Generator	L.S	Draft Tube; Spiral Case; Turbin
	Trans. Switchyard	L.S	
	Transmission Line	L.S	

RUCTION SCHEDULE OF KIKULETWA NO.2 HYDROPOWER PROJECT



CHAPTER 11
CONSTRUCTION COST ESTIMATION

CHAPTER 11 CONSTRUCTION COST ESTIMATION

Page

CHAPTER 11 CONSTRUCTION COST ESTIMATION

11.1 ASSUMPTIONS AND CONDITIONS

The construction costs for the Kikuletwa No. 1 and No. 2 Hydropower Stations were calculated on the basis of the following assumptions and conditions.

(1) The construction cost covers the following items: preparatory work, civil work, hydraulic equipment, electro-mechanical equipment, transmission and transformation facilities, engineering and administrative costs, and contingency.

(2) The construction cost was calculated based on data for similar projects undertaken in Tanzania. For some of the work, the costs for similar projects in other countries, including Japan, were also referred to.

(3) The exchange rate used was 93.56 T.sh per US$1.00, which was the rate as of March 1988.

(4) Engineering and administrative costs were calculated at 10 percent of the direct construction cost.

(5) Contingency was calculated at 10 percent of the direct construction cost plus the administrative cost.

(6) Land Acquisition Cost and Compensation Cost

All the civil work, appurtenant facilities, transmission lines, and substations will be on state-owned land, so that acquisition costs do not apply. As the construction areas are presently uncultivated or unused, compensation for crops or houses will also be unnecessary. Any required compensation for damaged crops or other such matters will be quite small, and will be covered by the contingency.

11.2 CONSTRUCTION COST ESTIMATION

11.2.1 Direct Construction Cost

(1) Cost of Preparatory Work

Facilities which must be prepared before construction work starts include access roads, TANESCO's accommodation facilities (including field offices and camp facilities), detailed investigation work, materials testing, and electric power facilities for the construction. The costs of all of the above are included in preparatory work cost.

(2) Civil Works Cost

The quantities for estimating construction were estimated based on the drawings in Chapter 9, Preliminary Design.

The unit costs for civil work were calculated by referring to TANESCO's data on labor costs, materials costs, and unit rates for similar work.

Domestically produced construction equipment, materials, cement, aggregates, lumber and miscellanoues items will be used to the greatest extent possible and insofar as quality allows. Steel materials (reinforcing bars, steel forms, etc) and construction machines will be imported.

(3) Hydraulic Equipment Cost

Gates, screens, and penstocks will all to be imported from abroad. The costs for these facilities were estimated based on FOB prices, transportation costs, and installation costs in Japan, as of March 1988.

(4) Electro-mechanical Facilities

Turbines, generators, transformers and auxiliary equipment will all be imported. The costs for these facilities were estimated based on FOB prices, transportation costs, and installation costs in Japan, as of March 1988.

(5) Power Transmission and Transformation Facilities Cost

Materials and equipment for the transmission lines, distribution lines, and substations and power supply equipment for construction, will all be imported. The costs of these facilities were estimated based on FOB prices, transportation costs, and installation costs in Japan, as of March 1988.

11.2.2 Indirect Construction Cost

(1) Project Administration Cost

TANESCO's administration cost for carrying out the construction work is estimated at 10 percent of the direct construction cost. Of this amount, 80 percent was allocated to engineering management cost (including the engineering consultant's fee) and 20 percent to general administration costs. For the engineering management cost, 80 percent was calculated as a foreign currency requirement (F.C.) (as the greater part will consist of the engineering consultant's fee), and 20 percent as local currency requirement (L.C.). The general administration cost, was calculated as a local currency requirement (L.C.) as it is all part of TANESCO's general administration cost.

(2) Contingency

As it is possible that the work quantity will be increased due to changes in designs and conditions during the course of construction work, 10 percent of the sum of direct construction cost and administration cost was calculated as contingency.

11.2.3 Local Currency (L.C.) and Foreign Currency (F.C.)

Labor costs and costs of materials procurable domestically (cement, lumber, etc.) are estimated under the local currency portion. Imported materials such as steel (reinforcing bars, forms, etc.) and construction machines are estimated under the foreign currency portion.

Electro-mechanical equipment, hydraulic equipment, and transmission facilities will all be imported, and their CIF prices and part of their installation costs are included under the foreign currency portion, while import duties, inland transportation costs, and the remainder of installation costs are included under the local currency portion.

11.2.4 Construction Cost

The total construction cost, separated into local and foreign currency portions and is expressed in terms of U.S. dollars. The total construction costs are listed in Tables 11.2.1 and 11.2.2, and the yearly fund requirements in Tables 11.2.3 and 11.2.4. The construction costs for Kikuletwa No. 1 and No. 2 Hydropower Stations of optimum scale (as selected in Chapter 7) are shown below.

(Unit: Thousand US$)

	Kikuletwa No. 1 Power Station	Kikuletwa No. 2 Power Station
1. Preparation Work	81	8,450
2. Civil Work	2,365	18,341
3. Hydraulic Equipment	210	2,505
4. Electro-Mechanical Equipment	3,168	10,730
5. Transmission Line	125	800
Sub-Total	5,949	40,826
6. Administration & Engineering Fee	595	4,083
7. Contingency	654	4,491
Total	7,198	49,400

Table 11.2.1 ESTIMATED CONSTRUCTION COST OF KIKULETWA NO. 1 HYDROPOWER PROJECT (REHABILITATION)

(Unit: Thousand US$)

	Work Item	Local Currency	Foreign Currency	Total
1	Preparation Work	19	62	81
	(i) Access Road	4	7	11
	(ii) Camp for TANESCO	10	40	50
	(iii) Miscellaneous Work	5	15	20
2	Civil Work	455	1,910	2,365
	(i) Dam and Intake	-	-	-
	(ii) Headrace	208	1,022	1,230
	(iii) Head Tank	61	235	296
	(iv) Penstock (v) Power House	183	639	822
	(vi) Miscellaneous Work	3	14	17
3	Hydraulic Equipment	10	200	210
4	Electro-Mechanical Equipment	310	2,858	3,168
5	Transmission Line	3	122	125
	Total (1 - 5)	797	5,152	5,949
6	Administrational Engineering Fee	119	476	595
7	Contingency	65	589	654
	Grand Total	981	6,217	7,198

Table 11.2.2 ESTIMATED CONSTRUCTION COST OF KIKULETWA NO. 2 HYDROPOWER PROJECT

(Unit: Thousand US$)

	Work Item	Local Currency	Foreign Currency	Total
1	Preparation Work	2,065	6,358	8,450
	(i) Access Road	915	2,135	3,050
	(ii) Camp for TANESCO	800	3,200	4,000
	(iii) Miscellaneous Work	350	1,050	1,400
2	Civil Work	2,754	15,587	18,341
	(i) Dam and Intake	220	1,252	1,472
	(ii) Headrace	1,768	9,848	11,616
	(iii) Head Tank	110	710	820
	(iv) Penstock	216	1,401	1,617
	(v) Power House	240	1,576	1,816
	(vi) Miscellaneous Work	200	800	1,000
3	Hydraulic Equipment	143	2,362	2,505
4	Electro-Mechanical Equipment	1,073	9,657	10,730
5	Transmission Line	160	640	800
	Total (1 - 5)	6,195	34,631	40,826
6	Administrational Engineering Fee	620	3,463	4,083
7	Contingency	682	3,809	4,491
	Grand Total	7,497	41,903	49,400

Table 11.2.3 DISBURSEMENT SCHEDULE FOR KIKULETWA NO. 1 HYDROPOWER PROJECT

(Unit: 10^3 US$)

Work Item	1st Year	2nd Year	3rd Year	4th Year	Total
1. Civil Works	2,202	244			2,446
1-1 Preparatory Works	73	8			81
1-2 Headrace	1,107	123			1,230
1-3 Head Tank	267	29			296
1-4 Penstock & Powerhouse	740	82			822
1-5 Miscellaneous Works	15	2			17
2. Hydraulic Equipment	189	21			210
3. Electromechanical Equipment	2,851	317			3,168
4. Transmission Line & Substation	113	12			125
5. Total Cost (1+2+3+4)	5,355	594			5,949
6. Engineering & Administration (5 x 10%)	536	59			595
7. Physical Contingency (5+6) x 10%	589	65			654
Grand Total (5+6+7)	6,840	718			7,198

Table 11.2.4 DISBURSEMENT SCHEDULE FOR KIKULETWA NO. 2 HYDROPOWER PROJECT

(Unit: 10^3 US$)

Work Item	1st Year	2nd Year	3rd Year	4th Year	Total
1. Civil Works	10,731	8,827	5,089	2,144	26,791
1-1 Preparatory Works	5,915	1,690	845	-	8,450
1-2 Diversion Weir	-	736	442	294	1,472
1-3 Headrace	3,486	4,646	2,323	1,161	11,616
1-4 Head Tank	-	82	492	246	820
1-5 Pensotck & Powerhouse	1,030	1,373	687	343	3,433
1-6 Miscellaneous Works	300	300	300	100	1,000
2. Hydraulic Equipment	-	500	1,755	250	2,505
3. Electromechanical Equipment	-	3,220	3,220	4,290	10,730
4. Transmission Line & Substation	800	-	-	-	800
5. Total Cost (1+2+3+4)	11,531	12,547	10,064	6,684	40,826
6. Engineering & Administration (5 x 10%)	1,153	1,255	1,006	669	4,083
7. Physical Contingency (5+6) x 10%	1,268	1,380	1,107	736	4,491
Grand Total (5+6+7)	13,952	15,182	12,177	8,089	49,400

CHAPTER 12
ECONOMIC EVALUATION FOR SELECTING CANDIDATE PROJECTS

CHAPTER 12 ECONOMIC EVALUATION FOR SELECTING CANDIDATE PROJECTS

Page

CHAPTER 12 ECONOMIC EVALUATION FOR SELECTING CANDIDATE PROJECTS

12.1 METHODOLOGY

12.1.1 General

The economic performance of a hydropower project may be evaluated by utilizing an equalizing discount rate ("the economic internal rate of return," or "EIRR") which compares the total costs of the project, incurred from the beginning of construction through to a given period of operation, to the corresponding total costs of an alternative thermal power station. All costs are converted to present values.

The calculated equalizing discount rate is compared against a social discount rate which reflects the opportunity cost of capital. The project is judged to be economical if its equalizing discount rate is higher than the social rate of discount.

12.1.2 Alternative Thermal Power Station

Among the various types of thermal power station, (gas turbine, diesel, steam, and combined cycle), the most appropriate alternative to the proposed hydropower project, in view of the project magnitudes and their high plant factors, would be a diesel power station.

The unit size and estimated investment cost per kW of the alternative diesel power stations selected for economic comparison with the proposed Kikuletwa projects are as follows:

	Kikuletwa No. 1 (1.5 MW)	Kikuletwa No. 2 (11.0 MW)
Alternative diesel:		
Unit size	0.5 MW x 3	5.5 MW x 2
Unit cost/kW	US$1,200	US$950

12.1.3 Adjustment of Investment Cost Due to Difference in Service Lives

The economic service life for a hydropower station is generally estimated to be 50 years while that for a diesel power station is estimated to be 15 years. To make an economic evaluation of both types on a similar basis, it is necessary to adjust the investment costs.

Two adjustment methods are available. In one, the costs of the hydro and diesel power stations would be calculated over a 150-year period - because 150 years is the least common multiple of their respective service lives. The other method is to calculate the cost over the period of shorter service life - in this case, 15 years - and to adjust the investment cost of the longer-lived investment so that it corresponds to the shorter period. Both methods yield the same comparison result. The latter method was used here.

The adjustment factor for the hydro investment cost is calculated as follows:

- Service life of hydropower project ... n (50 years)
- Service life of diesel power station ... n'(15 years)
- Investment cost of hydropower project ... D
- Discount rate ... R

The annuitized cost of investment (discounted annual cost) of the hydropower project is:

$$D \times \frac{R(1 + R)^n}{(1 + R)^n - 1}$$

The cumulative discount factor of annual cost over the service life of the diesel power station is:

$$\frac{(1 + R)^{n'} - 1}{R(1 + R)^{n'}}$$

The investment cost of the hydropower project corresponding to the service life of the diesel power station is thus calculated to be:

$$D \times \frac{R(1 + R)^n}{(1 + R)^n - 1} \times \frac{(1 + R)^{n'} - 1}{R(1 + R)^{n'}}$$

12.2 CONDITIONS FOR EVALUATION

12.2.1 Technical Conditions

Technical conditions used for the economic evaluation are as follows:

Item	Hydropower project		Trans-mission line	Diesel power alternative
a) Station service loss				
Power loss	1.5%			2.0%
Energy loss	1.8%			2.5%
b) Transmission losses			1.0%	
c) Non-availability factor of the power plant	2.5%			20%
d) Ratio of operation and maintenance cost to investment cost	1.9%		2.4%	5.0%
e) Economic service life	50 years		40 years	15 years
f) Thermal efficiency				37% (2324 kcal/kWh)
g) Calorific value of diesel oil				8,900 kcal/lt
h) Specific consumption of lubrication				6.0 g/lt
i) Annual disbursement of investment:				
	Kikuletwa			
	No.1	No.2		
1st year	91.62%	28.7%	-	-
2nd year	8.38%	31.24%	-	-
3rd year	-	25.06%	-	20%
4th year	-	15.0%	100%	80%

12.2.2 Other Conditions

a) Price of diesel oil — Tsh 18.50/lt
(Current price at Arusha power station)

b) Price of lubricants — Tsh 150.0/lt
(Specific gravity: 0.9)
(Current price at Arusha power station)

The price of fuel for a diesel power station is very high in Tanzania, as compared with the international price, because of the long transport distance involved.

In general, the economic price of diesel oil is estimated to be about 1.25 to 1.30 times the international price of crude oil. If the medium-term price of imported crude oil in Tanzania is estimated at US$ 18 per barrel (159 litres), the corresponding economic price of diesel oil ex. refinery will be:

US$ 18 x 68.5 x 1.25 (or 1.30)/159
= Tsh 9.69 (or 10.08) per lt

The cost for transporting petroleum products by road within Tanzania is Tsh 10/kl-km. The project area entails a transportation distance of about 600 km. Thus, the cost of transporting the diesel oil to the project area is calculated to be:

Tsh 10/kl x 600/1000 = Tsh 6.0/lt

The economic price of diesel oil at the project area thus becomes:

Tsh 15.7/lt to Tsh 16.1/lt

The current price of diesel oil (Tsh 18.50/lt) is therefore slightly higher than the economic price calculated. However, the fact that petroleum product prices will probably rise in the future makes it acceptable to use the current diesel oil price for making a long-run economic evaluation of the proposed hydro power projects.

c) Currency exchange rate US$ 1.0 = Tsh 68.50 (Official rate on 30 September, 1987)

d) Price conditions For all items, prices as of the end of September 1987 were used for the economic evaluation

12.3 RESULTS OF ANALYSIS

12.3.1 Evaluation for Determining Optimum Scale of Power Development

As Chapter 7 details, various scales of power development for the Kikuletwa No. 1 and No. 2 projects were considered and studied. The total costs of these hydro power projects and those of alternative diesel power projects, both converted to present value using a discount rate of 10%, were calculated, and the benefit/cost ratios of the hydro power projects obtained. The analysis results are as follows:

Project	Firm Capacity (MW)	Energy Generation (GWh)	Investment (M. US$)	Benefit/ cost ratio
Kikuletwa No. 1 project:				
A (15.4 cu.m/s)	1.055	10.53	7.073	1.267
B (13.3 cu.m/s)	1.055	10.25	6.965	1.260
C (12.0 cu.m/s)	1.055	9.91	6.763	1.264
D (11.0 cu.m/s)	1.055	9.36	6.641	1.234
E (16.4 cu.m/s)	1.055	11.54	8.300	1.161
Kikuletwa No. 2 project:				
A' (20.6 cu.m/s)	12.7	67.30	52.040	1.150
B' (17.9 cu.m/s)	11.0	67.09	48.600	1.174
C' (15.1 cu.m/s)	9.3	64.50	45.900	1.153
D' (13.8 cu.m/s)	8.5	63.29	44.370	1.148

The above results show that alternative A is optimum for the Kikuletwa No. 1 project, and alternative B' is optimum for the Kikuletwa No. 2 project.

Details of the calculations relating to the Kikuletwa No. 1 project are shown in Tables 12.3.1 to 12.3.5; details for the Kikuletwa No. 2 project are shown in Tables 12.3.6 to 12.3.9.

12.3.2 Equalizing Discount Rate

The calculated equalizing discount rates of these optimum alternatives, and of other considered mini hydro power projects, compared against alternative diesel power projects, are as follows:

Project	Equalizing discount rate	Benefit/ cost ratio (at 10% discount discount rate)
Kikuletwa No. 1 (Rehabilitation)	13.30%	1.267
Kikuletwa No. 2	12.03%	1.174
Himo No. 1 (Rehabilitation)	11.03%	1.08
Himo No. 2	Less than 0.1%	0.21
Hingilili	6.63%	0.70
Ndungu	8.52%	0.87
Ihindi	0.96%	0.34
Gulutu	1.97%	0.39

Details of the calculations relating to the Kikuletwa No. 1 project are shown in Tables 12.3.10 to 12.3.12; details for the Kikuletwa No. 2 project are shown in Tables 12.3.13 to 12.3.15.

12.4 CONCLUSION

Based on the above-described economic evaluation of the projects, and on their expected contribution to the electricity supply, it is recommended that Kikuletwa No. 1 (rehabilitation) and Kikuletwa No. 2 projects be implemented in the near future.

KIKULETWA NO. 1 PROJECT

Table 12.3.1 - Table 12.3.5

Table 12.3.1 BENEFIT/COST RATIO
(15-Year Operation)

Discount rate: 10.00%
Hydro firm capacity: 1055 kW
Hydro power generation: 10530 MWh
Hydro investment cost: 7073 T.US$

(US$ thousand)

PRESENT WORTH	Kikuletwa No.1	Diesel Power Plant
Investment cost	5218.4	1357.4
Operation & maintenance cost	905.8	506.1
Fuel cost		4882.4
Lubricating oil cost		1010.5
Total cost	6124.1	7756.4
Benefit - Cost		1632.3
Benefit/Cost ratio		1.267

Table 12.3.2 BENEFIT/COST RATIO
(15-Year Operation)

Discount rate: 10.00%
Hydro firm capacity: 1055 kW
Hydro power generation: 10250 MWh
Hydro investment cost: 6965 T.US$

(US$ thousand)

PRESENT WORTH	Kikuletwa No.1	Diesel Power Plant
Investment cost	5140.0	1357.4
Operation & maintenance cost	892.2	506.1
Fuel cost		4752.5
Lubricating oil cost		983.7
Total cost	6032.2	7599.7
Benefit - Cost		1567.5
Benefit/Cost ratio		1.260

Table 12.3.3 BENEFIT/COST RATIO (15-Year Operation)

Discount rate: 10.00%
Hydro firm capacity: 1055 kW
Hydro power generation: 9910 MWh
Hydro investment cost: 6763 T.US$

(US$ thousand)

PRESENT WORTH	Kikuletwa No.1	Diesel Power Plant
Investment cost	4993.3	1357.4
Operation & maintenance cost	866.9	506.1
Fuel cost		4594.9
Lubricating oil cost		951.0
Total cost	5860.3	7409.4
Benefit - Cost		1549.2
Benefit/Cost ratio		1.264

Table 12.3.4 BENEFIT/COST RATIO (15-Year Operation)

Discount rate: 10.00%
Hydro firm capacity: 1055 kW
Hydro power generation: 9360 MWh
Hydro investment cost: 6641 T.US$

(US$ thousand)

PRESENT WORTH	Kikuletwa No.1	Diesel Power Plant
Investment cost	4904.8	1357.4
Operation & maintenance cost	851.7	506.1
Fuel cost		4339.9
Lubricating oil cost		898.3
Total cost	5756.4	7101.6
Benefit - Cost		1345.2
Benefit/Cost ratio		1.234

Table 12.3.5 BENEFIT/COST RATIO
(15-Year Operation)

Discount rate: 10.00%
Hydro firm capacity: 1055 kW
Hydro power generation: 11540 MWh
Hydro investment cost: 8300 T.US$

(US$ thousand)

PRESENT WORTH	Kikuletwa No.1	Diesel Power Plant
Investment cost	6109.0	1357.4
Operation & maintenance cost	1059.5	506.1
Fuel cost		5350.7
Lubricating oil cost		1107.5
Total cost	7168.5	8321.6
Benefit - Cost		1153.2
Benefit/Cost ratio		1.161

KIKULETWA NO. 2 PROJECT

Table 12.3.6 - Table 12.3.9

Table 12.3.6 BENEFIT/COST RATIO
(15-Year Operation)

Discount rate: 10.00%
Hydro firm capacity: 12700 kW
Hydro power generation: 67300 MWh
Hydro investment cost: 52040 T.US$

(US$ thousand)

PRESENT WORTH	Kikuletwa No.2	Diesel Power Plant
Investment cost	34353.5	10690.9
Operation & maintenance cost	5492.0	3986.1
Fuel cost		25788.8
Lubricating oil cost		5337.7
Total cost	39845.5	45803.4
Benefit - Cost		5957.9
Benefit/Cost ratio		1.150

Table 12.3.7 BENEFIT/COST RATIO
(15-Year Operation)

Discount rate: 10.00%
Hydro firm capacity: 11000 kW
Hydro power generation: 67090 MWh
Hydro investment cost: 48600 T.US$

(US$ thousand)

PRESENT WORTH	Kikuletwa No.2	Diesel Power Plant
Investment cost	32112.1	9259.8
Operation & maintenance cost	5135.9	3452.5
Fuel cost		25708.3
Lubricating oil cost		5321.0
Total cost	37248.0	43741.7
Benefit - Cost		6493.7
Benefit/Cost ratio		1.174

Table 12.3.8 BENEFIT/COST RATIO
(15-Year Operation)

Discount rate: 10.00%
Hydro firm capacity: 9300 kW
Hydro power generation: 64500 MWh
Hydro investment cost: 45900 T.US$

(US$ thousand)

PRESENT WORTH	Kikuletwa No.2	Diesel Power Plant
Investment cost	30352.9	7828.8
Operation & maintenance cost	4856.4	2918.9
Fuel cost		24715.9
Lubricating oil cost		5115.6
Total cost	35209.2	40579.2
Benefit - Cost		5369.9
Benefit/Cost ratio		1.153

Table 12.3.9 BENEFIT/COST RATIO
(15-Year Operation)

Discount rate: 10.00%
Hydro firm capacity: 8500 kW
Hydro power generation: 63290 MWh
Hydro investment cost: 44370 T.US$

(US$ thousand)

PRESENT WORTH	Kikuletwa No.2	Diesel Power Plant
Investment cost	29356.0	7155.3
Operation & maintenance cost	4698.0	2667.8
Fuel cost		24252.2
Lubricating oil cost		5019.6
Total cost	34053.9	39095.0
Benefit - Cost		5041.1
Benefit/Cost ratio		1.148

KIKULETWA NO. 1 PROJECT

Table 12.3.10 - Table 12.3.12

Table 12.3.10 EQUALIZING DISCOUNT RATE (15-Year Operation)

Discount rate: 13.20%

(US$ thousand)

PRESENT WORTH	Kikuletwa No.1	Diesel Power Plant
Investment cost	5657.4	1308.4
Operation & maintenance cost	729.6	407.7
Fuel cost		3932.9
Lubricating oil cost		814.0
Total cost	6387.1	6463.0
Benefit - Cost		75.9
Benefit/Cost ratio		1.012

Table 12.3.11 EQUALIZING DISCOUNT RATE (15-Year Operation)

Discount rate: 13.30%

(US$ thousand)

PRESENT WORTH	Kikuletwa No.1	Diesel Power Plant
Investment cost	5667.7	1306.9
Operation & maintenance cost	724.9	405.1
Fuel cost		3907.6
Lubricating oil cost		808.8
Total cost	6392.6	6428.3
Benefit - Cost		35.7
Benefit/Cost ratio		1.006

Table 12.3.12 EQUALIZING DISCOUNT RATE (15-Year Operation)

Discount rate: 13.40%

(US$ thousand)

PRESENT WORTH	Kikuletwa No.1	Diesel Power Plant
Investment cost	5677.8	1305.5
Operation & maintenance cost	720.3	402.5
Fuel cost		3882.5
Lubricating oil cost		803.6
Total cost	6398.1	6394.0
Benefit - Cost		-4.0
Benefit/Cost ratio		0.999

KIKULETWA NO. 2 PROJECT

Table 12.3.13 - Table 12.3.15

Table 12.3.13 EQUALIZING DISCOUNT RATE (15-Year Operation)

Discount rate: 12.02%

(US$ thousand)

PRESENT WORTH	Kikuletwa No.2	Diesel Power Plant
Investment cost	33313.5	8722.9
Operation & maintenance cost	4310.5	2897.7
Fuel cost		21577.0
Lubricating oil cost		4465.9
Total cost	37624.0	37663.5
Benefit - Cost		39.5
Benefit/Cost ratio		1.001

Table 12.3.14 EQUALIZING DISCOUNT RATE (15-Year Operation)

Discount rate: 12.03%

(US$ thousand)

PRESENT WORTH	Kikuletwa No.2	Diesel Power Plant
Investment cost	33317.9	8720.3
Operation & maintenance cost	4306.9	2895.2
Fuel cost		21558.8
Lubricating oil cost		4462.2
Total cost	37624.8	37636.5
Benefit - Cost		11.7
Benefit/Cost ratio		1.000

Table 12.3.15 EQUALIZING DISCOUNT RATE (15-Year Operation)

Discount rate: 12.04%

(US$ thousand)

PRESENT WORTH	Kikuletwa No.2	Diesel Power Plant
Investment cost	33322.4	8717.8
Operation & maintenance cost	4303.3	2892.8
Fuel cost		21540.6
Lubricating oil cost		4458.4
Total cost	37625.6	37609.5
Benefit - Cost		-16.1
Benefit/Cost ratio		1.000

CHAPTER 13
FINANCIAL ANALYSIS

CHAPTER 13 FINANCIAL ANALYSIS

Page

13.1 METHODOLOGY

The financial analysis of the projects has been conducted using the following two methods:

a) Calculation of an equalizing discount rate. This rate offsets total revenue obtained from energy sales against total expenses incurred from the beginning of plant construction work to the conclusion of plant service life. This discount rate, compared against the social rate of discount in Tanzania, will serve as the basis for evaluating the financial soundness of the projects.

b) Preparation of a repayment schedule for borrowing funds, based on assumed loan conditions, and preparation of profit and loss statements and cash flow sheets to identify appropriate loan conditions.

c) These analyses have been carried out independently for both Kikuletwa No. 1 and Kikuletwa No. 2 projects.

13.2 CONDITIONS FOR ANALYSIS

13.2.1 Conditions for Calculating Equalizing Discount Rate

(1) System Loss Factor

For the interconnected system, the system loss factor - which includes station service loss and transmission and distribution losses - has been high: 20.6% in 1983, 22.0% in 1984, 21.7% in 1985, and 21.0% in 1986. Between 1973 and 1979, however, the loss factor held at about 16%. While it is important for TANESCO to reduce the energy loss factor, a significant reduction will require a considerable time. In this study, it has been assumed that the system loss factor will decrease in the following steps:

After commissioning of power plant (Kikuletwa No. 1):

1st 5 years	Loss factor	20%
2nd 5 years		19%
3rd 5 years		18%
4th 5 years		17%
Thereafter		16%

(2) Energy Generated and Energy Sold

Annual energy generation for the two projects is estimated as follows:

Kikuletwa No. 1 power plant	10,530 MWh
Kikuletwa No. 2 power plant	67,090 MWh

For each project, the energy sold is obtained by subtracting the anticipated system loss from the annual generation.

(3) Average Rate per Unit Sold

For electricity in Tanzania, the average rate per unit sold has risen rapidly, from T. Cents 64.38 in 1980 to T. Cents 132.81 in 1984, and to T. Cents 294.53 in 1986. If the rates are expressed in terms of UC currency, however, the rise is much less dramatic - from US Cents 6.03 in 1980 to US Cents 8.47 in 1984, which translates into an average annual increase (for 1980 to 1984) of 8.8%.

Average unit rates for the years from 1980 to 1987 are shown below:

Year	T. Cents/kWh	Currency exchange rate per 1 US$	US Cents/kWh
1980	64.38	10.67	6.03
1981	65.58	9.77	6.71
1982	70.60	10.25	6.89
1983	104.60	11.91	8.78
1984	132.81	15.68	8.47
1985	196.96	17.74	11.10
1986	294.53	38.36	7.67
1987	395.80	68.50	5.78

The above shows that the average unit rate (in terms of US currency) rose fairly high in 1985, but then fell abruptly in 1986 and 1987. This abnormality was the result of insufficient tariff adjustment, which did not smoothly follow the rapid fluctuation of the currency exchange rates. It is therefore not appropriate to use the 1987 US-currency rate as a basis for forecasting the operating revenue from future energy sales.

This study therefore assumes an average unit rate for 1988 calculated by applying an 8.8% annual price rise to the 1984 rate. This is because the (US-currency based) rate rose 8.8% per year from 1980 - 1984, which was a period during which the exchange rate held fairly steady.

The electricity supply cost includes the costs of the power generation sector, the transmission and distribution sector, and the general administration sector. In most countries, the share of generation sector cost to total electrical supply cost is generally within 65 to 70%. In this study, 67% shall be used. Thus, for the power generation sector, the average revenue per kWh sold is US Cents 7.95:

$$8.47 \times (1 + 0.088)^4 \times 0.67 = \text{US Cents } 7.95 \text{ kWh}$$

(4) Investment Costs

The annual disbursements of the investment costs of the Kikuletwa No. 1 and No. 2 projects are as follows:

(Unit: US$ thousand)

	Kikuletwa No. 1			Kikuletwa No. 2		
Year	Foreign currency	Local currency	Total	Foreign currency	Local currency	Total
1989	5,597	883	6,480	-	-	-
1990	620	98	718	11,835	2,117	13,952
1991	-	-	-	12,877	2,305	15,182
1992	-	-	-	10,329	1,848	12,177
1993	-	-	-	6,862	1,227	8,089
Total	6,217	981	7,198	41,903	7,497	49,400

(5) Annual Operation and Maintenance Costs

The operation and maintenance costs vary according to the maintenance cycle and the salary level of the plant staff. In general, however, these costs for a hydro power plant are roughly estimated to be about 1 to 2% of the investment cost. In this study, 1.5% shall be used. Therefore:

Kikuletwa No. 1	$7,198 \times 10^3 \times 0.015 =$ US\$ 108.0×10^3
Kikuletwa No. 2	$49,400 \times 10^3 \times 0.015 =$ US\$ 741.0×10^3

(6) Annual Administration Expenses

The administration expenses are statistically estimated to be about 0.3 to 0.5% of the investment cost. In this study, 0.4% shall be used. Therefore:

Kikuletwa No. 1	$7,198 \times 10^3 \times 0.004 =$ US\$ 28.8×10^3
Kikuletwa No. 2	$49,400 \times 10^3 \times 0.004 =$ US\$ 197.6×10^3

(7) Service Life of the Power Plant, and Calculation Period

The service life of the Kikuletwa No. 1 and No. 2 power plants is estimated to be 50 years. The revenue and expenses for each power plant shall be calculated over the following periods:

- Operating revenue:	50 years from commissioning
- Expenses:	
. Investment cost	Construction period (2 years for No. 1, 4 years for No. 2 power plants)
. O & M costs	50 years from commissioning
. Administration expenses	50 years from commissioning

13.2.2 Conditions for Preparation of Income Statement and Cash Flow

(1) Loan Conditions

Hydro power plant construction requires a large investment, while the turn-over ratio of the total assets is low. It is therefore desirable that construction be financed at a low interest rate and with a long repayment period. In this study, the following two fund sources are assumed:

- Government-based soft loan from a cooperating country
- Commercial-based project loan from an international financial institution

Loan conditions assumed for these sources are as follows:

- Foreign Government Loan:

. Interest rate	1.5% per annum
. Repayment period	30 years, including 10-year grace period

- International Financial Institution Project Loan:

. Interest rate	7.64% per annum
. Repayment period	15 years, including 5-year grace period

Repayment shall be made in equal annual installments of principal and interest. The annual repayment amount will therefore be:

- Foreign Government Loan:

$$\text{Loan amount} \times 0.015 \times (1 + 0.05)^{20}/((1 + 0.015)^{20} - 1)$$

- International Financial Institution Project Loan:

$$\text{Loan amount} \times 0.0764 \times (1 + 0.0764)^{10}/((1 + 0.0764)^{10} - 1)$$

(2) Depreciation Cost

The capital cost shall be depreciated using the straight line method, assuming no scrap value. Depreciation cost is therefore:

(Investment cost + Interest during construction)/50

(3) Operating Revenue, Operation and Maintenance Costs, and Administration Expenses

The estimates of operating revenue, operation and maintenance costs, and administration expenses are described in Section 13.2.1.

(4) Calculation Period

It is adequate to prepare income statements and cash flow sheets over the loan repayment period. In this study, calculation shall be made for the period of 30 years from commissioning.

13.3 RESULTS OF ANALYSIS

13.3.1 Equalizing Discount Rate

The data used as the basis for analysis are shown in Table 13.3.1 for Kikuletwa No. 1 project, and in Table 13.3.2 for the Kikuletwa No. 2 project. The calculations of equalizing discount rates are shown in Tables 13.3.3(A) to 13.3.3(C) for the Kikuletwa No. 1 project, and in Tables 13.3.4(A) to 13.3.4(C) for the Kikuletwa No. 2 project. These tables show that the equalizing discount rates are:

Kikuletwa No. 1 Project: 6.08%
Kikuletwa No. 2 Project: 5.93%

TANESCO's electricity tariff is made on a cost basis, and its price level is almost the same as that of industrially advanced countries. It should be noted that the current international interest rate has stabilized at about 5.5 to 6.5%.

Taking these conditions (and specifically, the equalizing discount rates of about 6%) into account, it can be concluded that the Kikuletwa No. 1 and No. 2 projects are financially sound.

13.3.2 Income Statement and Cash Flow

The income statements (profit and loss statements) and cash flow sheets for the projects are provided in the tables listed below:

- Foreign Government Soft Loan:

. Kikuletwa No. 1 project	Tables 13.3.5(A) to 13.3.8
. Kikuletwa No. 2 project	Tables 13.3.9 to 13.3.12

- International Financial Institution Project Loan:

. Kikuletwa No. 1 project	Tables 13.3.13(A) to 13.3.16
. Kikuletwa No. 2 project	Tables 13.3.17(A) to 13.3.20

The data in the above tables lead to the following conclusions:

a) For the case of the foreign government loan, the cash balances for both projects will be favorable every year from commissioning. The accumulated net incomes over 30 years will amount to US$6,958.4 thousand for the Kikuletwa No. 1 project and to US$36,989.9 thousand for the Kikuletwa No. 2 project, as respectively shown in Tables 13.3.8 and 13.3.12.

b) In the case of the international financial institution project loan, the cash balances for both projects will show deficits every year throughout the repayment periods. The accumulated net income over 30 years will amount only to US$2,501.1 thousand for the Kikuletwa No. 1 project, and to US$3,947.9 thousand for Kikuletwa No. 2 project, as respectively shown in Tables 13.3.16 and 13.3.20.

c) Both projects are financially justifiable based on the equalizing discount rates stated in Section 13.3.1 and on the rates of return stated in Section 13.3.3 However, the financial burden will be very large if the required funds are financed by loans from international financial institutions. It is recommended that the project be financed by a government-to-government-based soft loan from a cooperating country.