Fig. 7-12 shows the power flow with the tap ratio of Ubungo S.S. transformers set to 0.85 P.U. or 0.90 P.U. and the tap ratio of the Ilala S.S. transformers changes from 0.85 P.U. to 1.00 P.U. It shows that the ratio of power flow on both lines largely changes and a reactive cross current flows on the lines.

(5) Impedance voltage of new transformers at Ilala S.S.

An adequate impedance voltage of the new transformers of Ilala S.S. is 8.0% at the rated capacity base.

When the 132 kV and 33 kV lines are operated in parallel, the ratio of power flow on the both lines is affected by the impedance of the lines, the impedance voltages of Ubungo S.S. 132/33 kV transformers (50 MVA x 2) and Ilala S.S. 132/33 kV transformers (45 MVA x 2), and load ratio between the Ubungo and Ilala substations.

If the load ratio between the Ubungo and Ilala substations is set to the same value as that of the peak value in 1990, the power flow balance of the both lines is obtained by setting the impedance voltage of the Ilala S.S. new transformers to 8.0%.

Fig. 7-13 shows the power flow when the impedance voltage is set to 10% and 8.0%. When the impedance voltage is set to 10%, the Ilala S.S. transformers reach the rated capacity quicker than the Ubungo S.S. transformers do, but at 8%, the transformers of two substations reach the rated capacity almost at the same time.

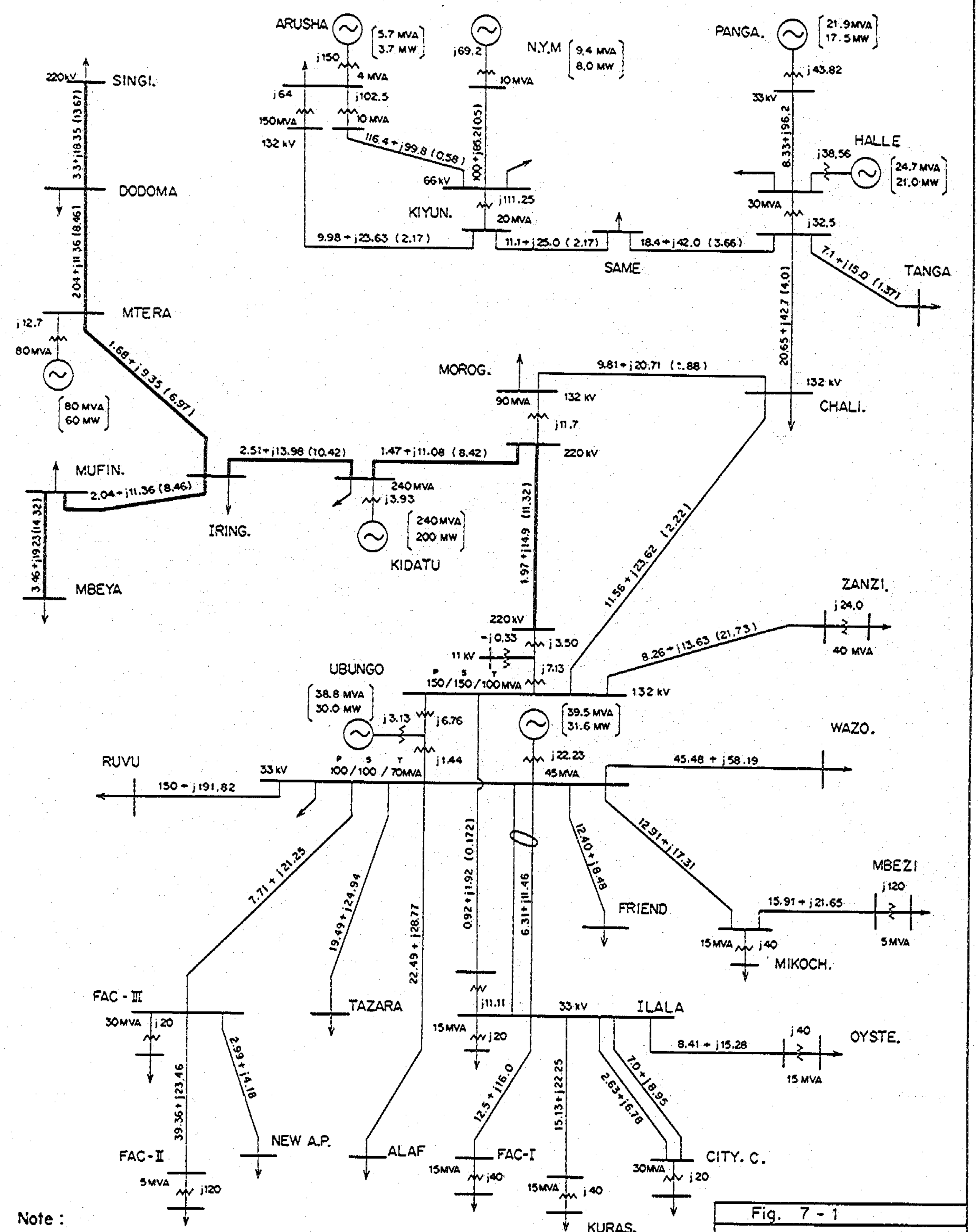
This makes the difference of supply ability to the two substations 11 MVA, and setting the impedance voltage to 8.0% is advantageous.

7.5 OPERATION OF DAR ES SALAAM NETWORK

After replacing transformers at Ilala S.S. and changing the connection of 33 kV lines (See 7.4.2), the power transmission from Ubungo S.S. to Ilala S.S. should be done under the existing method, i.e., parallel operation by means of a 132 kV line and two 33 kV lines, which has the following advantages:

- Reducing voltage drop
- Reducing transmission losses
- Improving power supply reliability

At the same time operation of a 132 kV line only is sometimes advantageous if a transformer at Ubungo S.S. or Ilala S.S. is stopped, depending on load conditions at both substations (Fig. 7-11).



Note :

Line impedance ······ r + j x (Y/2)

······ Transformer

······ Generator

LOCATION	DATE	DESCRIPTION	BY
REVISION			

Fig. 7 - 1

IMPEDANCE MAP

Positive phase sequence % : 100MVA base

EPDC International Ltd. TOKYO JAPAN

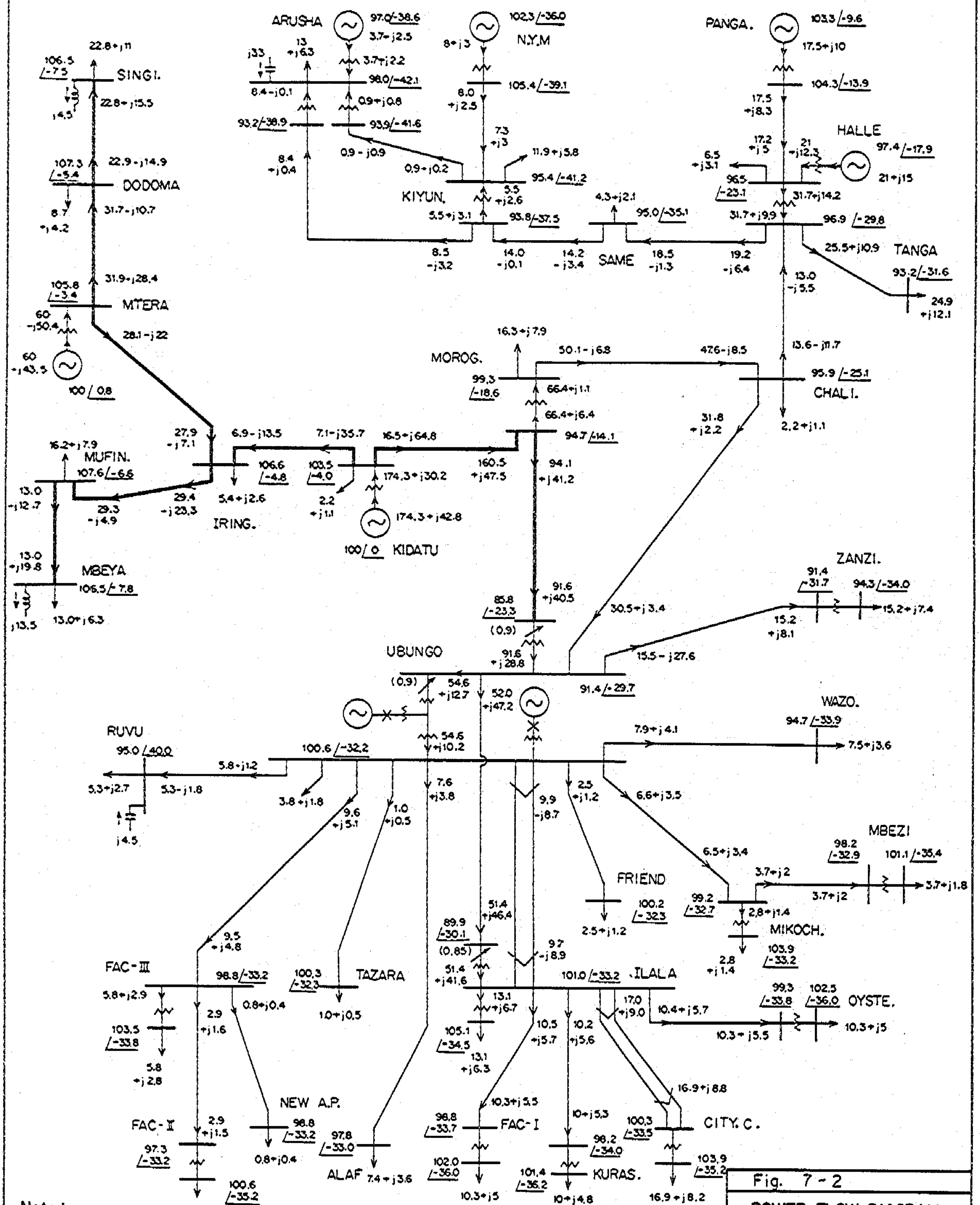
D.R.: SUBMITTED:
T.R.: RECOMMENDED:
C.K.: APPROVED:

SHEET NO. OF

Table 7-1 Techical Data

Constants / Power Station	Pcap (MVA)	Pout (MW)	Xd (%)	Xd' (%)	Xd" (%)	Xq (%)	Xℓ (%)	Tdo' (sec)	Tdo" (sec)	Tqo (sec)	Ta (sec)	M (sec)
Ubungo	78.3	61.6	110	20	12	90	18	6	0.05	0.07	0.4	4.0
Halle	24.7	21.0	80	30	20	60	14	6	0.04	0.10	0.2	7.4
Pangani F.	21.9	17.5	80	30	20	60	14	6	0.04	0.10	0.2	7.4
Nyumba Y.M.	9.4	8.0	190	39	25	109	14	6	0.04	0.10	0.2	5.0
Arusha	5.7	3.7	130	20	12	90	18	2	0.05	0.07	0.4	4.0
Kidatu	240.0	200.0	90	29	16	60	14	4.4	0.04	0.10	0.2	7.4
Mtera	80.0	60.0	90	30	20	60	14	5	0.04	0.10	0.2	7.4

Note :
Pcap ......Rated capacity (total)
Pout ......Rated output (total)
Xd ......Direct - axis synchronous react.
Xd' ......Direct - axis transient react.
Xd" ......Direct - axis sub-trasient react.
Xq ......Quadrature - axis synchronous react.
Xℓ ......Stator leakage react.
Tdo' ......Direct - axis open circuit Time C.
Tdo" ......Direct - axis open circuit sub-transi. Time C.
Tqo ......Quadrature - axis open circuit "
Ta ......Armature Time C.
M ......Inertia constant (= 2H)



Note:

P+jQ ······Effective power (MW) & Reactive power (MVar)

V/θ ······Bus voltage (%) & Leading angle (deg.)

······Transformer & (tap ratio)

······Generator

······Static condenser

······Shunt reactor

LOCATION	DATE	DESCRIPTION	BY
REVISION			

Fig. 7-2

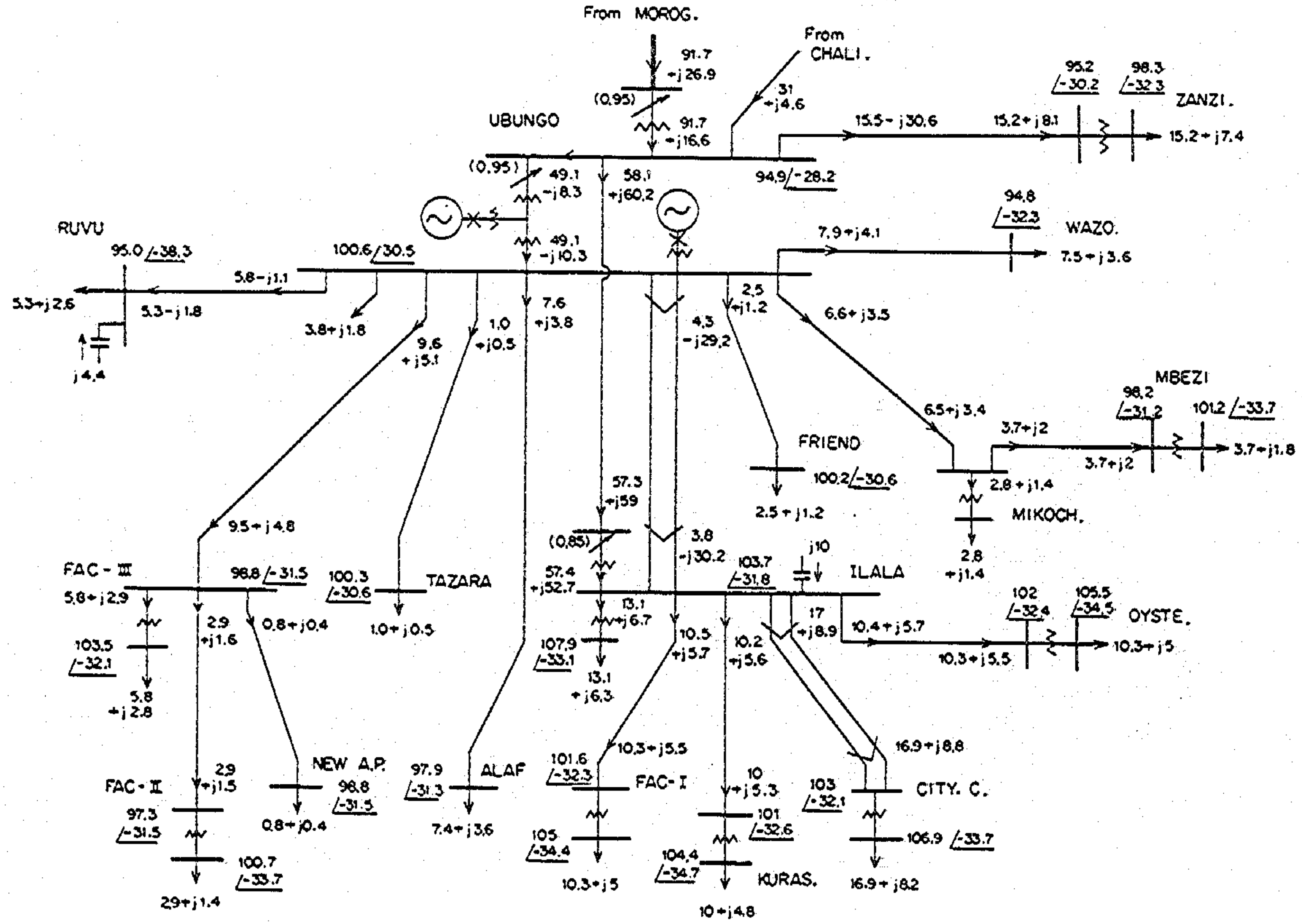
POWER FLOW DIAGRAM

Peak in 1990

EPDC International Ltd. TOKYO JAPAN

DR.: SUBMITTED:
T.R.: RECOMMENDED:
CK.: APPROVED:

SHEET NO. OF



Note :

P+jQ ······ Effective power (MW) & Reactive power (MVar)

V/θ ······ Bus voltage (%) & Leading angle (deg.)

······ Transformer & (tap ratio)

······ Generator

······ Static condenser

······ Shunt reactor

LOCATION	DATE	DESCRIPTION	BY
REVISION			

Fig. 7-3

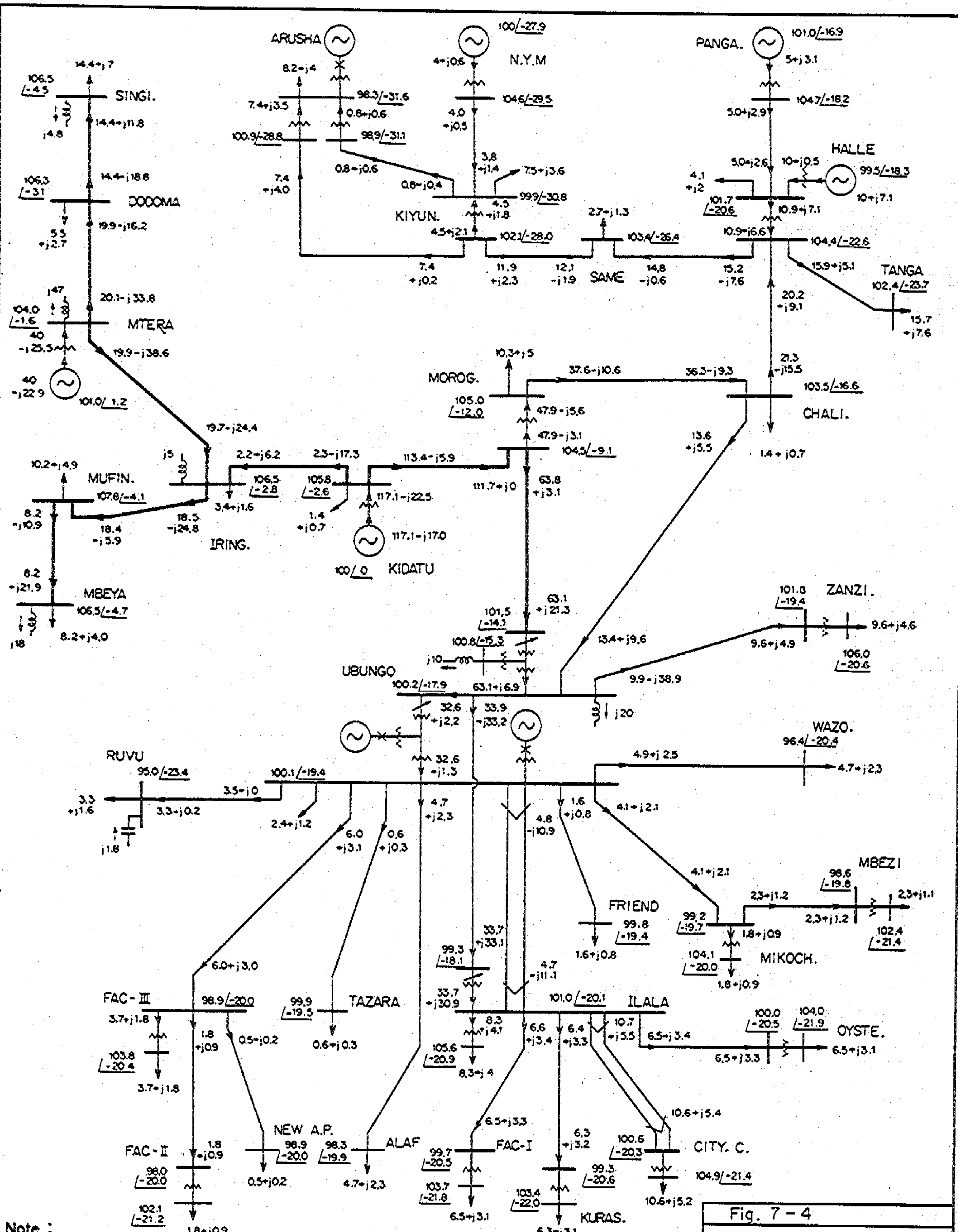
POWER FLOW DIAGRAM

Peak in 1990 (S.C. : 10MVA)

EPDC International Ltd. TOKYO JAPAN

DR. : SUBMITTED :
T.R. : RECOMMENDED :
C.K. : APPROVED :

SHEET NO. OF



Note :

P+jQ ·····Effective power (MW) & Reactive power (MVar)

V∠θ ····· Bus voltage (%) & Leading angle (deg.)

·····Transformer & (tap ratio)

·····Generator

·····Static condenser

·····Shunt reactor

Fig. 7 - 4

POWER FLOW DIAGRAM

Off - Peak in 1990

LOCATION	DATE	DESCRIPTION	BY
REVISION			

EPDC International Ltd. TOKYO JAPAN

D.R.: SUBMITTED:
T.R.: RECOMMENDED:
C.K.: APPROVED:

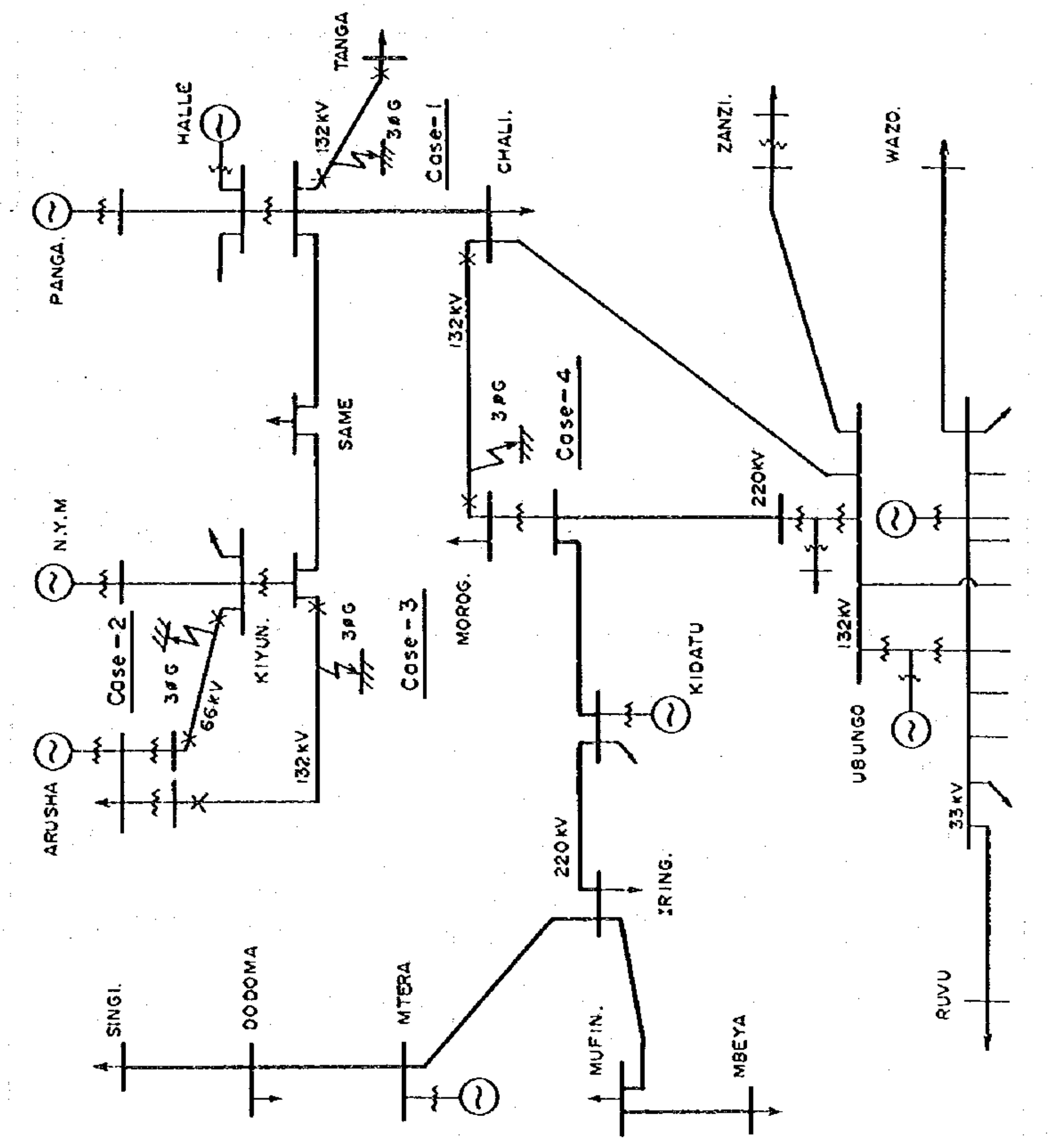


Fig. 7 - 5

3ØG - FAULT POINTS OF TRANSMISSION LINES

EPDC International Ltd TOKYO JAPAN

LOCATION	DATE	DESCRIPTION	BY

REVISION

SHEET NO. OF

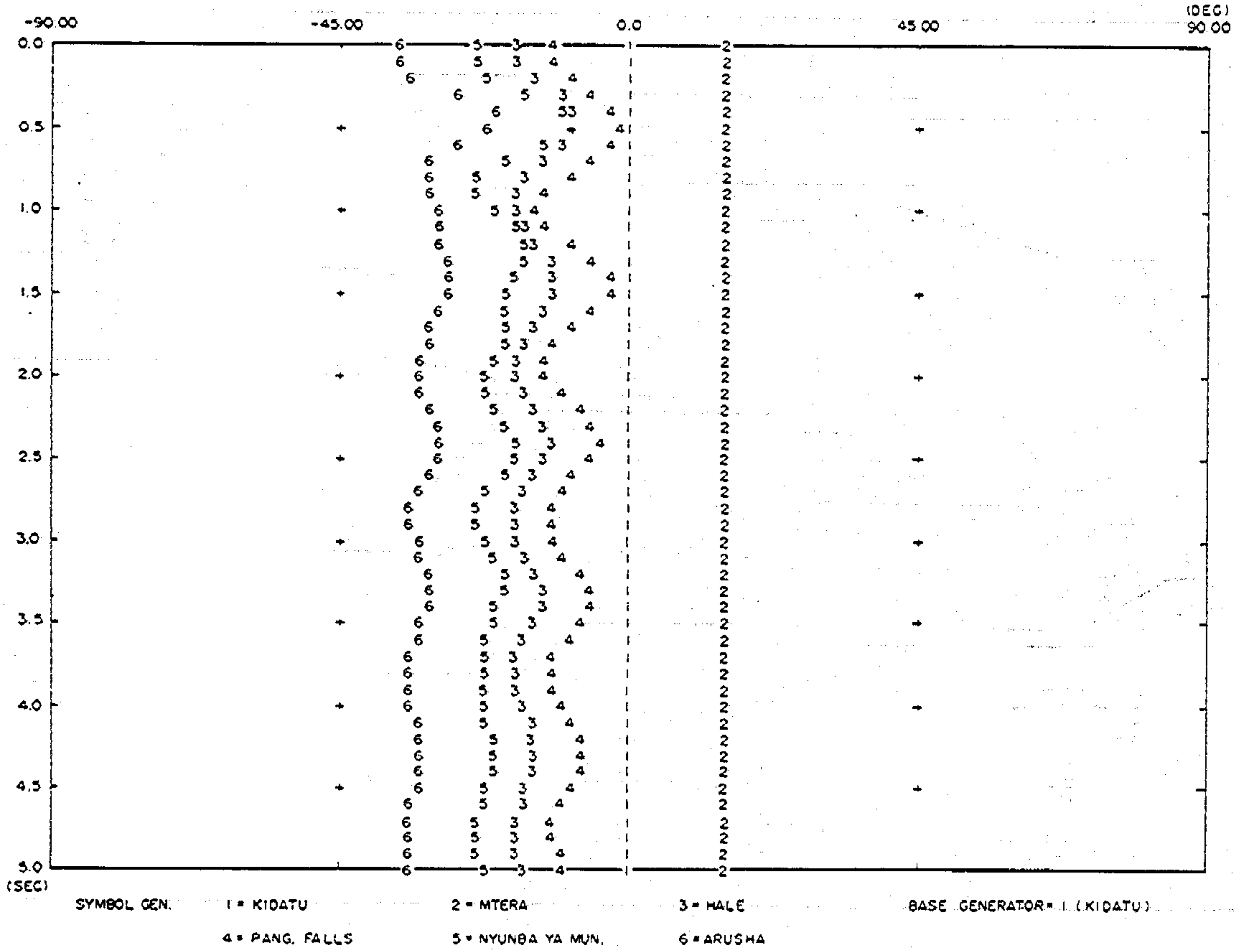


Fig. 7-6 (1) DYNAMIC STABILITY SWING CURVE (Case-1)

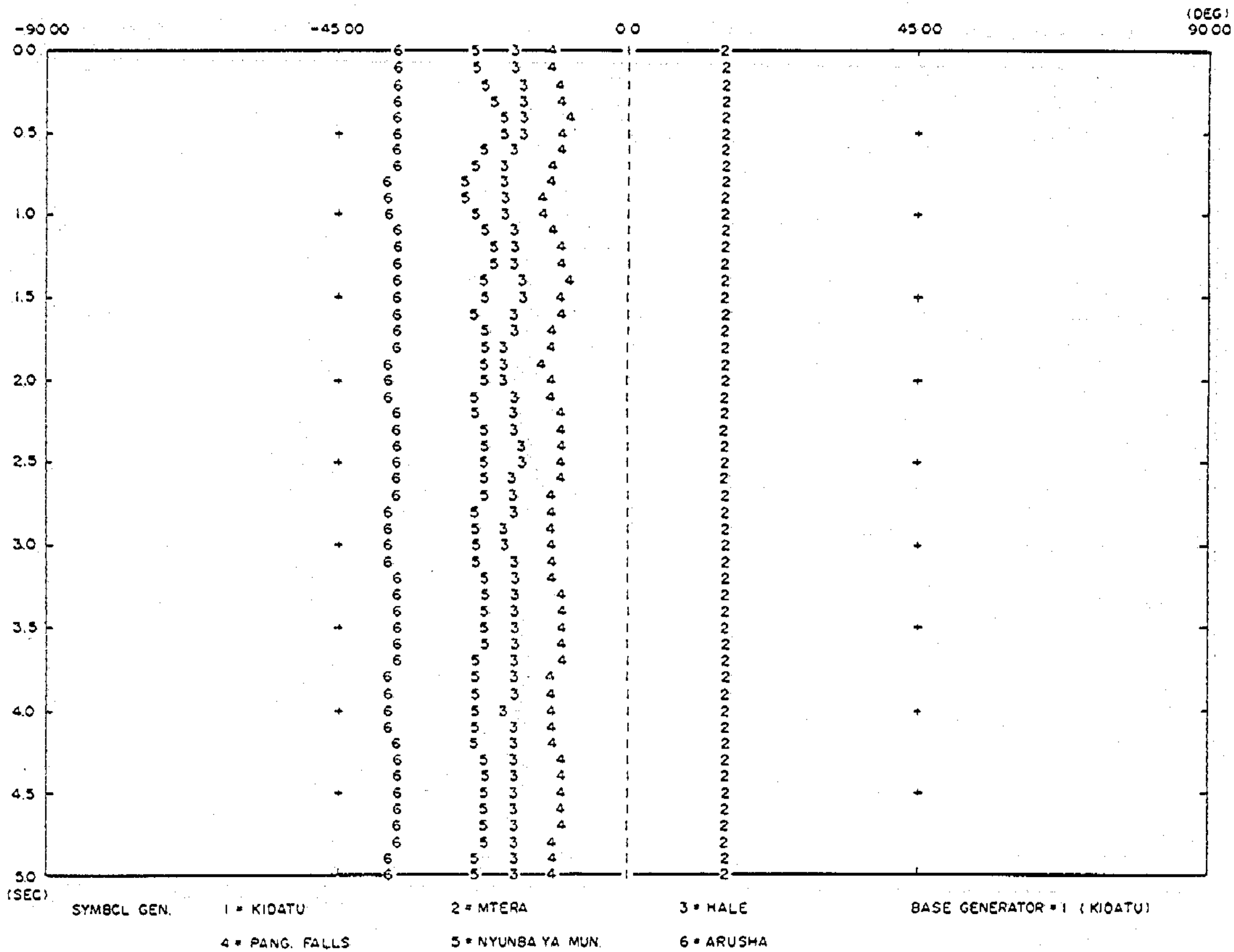


Fig. 7-6(2) DYNAMIC STABILITY SWING CURVE (Case-2)

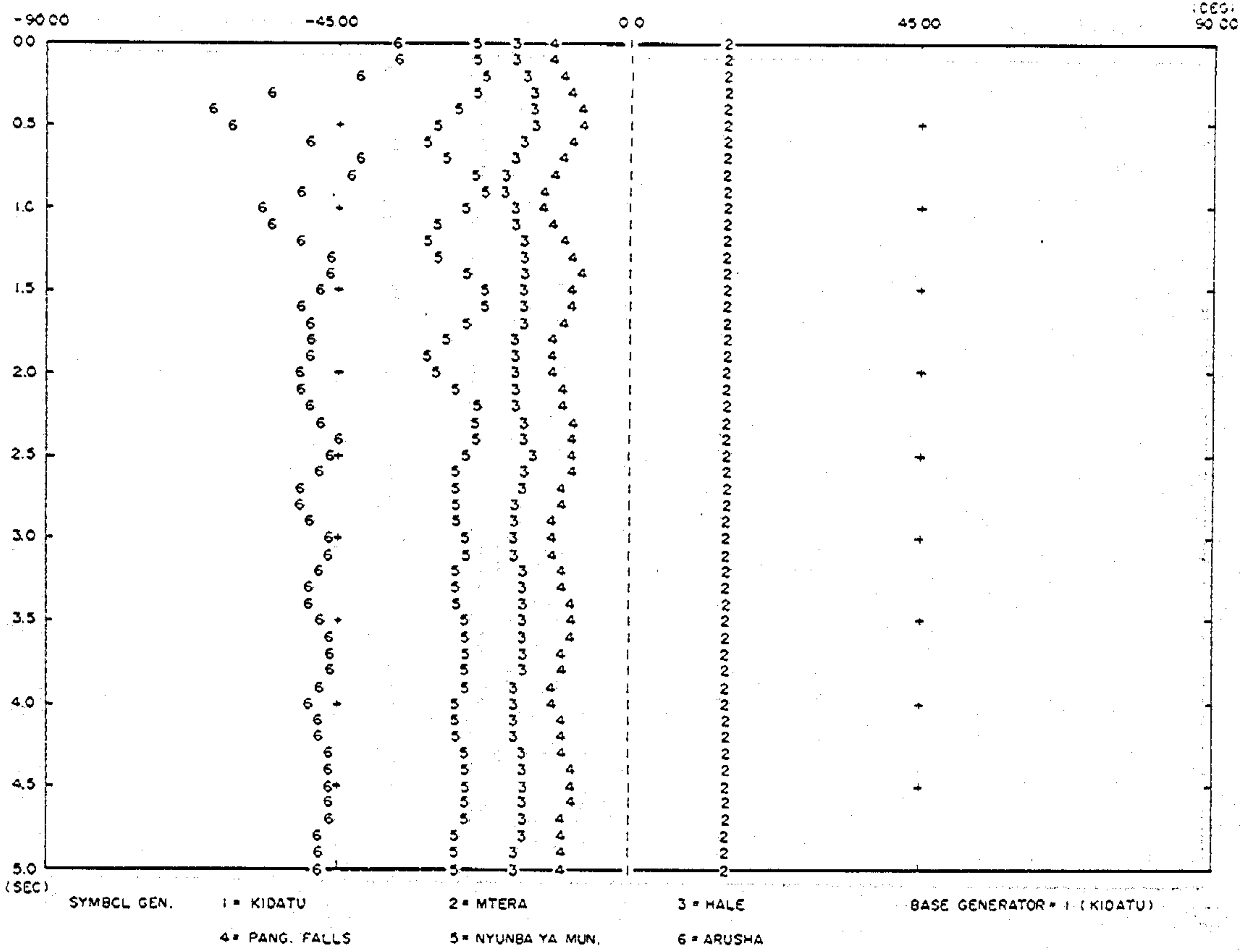
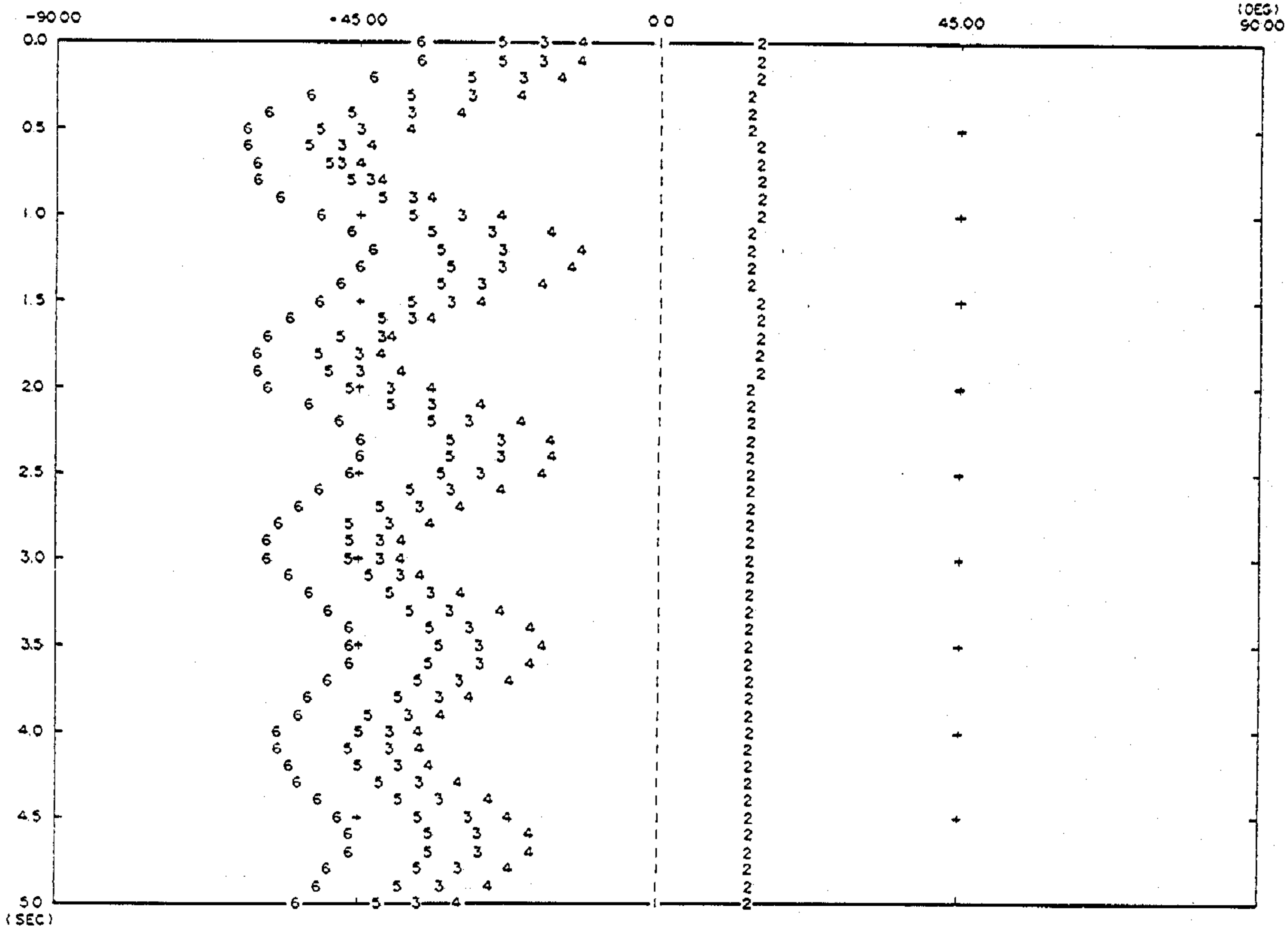


Fig. 7-6 (3) DYNAMIC STABILITY SWING CURVE (Case-3)



SYMBCL GEN 1 = KIDATU 2 = MTERA 3 = HALE BASE GENERATOR = 1 (KIDATU)
4 = PANG. FALLS 5 = NYUNBA YA MUN 6 = ARUSHA

Fig. 7-6 (4) DYNAMIC STABILITY SWING CURVE (Case-4)

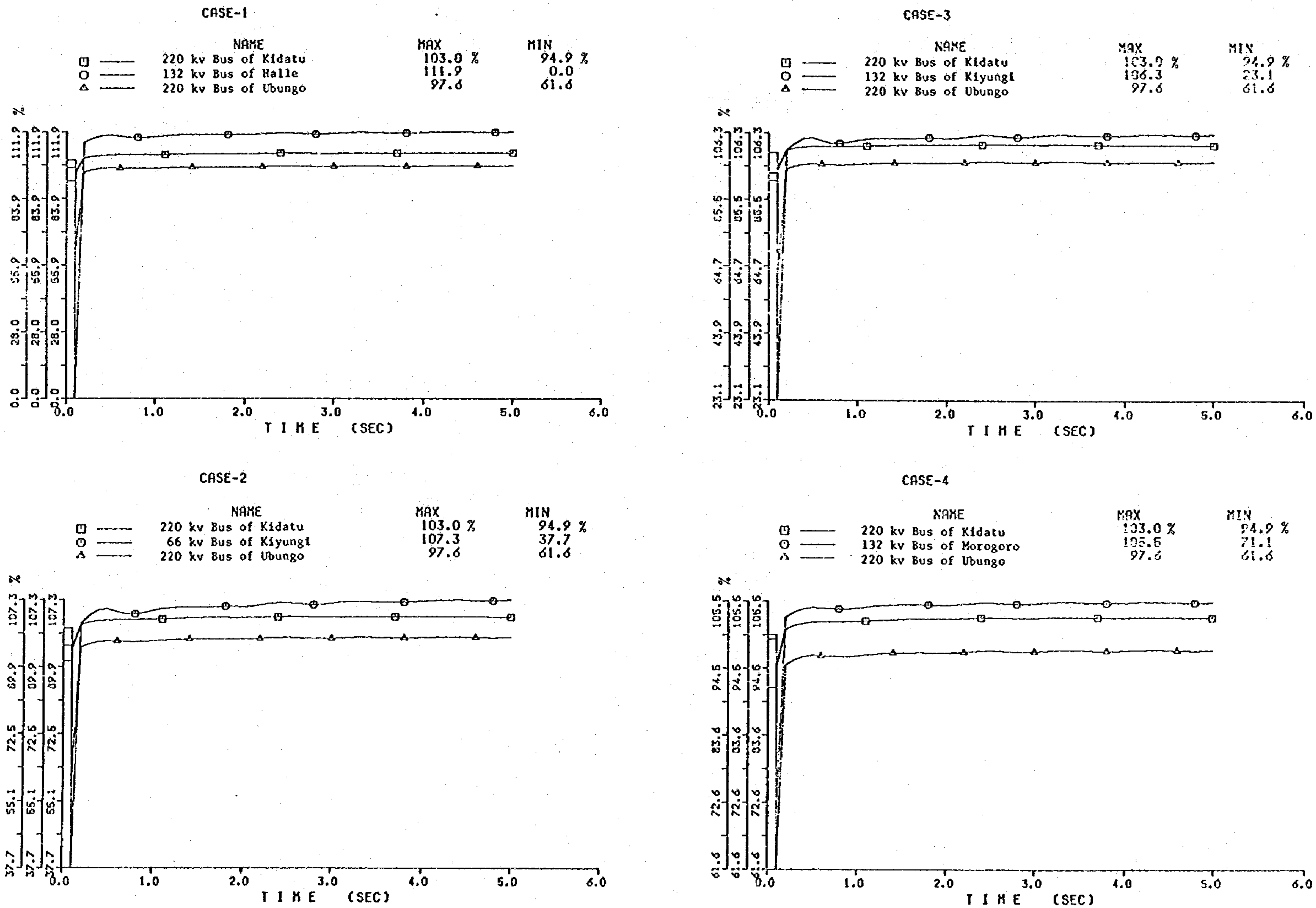


Fig. 7-7 VOLTAGE PERTUBATION AFTER 3ØG-Fault

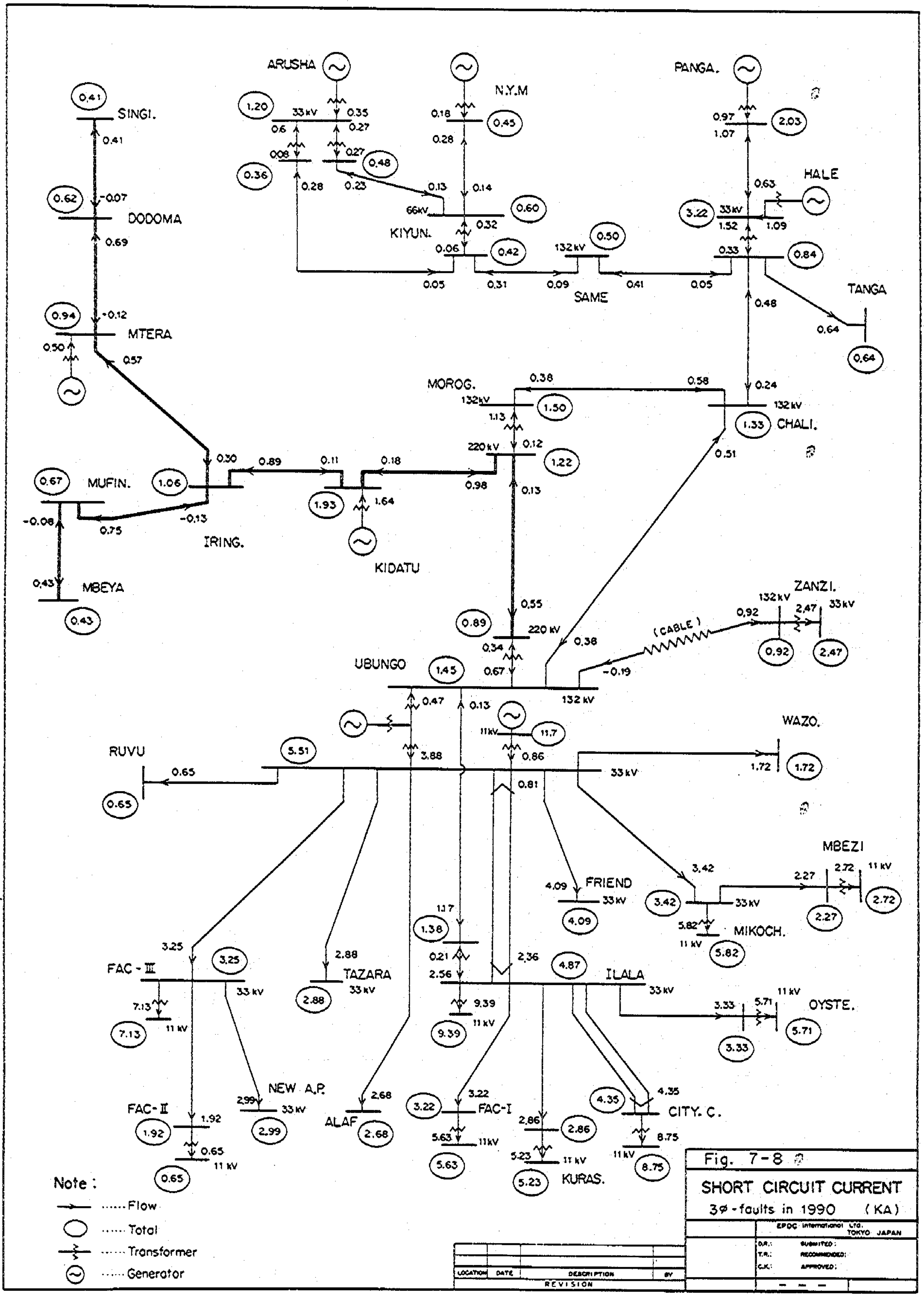
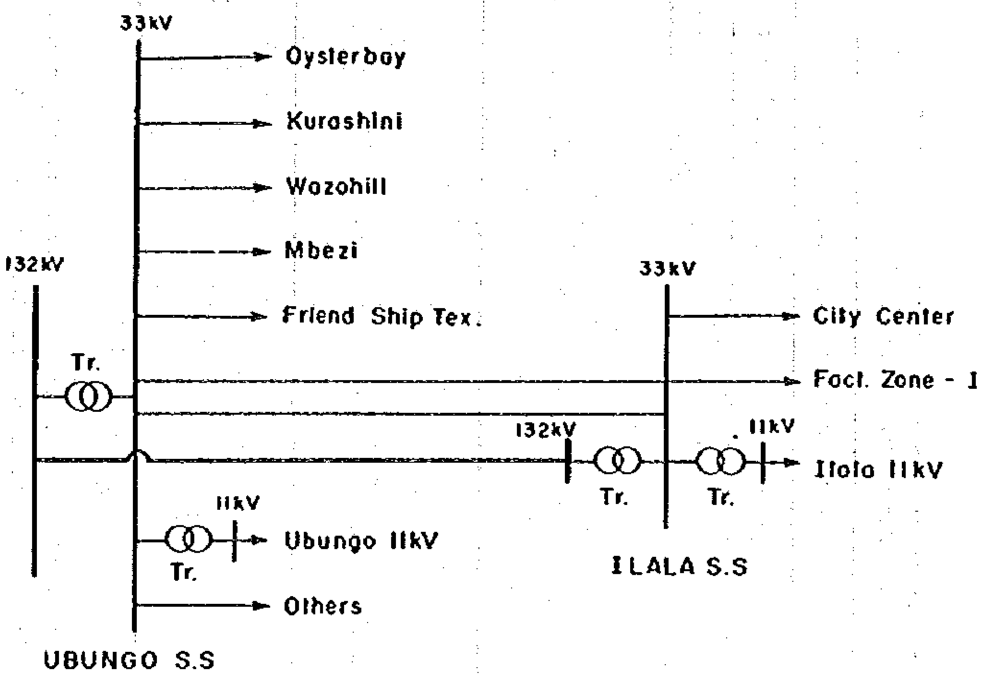


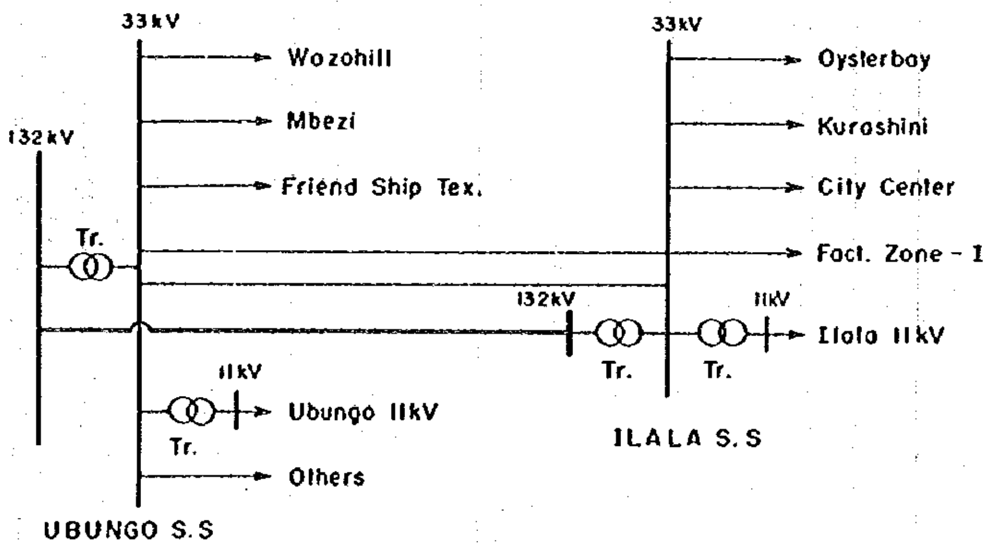
Fig. 7-8

SHORT CIRCUIT CURRENT

3φ-faults in 1990 (KA)



(1) Present Connection



(2) Altered Connection

Fig. 7 - 9

ALTERATION OF 33kV LINE CONNECTION

EPDC International Ltd TOKYO JAPAN

SUBMITTED:
RECOMMENDED:
APPROVED:

LOCATION	DATE	DESCRIPTION	BY
REVISION			

SHEET NO. OF

Table 7-2 Increase of 132 kV → 33 kV Flow-down Capacity by Improvement

	132 kV → 33 kV Flow-down Capacity (MVA)								
Operation Condition of Transformers	Case of all transformers working normally			Case of one transformer stopped out					
				Ubungo 50 MVA 1 bank out			Ilala 1 bank out		
Substation	at Ilala	at Ubungo	Total	at Ilala	at Ubungo	Total	at Ilala	at Ubungo	Total
Present Ubungo: 50 MVA x 2 Ilala : 10 MVA x 2	49	64	113	30	39	69	38	50	88
After improvement Ubungo: 50 MVA x 2 Ilala : 45 MVA x 2	110	80	190	*90	*50	*140	69	50	119
Increase of 132 kV → 33 kV Flow-down capacity by improvement	61	16	77	60	11	71	31	-	31

Note: * shows the case of 33 kV interlink opened.

(When one bank of Ubungo transformer is out of service, 132 kV → 33 kV flow-down larger capacity can be obtained in case the 33 kV interlink between Ubungo and Ilala are open, than the case of parallel running operation. See Fig. 7-11.)

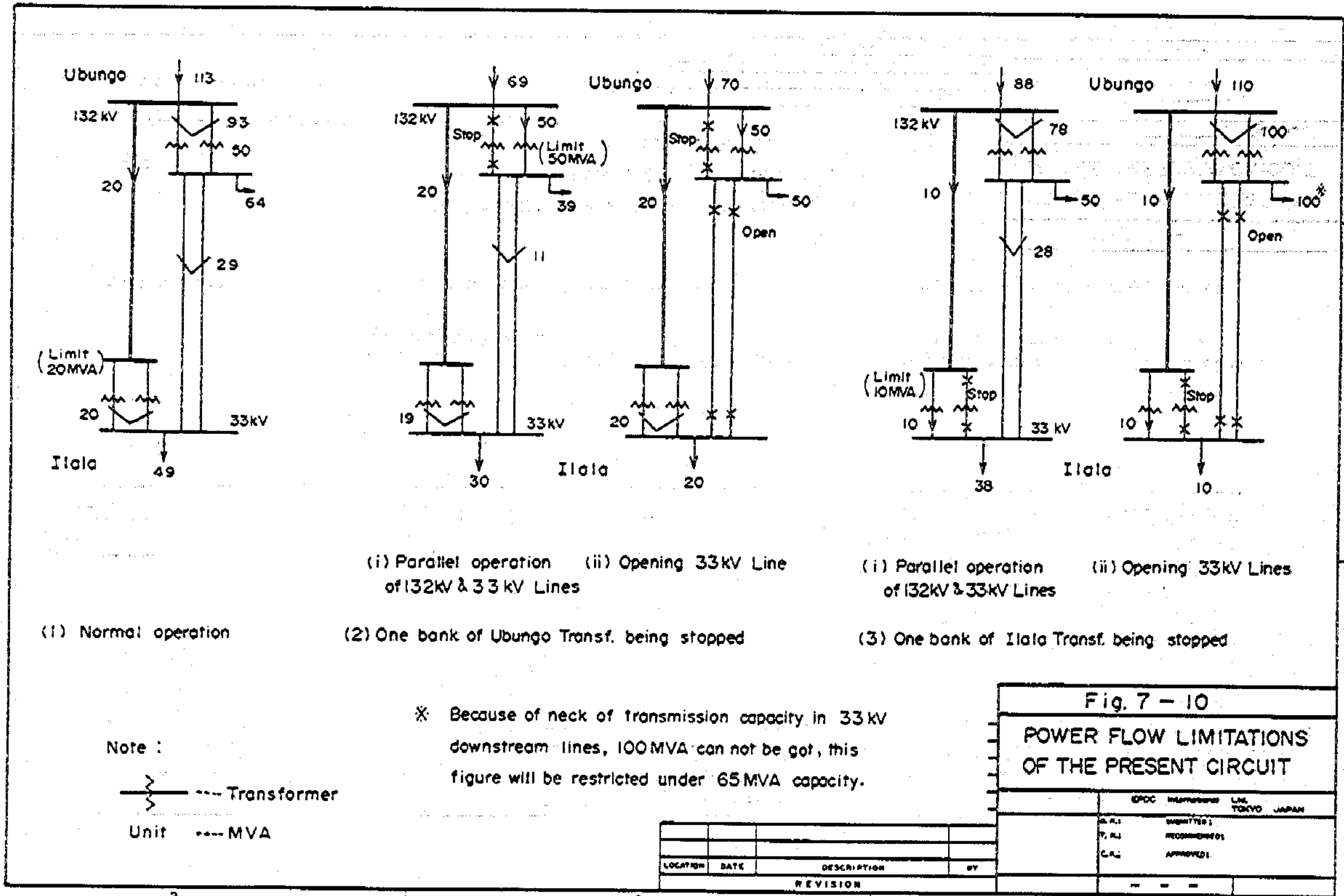
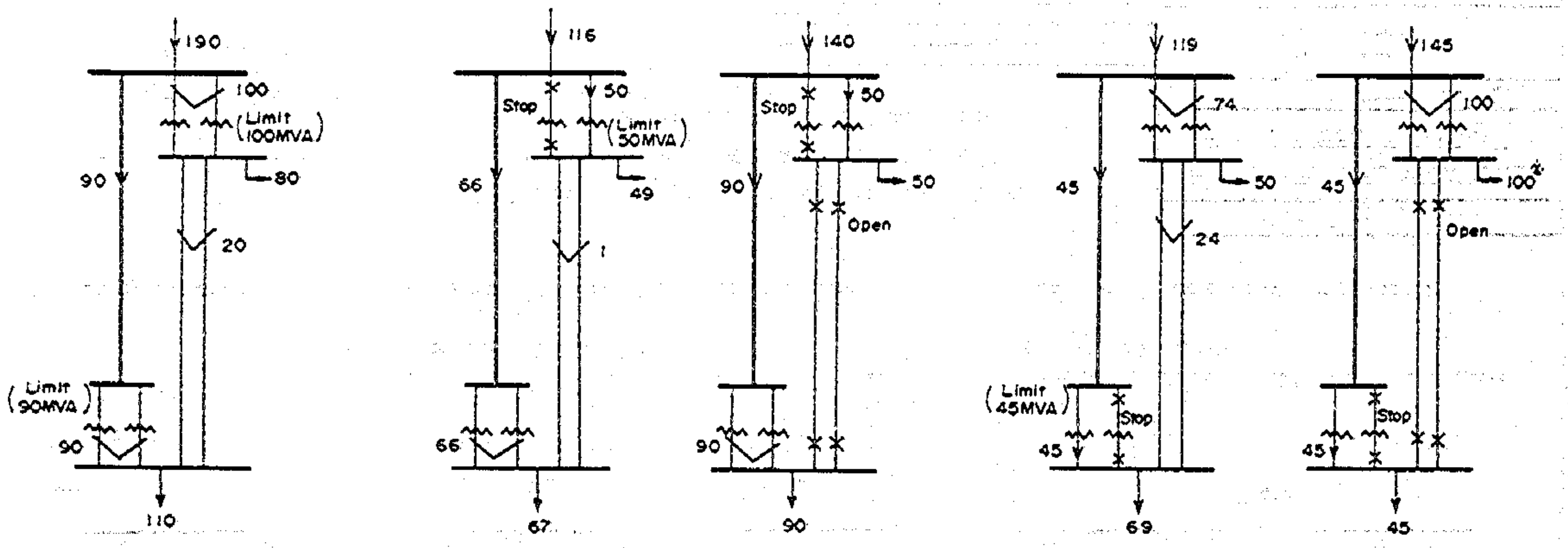


Fig. 7 – 10

POWER FLOW LIMITATIONS OF THE PRESENT CIRCUIT



(i) Parallel operation of 132 kV & 33kV Lines

(ii) Opening 33kV Lines

(i) Parallel operation of 132 kV & 33 kV Lines

(ii) Opening 33kV

(1) Normal operation

(2) One bank of Ubungo Transf. being stopped

(3) One bank of Ilala Transf. being stopped

※ Because of neck of transmission capacity in 33 kV downstream lines, 100 MVA can not be got, this figure will be restricted by about 80 MVA.

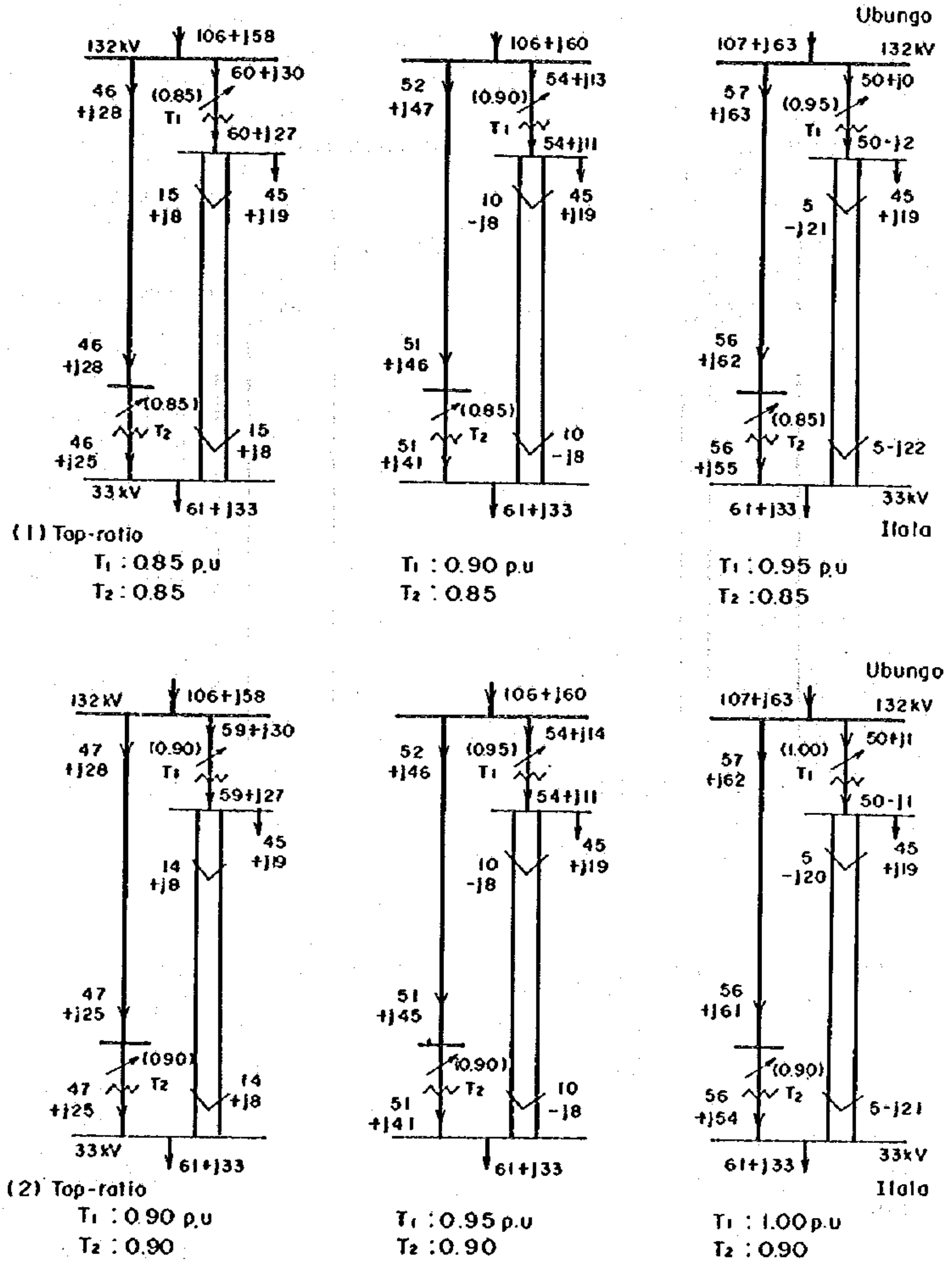
Note :
--- Transformer
Unit ---- MVA

Fig. 7 – 11

POWER FLOW LIMITATIONS OF THE IMPROVED CIRCUIT

LOCATION	DATE	DESCRIPTION	BY
REVISION			

SHEET NO. OF



Note:

T1 ··· Ubungo Transf.
T2 ··· Ilala Transf.
··· Transformer (Tap ratio)

P+jQ ··· MW and MVar

Fig. 7 - 12

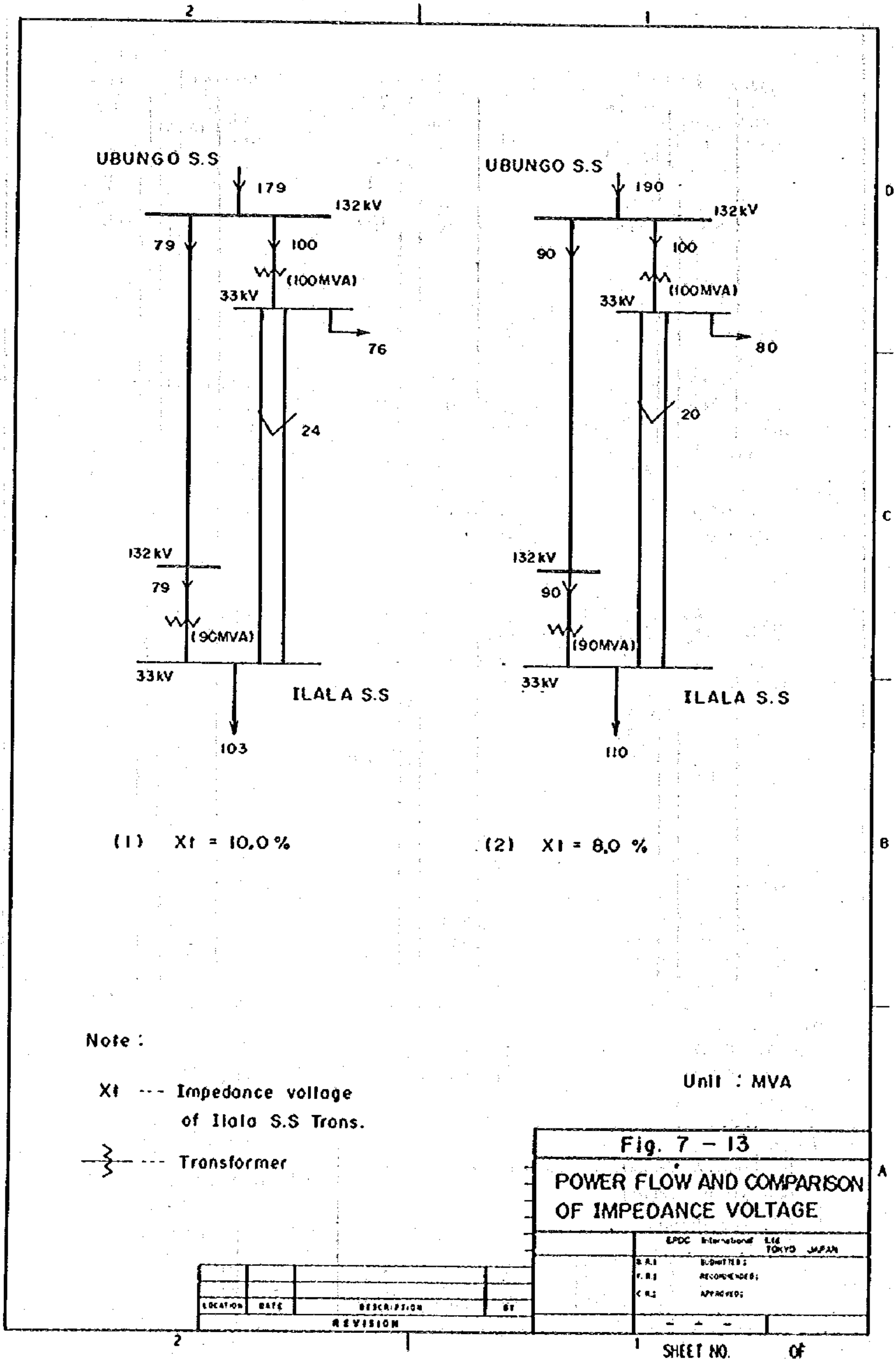
CONTROL OF TRANSFORMER TAP - RATIO

EPDC International Ltd TOKYO JAPAN

SUBMITTED:
RECOMMENDED:
APPROVED:

LOCATION	DATE	DESCRIPTION	BY
REVISION			

SHEET NO. OF


UBUNGO S.S
179
132 kV
79
100
(100MVA)
33kV
76
24
132 kV
79
(90MVA)
33kV
ILALA S.S
103
(1) Xt = 10.0 %
UBUNGO S.S
190
132kV
90
100
(100MVA)
33kV
80
20
132kV
90
(90MVA)
33kV
ILALA S.S
110
(2) Xt = 8.0 %
Note :
Xt --- Impedance voltage
of Ilala S.S Trans.
--- Transformer
Unit : MVA
Fig. 7 - 13
POWER FLOW AND COMPARISON
OF IMPEDANCE VOLTAGE
EPDC International Ltd
TOKYO JAPAN
LOCATION
DATE
DESCRIPTION
BY
REVISION
SHEET NO.
OF

CHAPTER 8

DISTRIBUTION NETWORK REHABILITATION PROGRAM

CHAPTER 8 DISTRIBUTION NETWORK REHABILITATION PROGRAM

CHAPTER 8 DISTRIBUTION NETWORK REHABILITATION PROGRAM

8.1 SUBSTATIONS

8.1.1 Outline of rehabilitation

We have studied the capacity of each transformer to be installed at each substation with the target to accomplish for the time being set to 1990.

As the measures to control the voltage fluctuation, the load tap changer (L.T.C.) attached to each transformer shall be automatic for the 132/33 kV transformer at the Ubungo S.S. and all transformers installed at the Ilala S.S., Oysterbay S.S. and Factory Zone I S.S. Thus adequate measures for this will be taken.

As the measures to increase the reliability, if a fault occurs at one substation, the other substations shall be protected from the spreading of such a failure.

Additionally, measures shall be taken on the existing equipment, particularly those now having problems and those bear near future operational or safety problems due to deterioration.

Table 8-1-1 shows the reinforcement plan of main transformers of each substations and Table 8-1-2 shows the new equipment needed for improvement of major facilities of substations including the main transformers, based on Chapter 4 and Chapter 6.

Table 8-1-1 Reinforcement plan of main transformers of substations

Substation \ Item		Demand forecast (MVA)		Transformer capacity		Remark
		1983	1990	Existing	Proposed	
Ilala S.S.	132/33 kV	-	-	20 MVA (10MVA x 2)	90 MVA (45MVA x 2)	
	33/11 kV	15.3	20.2	15 (7.5 x 2)	22.5 (7.5 x 1) (15 x 1)	One transformer change 7.5 MVA to 15 MVA
City Centre S.S.	33/11 kV	20.6	26.1	30 (15 x 2)	30 (15 x 2)	
Oysterbay S.S.	33/11 kV	14.4	20.2	15 (5 x 3)	30 5 x 3 (15 x 1)	15 MVA x 1 set up to new S.S.
Factory Zone I S.S.	33/11 kV	14.8	26.1	15 (5 x 3)	30 5 x 3 (15 x 1)	15 MVA x 1 set up to new S.S.

(Provided that power factor is 0.85)

Table 8-1-2 New equipment for improvement of major facilities of substations

Major facilities		Substation name									
		Ilala		Oysterbay	City Centre	Factory Zone I	Mikocheni		Factory Zone III		Ubungo
Transformer	Capacity	45 MVA	15 MVA				15 MVA		15 MVA		
	Number of phases	3 φ	3 φ				3 φ		3 φ		
	Frequency	50 Hz	50 Hz				50 Hz		50 Hz		
	Rated voltage	132/33 kV	33/11				33/11 kV		33/11 kV		
	Connections	⅄+ ⅄+ ▷	⅄ ⅄+ ▷				⅄ ⅄+ ▷		⅄ ⅄+ ▷		
	Tap-changing equipment	L.T.C.	L.T.C.				L.T.C.		L.T.C.		
	Number of units	2	1				1		1		
Circuit breaker	Rated voltage	145 kV	36 kV	36 kV		36 kV	36 kV		36 kV		36 kV
	Rated current	800 A	1200 A	600 A		600 A	600 A		600 A		600 A
	Rated interrupting current	12.5 kA	12.5 kA	12.5 kA		12.5 kA	12.5 kA		12.5 kA		12.5 kA
	Number of units	1	3	2		3	2		3		1
	Rated voltage						12 kV	12 kV	12 kV	12 kV	
	Rated current						1200 A	600 A	1200 A	600 A	
	Rated interrupting current						25 kA	25 kA	25 kA	25 kA	
	Number of units						1	3	1	5	
Disconnecting switch	Rated voltage	145 kV		36 kV		36 kV	36 kV		36 kV		36 kV
	Rated current	800 A		600 A		600 A	600 A		600 A		600 A
	Number of units	2		2		3	3		5		1
	Rated voltage	36 kV	36 kV	36 kV	36 kV	36 kV	36 kV		36 kV		36 kV
	Rated current	1200 A	800 A	600 A	600 A	600 A	600 A		600 A		600 A
	Accessories	--	--	with earthing blade	with earthing blade	with earthing blade	with earthing blade		with earthing blade		with earthing blade
	Number of units	2	2	1	2	2	2		3		1
Instrument transformer	Rated voltage	132 kV	33 kV	33 kV		33 kV	33 kV	33 kV	33 kV	33 kV	33 kV
	Insulation level	BCT	BCT	BCT		BCT	BCT	BCT	BCT	BCT	BCT
	Rated current	800/5A,400/5A	1200/5A,400/5A	600/5 A		600/5 A	600/5 A	400/5 A	600/5 A	400/5 A	600/5 A
	Number of units	1, 2	5, 1	2		3	2	1	3	1	1
	Rated voltage	11 kV	11 kV				11 kV	11 kV	11 kV	11 kV	$\frac{132}{\sqrt{3}}$ kV/$\frac{110}{\sqrt{3}}$ V
	Insulation level	BCT	10A				BCT	10A	BCT	10A	120
	Rated current	1200/5 A	1200/5 A				1200/5 A	1200/5A,600/5A	1200/5 A	1200/5A,600/5A	--
	Number of units	1	1				1	1, 3	1	1, 5	1
Enclosed switchboard	Number of units	3		--	--	--	6		8		--

8.1.2 Way of thinking on reinforcement related to substation equipment

(1) Reinforcement of 132 kV/33 kV transformers at Ilala Substation

Although the Ilala Substation is located at almost the center of the city and a 132 kV transmission line made of sturdy iron structure is introduced to it, since only two banks of 10 MVA transformer are connected to the line, the carrying capacity is limited to 20 MVA. Furthermore, since it is difficult to obtain the matched impedance with the 33 kV transmission line that is operating in parallel, the receiving power of Ilala Substation is limited to 49 MVA (20 MVA of 132 kV and 29 MVA of 33 kV). Therefore, while it is preferable that the Oysterbay and Kurasini substations receive the power from the Ilala S.S.that is near to them, the two substations have no choice other than receiving the power from the Ubungo S.S. thereby creating disadvantages on the reliability and power loss.

In order to effectively use the reliable 132 kV transmission line, the two banks of 10 MVA transformer at the Ilala S.S. should be changed to two banks of 45 MVA transformer, the receiving capacity at the 33 kV bus of Ilala S.S. is substantially increased (See Chapter 7), thereby making it a major secondary substation (manned substation).

The main purpose of this reinforcement is needless to say increase of the reliability of the receiving capacity at the Ilala S.S., and it has the following auxiliary but important merits.

i) Reduction of heavy load on two banks of 50 MVA transformer of 132 kV/33 kV at Ubungo S.S.

These transformers are trunk facilities that supply the majority of power to the Dar es Salaam distribution system, but they have the problem of oil leakage and must be overhauled. However, since they are heavily loaded, they cannot be shut down for the repair.

If the carrying capacity of the 132 kV line connected with the Ilala S.S. increases, the bank-down power flow of these transformers will decrease and the necessary inspection and repair can be given them.

ii) Use of 132 kV/33 kV transformers removed from Ilala S.S. at Ruvu S.S.

Since the 33 kV Nordic distribution line that supplies power to the Ruvu Pump Station is as long as 80 km from the Ubungo S.S. and since the Ruvu pump motor is a large capacity squirrel-cage induction motor, the rush current at the time of starting the motor is great, causing a sharp voltage drop, the whole operation of Ruvu Pump Station is difficult.

TANESCO is planning to change the supply method to the Ruvu Pump Station by constructing a new Ruvu Substation to receive the power from the Chalinze-Ubungo line that passes in the neighborhood of the Ruvu S.S. The 10 MVA (132 kV/33 kV) transformers removed from the Ilala Substation can be used for this plan.

Also, it is expected that this new setup will be very effective measures for the control of voltage fluctuations at the consumers along the Nordic line.

(2) Reinforcement of distribution transformers

The reinforcement plan of distribution substations shall be studied based on the demand forecast (See Table 6-5) to the existing transformer capacities. The table below summarizes the plan.

Substation Capacity		Maximum Demand in 1983	Demand Forecast in 1990	(Reference) Demand Forecast in 1992
Ilala	15 MVA	15.3 MVA	20.2 MVA	22.4 MVA
City Centre	30	20.6	26.1	29.1
Oysterbay	15	14.4	20.2	22.4
Factory Zone I	15	14.8	26.1	29.3

(Provided that power factor is 0.85)

From the contents of this table, we consider that the capacities of Ilala, Oysterbay and Factory Zone I substations must be increased but not the capacity of City Centre Substation.

When planning a capacity scale of substation, the plan should naturally be made to that the normal supply power is greater than the demand. In our plan, we set the capacity of each substation with some allowance to the forecasted demand and to operate the power system by flexibly using the equipment so as not to cause a serious trouble in the supply, for example, when a transformer in operating is shut down, the transmission line will be switched to other normally operating bank (See 8.1.3 (5)).

(3) Standard capacities of distribution transformers

As described in Item 4.2, the standard capacities of transformers installed in distribution substations of the Dar es Salaam area are 5, 7.5, 10 and 15 MVA. However, in view of the power demand scale and its increasing situation, we consider that 5 and 7.5 MVA are too small, and we review these transformers in the capacities of 10 MVA and 15 MVA.

5 MVA is a capacity outside of the standards stipulated by the Japanese Electro-Technical Committee.

(4) Timing of the reinforcement

The timing of the reinforcement shall be studied based on the contents of the following table.

Substation capacity		Demand forecast/Transformer capacity ($\cos\theta = 0.85$)	
		Year of more than 105%	Year of more than 110%
Ilala	15 MVA	1985	1985
Oysterbay	15 "	1986	1987
Factory Zone I	15 "	1988	1988

8.1.3 Selection of optimum reinforcement scheme at each substation

(1) 132 kV/33 kV transformers at Ilala S.S.

If the power transmission from the Ubungo and Ilala substations to each distribution substations is continued as is done at present (See Table 4-1-1), the loads on each 132 kV/33 kV transformer of the Ubungo and Ilala substations based on the demand forecast (See Table 6-5) are as follows:

(MVA)

Item \ Year	1983	1990	1992 (Referred)
(Transmitted power from Ubungo S.S.)			
Total maximum demand:	66.4	88.2	96.4
Peak load as Div. factor is 1.04:	63.8	84.8	92.7
Peak load as Div. factor is 1.312:	50.6	67.2	73.5
(Transmitted power from Ilala S.S.)			
Total maximum demand:	50.7	72.5	80.7
Peak load as Div. factor is 1.04:	48.8	69.7	77.6
Peak load as Div. factor is 1.312:	38.6	55.3	61.5
(132/33 kV Transf. load, as diversity factor is 1.04)			
Ubungo S.S.	93.1	126.6	139.3
Ilala S.S.	19.5	27.9	31.0
(132/33 kV Transf. load, as diversity factor is 1.312)			
Ubungo S.S.	73.8	100.4	110.4
Ilala S.S.	15.4	22.1	24.6

The power factor applied is 0.85. On the diversity factor, we studied "1.04" as contained in the Electrical Engineering Handbook and "1.312" selected in Chapter 3.

It seems that the large figure of 1.312 resulted in since there is a difference in the load characteristics between the urban area load and plant operating load of ALAF, WAZO Hill and Factory Zone I substations, and if we take up the diversity factor between distribution substations in the urban area only, it would be a value close to 1.04. Therefore, it seems that use of a diversity factor in a range of 1.04 to 1.312 is good enough on the review of dividing the Ubungo and Ilala substations.

The ratio of power flow of 132 kV and 33 kV lines from the Ubungo S.S. to the Ilala S.S. is calculated based on 132 kV line: 45% and 33 kV lines: 55% for current state.

The load to the Oysterbay S.S. and Factory Zone I S.S. is suppressed to 13.5 MW (15.9 MVA = 106%) and the remaining load will be substituted by the Mikocheni S.S. and Factory Zone III S.S. (See 8.1.3 (3)) Also, all distribution substations are to receive the power from substations in the neighborhood, that is, the Mikocheni and Factory Zone III substations are to receive from the Ubungo S.S. and the Oysterbay, City Centre, Factory Zone I and Kurasini substations are to receive from the Ilala S.S. Based on this plan, the preceding table can be revised as shown below.

The ratio of power flow if 132 kV and 33 kV lines from the Ubungo S.S. to the Ilala S.S. is calculated based on 132 kV line: 80% and 33 kV lines: 20% after reinforcement of the Ilala 132/33 kV transformers.

(MVA)

Item \ Year	1983	1990	1992 (Referred)
(Transmitted power from Ubungo S.S.)			
Total maximum demand:	66.4	67.2	76.2
Peak load as Div. factor is 1.04:	63.8	64.6	73.3
peak load as Div. factor is 1.312:	50.6	51.2	58.1
(Transmitted from Ilala S.S.)			
Total maximum demand:	50.7	93.5	100.8
Peak load as Div. factor is 1.04:	48.8	89.9	96.9
Peak load as Div. factor is 1.312:	38.6	71.3	76.8
(132/33 kV Transf. load, as diversity factor is 1.04)			
Ubungo S.S.	93.1	82.6	92.7
Ilala S.S.	19.5	71.9	77.5
(132/33 kV Transf. load, as diversity factor is 1.312)			
Ubungo S.S.	73.8	65.5	73.5
Ilala S.S.	15.4	57.0	61.4

Comparing with these two tables, it is apparent that the operation of the substations is much easier on the plan shown in the second table, and furthermore which has the following merits.

(a) The 132 kV/33 kV transformers (existing 50 MVA x 2) of the Ubungo S.S. require no reinforcement.

(b) Since the 132 kV line between Ubungo and Ilala substations can be effectively used, it helps reducing the transmission loss and suppressing the voltage fluctuation.

(c) Each of the 132 kV/33 kV transformers of the Ubungo and Ilala substations can be inspected, while having it shut down.

(d) The LTC attached to each transformer can be automatically operated so that the voltage fluctuation can be kept within a target range.

(e) The power to the Oysterbay and Kurasini substations can be transmitted from the Ilala S.S. and this helps reducing the loss.

(f) The supply reliability of the whole system related to Dar es Salaam distribution is increased.

For all these reasons, removing the two banks of 10 MVA transformer at the Ilala S.S. and newly installing two banks of 45 MVA transformer is planned in consideration of the following points.

- The maximum carrying capacity of the 132 kV line between the Ubungo and Ilala substations is 96 MVA.

- Because of the renovation plan contents reviewed in the above, two banks of 35 to 40 MVA transformer are needed.

- The Standards of Japanese Electro-Technical Committee set 30 MVA and 45 MVA as standard capacities.

The construction period is set to 1986 since as early renovation as possible is better in consideration of the control of voltage fluctuation on the distribution network, inspection of the 132 kV/33 kV transformers of Ubungo S.S., measures for irregular operation of transmission lines, and improvement of the voltage drop on the Norudic line by using the removed transformers at the Ruvu S.S. (See to 8.6).

(2) <u>33 kV/11 kV 7.5 MVA at Ilala Substation</u>

The Ilala S.S. and City Centre S.S. are located comparatively closely, some of the existing 11 kV feeders connected to these substations serve as distribution lines in the same area of the city, and the transformer of the City Centre S.S. still has some surplus capacity. Therefore, the present level can be maintained until close to 1990 by organic connection or disconnection of load throughout the entire area served by these two substations.

However, the following problems are anticipated if the system keeps its current configuration.

- Construction of new distribution lines will be required, and switching-over operation of those lines need a lot of times.

- Long distribution lines result in increased loss. This would adversely affect the voltage fluctuation and the supply reliability.

- The supply reliability would be adversely affected if one transformer get into fault.

- The two banks of 7.5 MVA transformer now being used have been operating for over 20 years, which seem severely superannuated as observed from their appearance.

  To solve these problems, the No. 1 unit of the two banks of 7.5 MVA transformer, which is suffering heavy oil leakage and has trouble with its load tap changer, should be replaced with a 15 MVA capacity transformer. As a result of this replacement, the present 11 kV bus bar will be operated as the section bus bar. This replacement is scheduled for some time in 1986 for the first unit, and 7 years later for the second unit.

(3) <u>33 kV/11 kV transformers at Oysterbay and Factory Zone I substations</u>

i) The Oysterbay and City Centre substations are neighboring and some feeders of both substations are distributing the power in the same area of the city. From the demand forecast, the current equipment can supply enough power up to about 1990, but for the same reason as described in the preceding item and for an additional reason of the City Centre S.S. being fairly far from load centre of the City, it is not advisable to construct a long 11 kV line from the viewpoints of its construction cost and for control of the voltage fluctuation.

   Accordingly, we have determined to increase the capacity of Oysterbay S.S.

The capacity of Factory Zone I S.S. is to be increased according to the demand forecast.

ii) Economic evaluation has been made as follows for the selection of main-transformer capacity of each substation.

Factors for economic evaluation:

- Interest rate	8%
- Transformer life	25 years with a 10% residual value
- Calculation term	25 years
- Demand forecast	Demand forecast value for this study is given in Table 6-5.
- Load power factor	90% for the Oysterbay S.S.
	85% for the Factory Zone I S.S.
- Economic evaluation method	Annual cost present value comparison method

The following costs have been excluded from the comparative calculation commonly to all patterns.

- Iron and copper loss and maintenance cost
- Prices and installation expenses of equipment other than main- transformers

iii) The prices of main transformers are set as follows:

Transformer provided with on-load voltage regulator,
33/11 kV 3 phase Outdoor, oil-filled, self-cooled type

Capacity (MVA)	5	10	15
Price ($\times 10^6$ yen)	16.0	23.0	28.0

(5 MVA was used for the calculation of the residual price.)

iv) Result of economic evaluation

Item \ Capacity (MVA)		Reinforcement of Existing Substation		Construction of New Substation	
		10	15	10	15
Annual expenditure Current price ($\times 10^6$ yen)	Oysterbay	70.4	63.3	58.1	52.5
	Factory Zone I	94.5	83.7	83.5	72.8

Based on the above results, we determined to construct new substations, and the following capacities were determined to be optimum.

- Mikochni S.S. (Near to Oysterbay S.S.)
  15 MVA. The first unit to be installed in 1987 and the second unit 11 years later.

- Factory Zone III S.S. (Near to Factory Zone I S.S.)
  15 MVA. The first unit is to be installed in 1988 and the second unit six years later.

(4) Next stage plan

Since it is conceivable that full loads will be applied to transformers of the City Centre, Ilala, Factory Zone I, Factory Zone III and Kurasini substations, which are the major distribution substations in the city, by 1991-1994, a plan for the next stage must be established by about 1990.

(5) Studies on stand-by transformers

We have studied installation of stand-by transformers as a method to cope with faults of transformers, capacity increase work and rapid increase of new demands.

The transformer to be used as a stand-by may have a capacity of 5 MVA, 33/11 kV. However, the following problems are anticipated if it does.

(a) Maintenance would hardly ever be performed on the stand-by transformer, because of the shortage of materials required for such maintenance.

(b) Although it may be better to keep the stand-by transformer always connected to the power system in order to protect deterioration of the equipment itself, it is not recommended considering efficient operation of the total system.

(c) The transformer requires a large truck whenever it is moved in and out. However, this truck would usually be idle because the transformer is not frequently used.

However, the stand-by transformer have the following advantages.

(a) The existing facilities can maintain their marginal reserve capacity by installation of the stand-by transformer. The operating temperature of each piece of equipment can also be maintained adequately.

(b) Change-over capacity for power transmission and distribution facilities as well as surplus capacity for each transformer should be required for both system operation and maintenance. In normal operation it would be better for system reliability if the system equipment could be switched over in a simple manner.

(c) If the transformer to be installed is completely anew and free of trouble, it would be possible to remedy any fault in a single existing transformer by changeover of the transmission or distribution line.

The fault rate of a transformer can be kept to a relatively low level if adequate maintenance is performed. This would eventually reduce use of the stand-by transformer. It is, therefore, advisable to continue additional installation of transformers, if and when necessary, in accordance with demand forecast.

After general consideration of merits and demerits, it has finally been decided to adopt the method of supplying from an operating normal bank, and not to install the stand-by transformer.

8.1.4 Details of substation rehabilitation

(1) Rehabilitation at each substation

(i) Ilala Substation

(a) The equipment that must be renewed matching the increase of capacity on the 132 kV/33 kV transformers are as follows:

- Circuit breakers and disconnecting switches at the low voltage side of 132 kV/33 kV transformers (because of capacity shortage)

- Buses of 132 kV and 33 kV circuit (because of capacity shortage)

- Lightning arresters for 132 kV and 33 kV circuit (for increase of reliability)

(b) New installation of a circuit breaker to sectionalize the 33 kV bus coping with the renewal of 33 kV bus and capacity increase of one 33 kV/11 kV transformer from 7.5 MVA to 15 MVA

(c) Installation of a circuit breaker at the receiving end of 132 kV transmission line and removal of the fault throw switch (FT) in consideration of the important of Ilala Substation and to improve the existing protection system.

Also, a bypass disconnecting switch will be installed along with the installation of circuit breaker at the 132 kV receiving circuit so that the station service power is shut down at the time of inspection of the circuit breaker. A transfer trip circuit is installed using the pilot wire between the Ubungo and Ilala substations as protective measures of the Ilala S.S. during the use of bypass disconnecting switch.

Fig. 8-1-1 through Fig. 8-1-3 show the plans of these renovations.

(ii) Oysterbay S.S. and Factory Zone I S.S.

Both of the Oysterbay and Factory Zone I substations will have two or more of 33 kV transmission lines. In order to improve the protection system of these lines and to realize effective use of these lines, circuit breakers will be installed at the receiving ends of 33 kV lines and the FT will be removed. Also, the faulty disconnecting switches for 33 kV line (Ilala S.S. line) of Oysterbay S.S. will be replaced.

Fig. 8-1-4 and Fig. 8-1-5 show the plans of these renovations.

(iii) City Centre S.S.

A circuit breaker has already been installed at the high voltage side of 33 kV/11 kV transformer and FT has been removed, but no disconnecting switch nor circuit breaker has been installed to the receiving end of the 33 kV line.

Installation of a new 33 kV line is planned between the City Centre and Ilala substations, and to cope with it, a disconnecting switches will be installed to the receiving end of 33 kV line for operation and maintenance. Fig. 8-1-6 shows the plan of this renovation.

(2) <u>Measures to voltage fluctuation</u>

(i) Automatic operation of load tap changer (LTC)

The necessary measures for "automatic operation" of the LTC attached to each transformer will be performed. In addition to repairing the faulty LTC control panel, main unit resistor and operating motor (See 4.6.1 (3)) and replacement of LTC insulation oil will be performed and reviews will be made on the load dispatching communication system so as to monitor the necessary information of each substation at the Ilala S.S. (See Item 9.7).

With these renovations, the sending voltage from substations can be controlled within ±2% of the target value.

(ii) Selection of adequate impedance voltage for 132 kV/33 kV new transformer of Ilala S.S.

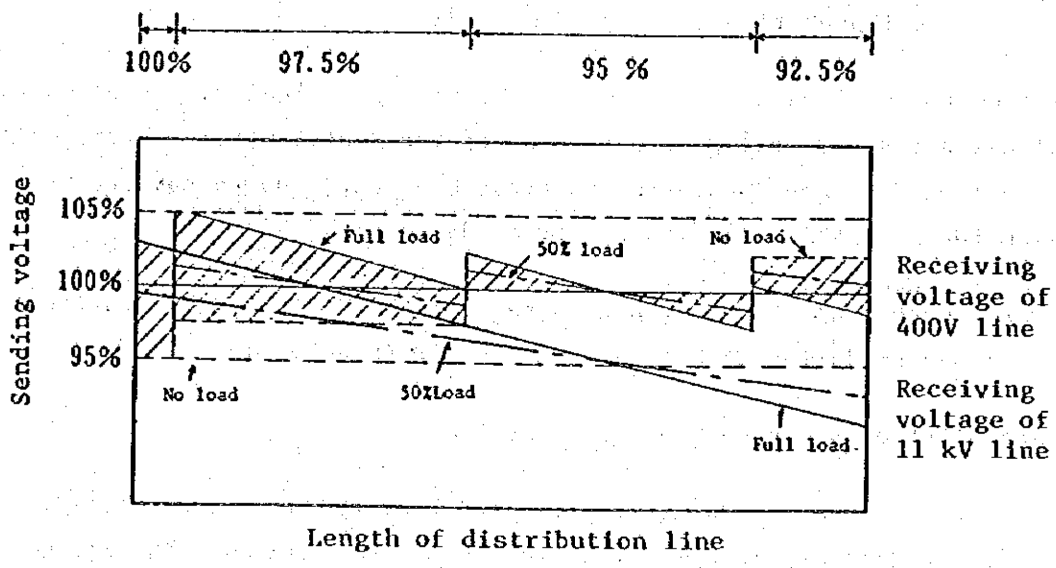
Normal sharing of power flow even during operation of the 132 kV and 33 kV lines in parallel is taken into design consideration by selecting the proper impedance voltage for the 45 MVA to be installed (See 7.4.2).

(iii) Proper control of sending voltage from substations

In order to keep up the receiving end voltage at a constant level, improvements will be done in such a way that the sending voltage can be maintained at the level suitable for the magnitude of load. The best equipment for this improvement is the LTC control device with its control circuit functioning as the line drop compensator (LDC).

The LDC functions to keep the receiving voltage of the consumers at the suitable level by controlling the set-voltage of the LDC according to the feeder current, since the line voltage drop is in proportion to the sending current as assuming that the ratio of distributed load in peak time and off-peak time is same.

Distribution transformer tap



(Conditions)

- Voltage drop between substation and consumer should be 12% (full load time).
- Distribution transformer Tap is 100, 97.5, 95, 92.5%.
- Sending voltage from substation is kept up at 103% (full load time), 95% (no load time) by LDC.
- Hatching area shows voltage fluctuation of consumer terminals.

As a result, the consumer can control the voltage within about ±7% (LTC ±2% and LDC ±5%) of the rated voltage.

However, to determine the optimum target voltage, the actual situation of the following items must be grasped, and the set-voltage of the control device must be determined.

- Characteristic of load on transformers
- Minimum and maximum values of load
- Increasing tendency of load
- Voltage fluctuation

Typical set value of the target voltages is shown below.

132 kV: Ubungo S.S. ...... 132 kV ± 2%
33 kV: Ubungo S.S. ...... 33 kV ± 2%
33 kV: Ilala S.S. ...... 33 kV ± 2%

11 kV: each substation

Peak time .... 11.3 kV $\pm$ 2%

Off peak time .... 11.0 kV $\pm$ 2%

At the time to set a value of the control device practically. It needs to supervise a secondary voltage fluctuation of the distribution transformers and bus voltage of each substation in first one year, and to correct the set value for a final fixing after a fine adjustment.

It is hard to keep up the 33 kV bus voltage of the Ilala S.S. at rating without condenser during peak load time in 1990 (See 7.3.1).

(3) Renewal of DC power source equipment

The DC power source equipment (rectifier and battery) of the Oysterbay, City Centre and Factory Zone I substations shall be renewed. The ratings shall be DC output 100V, AC input 230V single-phase and battery capacity 60 AH, and which will be installed indoors.

(4) Renovation contents of existing transformers

Almost all transformers operating in each substation have been used for 10 to 20 years (some are longer than 20 years), and since they are not in good conditions any longer, they need detailed inspection of the inside and insulation as well as dissolved gas analysis of insulating oil (See 8.1.5). On transformers which have the problem of oil leak, the packing must be replaced and the oil must also be inspected. The insulation oil of LTC shall be replaced with new oil.

These renovation contents are summarized in the table below.

Transformer	Capacity x unit	Interior inspection	Withstand oil pressure Dissolved gas analysis	Change packing
Ubungo	MVA			
220 kV/132 kV	150 x 2	2	2	2
132 kV/ 33 kV	50 x 2	2	2	2
Ilala				
33 kV/ 11 kV	7.5 x 1	1	1	1
Oysterbay				
33 kv/ 11 kV	5 x 3	2	3	2
City Centre				
33 kV/ 11 kV	15 x 2	-	2	-
Factory Zone I				
33 kv/ 11 kV	5 x 3	1	3	1

(5) <u>Potential transformer</u>

As mentioned in 4.6.1, instrument transformer for the 132 kV circuit, which is faulty at present, shall be replaced with a new one. Fig. 8-1-7 shows a diagram related to this replacement.

(6) <u>Operation of section bus</u>

A section bus shall be operated based on the following concept. When one bank of transformers has tripped, it is preferable that the remaining bank can sustain the load and at the same two banks or more are operated in parallel on both of the primary and secondary sides, should there be no problem on the short-circuit capacity or induction trouble on communication lines. This is the same concept as parallel operation of multiple transmission lines, and the load can be transferred to a normal bank without power suspension even if one bank is shut down.

If there is a fear on automatic parallel operation of LTCs or the bank capacities are different, there is a merit to make outage range smaller at a time of shut down with a substation installed with a breaker at the bank primary side, and operation should be planned as a sectionarized bus.

For these reasons, we recommend that the Ilala and City Centre substations are operated as sectionarized buses.

(7) Insulation inspection by dissolved gas analysis for oil-immersed transformer

Foreseeing internal abnormality of the main transformer at as an early stage as possible and prevent a fault of the transformer is a very effective method to increase the reliability of power supply.

Conventionally, electrical inspections, such as, measuring of insulation resistance and tan δ, have mainly been used for the maintenance. However, since these require a large amounts of manpower, time and expenses, we recommend the method of insulation inspection based on analysis of gas contained in the oil.

This analysis makes use of abnormal phenomenon inside the transformer that usually accompanies heat generation. This heat generation is the result of insulating materials used inside the transformer such as paper, oil, press board and bakelite thermally decomposing into various gases such as CH_4 (methane), C_2H_2 (acetylene), C_2H_4 (ethylene), C_3H_8 (propane) and other low-grade hydrocarbon and H_2 (hydrogen), CO (carbon monooxide) and CO_2 (carbon acid gas). Most of these gases are solubable into insulation oil. Therefore, the inspections can be made to check normality or abnormality, type of trouble and degree by extracting gas from the oil and by analyzing the type, amount and composition of the gas.

Thus, this method can precisely examine the internal state of a transformer and it has been much used. Since the method allows inspections even during operation, we determined to adopt it on large transformers of major substations. It is very desirable that use of this method is standardized in the check guide.

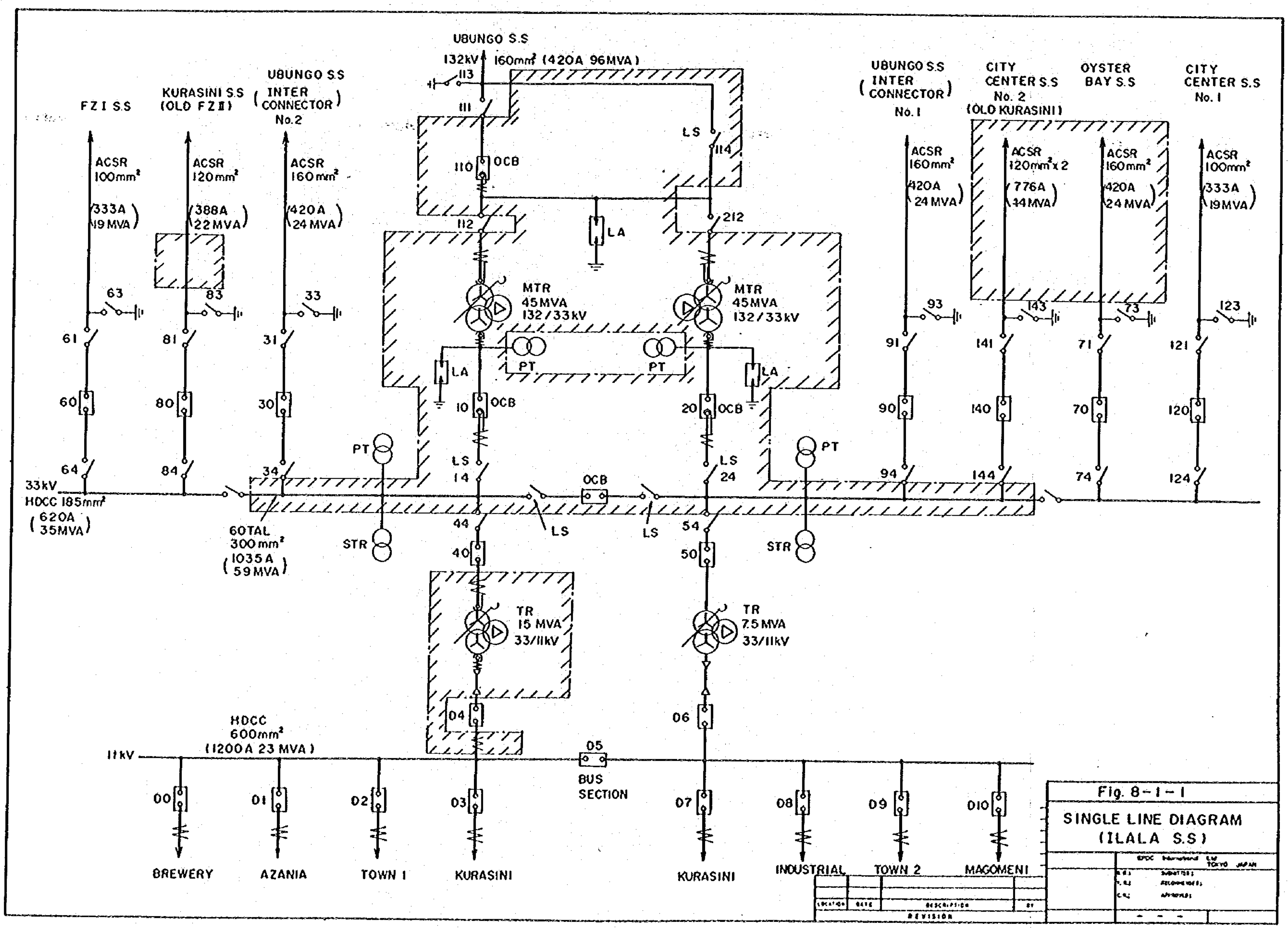


Fig. 8-1-1

SINGLE LINE DIAGRAM (ILALA S.S)

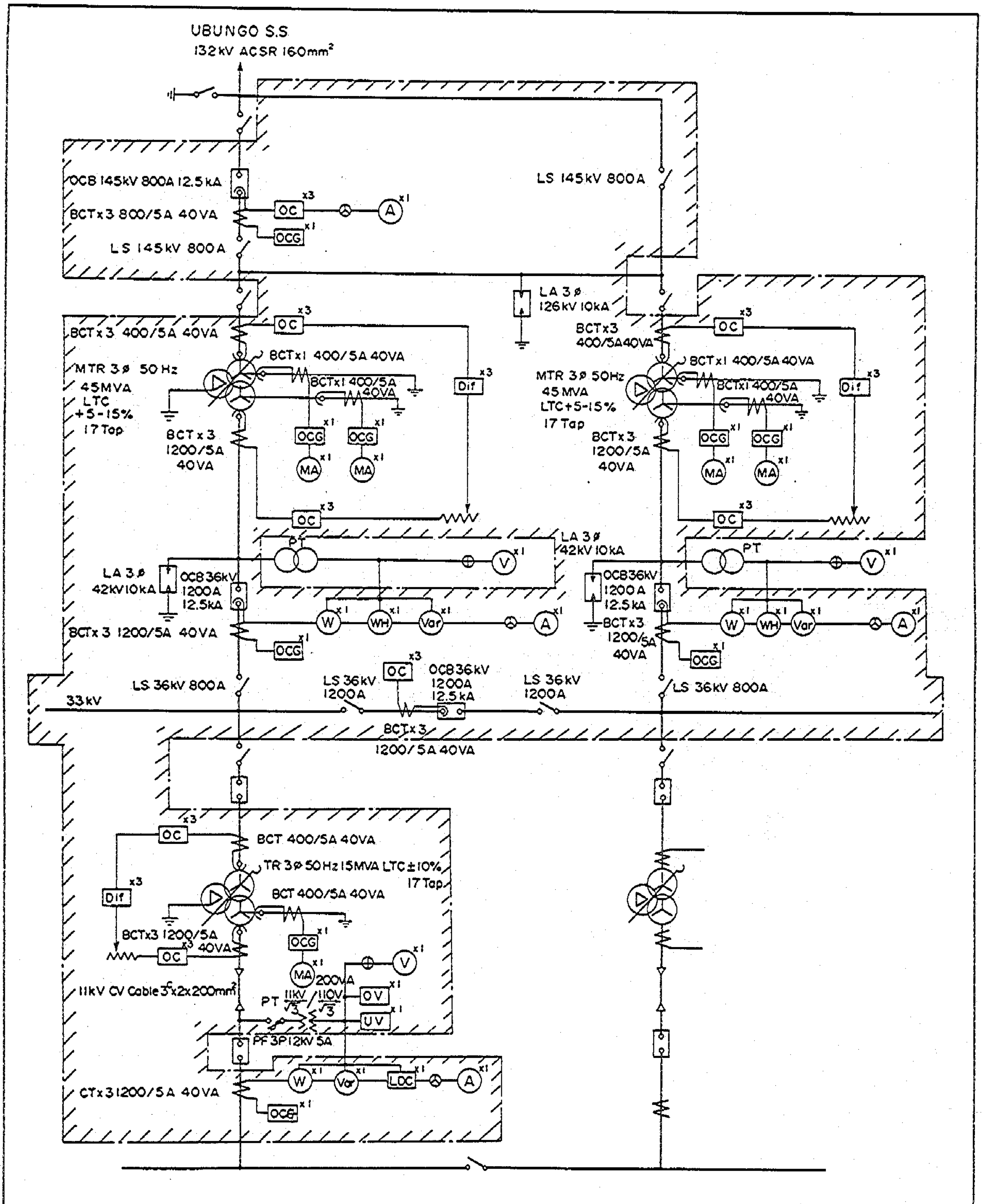


Fig. 8-1-2

SINGLE LINE DIAGRAM (ILALA S.S)

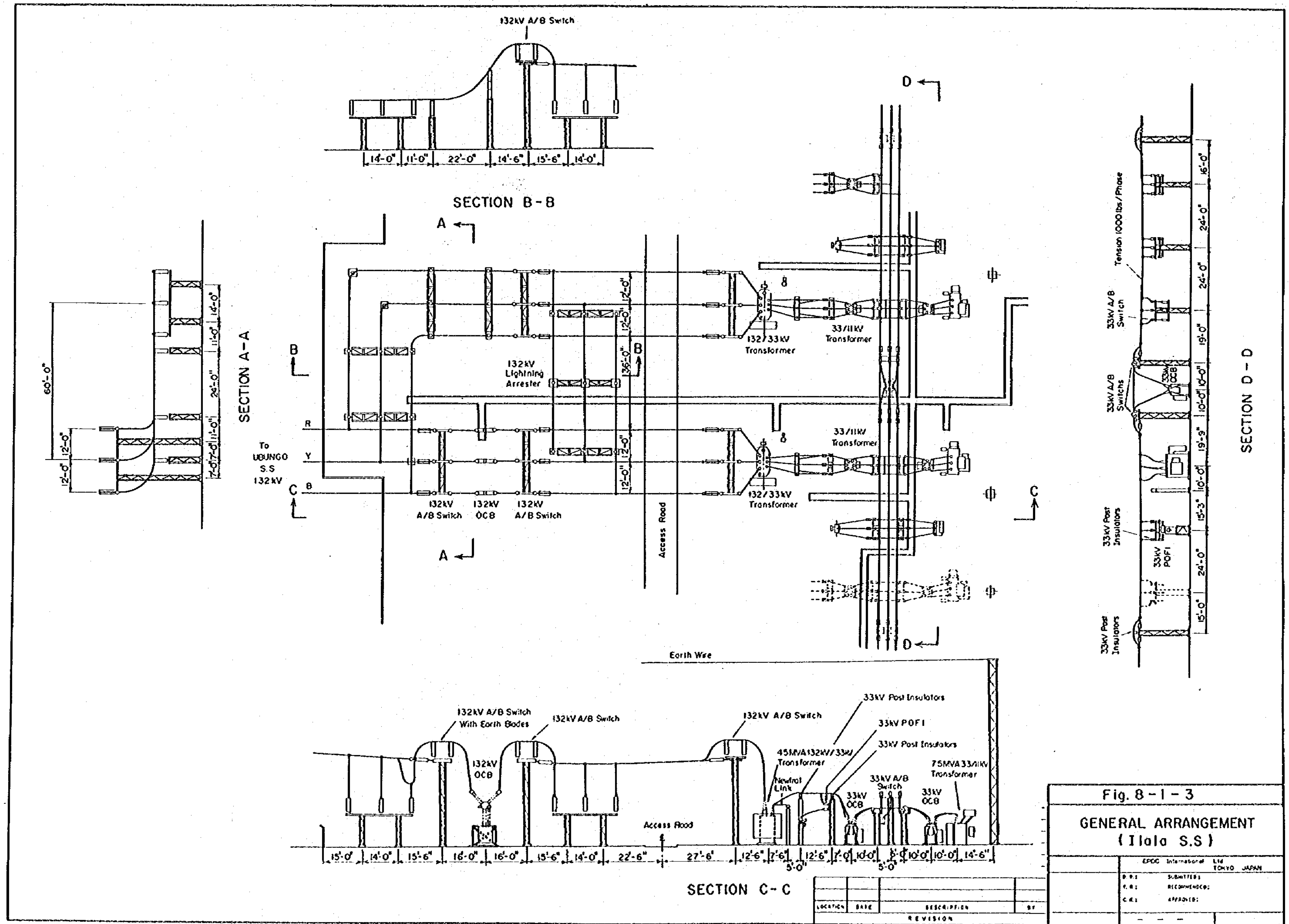


Fig. 8-1-3

GENERAL ARRANGEMENT
(Ilala S.S)

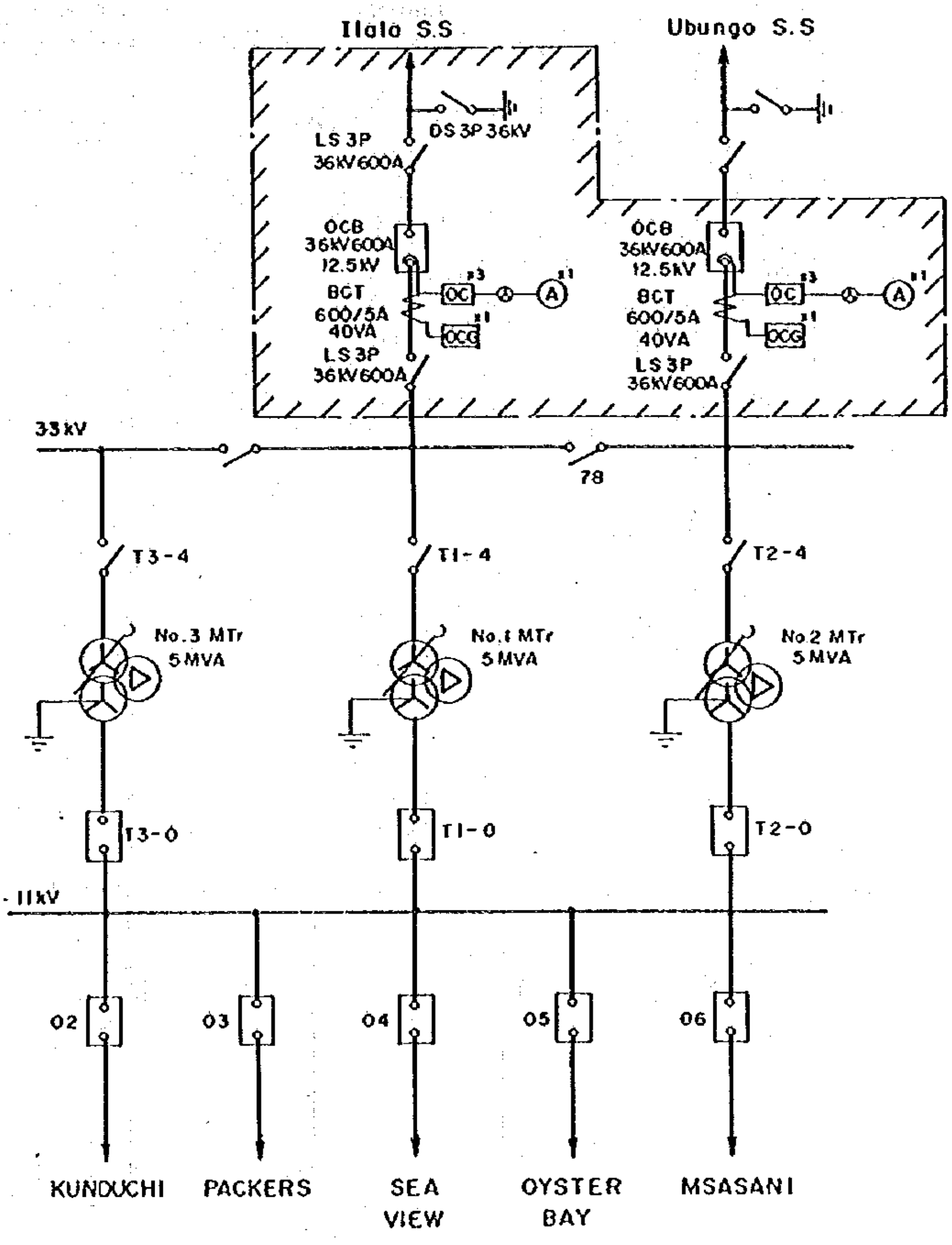


Fig. 8-1-4

SINGLE LINE DIAGRAM (OYSTERBAY S.S)

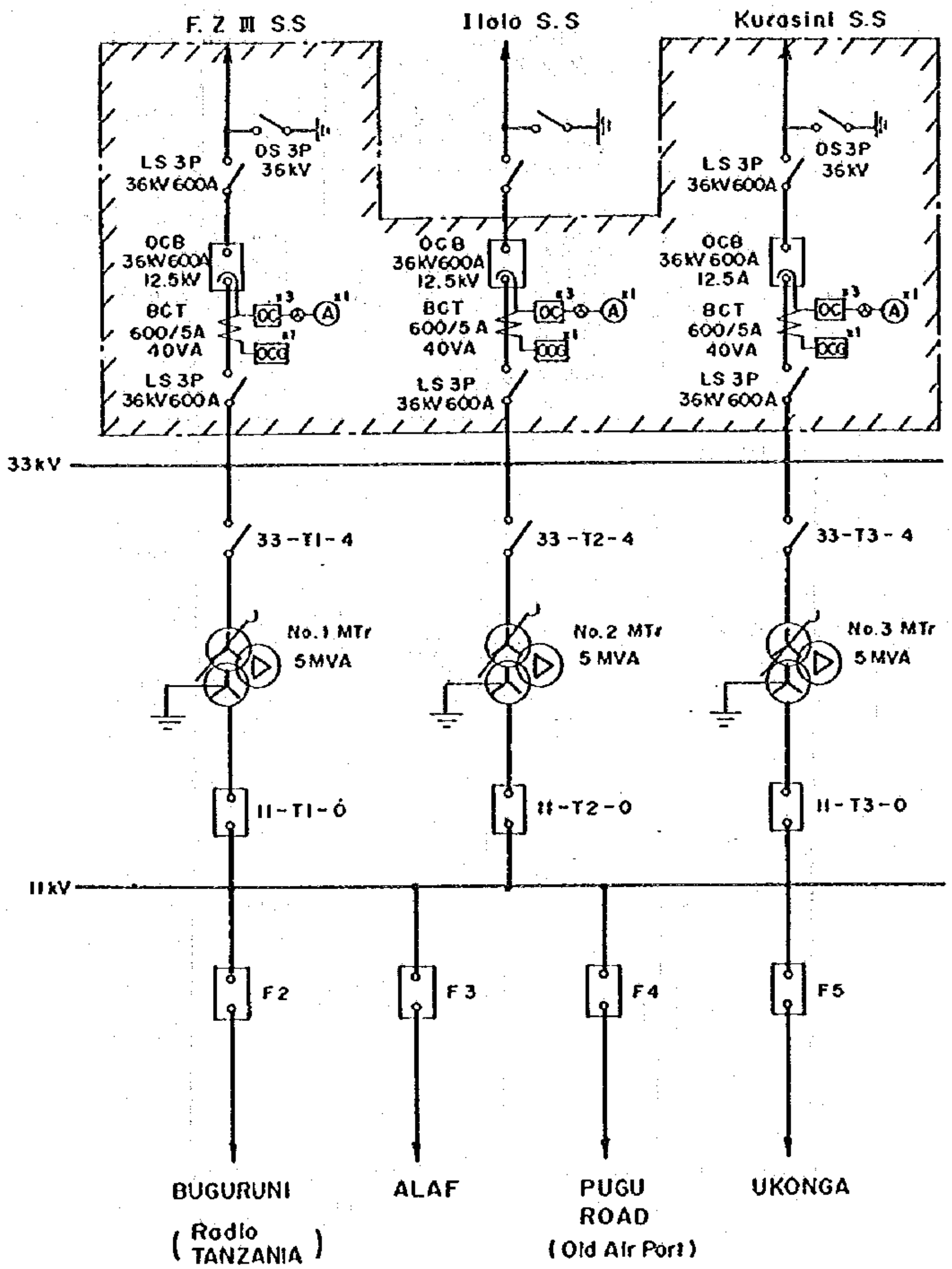


Fig. 8-1-5

SINGLE LINE DIAGRAM
(FACTORY ZONE I S.S)

EPDC International Ltd TOKYO JAPAN

SUBMITTED:
RECOMMENDED:
APPROVED:

LOCATION	DATE	DESCRIPTION	BY
REVISION			

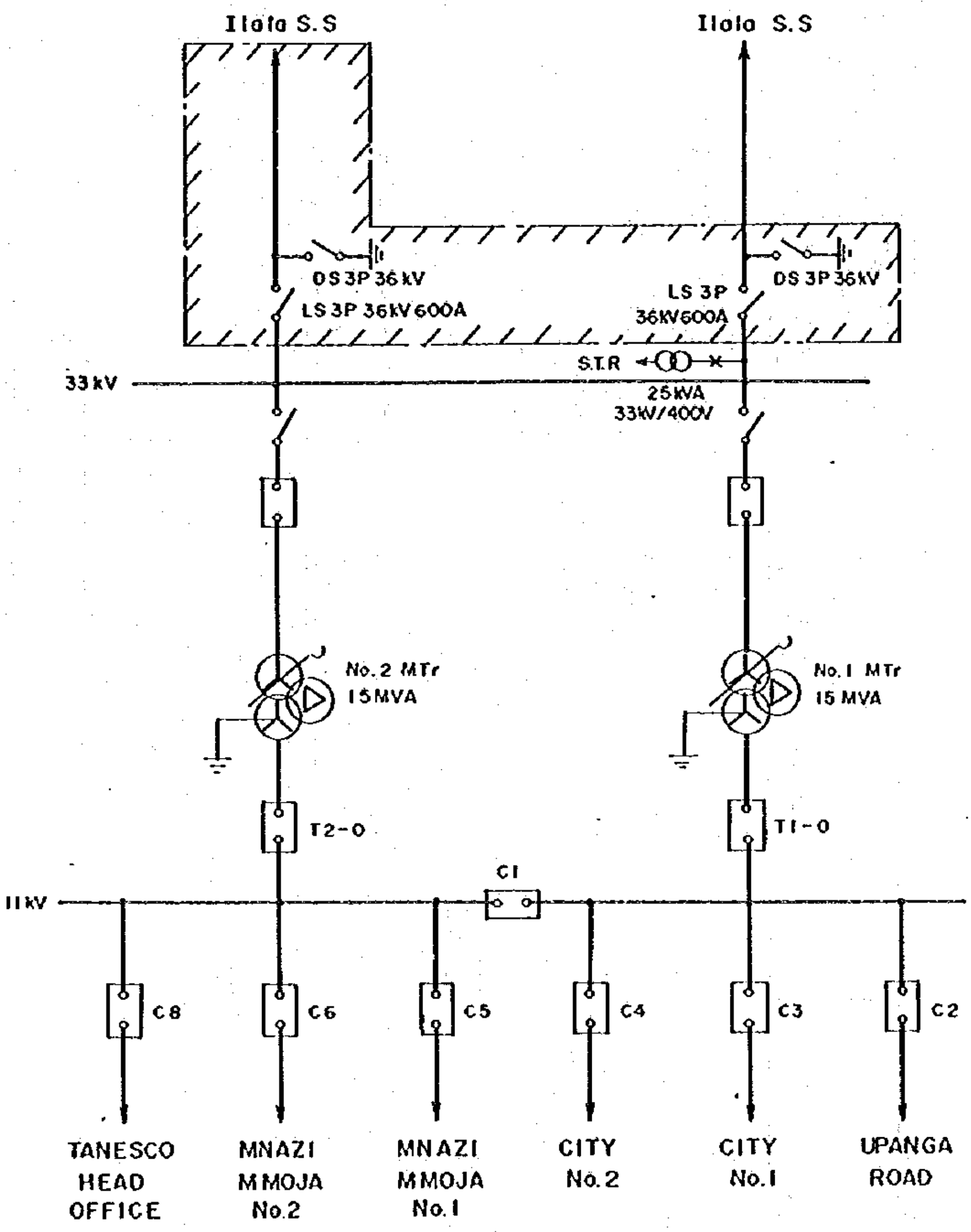
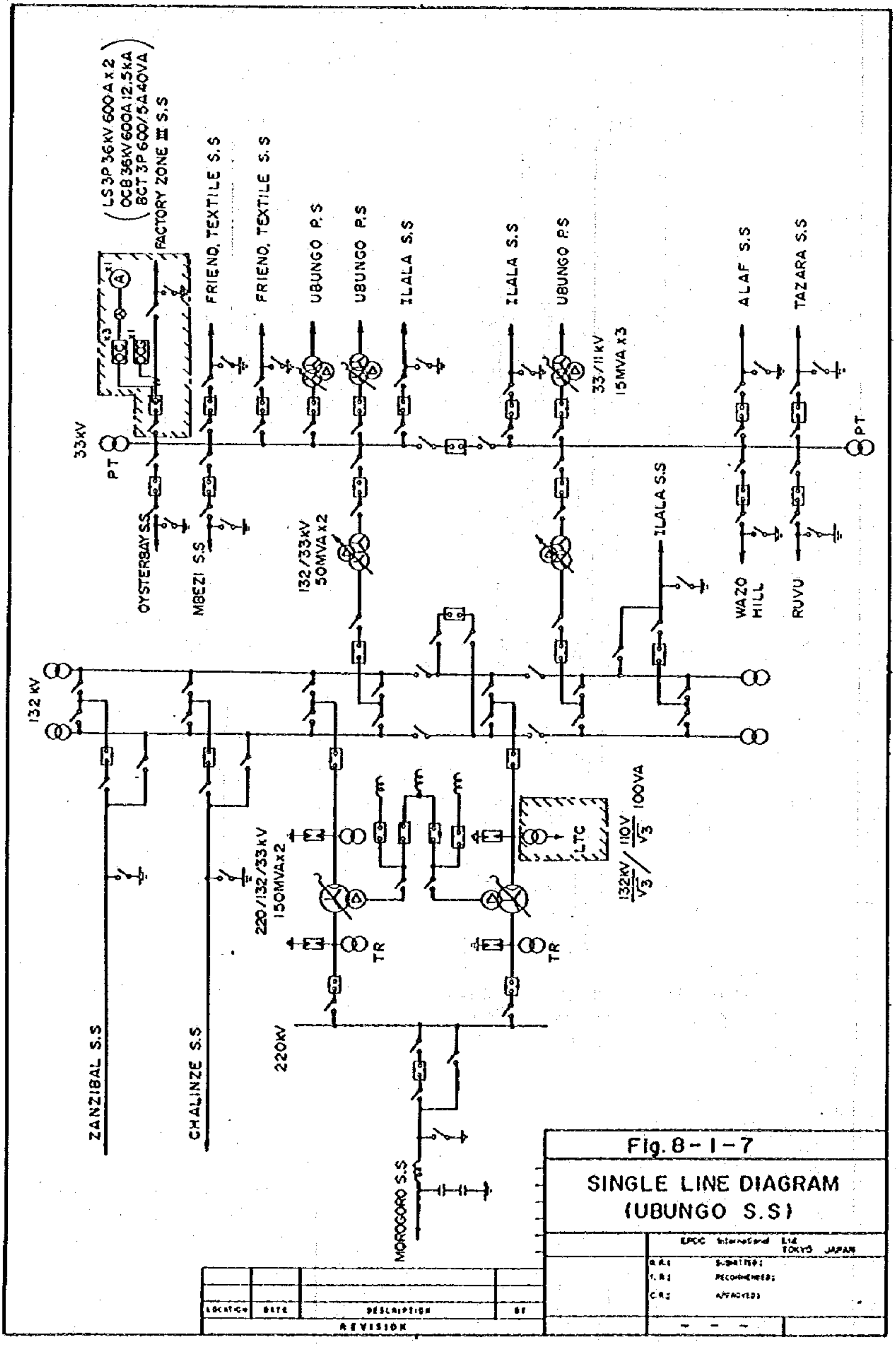


Fig. 8-1-6

SINGLE LINE DIAGRAM
(CITY CENTRE S.S)

EPDC International Ltd TOKYO JAPAN

LOCATION	DATE	DESCRIPTION	BY
REVISION			


LS 3P 36kV 600A x 2
OCB 36kV 600A 12.5kA
BCT 3P 600/5A 40VA
FACTORY ZONE III S.S
FRIEND, TEXTILE S.S
FRIEND, TEXTILE S.S
UBUNGO P.S
UBUNGO P.S
ILALA S.S
ILALA S.S
UBUNGO P.S
ALAF S.S
TAZARA S.S
33kV
PT
33/11kV
15MVA x3
PT
OYSTERBAY S.S
MBEZI S.S
132/33kV
50MVA x2
ILALA S.S
WAZO HILL
RUVU
132 kV
LTC
132kV/√3 / 110V/√3 100VA
220/132/33kV
150MVA x2
TR
TR
ZANZIBAL S.S
CHALINZE S.S
220kV
MOROGORO S.S
Fig. 8-1-7
SINGLE LINE DIAGRAM
(UBUNGO S.S)
EPDC International Ltd TOKYO JAPAN
SUBMITTED:
RECOMMENDED:
APPROVED:
LOCATION
DATE
DESCRIPTION
BY
REVISION

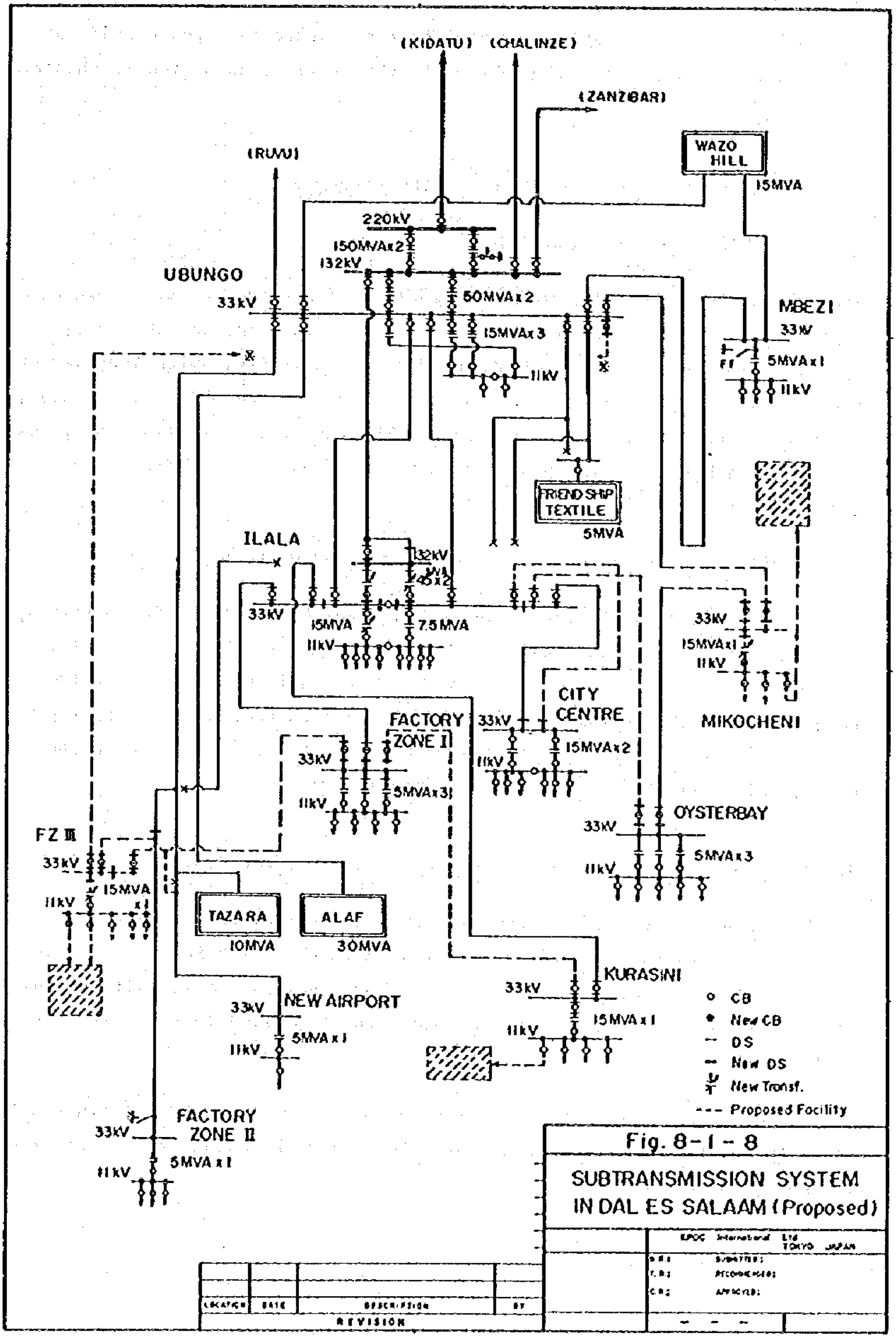


Fig. 8-1-8

SUBTRANSMISSION SYSTEM IN DAL ES SALAAM (Proposed)

8.2 33 KV SUB-TRANSMISSION LINE

The following rehabilitation program has been worked out upon consideration of the present situation and problems in the facility as stated in Chapter 4 (see Fig. 8-1).

8.2.1 Countermeasures to be taken in the first stage

(1) Switching-over of Kurasini line

Power supply to Kurasini S.S. is presently made from Ubungo S.S. through Textile No. 2 line. In this line, ACSR 50 mm^2 is used, and the carrying capacity will become insufficient in 1987. Accordingly, switching-over of the line from Ilala S.S. will be carried out by the end of 1986. However, the work of rehabilitation of the 132/33 kV transformers in Ilala S.S. must be completed beforehand. No new facilities for outgoing line will be necessary since the idle facilities can be used.

(2) Replacement of conductors between Ilala and Oysterbay

Power demand increase in recent years has been remarkable in the Oysterbay area where important loads exist. Since the line from Ugungo S.S. will become overloaded in 1988, some countermeasures will have to be provided before that time. To this end, it is effective to replace the existing ACSR 50 mm^2 lines between Ilala and Oysterbay substations with ACSR 160 mm^2 lines, which will be met power demand until 1993.

8.2.2 Transmission line related to proposed Mikocheni S.S.

The Mikocheni district is currently supplied with power from Oysterbay S.S., and new factory demands are estimated in this district. Oysterbay S.S. will become overloaded in 1986, so that a new substation will be built in the Mikocheni district to correspond with the demand in this district as stated in 8.1.3.

As the power supply line to the Mikocheni S.S., two ACSR 120 mm^2 lines will be built for 1.0 km by a -branching method from the existing line between Ubungo and Oysterbay.

8.2.3 Transmission lines related to proposed Factory Zone III S.S.

(1) Construction of new line between Ubungo and Factory Zone III

In the Tabata and Kiwalani districts located in southwest of Dar es Salaam, factory complexes are being rapidly developed in these years. These districts are being transmitted power from Factory Zone I S.S. However, in Factory Zone I S.S., it is extremely difficult to install an additional substation equipment due to the surrounding environmental restrictions. Accordingly, Factory Zone III S.S., on which details stated in 8.1.3, will be newly constructed to meet the power demands in these districts.

Power will be supplied to the newly built Factory Zone III S.S. via a 7.0 km new line from Ubungo S.S. in view of the conditions of location. The transmission line should be two circuits of ACSR 120 mm^2 to match the substation's capacity of 15 MVA x 2 (initially 15 MVA x 1). Initially, the conductor of ACSR 120 mm^2 will be provided only one circuit on the wooden pole designed two circuits, and the remaining one will be provided when the second 15-MVA substation will be built.

(2) Construction of Factory Zone II line

Factory Zone II is presently supplied with power from Ubungo S.S. at a distance of 15.2 km via TAZARA line. After completion of Factory Zone III S.S., power will be supplied to the power supply line of the existing Factory Zone II by 0.6 km of one circuit of ACSR 120-mm^2 line, and thus the power supply will be done at 13.2 km as shown in Fig. 8. Improvement of the reliability of power supply can be expected. A disconnecting switch will be installed at the connection point with the existing line.

(3) Construction of new airport line

At the present time, the new airport is supplied with power via one line of ACSR 100 mm^2 for 5.0 km, which is branched at the Ubungo-TAZARA line. After completion of the Factory Zone III S.S., Factory Zone III and existing airport line will be connected by 0.7 km of ACSR 120 mm^2 line to permit power supply for 1.3 km. Reduction of loss and improvement of reliability can thus be expected.

(4) Construction of Factory Zone I line

Increase of power demand for Factory Zone I S.S. will be met by Factory Zone III S.S., and the existing line between Ilala and Factory Zone I will not be reinforced.

However, with the present system there is no substitute power supply in case of emergency. Therefore, any trouble and/or failure in respect of power supply in the event of an accident will be serious. Accordingly, the Distribution Network Rehabilitation Program intends to newly construct one line of ACSR 120 mm^2 for 1.5 km between the TAZARA branching point of the TAZARA line to the existing new airport and Factory Zone I in order to secure a spare line in case of emergency.

(5) Construction of connecting line between Factory Zone I and Kurasini

Replacement of power supply method from Ugungo with direct from Ilala will meet the increase of demand in Kurasini. No shortage of power supply will be taken place for the time being, as stated in 8.2.1 (1).

However, one line of ACSR 120 mm^2 for 6.5 km will be built between Kurasini and Factory Zone I to secure a spare line in case of emergency in view of the power supply reliability improvement.

8.3 11 KV DISTRIBUTION LINE

8.3.1 11 kV feeder for the proposed substation

(1) Countermeasures for the Mikocheni S.S.

By withdrawing 3 feeders, M1, M2 and M3 from the Mikocheni S.S. which is now planned to be newly constructed and the M1 feeder is to be connected to the Oysterbay S.S. 03 feeder and supply power to the area where now served through the 03 feeder. This makes it possible to use the 03 feeder exclusively for the Msasani area, and since the supply to the heavy load area of Msasani is made through 2 feeders, 03 and 06, the heavy load problem can be solved. The M2 is connected to the Packers feeder of the Mbezi S.S. and the present 03 feeder, which is used for the official residence of the President. The remaining feeder M3 is used for the industrialization scheme in Mikocheni area (See Fig. 8-3-2).

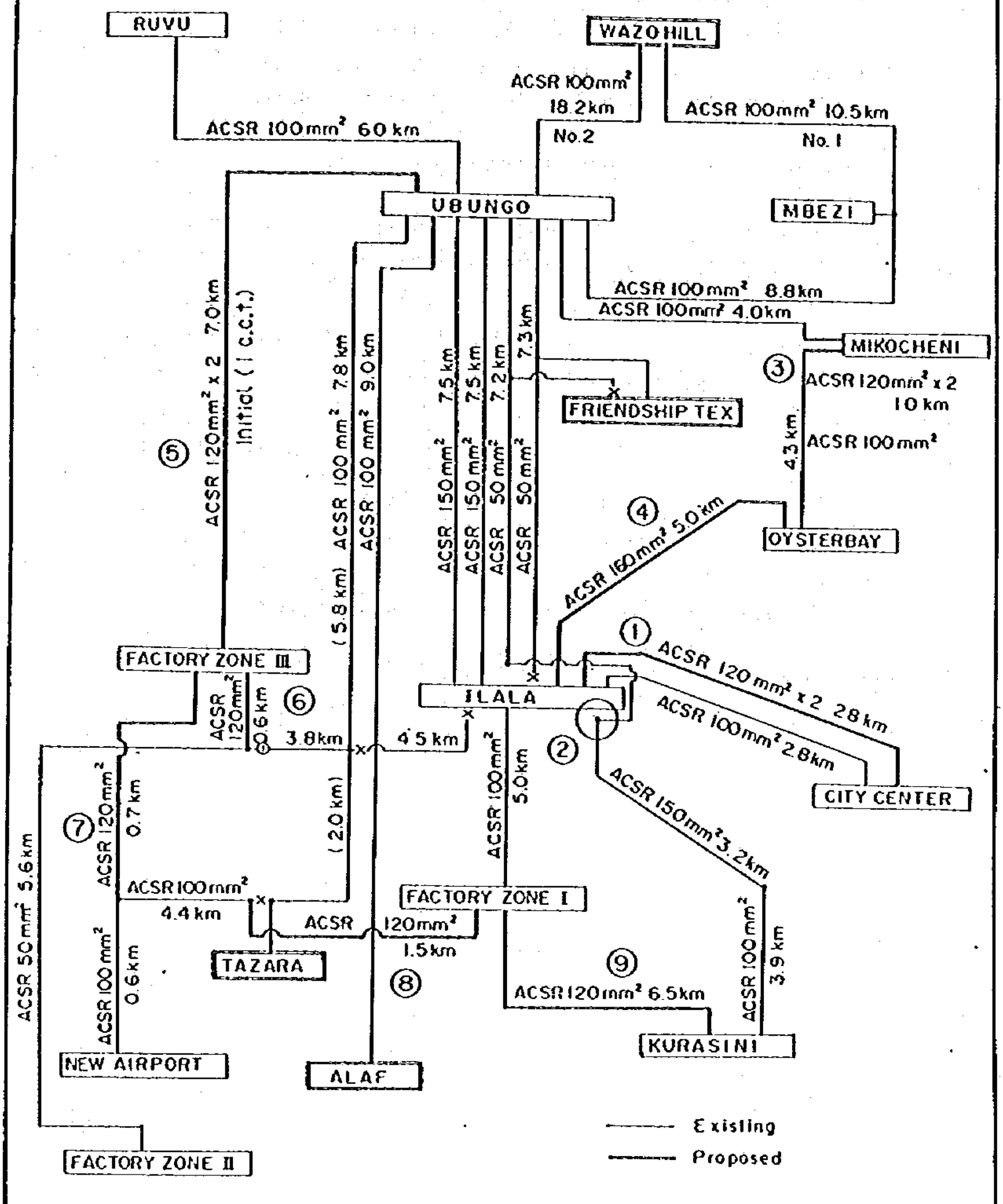


Fig. 8 - 2 - 1

33kV SUB-TRANSMISSION LINE SYSTEM

The contents of the plan are as follows:

(a) Underground cable: 0.3 km (11 kV CVTAZV 200 m^2 x 3C)
(b) Overhead line (trunk line): 5.0 km (ACSR 120 mm^2)
(c) Overhead line (branch line): 1.0 km (ACSR 58 mm^2)
(d) New installation of section switches: 2 units

(2) <u>Countermeasures for the Factory Zone III S.S.</u>

The heavy load of the Factory Zone I S.S. will be solved by withdrawing 5 feeders, F31, F32, F33, F34 and F35 from the Factory Zone III S.S. now planned to be newly constructed and connecting the F31 and F32 to the F4 and F3 of the Factory Zone I S.S. The F33 and F34 will be used for the new demand and will be made ready for the advance of factories anticipated in the future. The F35 is connected to the Factory Zone II S.S. for reinforcement. The contents of the plan are as follows (See Fig. 8-3-3).

(a) Underground cable: 0.5 km (11 kV CVTAZV 200 m^2 x 3C)
(b) Overhead line (truck line): 6.5 km (ACSR 120 mm^2)
(c) Overhead line (branch line): 3.0 km (ACSR 58 mm^2)
(d) New installation of section switches: 6 units

The specific contents of the above (1) and (2) are listed in Table 8-3-1.

Table 8-3-1 New feeders for the proposed substations

Item / Feeder	Underground Line (km) 200 sq mm x 3	Overhead Line (km)		Section Switch	Remarks
		ACSR 120	ACSR 58		
Msasani S.S.					
M1	0.1	1.5		1	To be connected with 03
M2	0.1	1.5		1	To be connected with Mbezi S.S.
M3	0.1	2.0	1.0	2	For new demand
Factory Zone III S.S					
F31	0.1	0.5		1	To be connected with F4
F32	0.1	1.5	1.0	1	To be connected with F3
F33	0.1	2.0	1.0	2	For new demand
F34	0.1	2.0	1.0	2	"
F35	0.1	0.5		2	To be connected with F.Z. II S.S.
Total	0.8	11.5	4.0	10	

8.3.2 Countermeasures for system interconnection

In order to minimize the service interruption area and interchanged power during power-off working or faulty period, the system interconnection work as shown in Table 8-3-2 is to be conducted and the section switches will be installed. (See Figs. 8-3-1, 8-3-2 and 8-3-3)

The contents of the plan are as follows:

(a) Overhead line linkage: 5.5 km (ACSR 120 mm^2)

(b) Underground line: 2.7 km (11 kV CVTAZV 200 mm^2 x 3C)

(c) Multi-circuit switch: 4 units

(d) Section switches: 9 units

Concerning the C5 and C6 feeders of the City Centre S.S. which are 100% underground lines, the C6 will be improved and 4 multi-circuit switch boxes will be installed for reinforcement. By doing so, C6 will cover the C5 supply area. The C5 thus became unnecessary will be used for load sharing in the Upanga area (See Fig. 8-3-1).

Table 8-3-2 System interconnection

Item / Feeder	Underground Line (km) 200 sq.mm x 3	Overhead Line ACSR 120	Section Switch	Remarks
C5 - C2	0.5		1	Upanga Area
C6 - D2	0.6		1	Independence Av.
C6 - the city	1.6	0.5		Multi-circuit Switch Boxes: 4 units
C4 - D2		1.5	2	Independence Av.
D1 - Port Feeder		0.5	1	Ilala S.S. - Kurasini S.S.
F2 - Kilwa Feeder		1.5	1	F.Z. I S.S. - Kurasini S.S.
F5 - D8		0.5	1	F.Z. I S.S. - Ilala S.S.
O5 - O4		0.2	1	Oysterbay S.S.
C2 - D10		0.8	1	City Centre S.S. - Ilala S.S.
Total	2.7	5.5	9	

8.3.3 Extension of branch lines

In step with the new installation of transformers as the countermeasures for a new demand described in 8.4.2, the extension of the 11 kV branch lines is planned as follows (See Table 8-3-3).

(a) Overhead line: 10.0 km (ACSR 58 mm^2)

(b) Underground line: 2.4 km (11 kV CVTAZV 38 mm^2 x 3C)

(c) Installation of section switches: 10 units

Table 3-3-3 Extension of branch lines

Item / Feeder	Underground Line (km) 38 sq.mm x 3C	Overhead Line ACSR 58	Section Switch
Msasani		2.0	2
Upanga		2.0	2
Oysterbay		2.0	2
City Centre	2.4	2.0	2
Ilala		2.0	2
Total	2.4	10.0	10

8.3.4 Replacement of deteriorated overhead conductors

The deteriorated conductors and small size conductors will be replaced to improve the carrying capacity and the defective connection parts of conductors will be repaired. Even through this plan only, it is considered that the supply reliability of the 11 kV network in the city of Dar es Salaam will be considerably improved (See Table 8-3-4).

(1) Overhead lines

(a) Trunk line: 58.5 km (ACSR 120 mm^2)

(b) Branch line: 21.0 km (ACSR 58 mm^2)

(2) Reinforcement of poles: 140 poles (wooden poles 70, steel poles 70)

(3) Reinforcement of stay wires: 200 places

(4) Installation of section switches: 25 units

Table 8-3-4 Replacement of deteriorated overhead conductors

Item / Feeder	Overhead Line (km)		Section Switch
	ACSR 120	ACSR 58	
Oysterbay S.S.	(14.9)	(5.0)	(6)
02			
03	5.0	1.0	2
04	7.0	1.0	1
05	2.9	2.0	2
06		1.0	1
City Centre S.S.	(9.4)	(2.0)	(5)
C2	5.0	2.0	2
C3	1.8		1
C4	1.3		1
C5			
C6			
C8	1.3		1
Ilala S.S.	(19.2)	(7.0)	(8)
D1	2.0		1
D2	3.8	2.0	2
D3			
D8	4.0	2.0	2
D9	1.9	1.0	1
D10	7.5	2.0	2
F.Z. I S.S.	(15.0)	(7.0)	(6)
F2	6.5	2.0	1
F3	1.5	2.0	1
F4	4.5	2.0	2
F5	2.5	1.0	2
Total	58.5	21.0	25

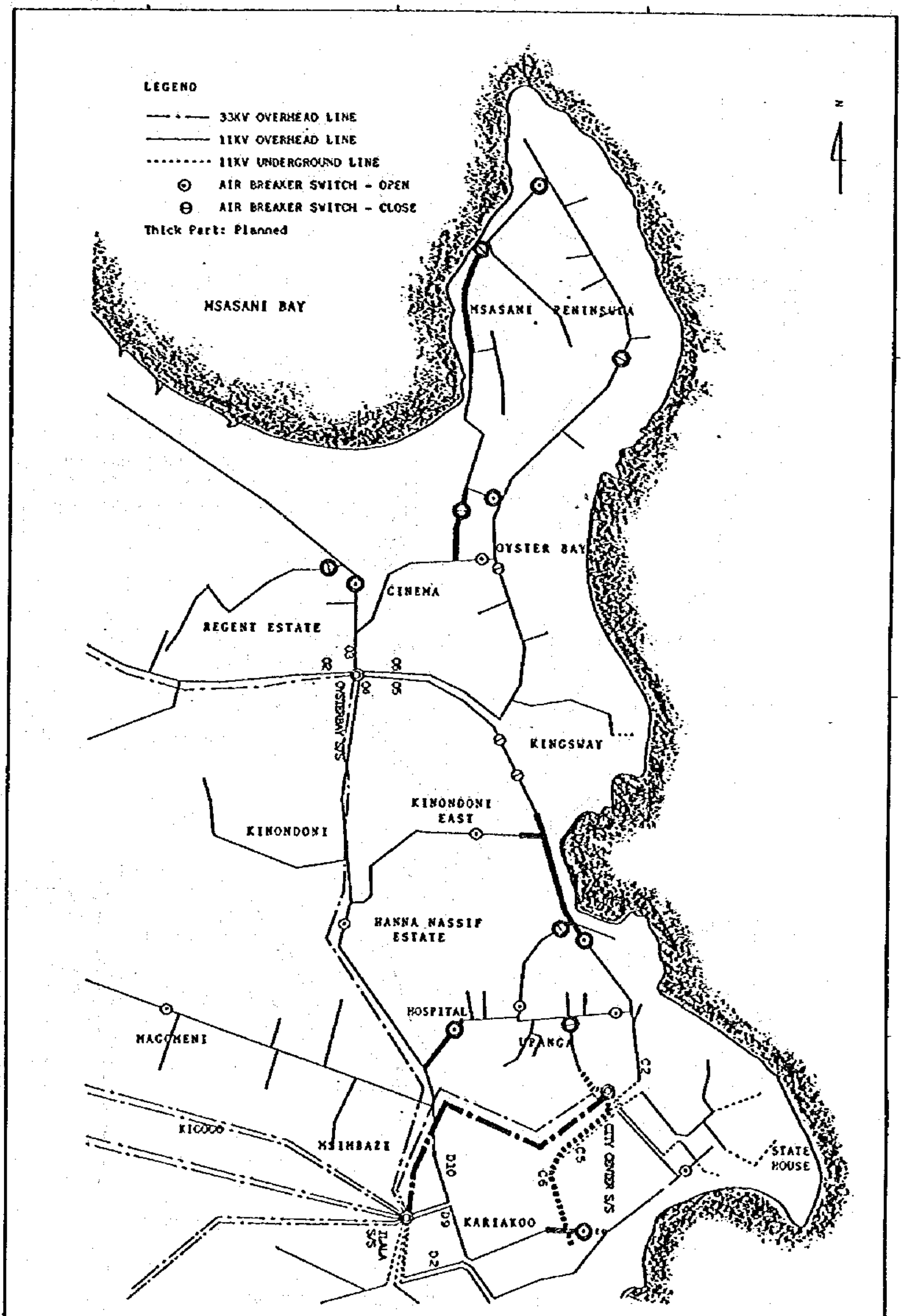


Fig. 8-3-1 DISTRIBUTION NETWORK PLANNED

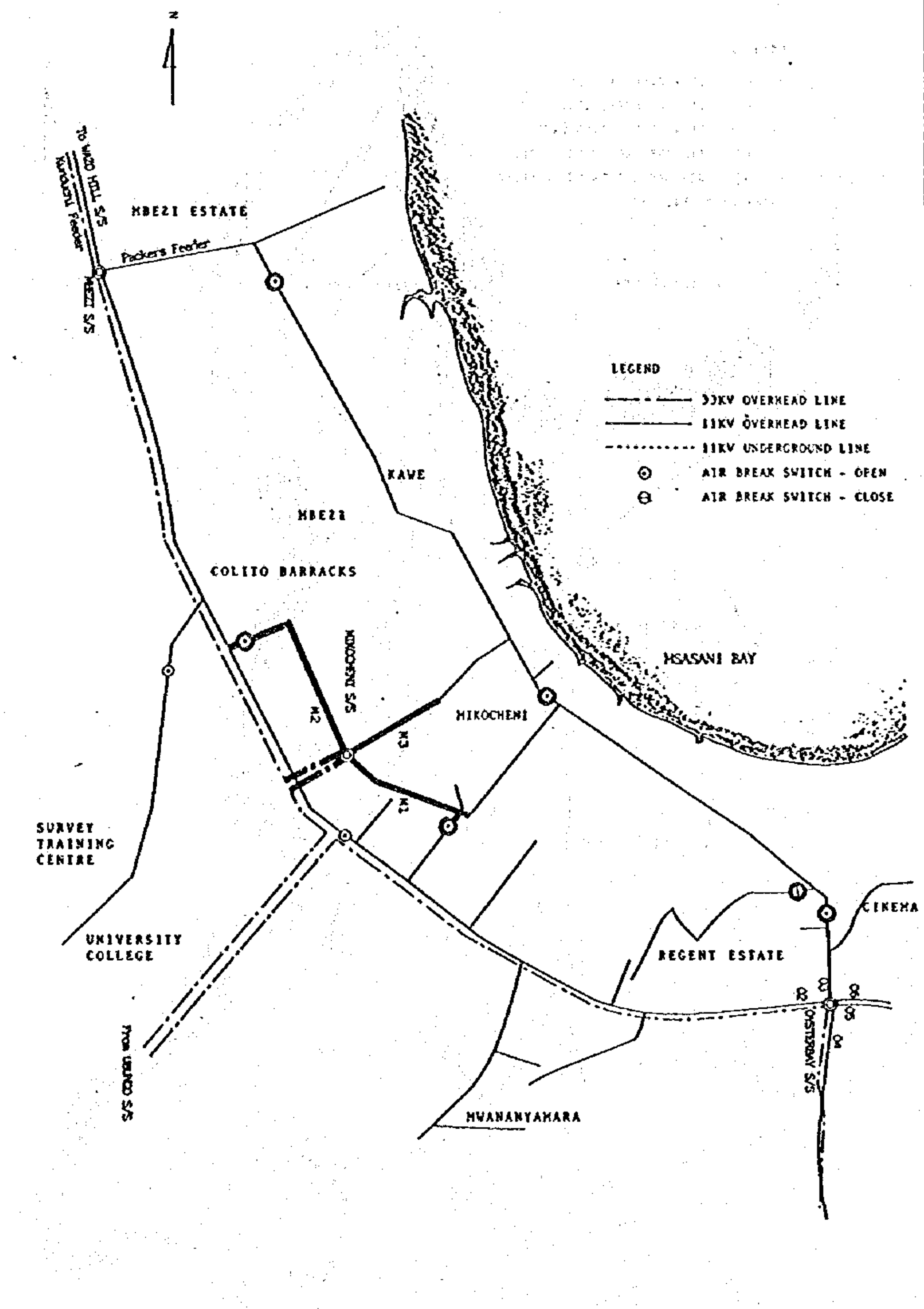


Fig. 8-3-2 DISTRIBUTION NETWORK PLANNED

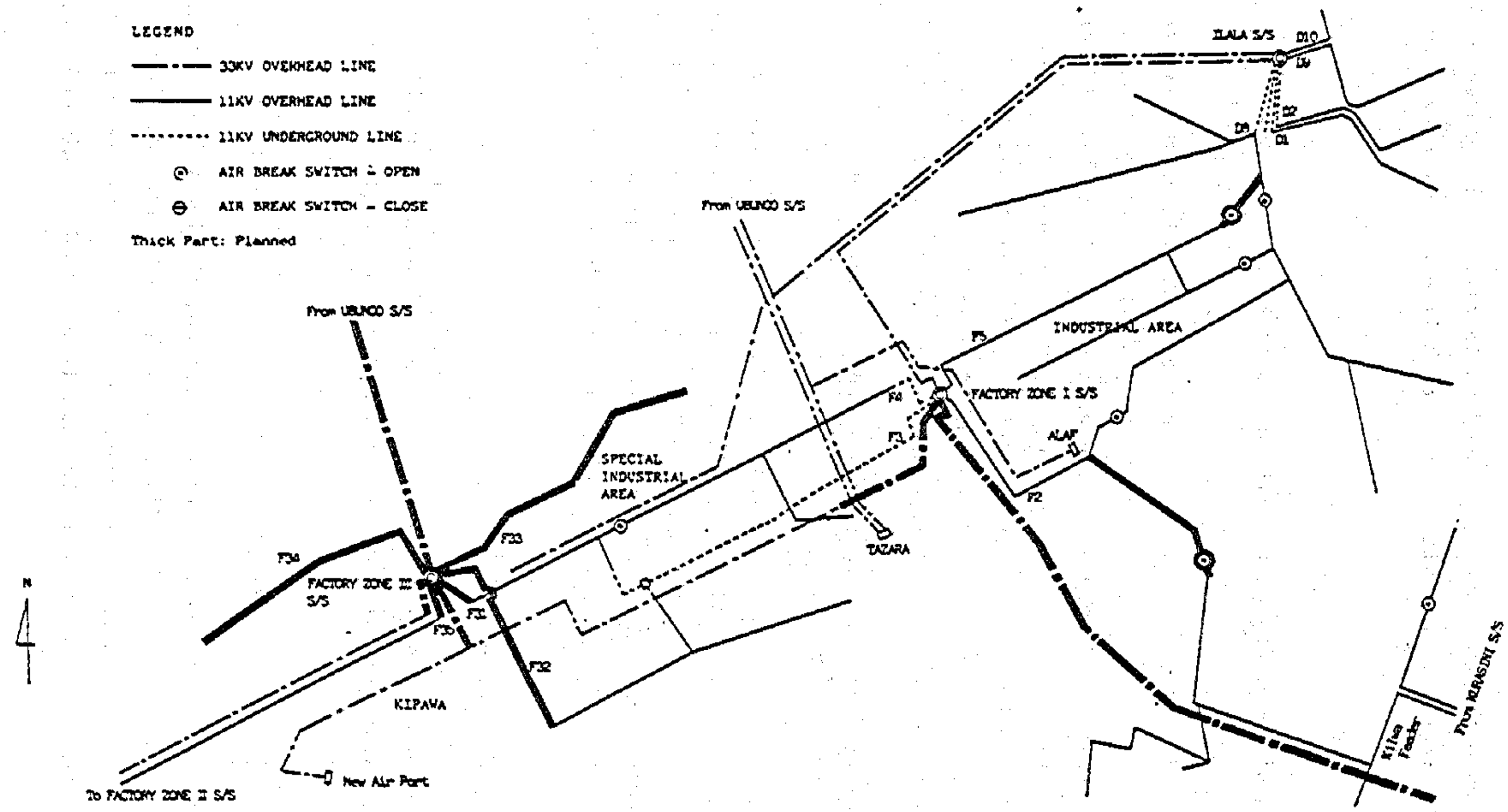


Fig. 8-3-3 DISTRIBUTION NETWORK PLANNED

8.3.5 Countermeasures for thunder

Installation of arrester 60 banks is planned to install at the places of 11 kV feeder usually open section switches and trunk line cable rising places.

8.4 LOW VOLTAGE LINE

8.4.1 Repairing of deteriorated facilities and improvement of service voltage

The total number of transformers in the target area of this project is 285 banks (88,775 kVA). 31 banks for Msasani area, which are improved based on the emergency materials aid program, are excepted from 285 banks. 60% of the balance 254 bank; i.e. 153 banks are entirely repaired. Especially, the deteriorated transformer protective devices and electric wires and cable connection places will be repaired to eliminate the causes for trouble and at the same time the entire line will be reinforced.

(1) Repairing of transformer primary and secondary sides protective devices and connections

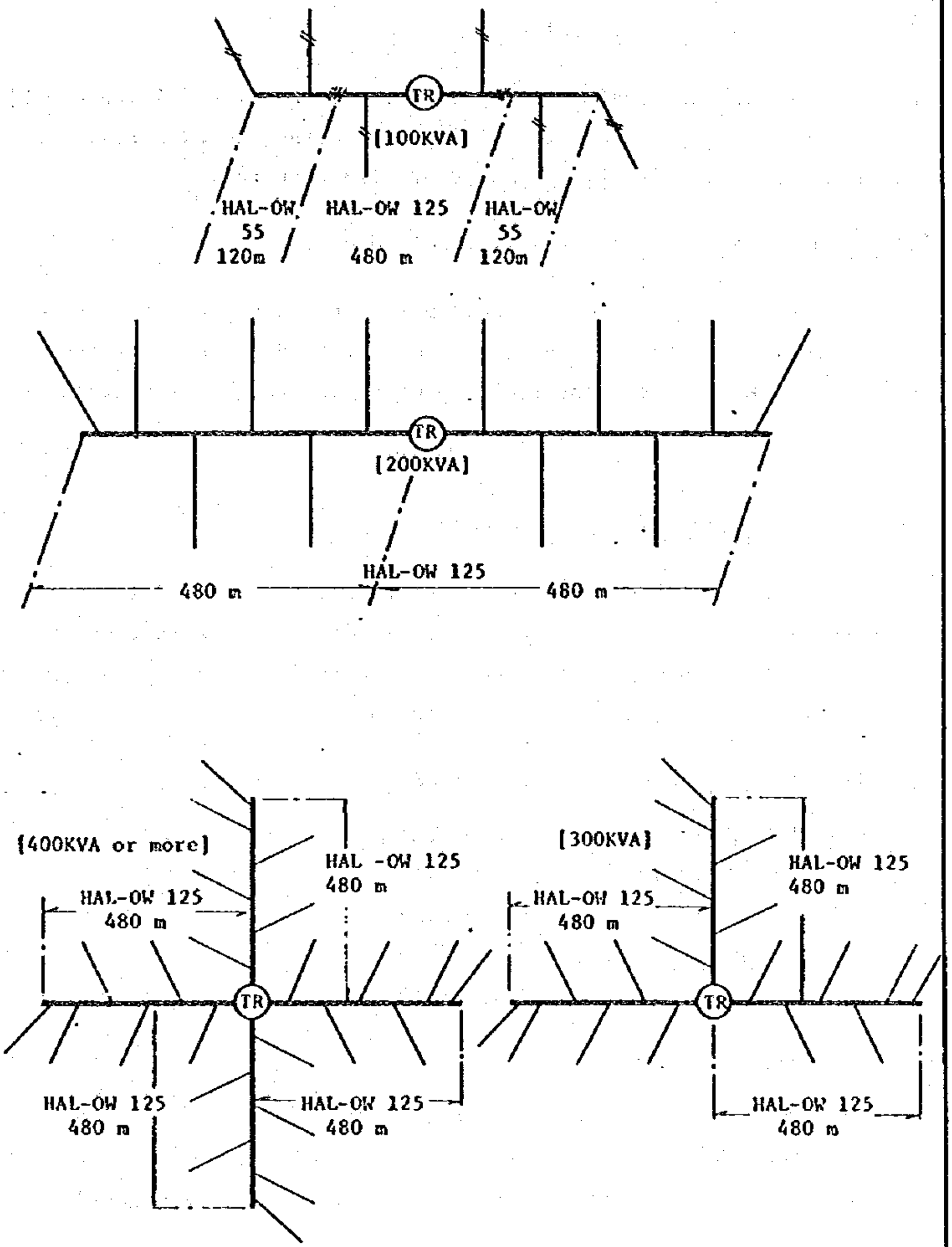
The transformers of 300 kVA or higher will be protected by the open fuse cutout for the primary side and by the distribution pillar for the secondary side. The transformers of lower capacity will be protected by the presently adopted system, i.e. the open fuse cutout for the primary side and by the low voltage cutout for the secondary, and the connections will also be repaired.

(2) Installation of distribution pillar

Of 153 transformer banks to be repaired this time, 83 banks of 300 kVA or higher will be provided with the distribution pillar as stated in the above (1).

(3) Wire replacement and extension

Concerning the transformer 153 banks to be repaired, the low voltage trunk line 190 km and branch line 290 km will be replaced and extended. Low voltage lines of each transformer are modelled as shown in Fig. 8-4-1 and the necessary volume of electric wire is calculated based on this model as follows:



Trank Line (3P4W)

Branch Line (1P2W, HAL-OW 55)

Fig. 8-4-1

MODEL OF LOW VOLTAGE LINES

LOCATION	DATE	DESCRIPTION	BY
REVISION			

(a) Trunk line: HAL-OW 125 mm^2, 751 km

(b) Branch line: HAL-OW 55 mm^2, 610 km

(4) Replacement of service line

On the basis of the local sampling survey (see Figs. 4-5-1 and 4-5-2), about 24,000 service lines will be replaced using the DV wires. The required volume of wire is 480 km of DV wire in total.

(5) Support replenishment and stay reinforcement

In order to replace the deteriorated poles, total 600 poles, 300 poles each of 9 m steel poles and wooden poles are estimated. Also estimated are the stay materials to meet about 2,000 poles to secure the mechanical strength of the lines.

8.4.2 Countermeasures for new demand

In order to cope with the future demand increase described in Chapter 6 and the general demand increase for the new feeders to be withdrawn from the substations to be newly constructed as described in 8.1.3, the new installation of transformer 35 banks (8,500 kVA) is planned as follows:

(1) Transformers to be newly installed

(a) 100 kVA: 10 units (1,000 kVA)

(b) 200 kVA: 10 units (2,000 kVA)

(c) 300 kVA: 10 units (3,000 kVA)

(d) 500 kVA: 5 units (2,500 kVA)

Total: 35 units (8,500 kVA)

(2) Protective devices

(a) Primary side open fuse cutout: 35 sets

(b) Secondary side low voltage cutout: 60 pcs.

(c) Distribution pillar: 15 units (for 300 kVA or higher)

(3) Low voltage lines to be newly installed

(a) Trunk line : 36 km (HAL-OW 125 mm^2)

(b) Branch line: 63 km (HAL-OW 55 mm^2)

(4) Service lines to be newly installed: 5,700 lines

(5) Support

(a) Steel poles : 800 poles

(b) Wooden poles: 1,600 poles

8.5 VEHICLES AND TOOLS USED FOR THE CONSTRUCTION WORK

8.5.1 Vehicles

The number of vehicles which TANESCO has at present is very limited. Therefore, they are not enough for daily maintenance work and/or emergency duty work including accident treatment, restoration work, etc. Especially, the vehicles used for the work of construction are mostly of an old type, and because of imperfect maintenance or shortage of spare parts, the operational efficiencies of the construction team and accident treatment & restoration work team are at a very low level.

The small-sized vehicles used for the construction work are seldom provided. Therefore, even for the construction work in the city center and/or in the housing area where houses are closely built, the large-sized vehicles are obliged to be used. Such environmental conditions interferes for workers to take the swift and prompt activities. In addition, therefore, the daily inspection drive which should be carried out as the basic duty has never taken place.

Based on these facts which have been made clear by the survey conducted at this time, it seems to be impossible that the construction work shall proceed only by the vehicles owned by TANESCO. Accordingly, the vehicles which are shown in Table 8-5-1 are necessary to be provided for this construction project. The greater part of this plan is the restoration construction work of the existing facilities. Therefore, this restoration construction work includes the factors of serious occurrency of the disasters due to the service interruption work, load switching, etc.

Therefore, when actually operated, all the construction sites and all the working groups communicate closely with each other to secure the safety, to shorten the service interruption time, and to carry out the correct and efficient construction work.

To accomplish this, the VHF transceivers are to be provided for all the vehicles to be used as shown in Table 8-5-1.

At present, Tanzania suffers also from the chronic shortage of spare parts for the vehicles. As a result, the life time of a vehicle is very short. Many vehicles are driven under poor conditions; leaving the troubled situations as they are. Accordingly, such a situation seriously influences the occurring of vehicles accidents especially accidents under the construction operations.

In order to remove these dangers and insure the safely construction work, sufficient considerations concerning the supply of spare parts, wear and tear parts, etc., must take place and the decision of appropriate parts selections and their quantities must also be made. These decisions are indispensably necessary.

Table 8-5-1

Vehicles \ Team	Construction	Materials	Design	Coordination	Management	Total
1. 6 ton crane truck	1	-	-	-	-	1
2. 6 ton truck	2	2	-	-	-	4 (4)
3. 3 ton crane truck	4	1	-	-	-	5
4. High place operation vehicle	6					6
5. Pick-up truck	6	1	-	-	-	7 (2)
6. 4WD wagon	-	-	2	2	2	6 (6)
7. Motorcycle	10					10 (10)
8. Forklift truck	-	2	-	-	-	2

(Note) 1. The figures shown in ( ) are the supply quantities based on the emergency materials aid.
2. Transceivers are provided except for Nos 1, 7 and 8.

8.5.2 Tools and measuring instruments

The tools and measuring instruments which have been prepared for TANESCO's construction team and for the accident restoration team are extremely deficient and daily inspection work is impossible for execution. Even rubber-made dielectric gloves, voltage detectors, etc. which are indispensable necessary for the securing of safety operational work have not been provided. Such environmental conditions largely depresses the moral of the workers and influences to induce a bad quality construction level which are main factors to cause serious accidents. In order to overcome these present difficulties as well as to develop a safely and stable work, the following tools are indispensably needed.

(a) Portable tools for individual worker such as cutting pliers, spanners, knives, etc.

(b) Safety protection devices such as voltage detectors, low-tension rubber-made gloves, etc.

(c) Tools provided for each team such as drilling and cutting tools, tools for electric wire connections, tools for stringing, etc.

(d) Tools for cable operation

(e) Safety marking and indicating tools

(f) Ammeter and voltmeter for live line

(g) Recording ammeter and voltmeter

(h) Others

The necessary training regarding how to use the tools and how to maintain these tools must also be carried out.

8.6 OTHER SUPPLEMENTARY FACILITIES

(1) Electric power supply monitoring communication system

The communication network shall be constructed between 1) the Ilala Manned Substation and 2) the Oysterbay Substation, the City Center Substation, the Factory Zone I Substation, which have been surveyed at this time, and 3) the planned Mikocheni Substation, Factory Zone III Substation.

There are two communication methods, i.e., 1) the existing wire method and 2) the wireless method using VHF. In case of the existing communication system utilizing a pilot wire, destruction of the utility poles have occurred relatively many times caused by automobiles, etc. Their maintenances are difficult due to the shortage of poles and related materials, therefore, TANESCO is expecting the wireless method.

On the other hand, in case of VHF, it is possible to keep high reliability and the providing period is short with a low construction cost. Accordingly, as the communication method between the Ilala Substation and each of the substations, we have adopted the VHF method.

(2) <u>Countermeasures for voltage drop at the Ruvu Substation</u>

As mentioned in 4-6-1 (5), as the countermeasures for voltage drop at the Ruvu Substation, after two units of 132 kV/33 kV transformer (10 MVA) will be dismantled from the Ilala Substation, they will be used for the Ruvu Substation. The Ubungo-Chalinze 132 kV transmission line passes through the adjacent area of the Ruvu Substation. In this area, the new Ruvu Substation (132 kV/33 kV 10 MVA x 2 units) will be constructed in order to solve the voltage drop problems. This might be the best solution.

Since this matter is not included in the scope of this study conducted at this time, the method of execution will be discussed in another way.

CHAPTER 9

CONCEPTUAL DESIGN

CHAPTER 9 CONCEPTUAL DESIGN

CHAPTER 9 CONCEPTUAL DESIGN

9.1 DESIGN CONDITION

The conceptual design for distribution facilities which are going to construct in this project has been made based on the existing design criteria of TANESCO and also based on Japanese standard design practice.

As for the standards for the materials and equipment which are going to be procured with foreign currency, mainly Japanese standards, ANSI and BS standards as well for some items have been employed.

(1) Meteorological condition

(i) Elevation: less than 1,000 m above the sea level

(ii) Temperature

Maximum	40°C
Minimum	10°C
Mean	32°C

(2) Safety factor

In accordance with Japanese standards following figures are employed.

Items	Safety Factory
Supports	3
Foundation	2
Conductor	2.5
Insulator	2.5
Crossarm	2.5
Guy wire	2.5

(3) Conductor temperature

Allowable temperature rise: 90°C

(4) Wind load

From TANESCO design criteria; maximum wind velocity is 28 m/s, the wind load on the wire and wooden pole has been estimated 50 and 40 kg/m^2 respectively.

(5) Vertical clearance of overhead line

According to TANESCO criteria, minimum vertical clearance has been employed as follows. For low tension voltage line, however, Japanese standards have been employed.

Description	33 kV Line	11 kV Line	LT (including neutral line)
Ordinary place	5.0 m	4.8 m	4.0 m
Road crossing			
Vehicle passable	6.7	6.0	6.0
Vehicle impassable	6.0	4.8	4.0
Railroad crossing	9.0	9.0	9.0
Telecommunication line crossing	1.8	1.8	1.2

9.2 INSULATION DESIGN

(1) Insulation design

In order to protect lines and equipment from an inrush of lightning surge and low frequency abnormal voltage, the design was made by putting a coordinated insulation level among them and employed following criteria.

(i) For internal abnormal voltage (switching surge, persistent power frequency voltage etc.), a protection is made by insulation of equipment itself.

(ii) For external abnormal voltage (lightning surge), a protection is made by an arrester.

(2) Insulator type and number of discs connected

The principal idea of insulation design, as mentioned above, flashover may not occur against an internal abnormal voltage. As to internal abnormal voltage, according to the practice employed to transmission line so far, following values are employed.

Multiplying factor on direct grounded system

For persistent abnormal power frequency voltage: 0.8 Um
For switching surge abnormal voltage : 2.8 Um

where Um stands for allowable maximum system voltage

In deciding an insulator, a flashover characteristics in wet condition of the insulator for switching surge, and the same for commercial frequency are employed.

The required insulation strength against internal abnormal voltage and the electrical characteristics of the insulators are shown in the following tables ((i) - (iii)).

(i) Design for switching surge

Nominal Voltage	N (kV)	132	33	11	
Allowable Max. Voltage	Um (kV)	144	36	12	x 12/11
Peak Voltage to the Ground	(kV)	118	29.4	9.8	Um x $\sqrt{2/3}$
Switching Surge Multiplying Factor	n	2.8	2.8	2.8	Direct grounding
Switching Surge Voltage	(kV)	330	82.3	27.4	x n
Correction Factor	(kV)	1.2	1.2	1.2	Elevation & others
Required With-standing Voltage		396	99	33	x 1.2

(ii) Design for power frequency at abnormal condition

Nominal Voltage	N (kV)	132	33	11	
Allowable Max. Voltage	Um (kV)	144	36	12	
Multiplying Factor for Low Frequency	n	0.8	0.8	0.8	Direct grounding
Persistent Abnormal Voltage	(kV)	115	28.8	9.6	
Correction Factor		1.2	1.2	1.2	
Required Withstanding Voltage	(kV)	138	35	12	

(iii) Electrical characteristics of insulators

	Critical Impulse 50% FOV (kV)	Switching Surge (wet)		Power Freq. (wet)	
		50% FOV (kV)	Withstand Voltage (kv)	FOV (kV)	Withstand Voltage (kV)
250 mm Suspension, 1 pc	140	85	75	45	40
250 mm Suspension, 2 pcs	240	170	155	80	70
250 mm Suspension, 3 pcs	330	245	220	115	105
250 mm Suspension, 9 pcs	815	645	580	335	300
33 kV Pin Type	290	-	-	95	-
11 kV Pin Type	130	-	-	35	-

Note: a. Characteristics of 250 mm suspension insulator is based on "The Insulation Design Manual for Overhead Transmission Line - October 1966" issued by The Japanese Electrotechnical Committee (JEC).
b. Characteristics of 33 kV and 11 kV Pin Type insulators are based on BS 137 and ANSI C29.5 respectively.

(iv) Number of insulators to be installed

Comparing an insulation tolerance of insulators in Table (iii) with required withstanding voltage in Tables (i) & (ii), kind and quantity of insulator have been selected as following table.

Line Voltage	Tangent/Angle	33 kV Pin Type	11 kV Pin Type	250 mm Suspension
33 kV	Tangent	1 pc	-	-
	Angle or Deadend	-	-	3 pcs
11 kV	Tangent	-	1 pc	-
	Angle or Deadend	-	-	2 pcs

(3) Standard insulation clearance (phase to ground)

Standard insulation clearance is specified as equivalent rod to rod gap in which the 50% flashover would be taken place under the imposition of critical impulse.

Nominal Voltage (kV)	33	11
No. of 250 mm Insulators (pcs)	3	2
50% Impulse FOV on Insulator Strings * (kV)	330	240
Corresponding Rod to Rod Gap * (cm)	52	36
Standard Insulation Clearance (cm)	55	35

* Based on "The Insulation Design Manual for Overhead Transmission Line - October 1966"

(4) Minimum insulation clearance

Minimum insulation clearance is specified as the gap which withstands both switching surge and abnormal power frequency voltage.

Nominal Voltage (kV)	33	11	
Allowable Max. Voltage (kV)	36	12	$\times \frac{12}{11}$
Peak Voltage to Ground (kV)	29.4	9.8	$\times \frac{2}{\sqrt{3}}$
Switching Surge Multiplying Factor	2.8	2.8	Direct grounding
Switching Surge Peak (kV)	82.3	27.4	x 2.8
Required Withstanding Voltage (kV)	90.5	30.1	x 1.1
Required Clearance (cm)	15.3	3.8	
Minimum Insulation Clearance (cm)	15	5	

* Based on "The Insulation Design Manual for Overhead Transmission Line - October 1966"

(5) Insulation clearance in abnormal condition

When the maximum wind flow is considered, the clearance shall be checked by allowable maximum line voltage under the wet condition.

Nominal Voltage (kV)	33	11	
Allowable Max. Voltage (kV)	36	12	$\times \frac{12}{11}$
Allowable Max. Voltage (to Ground) (kV)	20.8	6.92	
Required Withstanding Voltage (kV)	22.9	7.62	x 1.1
Clearance at Abnormal Condition * (cm)	9	3	

* Based on "The Insulation Design Manual for Overhead Transmission Line - October 1966"

(6) Minimum phase clearance

Nominal Voltage (kV)	33	11	
Allowable Max. Voltage (kV)	36	12	$\times \frac{12}{11}$
Peak Voltage to Ground (kV)	29.4	9.8	$\times \frac{\sqrt{2}}{\sqrt{3}}$
Switching Surge Phase-to-Phase Multiplying Factor	4.5	4.5	Direct grounding
Switching Surge Voltage (kV)	133	44.1	x 4.5
Required Withstanding Voltage (kV)	146	48.5	x 1.1
Required Clearance * (cm)	26	8	

* Based on "The Insulation Design Manual for Overhead Transmission Line - October 1966"

(7) Basic lightning-impulse insulation level (BIL)

Employed BIL classes are No. 120 for 132 kV system, No. 30A for 33 kV system and No. 10A for 11 kV system respectively. The reason of said decision is described below.

Since shielding effect of overhead ground wires and protection by arrester has been anticipated, the BIL shall be selected so as to cope with a switching surge as well as lightning surge, by coordinating with the protection devices of arresters.

Namely, assuming that the protection tolerance of arrester and protected equipment against lightning surge to be 20%, BIL should be selected to be of more than 100% sparkover voltage and 1.2 times of restricted voltages. Next table shows the process of decision of BIL according to voltages classified.

	Substation		Distribution Line
	132 kV	33 kV	11 kV
Arrester			
Nominal Voltage (kV)	126	42	14
Nominal Discharge Current (kA)	10	10	5
100% Sparkover Voltage (kV)	401	135	50
Restricted Voltage (kV)	422	140	50
Required BIL			
Restricted Voltage x 1.2 (kV)	507	168	60
Lightning-impulse Withstanding Voltage (kV)	550	170	60
Required BIL Class	(100)	(30B)	(6A)
Decided BIL Class *	(120)	(30A)	(10A)

* The values was decided conforming to TANESCO's existing facilities.

(8) Lightning protection design

In the field study of this Project, accurate observation record on IKL (Isokeraunic Level) in Dar-es-Salaam area were not obtained.

In substations there are installed arresters, and for substations, 33 kV lines and 11 kV lines overhead ground wires are installed.

Though few frequency of lightning is expected in this area, in order to protect the facilities from the external abnormal voltage including lightning, installation of arresters for substations and 11 kV distribution transformers and overhead ground wires for the inside of substations and 33 kV lines have been scheduled.

9.3 SUBSTATION

(1) Selection of proposed substation site

Since proposed substations are constructed in urban areas, the following factors were considered on selecting their sites;

- harmony with the existing facilities
- proximity to the area with potential power demand
- location to flexibly dealing with the increasing demand
- location which permits smooth installation of transmission and distribution lines

And the following sites were selected.

(i) Mikocheni S.S. site

The site is located midway between Oysterbay S.S. and Mbezi S.S. In the city plan for Dar es Salaam, the area is expected to become an industrial district. Several factories near the site are already asking for power supply. Also, the site is situated relatively close to Msasani Peninsula, 1.4 km from the coast. The site is grass land at present. The required site area is 660 sq.m (30 m x 22 m).

(ii) Factory Zone III S.S. site

The site is located midway between Factory Zone I S.S. and Factory Zone II S.S., near New Airport S.S. In the area, several factories are being constructed, and some more are scheduled in the future. The site is situated 8.0 km from the coast, grass land at present. The required site area is 1,080 sq.m (36 m x 30 m).

(2) Unitizing the substation facilities

In consideration of economy and maintainability, the new substations are designed as a unit type automatic substation which consists of 33 kV equipment to be installed outside, and 11 kV equipment to be accommodated in cubicles, whereby eliminating indoor space requirement.

The unit type substation has the following advantages;

- design process can be easily standardized and simplified.
- small site area is required since no building is needed for accommodating power distribution panel and equipment.
- secondary side of transformers can be made compact in size and less cables are required to reduce control cable required.
- the construct period can be shortened because of streamlined installation of equipment.
- running cost can be reduced on account of simple operation and maintenance.
- the construction cost can be reduced.

(3) Connection system

Connection system in the substations was designed to simplify the connection without losing efficiencies in power supply, while aiming to satisfy;

- system operation requirements
- designed frequency of inspection and occurrence of troubles (reliability of cables and transformers has been improved)
- power supply requirements
- required site area

As a result, Mikocheni S.S. and Factory Zone III S.S. will have the connection system shown in Fig. 9-3-1 and Fig. 9-3-2 respectively.

Plans and sections of these substations are presented in Figs. 9-3-3, 9-3-4 and 9-3-5.

(4) Design for salt contamination

(i) Classification of salt contamination

To set out appropriate design criteria to compensate for effects of salt contamination, local weather conditions and distance from the coast are important factors to be considered. The main feature of weather in the area is a monsoon, as is typhoon or seasonal wind in Japan. The monsoon usually generates much rain, which washes away salt adhered to the equipment and facilities. Therefore in this respect the weather condition in the area is more suitable for substations than in Japan, although corona sometimes increases immediately before and after the monsoons. It is understandable that no washing equipment is provided in substations, in spite of localed less than 10 km from the coast.

Since measuring data of salt contamination are not available for the area on long term basis, establish an accurate design criteria is difficult. Nevertheless, the classification of salt contamination for design criteria is tentatively established as follows:

Contamination degree (equivalent salt) (mg/sq.cm)	Application section	Tanzania	Japan	
		Dar es Salaam area	Distance from seashore (km)	
			Against typhoon	Against seasonal wind
0.03	General	◎	More than 50	More than 10
0.06	Light salt contamination		10 - 50	3 - 10
0.12	Medium salt contamination		3 - 10	1 - 3
0.35	Heavy salt contamination		0.3 - 3	0.1 - 1

(ii) Withstanding voltage against contamination

The sound phase to ground voltage (V) at any one phase grounded is described below.

$V = qE$

where q: Rising factor of V (= 1.2)

E: Maximum system voltage

$(= \text{Nominal voltage} \times \frac{1.15}{1.1}) \times \frac{1}{\sqrt{3}}$

For 132 kV system

$$V = 1.2 \times 132 \times \frac{1.15}{1.1} \times \frac{1}{\sqrt{3}} = 95.6 \text{ (kV)}$$

For 33 kV system

$$V = 1.2 \times 33 \times \frac{1.15}{1.1} \times \frac{1}{\sqrt{3}} = 23.9 \text{ (kV)}$$

For 11 kV system

$$V = 1.2 \times 11 \times \frac{1.15}{1.1} \times \frac{1}{\sqrt{3}} = 8.0 \text{ (kV)}$$

(iii) Number of insulator to be installed

A standard withstanding voltage of one 250 mm suspension insulator against contamination classified are shown in the next table.

Equivalent salt contamination (mg/sq.cm)	0.01	0.03	0.045	0.06	0.12
Withstanding voltage (kV)	16.1	12.0	11.0	10.4	9.0

Number of insulators required for each system voltage and contamination are shown in the next table.

(Piece)

Equivalent salt contamination (mg/sq.cm)	0.03	0.045	0.06	
Nominal voltage (kV)				Existing
132	8 (8.0)	9 (8.7)	10 (9.2)	9
33	2 (2.0)	3 (2.2)	3 (2.3)	3
11	1 (0.7)	1 (0.7)	1 (0.8)	2

Note: The figures in the parenthesis show a calculated value.

The number of insulators installed in the existing facilities are based on 0.03 mg/sq.cm of equivalent amount of salt adhered, including one extra insulator. Since they can actually withstand 0.045 to 0.06 mg/sq.cm of salt, the present insulation is considered appropriate.

(iv) Withstanding voltage against contamination for station post insulators

The withstanding voltage of station post insulator, studied in this report, against salt contamination are shown in the table below.

Equivalent contamination mg/cm²	0.03	0.06		
Insulator type	(kV)	(kV)	Mean diameter (mm)	Leakage distance (mm)
SP-10	18	15	89	360
SP-30	37	30	115	830
SP800A + SP850B	108	97	152	3,240
(Reference)				
250 mm 2 pcs.	24	20.8	159	560
" 3 pcs.	36	31.2	159	840
" 9 pcs.	108	93.6	159	2,520

(5) Minimum insulation clearance

The minimum insulation clearance should be maintained or shown below:

Nominal voltage (kV)	132	33	11
Insulation level (Class)	120	30	10
BIL (kV)	650	200	90
Insulation clearance phase to ground (min) (cm)	130	35	15
Insulation clearance phase to phase (min) (cm)	165	48	19

Minimum insulation clearance, phase to ground and phase to phase in the table are determined from air gaps correspond to 50% flashover voltage for 120% and 150% of BIL, respectively.

(6) Operation control system

(i) The operation and control of the proposed substation will be done by simple monitoring system, which is used in the existing substations.

(ii) This system is used for substations of less than 100 kV and 10 MVA in Japan, and operators are sent from a station to a substation, as required, for monitoring, checking and operation the equipment.

(iii) For operation of on-load tap controlling devices, see 8-1-4 (2).

(iv) When the simple monitoring system is used, it is preferable to have various warming indicated at Ilala S.S. which serve as the operator's station. The communication between the substations will be provided by VHF system. See 9-7.

(7) Protection system

(i) Existing substations

As stated in 4.6.1 "Substations" the emergency power cut-off in the substations is made by circuit breakers of the substation located on power source side.

A protection system should be selected in accordance with criteria such as minimization of shut down area, coordination with main circuit systems, and reliability, and beside the protection system should fit into the present conditions of TANESCO's power transmission/distribution networks.

When plural incoming transmission lines are provided at the substations and have possibility subject to reverse power flow, the substation should be protected by breakers at intakes, as if they were outgoing lines, to take into consideration self side protection and possible current inflow from other lines.

The equipment to be protected in this way are Ilala 132 kV line (one breaker), Oysterbay 33 kV line (two breakers), Factory Zone I 33 kV line (three breakers).

When this improvement is made, the existing F.T. closing circuits can be used as it is to make the breakers trip. Nevertheless, Ubungo and Ilala substations should be checked as to whether setting values and times for interrelated protection relays are properly coordinated and as to whether the back up protective devices for main equipment can be operated in good condition.

(ii) Proposed substations

Protective devices for power transmission/distribution lines, bus bars and transformers in the proposed substations, employment of same system as in the existing ones is preferable, which is also used by electric power companies in Japan. Electromagnetic relays, used in the existing substations, will be employed with consideration of mainteinability.

(8) Special specifications of transformers

(i) Grounded neutral system

As discussed in 4.2 (5), neutral points of the transformers are directly grounded for all circuits of 220 kV, 132 kV, 33 kV and 11 kV.

For the proposed substations, grounded neutral systems will be employed with consideration of protective system and equipment configuration which are designed under same principle as existing facilities.

(ii) Connection system

To permit diversion which might be necessary in the future, grounded system of circuits and phase difference between primary and secondary coils of transformers in the proposed substations will be made equivalent to those in the existing substations, and the transformers will be designed of λ-λ-Δ connection (tertiary coils will be built-in type).

(iii) L.T.C.

L.T.C. to be attached to the new transformers will be set at the range of existing one, and will be installed on high voltage side, to be more economical. This arrangement will allow a parallel operation with existing transsformers in future.

(9) Specification of principal equipment

Outline of specification of principal equipment should be shown as follows:

(i) Main transformer

Applicable standard JEC 204-1978 Transformer

JEC 186-1972 On load tap changer equipment

Capacity	45,000 kVA	15,000 kVA
Rating	Continuous rating	Continuous rating
Number of phases	3	3
Frequency	50 Hz	50 Hz
Type of cooling	Oil-immersed self-cooled type	Oil-immersed self-cooled type
Rated voltage (1ry/2ndary)	132000V/33000V	33000V/11000V
Tap voltages (HV)	+5%, -15% 17 Tap	±10% 17 Tap
Insulation level (Class)	120/30A	30A/10A
Connection		
Primary	Y⏚	Y
Secondary	Y⏚ Tertiary (Δ)	Y⏚ Tertiary (Δ)
Angular displacement	0°	0°
Polarity	Subtractive polarity	Subtractive polarity
Indoor or outdoor service	Outdoor	Outdoor
Tap changer equipment	L.T.C.	L.T.C.
Altitude	Below 1000 m	Below 1000 m
Number of units	2	3

(ii) Circuit breaker

Applicable standard JEC 181-1975 Circuit breaker

Rated voltage	145 kV	36 kV	36 kV
Insulation level (Class)	120	30 A	30 A
Rated current	800 A	1200 A	600 A
Rated frequency	50 Hz	50 Hz	50 Hz
Rated interrupting current	12.5 kA	12.5 kA	12.5 kA
Rated interrupting time	5 cycle	5 cycle	5 cycle
Rated making voltage	DC 100 V	DC 100 V	DC 100 V
Rated tripping voltage	DC 100 V	DC 100 V	DC 100 V
Standard operating duty	A O-(1 min.)-CO -(3 min.)-CO	B CO-(15 sec.)-CO	
Indoor or outdoor service	Outdoor		
Altitude	Below 1000 m		
Maximum ambient temperature	40°C		
Number of units	1	3	11

Rated voltage	12 kV	12 kV
Insulation level (Class)	10 A	10 A
Rated current	1200 A	600 A
Rated frequency	50 Hz	50 Hz
Rated interrupting current	25 kA	25 kA
Rated interrupting time	5 cycle	5 cycle
Rated making voltage	DC 100 V	DC 100 V
Rated tripping voltage	DC 100 V	DC 100 V
Standard operating duty	B CO-(15 sec.)-CO	
Indoor or outdoor service	Cubicle type	
Altitude	Below 1000 m	
Maximum ambient temperature	40°C	
Number of units	2	8

(iii) Disconnecting Switch

Applicable Standard   JEC 196-1975 Disconnecting switch

Rated voltage	145 kV	36 kV	36 kV
Insulation level (Class)	120	30 A	30 A
Rated current	800 A	1200 A	800 A
Rated short time current	14 kA	14 kA	14 kA
Indoor or outdoor service	Outdoor		
Altitude	below 1000 m		
Maximum ambient temperature	40°C		
Control system	Manual control		
Number of units	2	2	2

Rated voltage	36 kV	36 kV
Insulation level (Class)	30 A	30 A
Rated current	600 A	600 A
Rated short time current	14 kA	14 kA
Indoor or out-door service	Outdoor	
Altitude	Below 1000 m	
Maximum ambient temperature	40°C	
Control system	Manual control	
Accessories	with earthing blade	-
Number of units	11	14

iv) Instrument transformer

Applicable Standard JEC 190-1974 Instrument transformer

Rated voltage	132 kV	132 kV	33 kV
Insulation level (Class)	(BCT)	(BCT)	(BCT)
Rated current	800/5 A	400/5 A	1200/5 A
Rated burden	40 VA	40 VA	40 VA
Rated current tolerance	40	40	40
Class	1.0	1.0	1.0
Number of units	1	2	5

Rated voltage	33 kV	33 kV	11 kV
Insulation level (Class)	(BCT)	(BCT)	(BCT)
Rated current	600/5 A	400/5 A	1200/5 A
Rated burden	40 VA	40 VA	40 VA
Rated current tolerance	40	40	40
Class	1.0	1.0	1.0
Number of units	11	3	3

Rated voltage	11 kV	11 kV
Insulation level (Class)	10 A	10 A
Rated current	1200/5 A	600/5 A
Rated burden	40 VA	40 VA
Rated current tolerance	40	40
Class	1.0	1.0
Number of units	3	8

(v) Potential transformer

Applicable Standard JEC 190-1974 Instrument transformer

Rated voltage	$\frac{132\ kV}{\sqrt{3}}$ $\frac{110\ V}{\sqrt{3}}$
Rated frequency	50 Hz
Insulation Level (Class)	120
Rated burden	200 VA
Class	1.0
Number of units	1

(vi) Lightning arrester

Applicable Standard JEC-203-1978 Lightning arrester

Rated voltage	126 kV	42 kV	14 kV
Rated frequency	50 Hz		
Nominal discharge current	10 kA		
Altitude	Below 1000 m		
Maximum ambient temperature	40°C		
Grounded neutral system	Directly-grounded system		
Number of units	3	12	6

(vii) Enclosed switchboard

Applicable Standard JEM-1153 Enclosed switchboard

Rated voltage	11 kV		
Indoor or outdoor service	Indoor	Outdoor	
Altitude	Below 1000 m		
Maximum ambient temperature	40°C		
Substation name	Ilala	Mikocheni	Factory Zone III
Relay board	1	0	0
Transformer switch gear board	1	1	1
High tension switch gear board	0	3	5
Station service	0	1	1
DC supply	1	1	1
Total	3	6	8

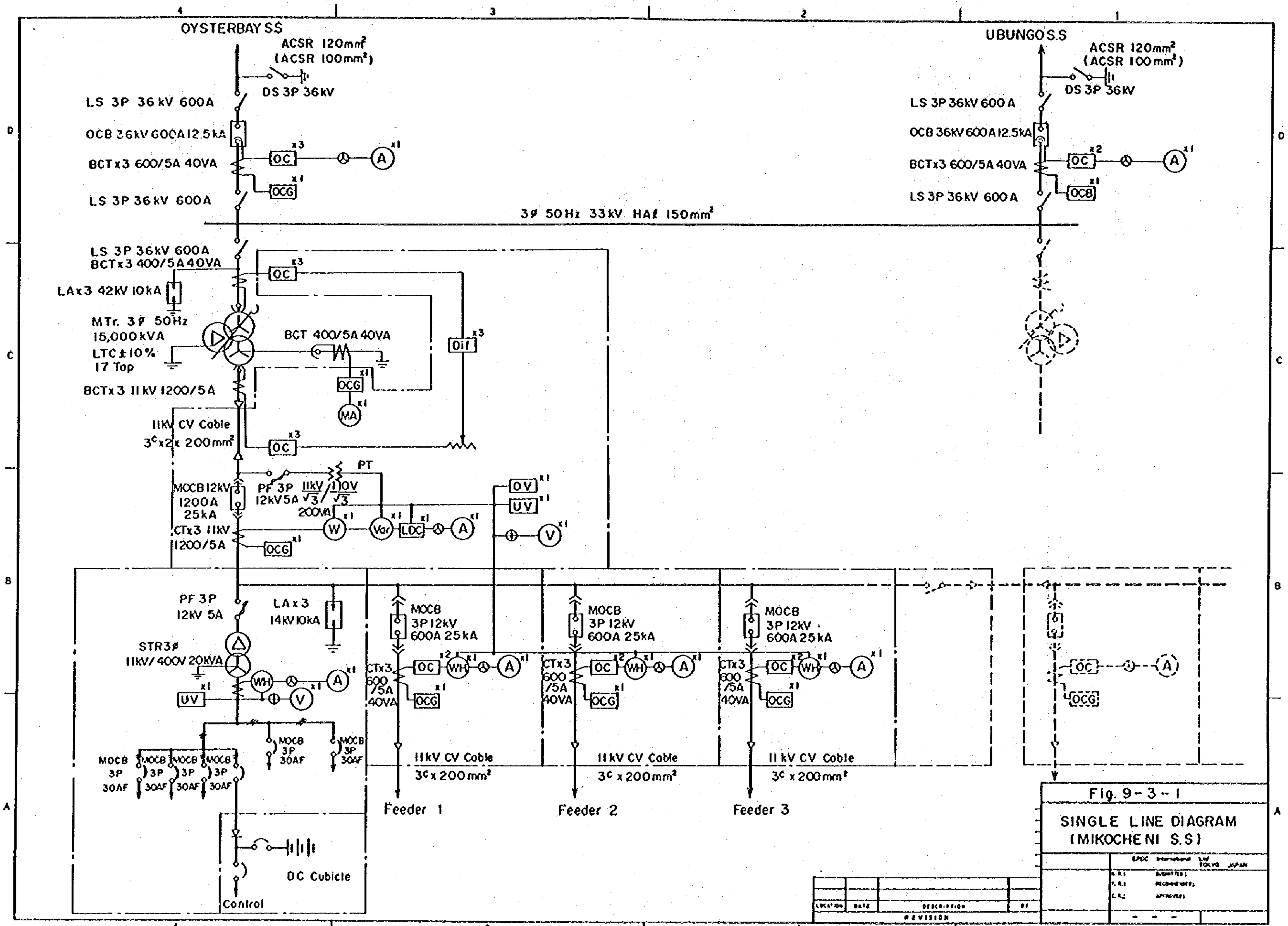


Fig. 9-3-1

SINGLE LINE DIAGRAM
(MIKOCHENI S.S)

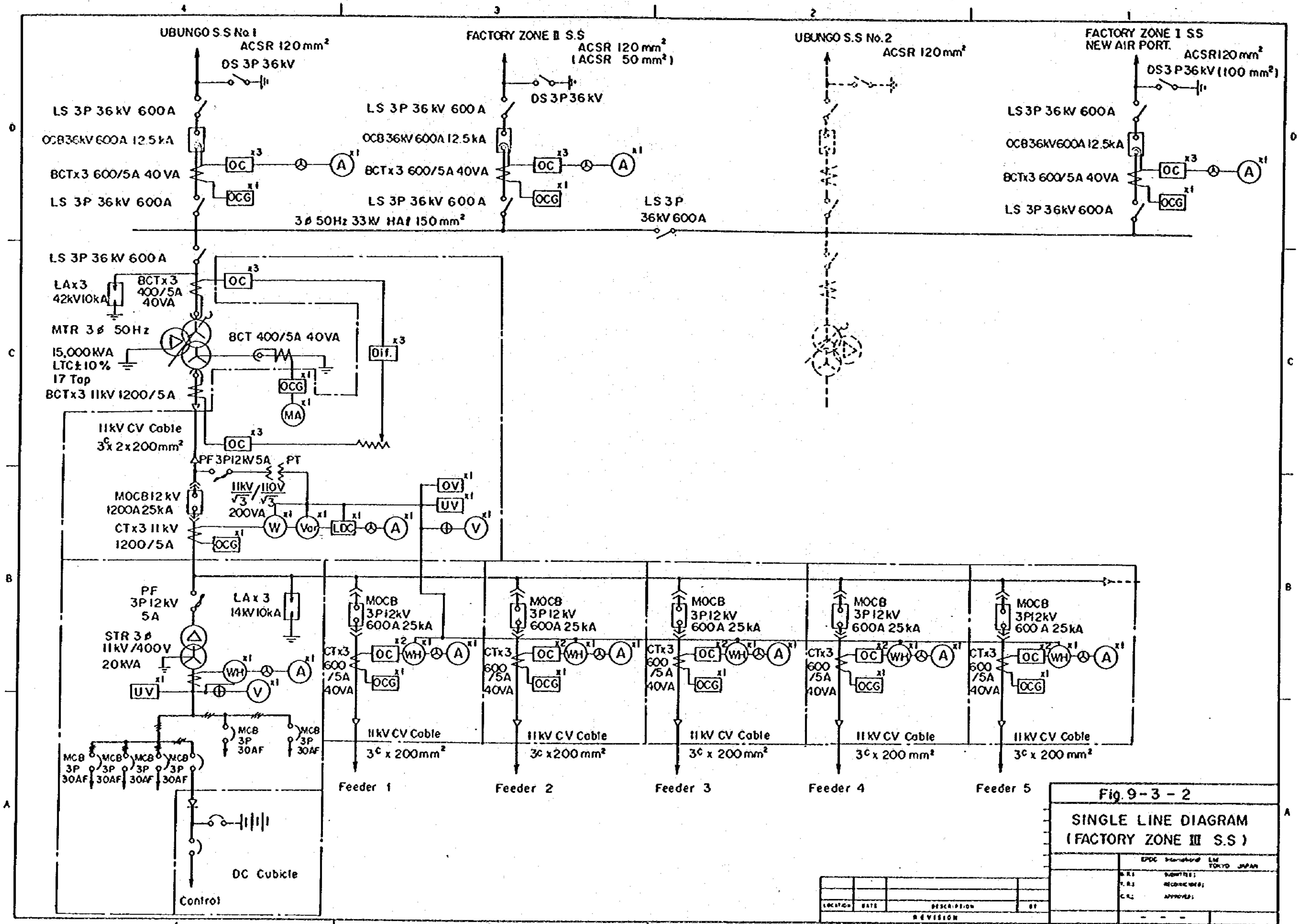


Fig. 9-3-2

SINGLE LINE DIAGRAM
(FACTORY ZONE III S.S)

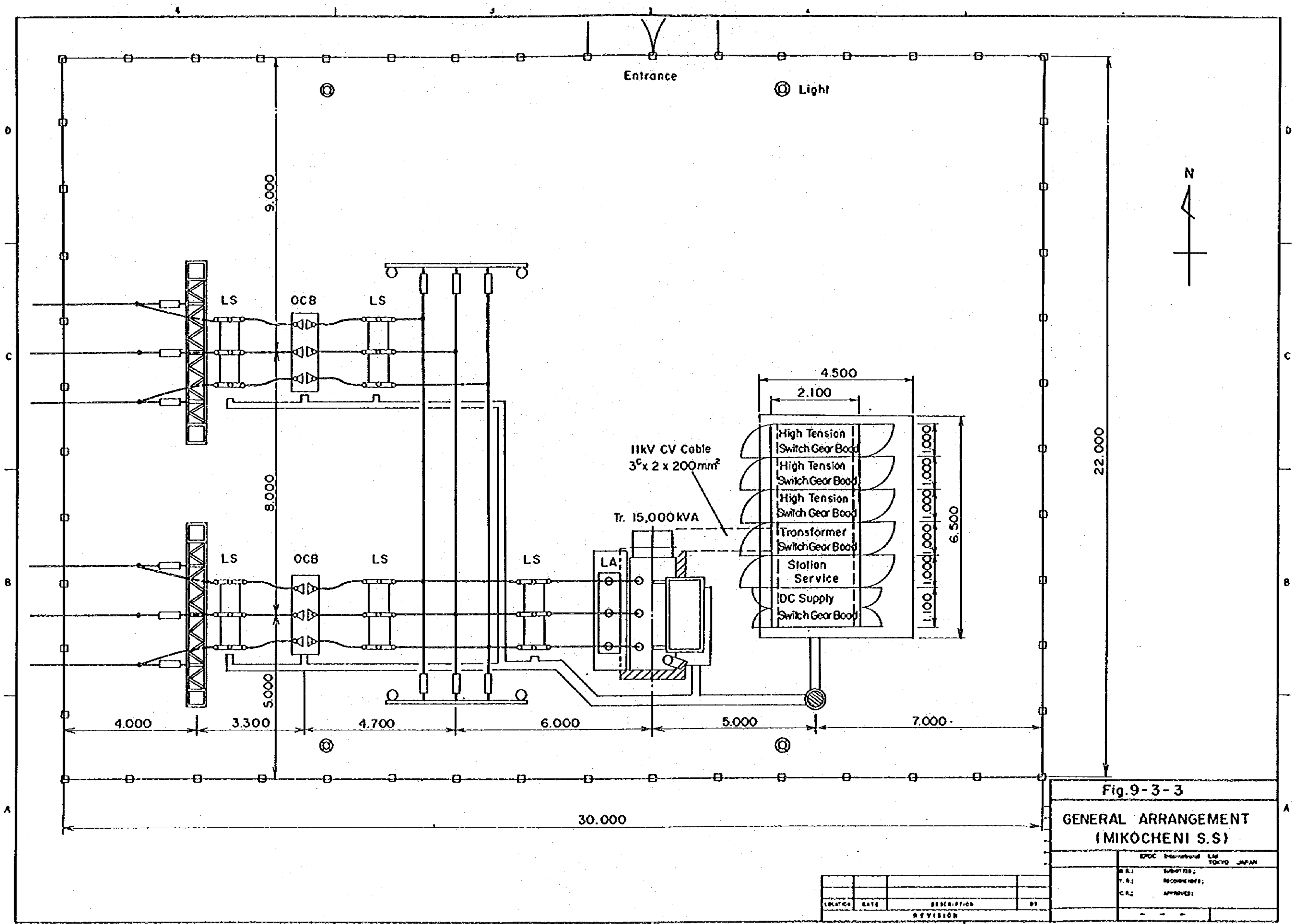
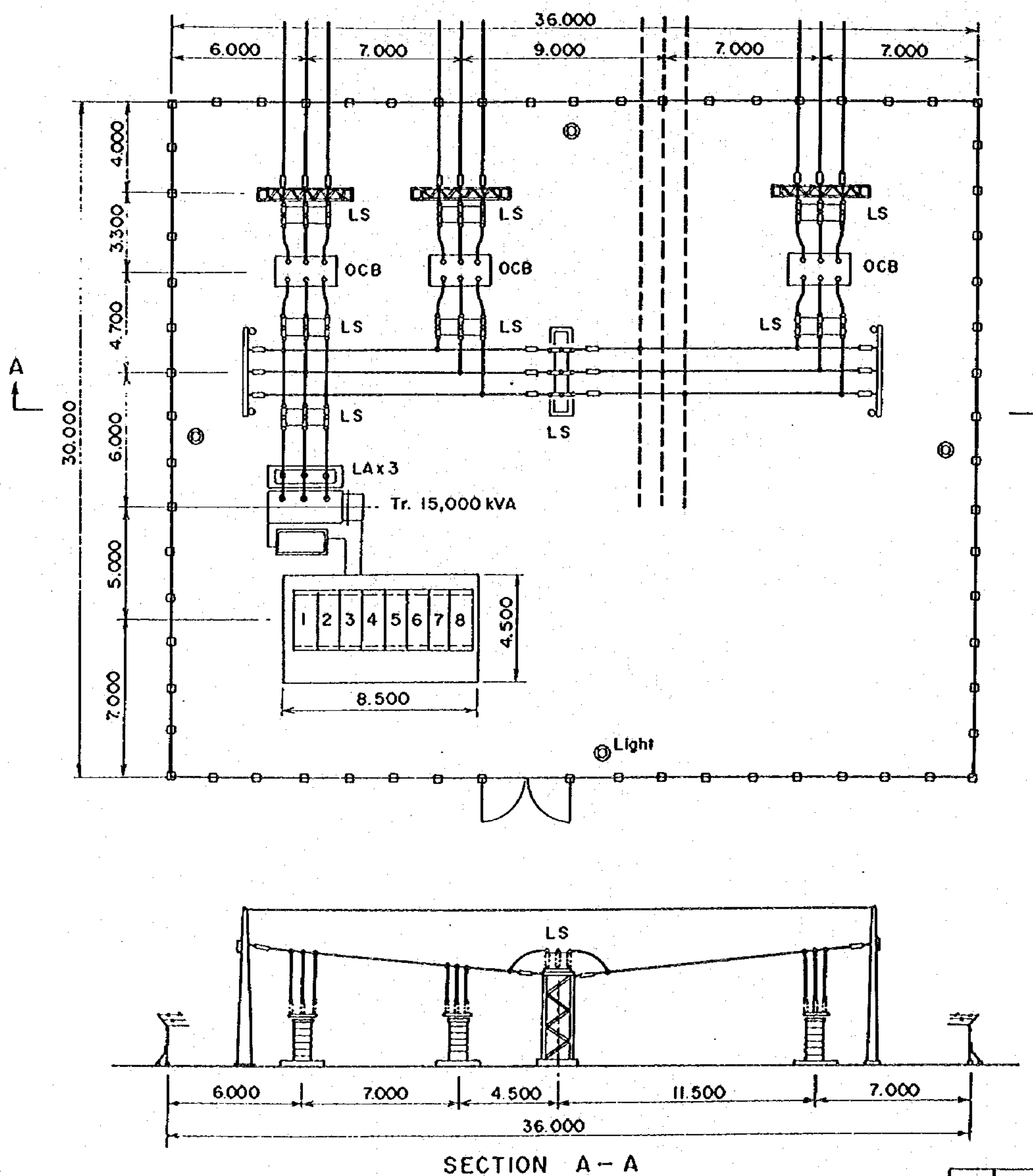


Fig. 9-3-3

GENERAL ARRANGEMENT (MIKOCHENI S.S)



Cubicle Name

1 : DC Supply Switch Gear Boad
2 : Station Service
3 : Transformer Switch Gear Boad
4~8 : High Tension Switch Gear Boad

Fig. 9-3-4

GENERAL ARRANGEMENT (FACTORY ZONE Ⅲ S.S)

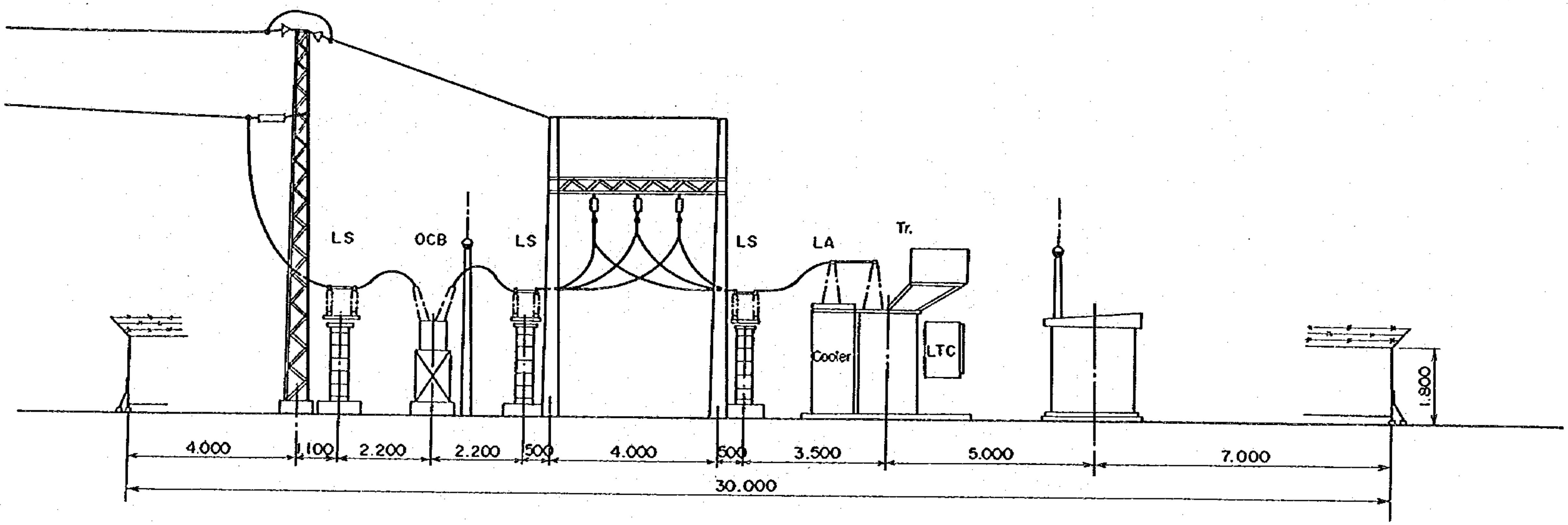


Fig. 9-3-5

GENERAL ARRANGEMENT
(MIKOCHENI S.S)
(FACTORY ZONE Ⅲ S.S)

EPDC International Ltd. TOKYO JAPAN

LOCATION	DATE	DESCRIPTION	BY
REVISION			

SHEET NO. OF

9.4 33 KV SUB-TRANSMISSION LINE

9.4.1 Summary of design

(1) Conductor

Conductors to be used for this Project should have an enough transmission capacity to send required demand in each connected section and also be satisfactory in respect of mechanical strength and anti-corrosion besides being more economical.

With regard to selection of conductors, hard drawn copper cable (HDCC), all aluminum alloy cable (AAC) and aluminum conductor steel reinforced (ACSR) have been compared. Such comparison proved that ACSR should finally be selected in view of its total advantages out of the said items. As to the conductor size, from view point of construction and maintenance, application of minimal size and standardization thereof are considered to be profitable. ACSR 120 mm^2 has been employed in this report. Thus, the joint mobilization of construction works, tools and instruments, etc. for 11 kV lines could be made available. Consequently, it is believed that economical advantages would be derived.

However, in replacing conductors for the section between Ilala and Oysterbay, ACSR 160 mm^2 was adopted on an account of the incapacity of ACSR 120 mm^2.

The dimensions of the above conductors are as shown in Table 9-4-1.

Table 9-4-1 Conductor and shieldwire

Kind of wire	ACSR 120 mm^2	ACSR 160 mm^2	GSW 30 mm^2
Stranding	A130/2.3 + st 7/2.3	A130/2.6 + st 7/2.6	st 7/2.6
Calculated Sectional Area (mm^2)	124.7 + 29.09 153.8	159.3 + 37.16 196.5	37.16
Overall Diameter(mm)	16.1	18.2	7.8
Ultimate Strength (kg)	5,540	6,980	3,080 (Class B)
Unit Weight (kg/m)	0.5737	0.7328	0.294
Electrical Resistance at 20°C (/km)	0.233	0.182	
Ampacity at 90°C (A)	388	454	

(2) Shield Wire

Although no observation records on lightning covering the Dar es Salaam area could be obtained, it is apparent that there were some lightnings in the inland hilly area of Dar es Salaam. Since IKL (isokeraunic level) in these areas is presumed to be approximately 10 judging from its geographical condition. Accordingly, one line of 30 mm^2 galvanized steel wire (GSW) is to be employed in anticipation of perfect shielding against lightnings.

Table 9-4-1 shows the dimension of shield wires to be installed.

(3) Design for salt contamination

Dar es Salaam is a seaside city faced with Indian sea, located in a latitude of 6°50'S roughly and in the tropical climate zone. The month of November to April are a rainy season. The temperature therein is very high and there is much precipitation. It is the dry season from May to October. Nevertheless, it has a shower once a day in usual. A strong wind exceeds 21 knots (10.8 m/s) is rarely observed. Accordingly, it is considered to be seldom that the wind stated above moves away sea water spray onto the inland area of Dar es Salaam. In addition to above, it can be expected that the purification effect of a suitable quantity of rainfall will hinder from accumulation of severe salt contamination to insulators.

However, the possibility of salt contamination on lines in Dar es Salaam will be larger than that of in the inland area of the country. In this regard, effects of possible salt contamination was taken into account particularly in selection of pin type insulator.

Table 9-4-2 shows the main dimensions of the insulators employed.

Table 9-4-2 Insulator

Insulator Type	Suspension		Pin
Applicable Standard	ANSI C29.2 Class 52-4		BS 137: Part 1
System Voltage (kV)	33		33
Porcelain Diameter (mm)	254		343 (Top shell)
Unit spacing/Pin Height (mm)	146		280
Combined M&E Strength (kg)	6,810		-
Cantilever Strength (kg)	-		1,090
	(Unit)	3 pcs	
Leakage Distance (mm)	(292)	876	699
Flashover Voltage (kV)			
Power Frequency, wet	(50)	130	95
50% Impulse, positive	(125)	355	215
Net Weight (kg)	(4.1)	12.3	10

(4) Support

Concrete pole, steel tube pole and wooden pole are taken into consideration for the 33 kV subtransmission line supports. The concrete pole is proved to be reliable in respect of its high mechanical strength and durability, wherease due to its heavy weight, special trailer and equipment are required for construction works.