14.2 Detailed Design of Transmission Facilities

Of the emergency projects that are included in the expansion plan (Case-B'), those which are planned to be carried out in 2004 shall be divided into two groups (Priority 1 and Priority 2) for the purpose of detail design.

14.2.1 Facilities Subject to Detail Design

Table 14.2.1 Transmission Line Expansion Projects (Dar es Salaam)

Year	Name of TL	Specification of conductor	Construction	Length (km)
2004 1st	FZ I-Chang'ombe	33kV 240mm^2 1cdt 2cct	New	4.2
	FZIII-Tandika	33kV 150mm^2 2cdt 1cct	New	10.0
2004 2nd	City Center-Sokoine	33kV 100mm^2 1cdt 1cct	Reinforce	3.0
	Tandale-Magomeni	33kV 150mm^2 1cdt 1cct	New	3.0
	Ubungo-Ilala	33kV 150mm^2 2cdt 1cct	Replace	7.5
	Ubungo-New Oysterbay	132kV 240mm^2 1cdt 1cct	New	8.5
	New Oysterbay-Oysterbay	33kV 240mm^2 2cdt 1cct	New	1.6

Table 14.2.2 Transmission Line Expansion Projects (Arusha/Kilimanjaro)

Year	Name of TL	Specification of conductor	Construction	Length (km)
2004 1st	Njiro-Mt.Meru	33kV 100mm^2 1cdt 1cct	Reinforce	7.3
	Njiro-Unga LTD	33kV 100mm^2 1cdt 1cct	Reinforce	5.8
	Kiyungi-Boma Mbuzi	33kV 100mm^2 1cdt 1cct	Reinforce	7.0
	Kiyungi-Trade School	33kV 100mm^2 1cdt 1cct	Reinforce	10.0
	Kiyungi-Mikuu Rombo	33kV 100mm^2 1cdt 1cct	New	69.0
2004 2nd				

14.2.2 Outline of Detail Design of 132 kV Transmission Line

(1) Design conditions for 132 kV transmission line

(a) Applicable standards

As a rule, the 132 kV transmission line shall be designed in accordance with IEC and IEC-compatible standards.

(b) Height of conductor

In view of the conductor heights of the existing 132 kV transmission lines, the values shown in Table 14.2.3 shall be used.

Table 14.2.3 132kV Transmission Line Heights

Item	Minimum height (m)
General points	6.7
Road	8.0
Railway	9.0
Waterway, sea-lane	10.0

(c) Wind load

Based on TANESCO's record of wind loads in Dar es Salaam, the value shown in Table 14.2.4 shall be used as the wind load applied to the supporting structures.

Table 14.2.4 Wind Load Applied to 132 kV Transmission Line

Item	Wind pressure (kg/m^2)*
Region	Dar es Salaam
Steel tower	266
Conductor	92

*: Design wind velocity (Steel tower)=38m/sec
〃 (Conductor)=40m/sec

(d) Natural conditions

As the natural conditions, the values shown in Table 14.2.5 shall be used.

Table 14.2.5 Natural Condition Considered for 132 kV Transmission Line Design

Region		Dar es Salaam
Altitude		1,000m or less
Outside temp.	Maximum	40℃
	Minimum	10℃
	Average	20℃

(e) Number of circuits of transmission line

In consideration of future increases in electricity demand, a double-circuit transmission line shall be designed. Initially, however, only single circuit shall be strung. The second circuit shall be strung when it becomes necessary.

(f) Supporting structure

As the supporting structure for the transmission line, a self-supporting, double-circuit steel tower shall be used. This type of supporting structure, which is used on the existing Ubungo-Ilala and Ubungo-FZ III routes, facilitates expanding the line capacity to meet increases in electricity demand in the future. Besides, the portion of the structure under the conductor is narrow and no stays are required. The number of adjoining suspension steel towers shall be 10 or less. As a rule, the span between steel towers shall be 300 m.

(g) Foundation

As the steel tower foundation, various types of foundation can be considered. The optimum type depends on ground conditions of the site at which the steel tower is erected. In the present design, a concrete foundation shall be used at places where the ground conditions are good. However, at places where the ground conditions are poor (e.g., marshland), a steel pipe pile foundation shall be used.

(h) Selection of conductor type

From the results of power flow calculations based on the demand forecast and from the viewpoint of standardizing conductors used by TANESCO, ACSR 240 mm^2 shall be used for the transmission line. Reportedly, in the past, salt contamination has occurred over a wide area of the Dar es Salaam region. In this region, therefore, it is advisable to adopt an ACSR of corrosion-proof type. The safety factor of the conductor at the point of support shall be 2.5 or more.

(i) Ground wire

As the ground wire, AAC (IEC-compatible, hard-drawn aluminum stranded wire) 55 mm^2 shall be used. In the Dar es Salaam region, it is advisable to adopt ACS (aluminum-covered, steel-cored stranded wire) 55 mm^2 for the reason mentioned above. The safety factor of the ground wire at the point of support shall be 2.5 or more.

(j) Insulator

The insulator set shall be designed in accordance with IEC or an IEC-compatible standard. In the Dar es Salaam region, it is advisable to adopt a zinc-sleeved suspension insulator for the reason mentioned above.

In a Dar es Salaam power supply expansion project (Ubungo-Ilala/Ubungo-FZ III routes) carried out in the past, eleven 250 mm suspension insulators were used per insulator set since the equivalent salt deposit density was assumed to be 0.25 mg/cm^2. However, since the survey point P14A-New Oysterbay section is along Old Bagamoyo road, now under consideration is closer to the coastline than are the routes shown above. Therefore the equivalent salt deposit density shall be assumed to be 0.35 mg/cm^2 (insulator contamination class one rank higher) in consideration of the possibility of salt contamination. As in the past, 0.25 mg/cm^2 is adopted in Ubungo-the survey point P17 section. Fig. 14.2.1 shows Insulator Strings.

(k) Armor rod and damper

In order to prevent vibration fatigue of the conductor at the point of support, an armor rod shall be installed at the point of support of each suspension tower. In addition, each suspension tower shall be provided with a damper to prevent the oscillation of conductor caused by a breeze.

(2) Insulation design of 132 kV transmission line

(a) Basic data

Table 14.2.6 Insulation Design for 132kV T/L; Basic Items

Item	Number	Remark
Nominal voltage; U_0(kV)	132	
Maximum allowable voltage; U_m(kV)	144	1.2/1.1
Switching surge ratio to ground	2.8	
Switching surge ratio between phases	4.5	
Altitude compensation	1.1	1000m or less
Arcing hone gap efficiency	0.85 or less	Ratio for length of insulators and hone gap

(b) Resistance to switching surge

Table 14.2.7 Insulation Design for 132kV T/L; Switching Surge Withstand Design

Item	Number	Remark
Nominal voltage; U_0(kV)	132	
Maximum allowable voltage; U_m(kV)	144	1.2/1.1 U_0
Peak value (kV)	118	$\sqrt{2}/\sqrt{3}U_m$
Switching surge ratio to ground	2.8	
Switching surge voltage to ground (kV)	330	
Switching surge Altitude compensation	1.1	1000m or less
Required voltage to ground (kV)	363	
Required number of insulators (piece)	7	* By switching impulse wet flashover and withstand voltage characteristics for 250mm suspension insulator. * Including one piece of insulator for spare
Minimum insulation gap (cm)	80	* By switching impulse wet flashover and withstand voltage characteristics between conductor and steel tower.
Switching surge ratio between phases	4.5	
Switching surge voltage between phases (kV)	531	
Altitude compensation	1.1	1000m or less
Required voltage between phases(kV)	585	
Minimum phase to phase insulation distance (cm)	120	

(c) Resistance to commercial frequency

Table 14.2.8 Insulation Design for 132kV T/L; Power Frequency Withstand Design

Item	Number	Remark
Nominal voltage; U_0(kV)	132	
Maximum allowable voltage; U_m(kV)	144	1.2/1.1 U_0
Voltage to ground (kV)	84	$U_m/\sqrt{3}$
Altitude compensation	1.1	1000m or less
Required voltage to ground (kV)	93	
Required number of insulators (piece)	4	* By commercial frequency wet flashover and withstand voltage characteristics for 250mm suspension insulator. * Including one piece of insulator for spare
Abnormal state insulation gap (cm)	35	
Required voltage between phases (kV)	159	
Abnormal state phase to phase insulation distance (cm)	56	

(d) Resistance to contamination

Table 14.2.9 Insulation Design of 132 kV T/L: Insulator Contamination Withstand Design

Item	Number		Remark
Voltage to ground (kV)	84		$U_m/\sqrt{3}$
Voltage increasing coefficient	1.0		In case of one line to ground fault
Required voltage (kV)	84		
Equivalent salt deposit density (mg/cm^2)	0.25*2	0.35*3	
Insulator withstand voltage (kV/piece)*1	7.7	7.2	250mm suspension insulator
Required number of insulators (piece)	11	12	

*1: *The contamination withstand voltage,* V_{132}, *per insulator (kV/piece) was calculated by* using the following equation:

$$V_{132} = \frac{28}{\left(\frac{w}{0.1}\right)^{\frac{1}{5}}\left[1.5\times\left(K^{\frac{1}{3}}+2\right)+\frac{5}{8}\times K\right]}\times k \qquad \text{[kV/piece]}$$

where,

V_{132}: Design withstand voltage per insulator (kV/piece)
w: Equivalent salt deposit density (mg/cm^2)
K: Primer deposit density (mg/cm^2) (assumed to be 0.1)
k: Withstand voltage correction factor (= 1.25)

*2: Ubungo-Survey point P17 section

*3: Survey point P14A-New Oysterbay section

(e) Resistance to lightning

Table 14.2.10 Insulation Design of 132 kV T/L: Lightning Surge Design

Item	Number	Remark
Arcing hone gap (cm)	144	As coordination of insulation, Arcing hone gap should be matched actual result in the past.
Arcing hone gap efficiency	0.85 or less	
Required insulation unit length (cm)	170	144/0.85
Required number of insulators (piece)	12	Height of 250mm suspension insulator =146mm
Standard insulation gap (cm)*4	165	It is finished in the unit 5cm.
Dip of jumper (cm)*5	200	1.25L, It is finished in the unit 5cm.

*4: The standard insulation distance, L, was calculated by using the following equation:

$L=1.115\times Z+0.021$(m) (Z: arcing horn clearance in m)

*5: The jumper depth was assumed to be 1.2 times of the standard insulation gap from the viewpoint of facilitating the installation work and reducing the error of installation work.

(f) Summary of insulation design

Table 14.2.11 Insulation Design of 132 kV T/L: Summary

Item		Number		Remark
Nominal voltage; U_0 (kV)		132		
Maximum allowable voltage; U_m (kV)		144		
Altitude compensation		1.1		1000m or less
Switching surge withstand design	Required voltage to ground (kV)	363		
	Required number of insulators (piece)	7		
	Minimum insulation gap (cm)	80		
	Required voltage between phases (kV)	585		
	Minimum phase to phase insulation distance (cm)	120		
Power frequency withstand design	Required voltage to ground (kV)	93		
	Required number of insulators (piece)	4		
	Abnormal state insulation gap (cm)	35		
	Required voltage between phases (kV)	159		
	Abnormal state phase to phase insulation distance (cm)	56		
Contamination withstand design	Required voltage (kV)	84		
	Equivalent salt deposit density (mg/cm^2)	0.25	0.35	
	Insulator withstand voltage (kV/piece)	7.7	7.2	
	Required number of insulators (piece)	11	12	
Lightning surge design	Arcing hone gap (cm)	144		
	Required number of insulators (piece)	12		
	Standard insulation gap (cm)	165		
	Dip of jumper (cm)	200		
Summary	Required number of insulators (piece)	11	12	
	Arcing hone gap (cm)	144		
	Standard insulation gap (cm)	165		
	Minimum insulation gap (cm)	80		
	Abnormal state insulation gap (cm)	35		
	Minimum phase to phase insulation distance (cm)	120		
	Abnormal state phase to phase insulation distance (cm)	56		
	Dip of jumper (cm)	200		

Fig.14.2.2 shows 132kV-transmission line Clearance diagram. Fig.14.2.3 shows 132kV steel tower proportion (Suspension type) and Fig.14.2.4 shows 132kV steel tower proportion (Tension type: 30° angle).

14.2.3 Outline of Detail Design of 33 kV Transmission Line

(1) Design conditions for 33 kV transmission line

(a) Applicable standards

As a rule, the 33 kV transmission line shall be designed in accordance with IEC and IEC-compatible standards.

(b) Height of conductor

In view of the conductor heights of the existing 33 kV transmission lines, the values shown in Table 14.2.12 shall be used.

Table 14.2.12 33kV Transmission Line Heights

Item	Minimum height (m)
General points	5.0
Road	6.7
Railway	9.0
Waterway, sea-lane	10.0

(c) Wind load

Based on TANESCO's record of wind loads, the values shown in Table 14.2.13 shall be used as the wind loads applied to the supporting structure.

Table 14.2.13 33kV Wind Pressure Load

Item	Wind pressure (kg/m^2)	
	Dar es Salaam	Arusha, Kilimanjaro
Wood pole, Steel pole	73	75
Conductor	50	50

(d) Natural conditions

The natural conditions used in the design of 33 kV transmission line shall be as shown in Table 14.2.14.

Table 14.2.14 Natural Condition Considered for 33kV Transmission Line Design

Item		Dar es Salaam	Arusha, Kilimanjaro
Altitude		1,000m or less	800～1,500m
Outside temp.	Maximum	40℃	40℃
	Minimum	10℃	10℃
	Average	20℃	32℃

(e) Number of circuits of 33 kV transmission line

The number of circuits shall be single or double depending on the results of power flow calculation based on the demand forecast.

(f) Supporting structure

As the supporting structure for the 33 kV transmission line, either a wooden pole or a steel pipe pole shall be used. Each pole shall be provided with stays as required. The standard distance between poles shall be 65 m.

(g) Selection of conductor type

Depending on the results of power flow calculation based on the demand forecast, ACSR 100 mm^2, ACSR 120 mm^2, ACSR 150 mm^2, or ACSR 240 mm^2 shall be used for the 33 kV transmission line. Reportedly, in the past, salt contamination has occurred over a wide area of the Dar es Salaam region. In this region, therefore, it is advisable to use an ACSR of corrosion-proof type.

(h) Ground wire

As the ground wire for the 33 kV transmission line, AAC (IEC-compatible, hard-drawn aluminum stranded wire) 30 mm^2 shall be used. In the Dar es Salaam region, however, it is advisable to use ACS (aluminum-covered, steel-cored stranded wire) 30 mm^2 for the reason mentioned above.

(i) Insulator

The insulator set for the 33 kV transmission line shall be designed in accordance with IEC or IEC-compatible standard. In the Dar es Salaam region, it is advisable to use a zinc-sleeved suspension insulator for the reason mentioned above.

(2) Insulation design of 33 kV transmission line

(a) Basic data

Table 14.2.15 Insulation Design for 33kV T/L; Basic Items

Item	Number	Remark
Nominal voltage; U_0 (kV)	33	
Maximum allowable voltage; U_m (kV)	36	1.2/1.1
Switching surge ratio to ground	2.8	
Switching surge ratio between phases	4.5	
Altitude compensation	1.1	1000m or less

(b) Resistance to switching surge

Table 14.2.16 Insulation Design for 33kV T/L; Switching Surge Withstand Design

Item	Number	Remark
Nominal voltage; U_0 (kV)	33	
Maximum allowable voltage; U_m (kV)	36	1.2/1.1 U_0
Peak value (kV)	30	$\sqrt{2}/\sqrt{3}U_m$
Switching surge ratio to ground	2.8	
Switching surge voltage to ground (kV)	84	
Switching surge Altitude compensation	1.1	1000m or less
	1.2	Over 1000m up to 2000m
Required voltage to ground (kV)	93	Dar es Salaam
	101	Kilimanjaro, Arusha
Required number of insulators (piece)	3	* By switching impulse wet flashover and withstand voltage characteristics for 250mm suspension insulator.
Minimum insulation gap (cm)	15	Dar es Salaam
	25	Kilimanjaro, Arusha

(c) Resistance to commercial frequency

Table 14.2.17 Insulation Design For 33kv T/L; Power Frequency Withstand Design

Item	Number	Remark
Nominal voltage; U_0 (kV)	33	
Maximum allowable voltage; U_m (kV)	36	1.2/1.1 U_0
Voltage to ground (kV)	21	$U_m/\sqrt{3}$
Altitude compensation	1.1	1000m or less
	1.2	Over 1000m up to 2000m
Required voltage to ground (kV)	24	Dar es Salaam
	26	Kilimanjaro, Arusha
Required number of insulators (piece)	2	* By commercial frequency wet flashover and withstand voltage characteristics for 250mm suspension insulator.
Abnormal state insulation gap (cm)	8	Dar es Salaam, Kilimanjaro, Arusha

(d) Resistance to contamination

Table 14.2.18 Insulation Design for 33kV T/L; Contamination Withstand Design

Item	Number	Remark
Voltage to ground (kV)	21	$U_m/\sqrt{3}$
Voltage increasing coefficient	1.0	In case of one line to ground fault
Required voltage (kV)	21	
Equivalent salt deposit density (mg/cm^2)	0.25	
Insulator withstand voltage (kV/piece)*6	7.7	250mm suspension insulator
Required number of insulators (piece)	3	

*6: For the contamination withstand voltage per insulator, see 14.2.2(2)(d).

(e) Constant insulation distance

In all the three regions under consideration (Dar es Salaam, Arusha, and Kilimanjaro), the constant insulation distance shall be 55 cm.

(f) Summary of insulation design

Table 14.2.19 Insulation Design for 33kV T/L; Summary

Item		Number	Remark
Nominal voltage; U_0 (kV)		33	
Maximum allowable voltage; U_m (kV)		36	
Altitude compensation		1.1	1000m or less
		1.2	Over 1000m up to 2000m
Switching surge withstand design	Required voltage to ground (kV)	93	Dar es Salaam
		101	Kilimanjaro, Arusha
	Required number of insulators (piece)	3	Dar es Salaam, Kilimanjaro, Arusha
	Minimum insulation gap (cm)	15	Dar es Salaam
		25	Kilimanjaro, Arusha
Power frequency withstand design	Required voltage to ground (kV)	24	Dar es Salaam
		26	Kilimanjaro, Arusha
	Required number of insulators (piece)	2	Dar es Salaam, Kilimanjaro, Arusha
	Abnormal state insulation gap (cm)	8	Dar es Salaam, Kilimanjaro, Arusha
Contamination withstand design	Required voltage (kV)	21	
	Equivalent salt deposit density (mg/cm^2)	0.25	
	Insulator withstand voltage (kV/piece)	7.7	
	Required number of insulators (piece)	3	
Standard insulation gap (cm)		55	Dar es Salaam, Kilimanjaro, Arusha
Summary	Required number of insulators (piece)	3	
	Standard insulation gap (cm)	55	Dar es Salaam, Kilimanjaro, Arusha
	Minimum insulation gap (cm)	15	Dar es Salaam
		25	Kilimanjaro, Arusha
	Abnormal state insulation gap (cm)	8	Dar es Salaam, Kilimanjaro, Arusha

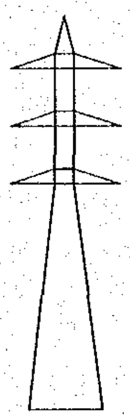
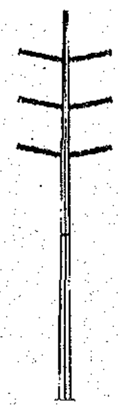
Fig.14.2.5 shows 33kV Pole Assembly.

14.2.4 Economic Evaluation of Steel Towers for 132 kV Transmission Line

In implementing the present detail design, we carried out an economic analysis of the conventional vertically arranged, double-circuit steel tower and an environment harmonaized steel tower.

(1) Cost of steel tower

Table 14.2.21 Comparison of cost of steel tower between vertically arranged, double-circuit steel tower and environment harmonaized steel tower

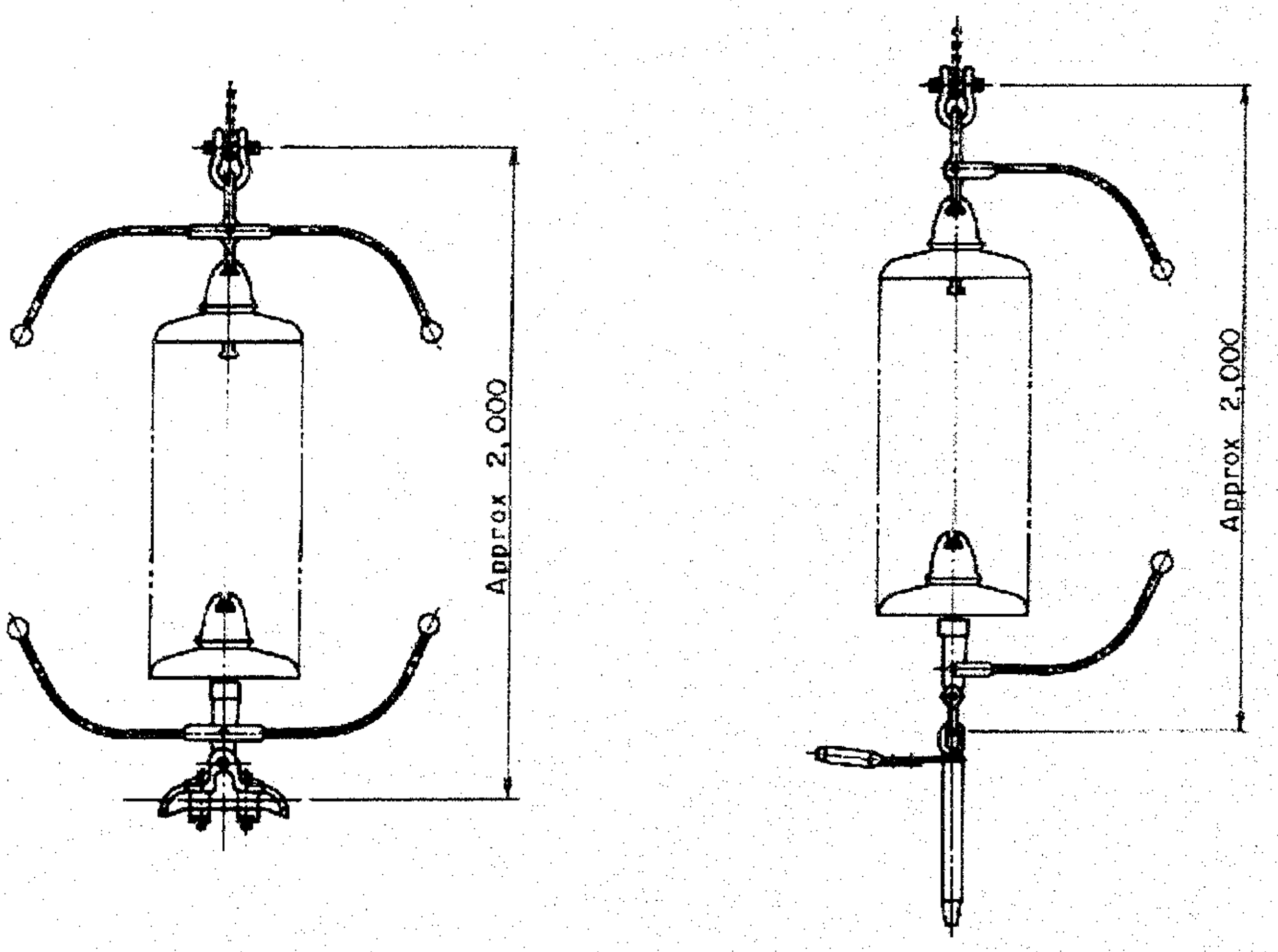
Structure Type	vertically arranged, double-circuit	Environment harmonaized
Structure material	Angle steel	Tubeless steel pipe
Steel Tower Structure		
Span length (m)	300	100
Tower Weight/km (%)	100	210
Material Cost/km (%)	100	290

(2) Summary

- A vertically arranged, double-circuit steel tower and an environment harmonaized steel tower were subjected to an economic analysis. As a result, it was found that the environment harmonaized steel tower is about 290% of verticaly arrenged, double-circuit steel tower higher in terms of the material cost par km.
- The stress applied to the foundation of the environment harmonaized steel tower is greater than that of the vertically arranged, double-circuit steel tower. Thus, at a place where the ground conditions are poor (e.g., marshland), there is the possibility that the cost of construction should become significantly high because of the need for a pile foundation, etc.
- The environment harmonaized steel tower uses tubeless steel pipe. This tubeless steel pipe is not standardized material, therefore it is difficult to find spear parts. (Normally standarized angle steel is used for steel towers in Tanzania.)
- The environment harmonaized steel tower of suspension type uses a line post

insulator. Unlike the ordinary suspension insulator, the line post insulator requires replacing the entire assembly even if only one insulator is damaged by a flashover, etc. Therefore, the cost of maintenance can increase.

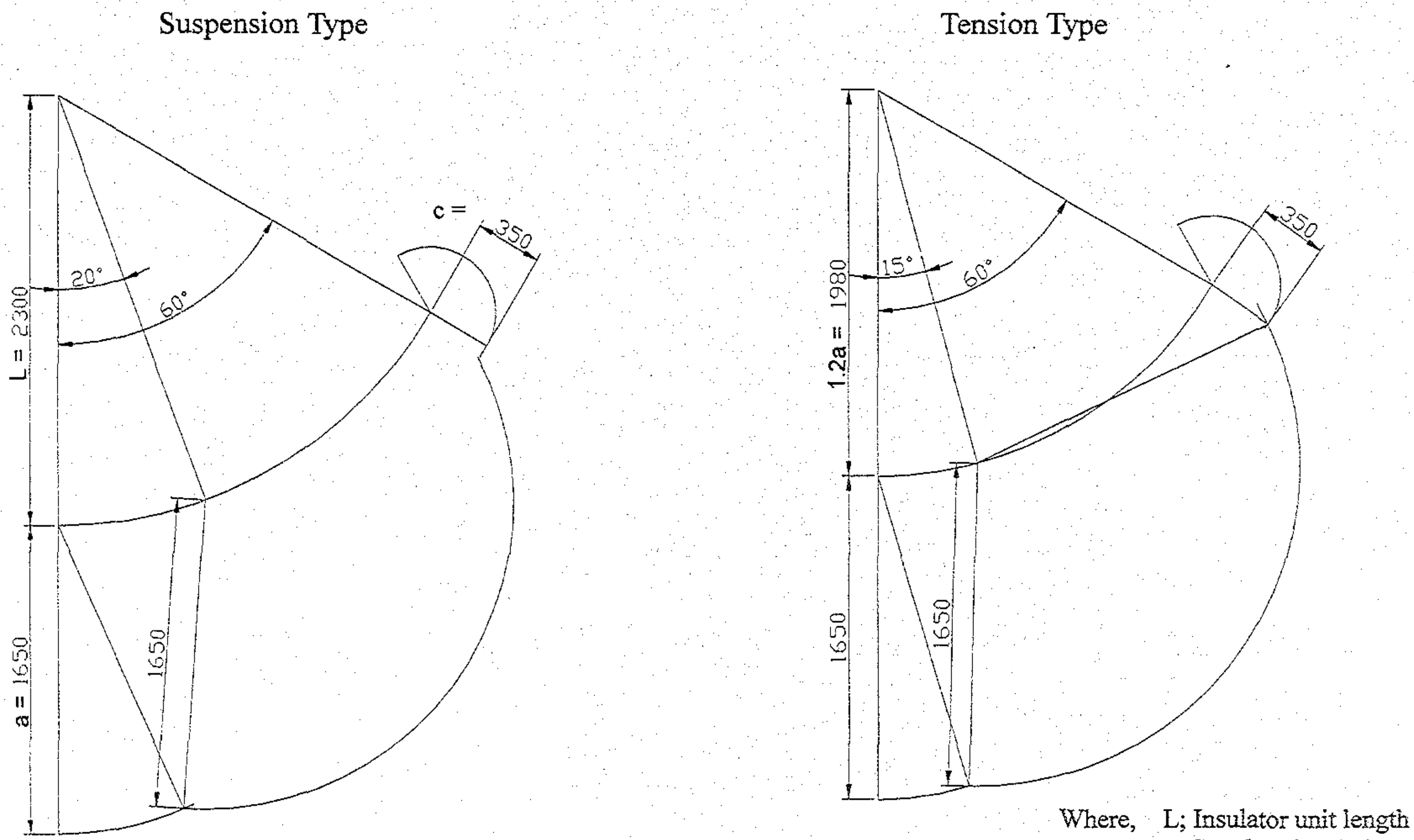
- At present, TANESCO uses 250 mm suspension insulators as standard (except for 11 kV, 33 kV pin insulators and line post insulators). For the trunk transmission lines (132 kV, 220kV), suspension insulators are used exclusively. Under this condition, introducing a 132 kV line post insulator runs counter to the current movement to unify the company standards.
- *From the facts mentioned above, it is recommended that the conventional vertically* arranged, double-circuit steel tower be used for the 132 kV transmission line.



Suspension Type

Tension Type

Fig. 14.2.1 Insulator Strings



Where, L; Insulator unit length
a; Standard insulation gap
c; Abnormal state insulation gap

Fig.14.2.2 132kV Transmission Line Clearance Diagram

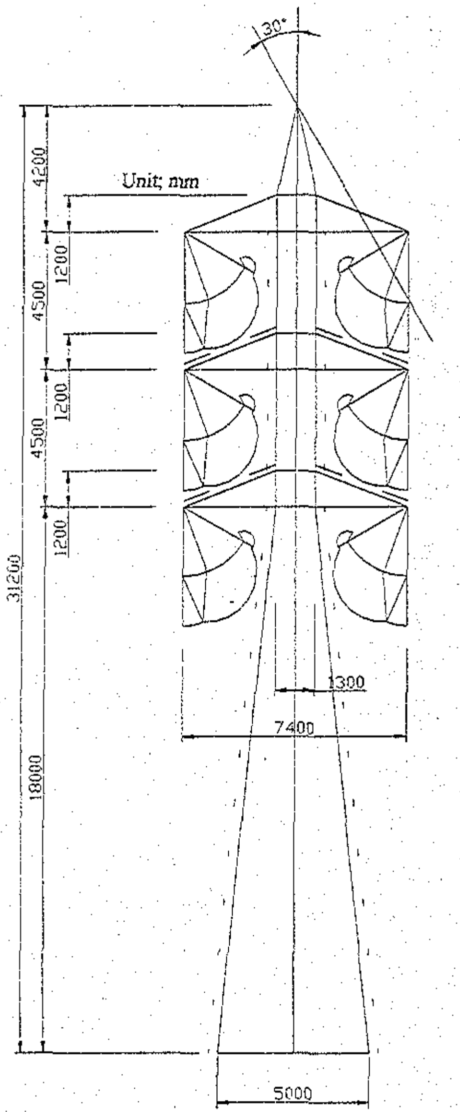


Fig.14.2.3 132kV Steel Tower Proportion (Suspension Type)

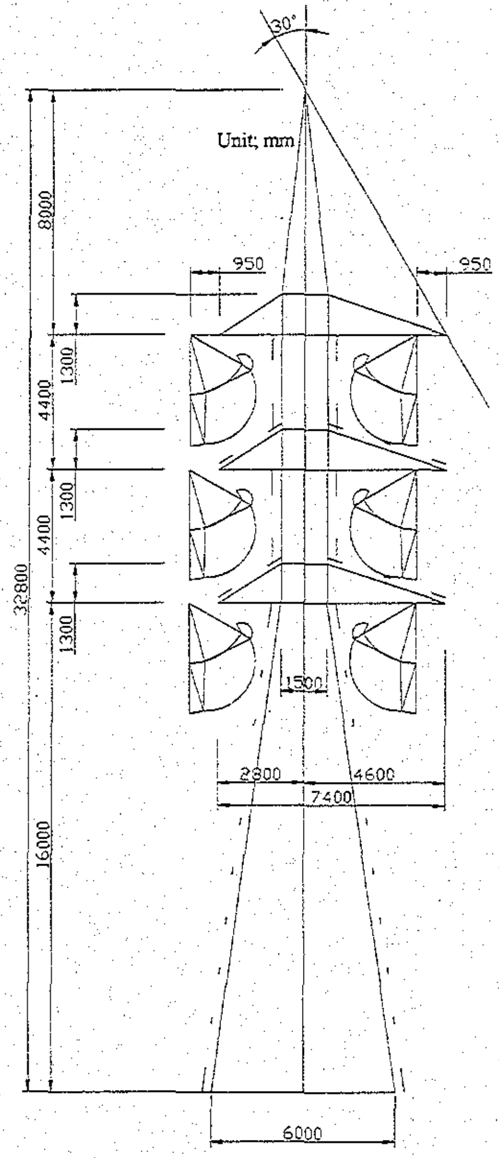
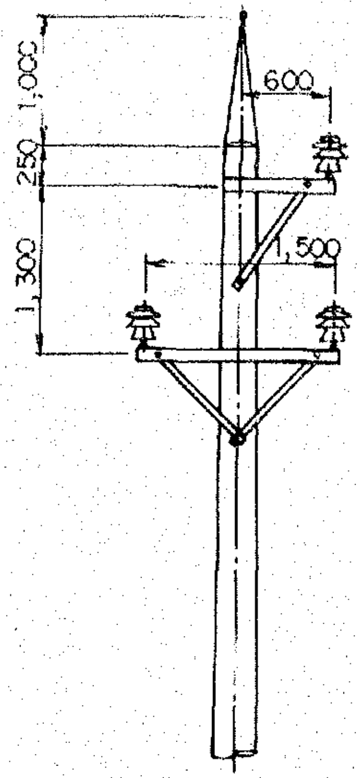
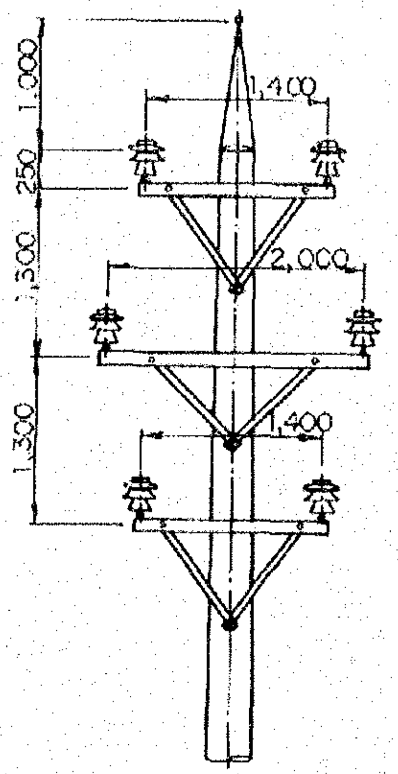


Fig.14.2.4 132kV Steel Tower Proportion (Tension Type: 30° Angle)



For Single Circuit



For Double Conductor or Double Circuit

Fig. 14.2.5 33kV Pole Assembly

14.3 Detailed Design of Substations

Of the substations included in the expansion plan (Case-B'), those which are planned to be completed by the end of 2004 were picked as the subjects of FS design.

14.3.1 Outline of Substations Subject to FS Design

The outline of the substations subject to FS design (substation name, project type (rehabilitation/expansion/construction), completion year, work description) is given below. Note that the substation projects already under way are not included.

(1) Dar es Salaam

Table 14.3.1 Substations Subjected to Feasibility Study (Dar es Salaam)

No	Name of Substation	Type	Prim. Voltage	Comp. Year	Project Summary	Remarks
1	Mbezi	R/E	33kV	2004	2x5MVA→15MVA All Equipment Rehabilitation	
2	Bagamoyo	New	33kV	2004	1x5MVA	
3	City Center	R/E	33kV	2004	15MVA →30MVA Switchgears and Cub. Replacement	
4	Mikocheni	Exp.	33kV	2004	1x15MVA	
5	Tandika	New	33kV	2004	1x15MVA	
6	FZ III	Exp.	132kV	2004	33kV TL lead out	For Tandika
7	FZ I	Rehab.	33kV	2004	Cub. Replacement	
8	FZ II	Rehab.	33kV	2004	Switchgears and Cub. Replacement	
9	Sokoine	Exp.	33kV	2004	1x15MVA	
10	City Center	Exp.	33kV	2004	33kV TL lead out	For Sokoine
11	Tandale	Exp.	33kV	2004	1x15MVA	
12	FZ III	Exp.	132kV	2004	1x15MVA	
13	New Oysterbay	New	132kV	2004	2x45MVA(132kV) 2x15MVA(33kV)	
14	Ubungo	Exp.	220kV	2004	132kV TL Lead out	For New OB
15	Oysterbay	R/E	33kV	2004	2x5MVA→15MVA Switchgears and Cub. Replacement 33kV TL lead out	For New OB

R/E: Rehabilitation and Expansion

(2) Arusha, Kilimanjaro

Table 14.3.2 Substations Subjected to Feasibility Study (Arusha, Kilimanjaro)

No	Name of Substation	Type	Prim. Voltage	Comp. Year	Project Summary	Remarks
1	Njiro	R/E	220kV	2004	1x45MVA(132kV) Switchgears Replacement	
2	Mt. Meru	Exp.	33kV	2004	3x5MVA→3x10MVA	
3	Unga LTD	R/E	33kV	2004	2x5MVA→3x10MVA	
4	Kiyungi	R/E	132kV	2004	1x45MVA(132kV) Switchgears Replacement	
5	Boma Mbuzi	R/E	33kV	2004	1x10MVA Switchgears Replacement	
6	Trade School	R/E	33kV	2004	1x10MVA Switchgears Replacement	
7	Marangu	New	33kV	2004	Booster and Switchgears	Sw/S
8	Kiltex	R/E	33kV	2004	1x10MVA Switchgears Replacement	
9	Machame	Exp.	33kV	2004	1x2.5MVA→1x5MVA	
10	Same	Rehab.	132kV	2004	Switchgears	

R/E: Rehabilitation and Expansion

14.3.2 Ratings of Devices Used

As a rule, the ratings of the devices used shall be decided in compliance with the concept of conceptual design of substations described in 7.2.

(1) Transformer

The applicable standard is IEC or an IEC-compatible standard.

As the cooling system, the conventional oil-immersed, self-cooling system shall be used in consideration of the comparatively small transformer capacity and from the viewpoint of simplifying the substation circuits, improving their reliability, and reducing the substation load.

Concerning the wire connection system, the same system as used in the existing substations shall be used for both the primary and secondary circuits so as to secure compatibility of the high- and low-order protective systems and coordinate their operations.

With respect to the rated capacity, the maximum capacity of the transformers now in use in the individual regions shall, as a rule, be adopted. Namely, the standard rated capacity shall be 45 MVA for 132 kV/33 kV transformers, 15 MVA for 33 kV/11 kV transformers used in the Dar es Salaam region, and 10 MVA for 33 kV/11 kV transformers used in the Arusha/Moshi region. It should be noted, however, that for those substations which are subject to load concentrations and site limitations (e.g., City Center

S/S), a larger rated capacity (30 MVA) shall be adopted. For the substations to be newly constructed in the Arusha/Moshi region, it has been decided to use a smaller rated capacity (5 MVA, 2.5 MVA, etc.) if a large load can hardly be expected for some time.

The range of tap changer adjustment shall, as a rule, be +-10% of rated voltage. For some 132 kV/33 kV transformers, however, the adjustable range has been set to -5% to +15% of their rated voltage in consideration of the voltage drop under heavy load.

City Center S/S is the substation that now appears to have noise problems. Therefore, it has been decided that the transformers to be newly installed in this substation should be of low-noise type.

The applicable transformer ratings are shown in Table 14.3.1.

Table 14.3.1 Transformer Ratings

No.	Voltage(kV)		Capacity (MVA)	OLTC Band +%、-%	Connec tion	Remark
	Pri.	Sec.				
1	132	33	45	+5、-15	Y-Y-△	
2	33	11	30	+10、-10	Y-△	for City Center
3	33	11	15	+10、-10	Y-△	
4	33	11	10	+10、-10	Y-△	for Arusha, Moshi
5	33	11	5	+10、-10	Y-△	for Arusha, Moshi

(2) Circuit breaker

(a) Types of circuit breakers

In recent years, the gas circuit breaker (GCB) is most widely used in electric power systems in the world because of excellent breaking performance and high durability/maintainability of the breaking unit, although the vacuum circuit breaker (VCB) is also used in a fairly large number of electric power systems.

The air-blast circuit breaker (ABB) and oil circuit breaker (OCB) that had been most commonly used in the past have come to be seldom employed in these years because of several problems, such as the inferior breaking performance and the excessive contact wear during arc suppression.

Besides, most of the circuit breaker manufacturers have already stopped production of air-blast circuit breakers and oil circuit breakers, hence it is extremely difficult to secure maintenance parts for these types of circuit breakers.

The same can be said of the circuit breakers employed at TANESCO. In particular, the oil circuit breakers that have been used for many years have become a serious problem in terms of the difficulty involved in securing their maintenance parts, as well as their performance.

In view of the facts mentioned above, in the present project, the gas circuit breaker that is advantageous in terms of both performance and maintenance shall be adopted.

(b) Ratings of circuit breaker

Concerning the rated voltage, the IEC-specified rated voltage appropriate to the voltage system to be used has been selected.

With respect to the rated interrupting current, it has been selected from the ones specified in IEC that will permit the circuit breakers planned for the present project to be safely used for about 20 years.

Concerning the rated current, values which nearly correspond to the IEC series have been selected with consideration given to the future transmission line capacity for circuit breakers for transmission lines and to the above transformer capacities for circuit breakers for transformer banks.

At present, the operating voltage and control voltage of circuit breakers are not uniform. However, since it is necessary to unify the voltages of all protective devices and control devices in the future, it has been decided to unify the working voltages of all DC power sources.

The ratings of circuit breakers are shown in Table 14.3.2.

Table 14.3.2 Circuit Breaker Ratings

No.	Voltage Class (kV)	Rated Voltage (kV)	Rated Current (A)	Breaking Capacity (kA)	Operational Voltage (V)	Interrupting Time (cycle)	Remark
1	132	145	1200	25	DC100	5	
2	66	72	800	20	DC100	5	for Moshi
3	33	36	600	12.5	DC100	5	for Arusha, Moshi
4	33	36	1200	12.5	DC100	5	
5	33	36	2000	25	DC100	5	for DSM
6	11	12	1200	25	DC100	5	
7	11	12	2000	25	DC100	5	for DSM

(3) Disconnecting switch

(a) Types of disconnecting switches

The disconnecting switches to be used shall, as a rule, be of single-point, horizontal-break type. For Ubungo S/S and some other substations where aluminum pipe is used as part of the bus, however, the pantograph-type disconnecting switch shall be used.

(b) Ratings of disconnecting switch

Since the disconnecting switch is used in series with the circuit breaker, it is necessary to coordinate the ratings of those devices.

Namely, the rated current of the disconnecting switch shall be the same as that of the circuit breaker, and the short-time current (normally for 2 seconds) of the disconnecting switch shall be one corresponding to the interrupting current of the circuit breaker.

Concerning the power sources for operation and control of the disconnecting switches, it has been decided to unify them as in the case of the circuit breakers.

The ratings of disconnecting switches are shown in Table 14.3.3.

(4) Instrument transformer, etc.

Instrument transformers, etc. for protection and monitoring shall be newly provided.

In order to secure coordination with the existing instrument transformers, etc., the secondary current of the current transformer (CT) shall be unified to 5 A and the primary current shall, as a rule, be set to the circuit breaker rated current.

The secondary voltage of the instrument transformer shall be 110 V/*3. If a tertiary voltage is required, it shall be 110 V/3. The primary voltage shall be the nominal voltage.

Table 14.3.3 Disconnecting Switch Ratings

No.	Voltage Class (kV)	Rated Voltage (kV)	Rated Current (A)	Shorttime Current Carring Capability (kA)	Operational Voltage (V)	Remark
1	132	145	1200	25	DC100	for Moshi
2	66	72	800	20	DC100	for Arusha, Moshi
3	33	36	600	12.5	DC100	for DSM
4	33	36	1200	12.5	DC100	
5	33	36	2000	25	DC100	

(5) Lightning arrester

(a) Types of lightning arresters

Most of the lightning arresters that are now in use are of zinc-oxide type, which is superior to other types in terms of both performance and maintenance (e.g., ease of deterioration judgment). Therefore, lightning arresters of this type shall be used.

(b) Selection of lightning arrester

Selecting a suitable lightning arrester is important from the viewpoint of securing protective coordination of the substation devices. However, since it has been decided that the insulation level of the devices to be protected shall be the same as that of the existing devices, the ratings of lightning arresters have not been lowered.

The ratings of several lightning arresters are shown in Table 14.3.4.

Table 14.3.4 Lightning Arrester Ratings

No.	Voltage Class (kV)	Rated Voltage (kV)	Discharge Voltage (kV)	BIL (kV)	LIWV of Protected Equipment(kV)
1	33	42	59	140	200
2	66	84	119	269	350
3	132	126	178	403	650
4	220	210	230	605	900

14.3.3 Substation Device Layout

For the substations that are to be expanded or newly constructed, the device layout shall be as designed based on conditions obtained during the field survey as long as the substation site conditions have been clearly known.

If the substation output has been decided but the substation site has not been decided definitely, a standard device layout and the site conditions required of the substation under consideration shall be indicated.

A typical example of device layout at one of the substations subject to FS is given below.

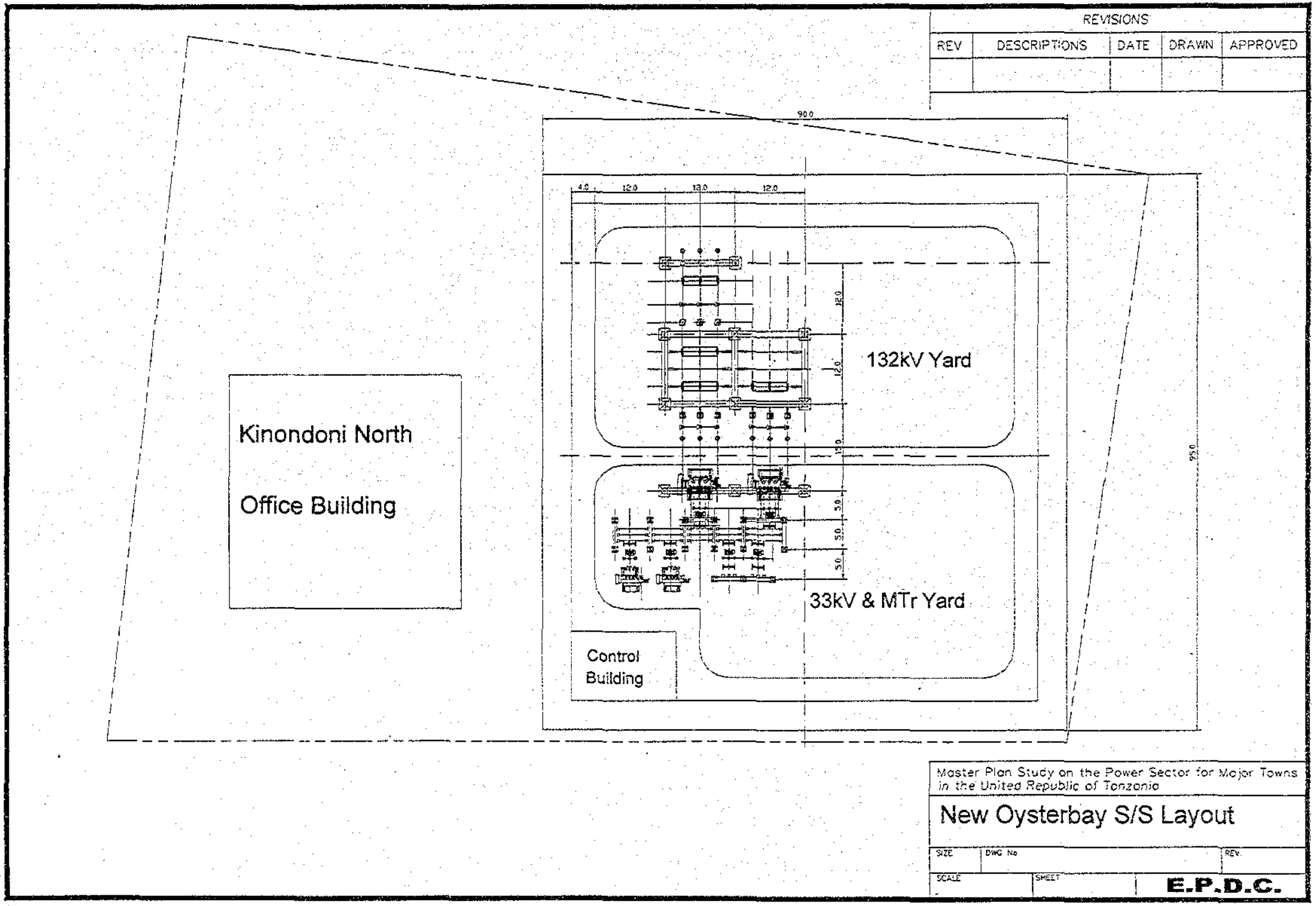


Fig. 14.3.1 New Oysterbay S/S Layout

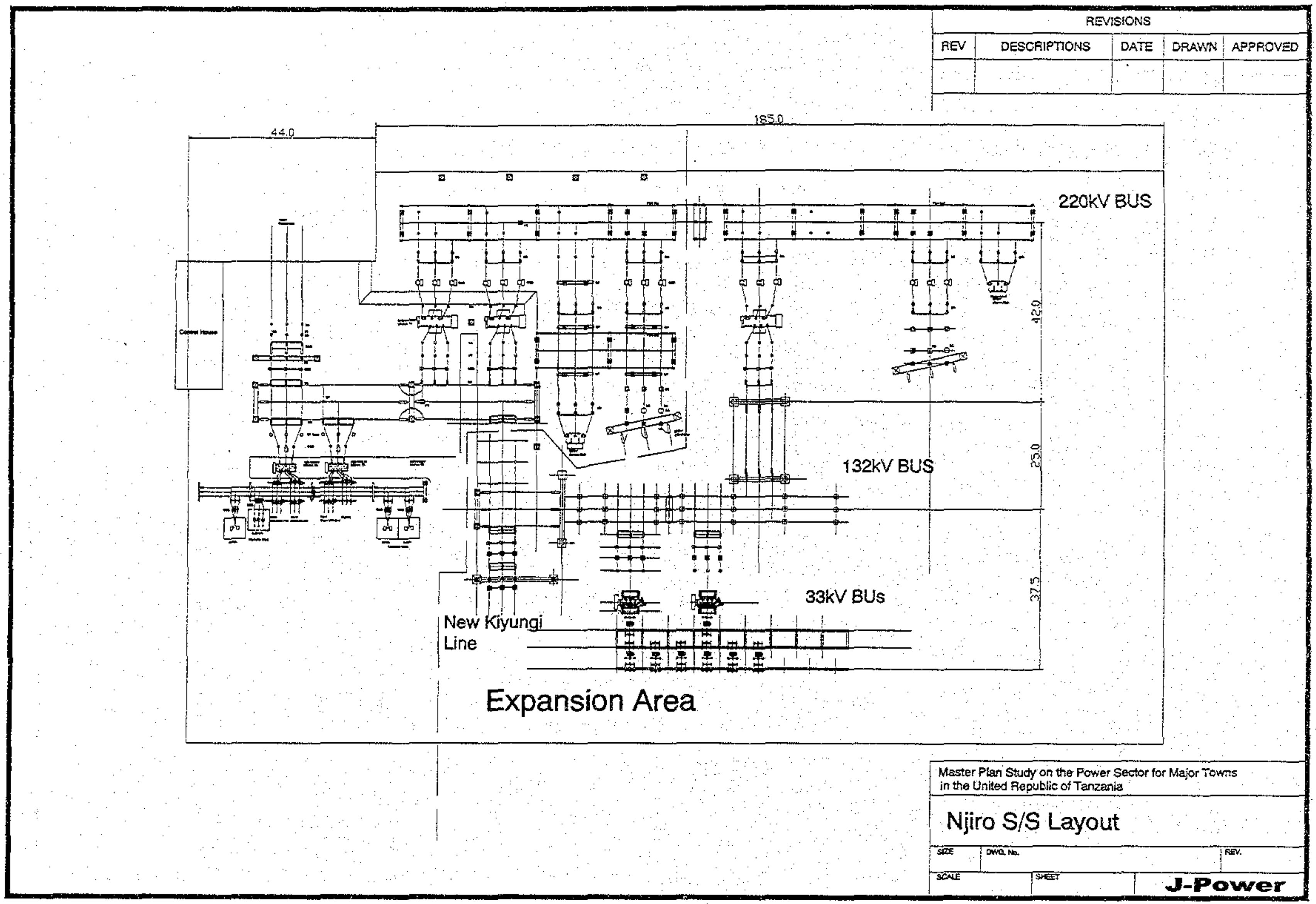


Fig. 14.3.2 Njiro S/S Layout

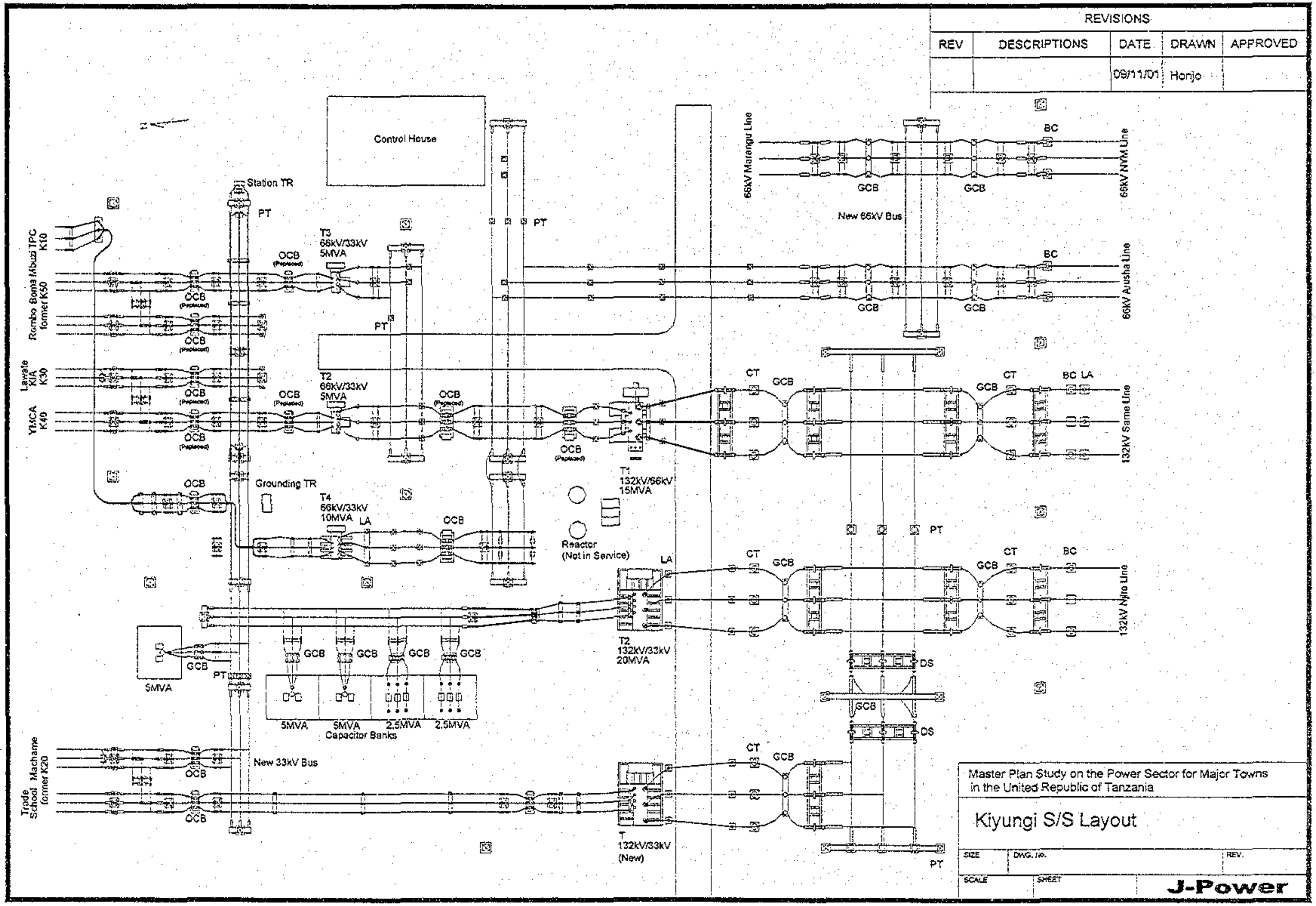


Fig. 14.3.3 Kiyungi S/S Layout

14.4 Detailed Design of Distribution Facilities

14.4.1 Basic Plan for Equipment Expansion

In the individual areas, the distribution facilities shall be improved and expanded as shown in the following tables at the same time that a new distribution substation is installed or an existing distribution substation is expanded.

Table 14.4.1a Feeder Expansion — Dar es Salaam

Year	Feeders	New (km)	Recontor (km)	Cable (m)	ABS (set)
2002	Bahari Beach - BB4	6.0		50	3
	Ubungo - U9	6.0		50	3
	Magomeni - M01	3.0		50	3
	Magomeni - M02	3.0		50	3
	Magomeni - M03	3.0		50	3
	2002 total : 5 feeders	21.0		250	15
2003	Mbezi - MB5	8.0		50	3
	Bagamoyo - BA01	6.0		50	3
	City Center - C9	2.0		50	3
	Mikocheni - MK5	13.0		50	3
	Tandika - TK1	6.0		50	3
	Tandika - TK2	6.0		50	3
	Tandika - TK3	6.0		50	3
	2003 total : 7 feeders	47.0		350	21
2004	Sokoine - SK5	1.0		50	3
	Tandale - MG6	8.0		50	3
	Factory Zone III - F36	9.0		50	3
	Factory Zone III - F37	9.0		50	3
	New Oysterbay - KN1	10.0		50	3
	New Oysterbay - KN2	10.0		50	3
	New Oysterbay - KN3	10.0		50	3
	Oysterbay - O7	6.0		50	3
	Kisalawe Feeder (33kV)	25.0		0	0
	2004 total : 9 feeders	88.0		400	24
Total	21 feeders	156.0		1,000	60

Table 14.4.1b Feeder Expansion — Arusha

Year	Feeders	New (km)	Recontor (km)	Cable (m)	ABS (set)
2002	Monduli - MD1	1.0		50	3
	Monduli - MD2	1.0		50	3
	Monduli - MD3	1.0		50	3
	2002 total : 3 feeders	3.0		150	9
2003	Mt. Meru - M01		8.0	50	1
	Mt. Meru - M02		10.0	50	1
	Mt. Meru - M03		13.0	50	1
	Mt. Meru - M04		5.0	50	1
	Mt. Meru - M05	8.0		50	1
	Mt. Meru - M06	8.0		50	1
	Unga Ltd. – F1		6.0	50	1
	Unga Ltd. - F2		70.0	50	1
	Unga Ltd. - F3		6.0	50	1
	Unga Ltd. - F4	3.0		50	3
	2003 total : 10 feeders	19.0	118.0	500	12
2004	Kiltex - K'tex		5.0	50	12
	Kiltex - Brew		5.0	50	1
	Kiltex - Sinon	6.0		50	1
	2004 total : 3 feeders	6.0	10.0	150	3
Total	16 feeders	6.0	128.0	800	24

Table 14.4.1c Feeder Expansion — Moshi

Year	Feeders	New (km)	Recontor (km)	Cable (m)	ABS (set)
2002	YMCA	5.0			3
	2002 total : 1 feeder	5.0			3
2003	Boma Mbuzi - Kibo		10.0	50	1
	Boma Mbuzi - Town		10.0	50	1
	Boma Mbuzi - Boma		10.0	50	1
	Boma Mbuzi - B04	5.0		50	3
	Boma Mbuzi - B05	5.0		50	3
	Trade School - M1		10.0	50	3
	Trade School - M2		10.0	50	3
	Trade School - M3		10.0	50	3
	Machame -SP		15.0	50	1
	2003 total : 9 feeders	10.0	75.0	450	19
Total	10 feeders	15.0	75.0	450	22

14.4.2 Work Plans

The contents of work plans for construction of new 11 kV feeders and expansion of existing 11 kV feeders for newly-constructed or expanded substations are described below. In addition, the contents of load shedding to new feeders are summarized in Tables 14.4.2, 14.4.3 and 14.4.4.

(1) Dar es Salaam

(a) Plans for 2002

(i) Construction of Bahari Beach S/S

A new feeder (BB04) shall be constructed to shed about 43% of the load that is now supplied by the MB3 and MB4 feeders of Mbezi S/S. The area to be covered by the BB04 feeder includes Las Kilomoni, Bahari Beach, Kunduchi Beach, White Sand Beach, etc. There are new residential quarters, seaside resort hotels, broadcasting facilities, etc. in the area.

(ii) Reinforcement of Ubungo S/S

A new feeder (U9) shall be constructed to take over about one-half of the U8 load.

(iii) Reinforcement of Magomeni S/S

Three feeders shall be led out from the newly-constructed substation to take over about 48% of the load of D13 from Ilala S/S and MG4 and MG5 from Tandale S/S. This is expected to reduce the power loss by more than 50%.

(b) Plans for 2003

(i) Reinforcement of Mbezi S/S

A new feeder (MB05) shall be constructed to shed about 37% of the load of the existing feeders—MB2, MB3, and MB4.

(ii) Reinforcement of Bagamoyo S/S

A new feeder (BA01) shall be constructed to shed 70% of the existing load.

(iii) Reinforcement of City Center S/S

Since the existing 11 kV feeders are sound, no special measures shall be taken. The reinforcement of Sokoine S/S will reduce the load of City Center S/S by about 20%, preventing the occurrence of power supply problems for some time.

(iv) Reinforcement of Mikocheni S/S

Two new feeders shall be added to the existing four feeders to take over about 30% of the load.

(v) Construction of Tandika S/S

At present, the area to be covered by the new substation is supplied by the MBF3 feeder of Mbagala S/S and the KR3 feeder of Kurasini S/S. However, the excessively long feeders of the two substations have caused the problem of voltage fluctuation. As a means to solve this problem, a new distribution substation shall be constructed and three feeders of this substation shall be linked to the existing distribution network. It is expected that the new substation will significantly reduce the power loss of the existing distribution network.

(c) Plans for 2004

(i) Reinforcement of Sokoine S/S

A new feeder (SK05) shall be constructed to shed about 35% of the load of the existing feeders (SK1 ~ SK4).

(ii) Expansion of Tandale S/S

A new feeder (MG6) shall be constructed to reduce the load of the MG1 and MG2 feeders. Since about 49% of the MG4/MG5 feeder load will have been reduced by construction of Magomeni S/S in the preceding year, the fear of heavy loads with Tandale S/S will disappear at this point of time.

(iii) Reinforcement of FZ III S/S

Two new feeders shall be constructed to increase the capacity for supply to the industrial zone along Airport Road.

(iv) Construction of New Oysterbay S/S

The newly-constructed New Oysterbay S/S will function as the primary substation for the Oysterbay, Kinondoni, Mikocheni, and Msasani districts. Three feeders shall be constructed at the 11 kV side to increase the capacity for supply to those districts. At the same time, the newly-constructed feeders shall bear part of the load of the Oyster Bay S/S O2 feeder and the Mikocheni S/S MK1/MK4 feeders.

(v) Reinforcement of Oysterbay S/S

A new feeder (O7) shall be constructed to increase the capacity for supply to the Kinondoni district.

(vi) Reinforcement of Msasani S/S

As the capacity of the substation main transformer is increased, two new feeders shall be constructed to increase the supply capacity on the Msasani Peninsula.

Table 14.4.2 Feeder Load Sharing Plan — Dar es Salaam

Year	Substations	Feeders	Before (kW)	Load		After (kW)
				Feeders	(kW)	
2002	Bahari Beach	BB4	0			2,414
			3,693	MB3	2,031	
			1,915	MB4	383	
				Total	2,414	
	Ubungo	U9	0			3,006
			5,466	U8	3,006	
	Magomeni	M01-03	0			5,739
			4,399	D13	2,024	
			3,480	MG4	2,053	
			4,050	MG5	1,662	
				Total	5,739	

2003	Mbezi	MB5	0			2,481
			2,884	MB2	1,154	
			1,742	MB3	645	
			2,068	MB4	682	
				Total	2,481	
	Bagamoyo	BA01	0			770
			1,100	BA00	770	
	City Center	C9-C10	0			5,130
			28,500	C2-C8	5,130	
	Mikocheni	MK5	0			4,444
			5,505	MK2	1,652	
			5,899	MK3	1,770	
			5,112	MK4	1,022	
				Total	4,444	
	Tandika	TK1-3	0			5,808
			5,466	MBF3	4,100	
			4,616	KR3	1,708	
				Total	5,808	
2004	Sokoine	SK5	0			2,088
			5,093	SK1	255	
			2,271	SK2	114	
			3,244	SK3	162	
			5,191	SK4	1,557	
				Total	2,088	
	Tandale	MG6	0			4,967
			3,393	MG1	1,527	
			3,978	MG2	1,790	
			1,574	MG4	630	
			2,550	MG5	1,020	
				Total	4,967	
	FZ.III	F36-37	0			3,380
			16,900	F31-34	3,380	
	New Oysterbay	KN1-3	0			4,629
			3,912	O2	2,347	
			2,244	MK1	1,391	
			4,448	MK2	891	
				Total	4,629	
	Oysterbay	O7				6,309
			2,445	O3	734	
			9,537	O4	2,861	
			5,380	O5	1,614	
			3,668	O6	1,100	
				Total	6,309	

(2) Arusha

(a) Plan for 2002

As construction of Monduli S/S will be completed, four new feeders shall be constructed.

(b) Plans for 2003

(i) Reinforcement of Mt. Meru S/S

All the overhead conductors of the four existing feeders shall be replaced with ACSR 100. At the same time, supports and insulators which have deteriorated badly shall be replaced with new ones. It is expected that these measures will significantly reduce the power loss.

(ii) Reinforcement of Unga Ltd. S/S

The overhead conductors of the two existing feeders shall be replaced with ACSR 100. At the same time, supports and insulators which have deteriorated badly shall be replaced with new ones. In addition, one new feeder shall be constructed to increase the supply capacity.

(c) Plan for 2004

As Kiltex S/S will be reinforced, the overhead conductors of the two existing feeders shall be replaced with ACSR 100. At the same time, supports and insulators which have deteriorated badly shall be replaced with new ones.

(3) Moshi

(a) Plan for 2002

One feeder shall be led out from the newly-constructed YMCA S/S to reduce the load of Boma Mbuzi S/S.

(b) Plans for 2003

(i) Reinforcement of Boma Mbuzi S/S

The overhead conductors of the existing three feeders shall be replaced with ACSR 100. At the same time, supports and insulators which have deteriorated badly shall be replaced with new ones. In addition, two new feeders shall be constructed to increase the supply capacity of the S/S.

(ii) Reinforcement of Trade School S/S

The overhead conductors of the existing three feeders shall be replaced with ACSR 100. At the same time, supports and insulators which have deteriorated badly shall be replaced with new ones.

(iii) Reinforcement of Machame S/S

The overhead conductors of the existing feeder shall be replaced with ACSR 100. At the same time, supports and insulators which have deteriorated badly shall be replaced with new ones.

Table 14.4.3 Feeder Load Sharing Plan — Arusha

Year	Substations	Feeders	Before (kW)	Load		After (kW)
				Feeders	(kW)	
2002	Monduli	MD1-3	0			2,250
			2,500	F03	2,250	
2003	Unga Ltd.	F4	0			3,775
			6,225	F2	1,868	
			6,356	F3	1,907	
				Total	3,775	

Table 14.4.4 Feeder Load Sharing Plan — Moshi

Year	Substations	Feeders	Before (kW)	Load		After (kW)
				Feeders	(kW)	
2002	YMCA	Y1-3	0			6,546
			9,352	Town	6,546	
2003	Boma Mbuzi	BM04-05	0			8,700
			5,001	Kibo	1,500	
			9,999	Town	7,000	
			1,999	Boma	200	
				Total	8,700	

14.4.3 Design Outline

In designing new 11 kV distribution equipment, emphasis shall be placed on maintaining harmony with the existing equipment, securing stable power supply for a long period of time, operating the equipment efficiently, maintaining proper voltage, and improving the reliability of power supply. Concretely, construction of new feeders, replacement of worn conductors and cables, reinforcement of pole structures, and installation of section switches for efficient system operation shall be planned.

(1) Classification of application of overhead lines and underground lines

As a rule, distribution lines shall be overhead lines from the viewpoint of maintaining harmony with the existing facilities, minimizing the cost involved, and facilitating maintenance. Concerning feeders led out from substations, it is often difficult to use overhead lines because of a number of limitations e.g., arrangement of the power-transforming devices. Therefore, an underground cable line shall be used for them. The cable shall be laid by using the direct burying method that is employed today.

(2) Nominal voltage and electrical system

Nominal voltage: 33 kV/11 kV
Distribution system: 3-phase, 3-wire (neutral point direct grounded)
Line type: Tree branch type
Voltage drop: Maximum 10%

(3) Wire arrangement and pole configuration

There are various methods of wire arrangement—horizontal arrangement, vertical arrangement, triangular arrangement. The advantages and disadvantages of the three representative arrangements are described in Table 14.4.5.

When it comes to installing an additional pole transformer, horizontal arrangement is most widely used since it permits the lead wires to be easily led down to the pole mounted equipment and requires a shorter pole compared with the other methods of assembling (this means that the horizontal arrangement is more economical). In some of the busy districts of Dar es Salaam, the required space for a distribution line can hardly be secured. In those districts, therefore, either vertical arrangement or triangular arrangement shall be used with consideration given to the harmony with the existing facilities. In Arusha and Moshi, the horizontal arrangement method that is currently used shall be adopted.

Table 14.4.5 Comparison of Wire Arrangement and Pole Configuration

	Horizontal	Vertical	Triangular
Advantages	Use of long poles can be reduced. Pole mounted equipment can be led down easily.	Narrow wire width securing necessary clearance from houses, trees, etc. Effect of swinging of cable by winds can be neglected.	Wire width is comparatively small. Less long poles are required compared with vertical. Pole mounted equipment can be led down relatively easily.
Disadvantages	Wide wire width makes it difficult to secure necessary clearance from houses, trees, etc. Effect of winds must be considered when deciding cable horizontal spacing.	Long poles are required. Pole mounted equipment can hardly be lead down.	Longer poles are required compared with horizontal arrangement.
Application	Suitable in areas where space for distribution line can be secured easily.	Suitable in densely-populated areas where space for distribution line can hardly be secured.	Suitable in densely-populated areas where space for distribution line can hardly be secured.

(4) Overhead conductor

A 100 mm^2 aluminum conductor steel reinforced (ACSR 100) which is TANESCO's standard conductor for 11 kV distribution lines shall be used.

(5) Standard span

According to survey results, the present span of distribution lines is in the range 40 m to 110 m. In most cases, however, the span is 60 m to 70 m. Therefore, the design span was set at 65 m.

(6) Pole length

The pole length required for horizontal wire arrangement is calculated as follows:

$$\text{Pole length} \geq \frac{6}{5}(\text{ground height} + \text{dip} + \text{distance from top of bottom wire})$$

$$\geq (6.0 + 1.7 + 0.25) = 9.54\,(\text{m})$$

Taking into account irregularities of the ground surface, installation of a low-voltage line on the same pole, etc., the standard pole length for horizontal wire arrangement shall be 11 m. For triangular wire arrangement, the standard pole length shall be 12 m.

(7) Selection of suitable type of support

There are various types of supports—wooden pole, concrete pole, steel tubular pole, panzer mast. The characteristics of these supports are shown below.

Table 14.4.6 Characteristics of Support

	Wooden pole	Concrete pole	Steel pole	Panzer mast
Strength	×	○	△	△
Cost	○	△	×	×
Ease of use	△	×	○	○
Appearance	×	△	○	△

Note) ○Good △Average ×Bad

In the busy districts of Dar es Salaam, steel tubular poles are widely used, although wooden poles are used in the other districts. In the present design, therefore, steel tubular poles were selected for urban districts and wooden poles were selected for other districts.

(8) Protection for long feeders

Pole mounted auto reclosers are considered to protect long feeders against ground faults.

(9) Specifications of principal materials

Concerning the power cables, insulators, lightning arresters, etc., materials of the specifications shown in 7.3 shall be adopted.

(10) Standard pole configuration drawings

The standard pole configuration drawings for 11 kV distribution lines are given in Fig. 14.4.1 to 14.4.3.

(11) List of principal materials

The quantities of the principal materials required for execution of the project are shown in Table 14.4.4.

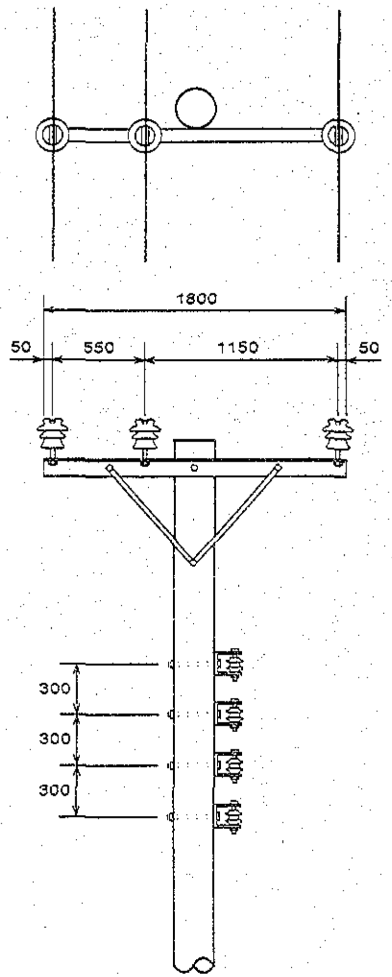


Fig.14.4.1 Typical Pole Configuration
Straight line Pole

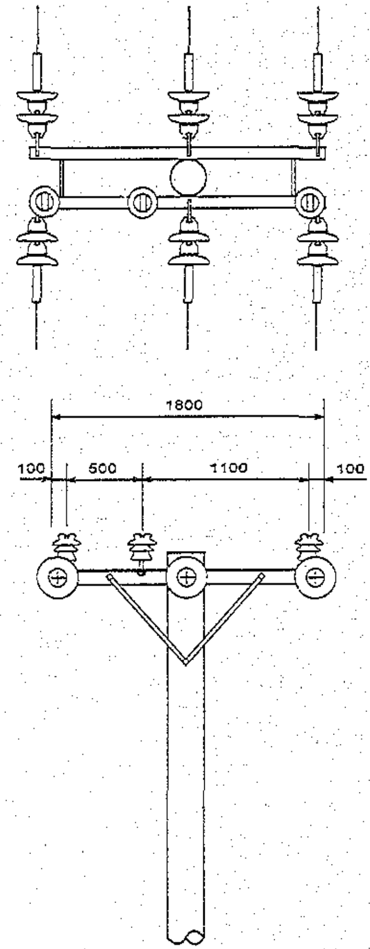


Fig.14.4.2 Typical Pole Configuration
Section Pole (Single Pole)

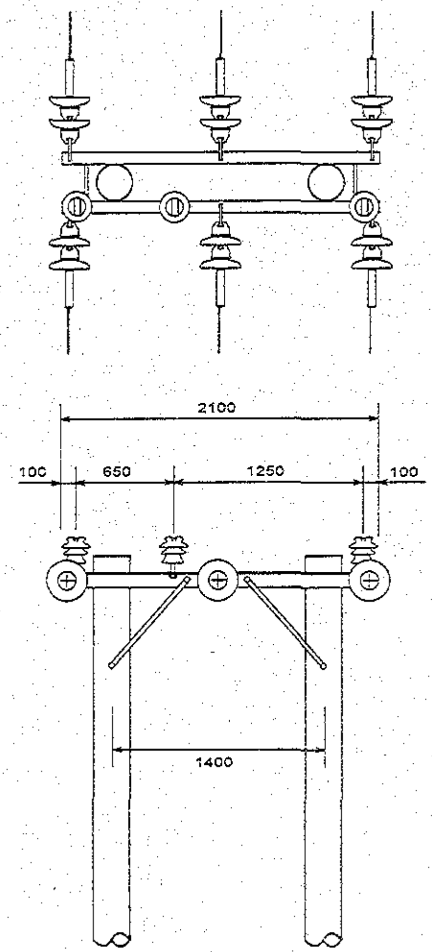


Fig.14.4.3 Typical Pole Configuration
Section Pole (H-Pole)

Table 14.4.7 Major Materials

Dar es Salaam

Year	Substations		Overhead line					Underground	
			Poles		Conductor	ABS	Arrester	Cable	Termination
			Wood	Steel	ACSR 100	400A		3C x 185	
			(pcs)	(pcs)	(m)	(set)	(set)	(m)	(set)
2002	Bahari Beach S/S	BB04	103		18,540	3	9	50	2
	Ubungo S/S	U9	103		18,540	3	9	50	2
	Magomeni S/S	M01	52		9,270	3	9	50	2
		M02	52		9,270	3	9	50	2
		M03	52		9,270	3	9	50	2
	2002 total		362		64,890	15	45	250	10
2003	Mbezi S/S	MB5	137		24,720	3	9	50	2
	Bagamoyo S/S	BA01	88		18,540	3	9	50	2
	City Center S/S	C9		34	6,180	3	9	50	2
	Mikocheni S/S	MK5	223		40,170	3	9	50	2
	Tandika S/S	TK1	103		18,540	3	9	50	2
		TK2	103		18,540	3	9	50	2
		TK3	103		18,540	3	9	50	2
	2003 total		757	34	145,230	21	63	350	14
2004	Sokoine S/S	SK5		17	3,090	3	9	50	2
	Tandale S/S	MG6	137		24,720	3	9	50	2
	Factory Zone III S/S	F36	155		27,810	3	9	50	2
		F37	155		27,810	3	9	50	2
	New Oysterbay S/S	KN1	172		30,900	3	9	50	2
		KN2	172		30,900	3	9	50	2
		KN3	172		30,900	3	9	50	2
	Oysterbay S/S	O7	103		18,540	3	9	50	2
	2004 total		1,066	17	194670	24	72	400	16
2002-2004 total			2,185	51	404,790	60	180	1,000	40

Arusha

Year	Substations		Overhead line: Poles Wood (pcs)	Overhead line: Poles Steel (pcs)	Overhead line: Conductor ACSR 100 (m)	Overhead line: ABS 400A (set)	Overhead line: Arrester (set)	Underground: Cable 3C x 185 (m)	Underground: Termination (set)
2002	Monduli S/S	M01	15		3,090	3	9	50	2
		M02	15		3,090	3	9	50	2
		M03	15		3,090	3	9	50	2
	2002 total		45		9,270	9	27	150	6
2003	Mt. Meru S/S	MM1	35		24,720	1	3	50	2
		MM2	44		30,900	1	3	50	2
		MM3	57		40,170	1	3	50	2
		MM4	22		15,450	1	3	50	2
	Unga Ltd. S/S	F2	309		216,300	1	3	50	2
		F3	26		18,540	1	3	50	2
		F4	44		9,270	3	9	50	2
	Kiltex	K'tex	22		15,450	1	3	50	2
		Brew	22		15,450	1	3	50	2
	2003 total		581	0	386,250	11	33	450	18
2002-2003 total			626	0	395,520	20	60	600	24

Moshi

Year	Substations		Overhead line					Underground	
			Poles		Conductor	ABS	Arrester	Cable	Termination
			Wood	Steel	ACSR 100	400A		3C x 185	
			(pcs)	(pcs)	(m)	(set)	(set)	(m)	(set)
2002	YMCA S/S		74		15,450	3	9	50	2
2003	Boma Mbuzi S/S	Kibo	44		30,900	1	3	50	2
		Town	44		30,900	1	3	50	2
		Boma	44		30,900	1	3	50	2
		B04	74		15,450	3	9	50	2
		B05	74		15,450	3	9	50	2
	Trade School S/S	M1	44		30,900	3	9	50	2
		M2	44		30,900	3	9	50	2
		M3	44		30,900	3	9	50	2
	Machame S/S	SP	66		46,350	1	3	50	2
Total			552	0	278,100	22	66	500	20

14.4.4 Improvement Effects

(1) Reduction of power loss

The reduction of annual power loss of the 11 kV distribution network brought about by the present project is calculated as shown in the following table. The improvement in power supply at each of the distribution substations in the project area is shown in Table 14.4.8

Table 14.4.8 Loss Reduction in Dar es Salaam

Year	Substations	Loss Reduced (kW)	per Year (MWh)
2002	Bahari Beach S/S	142	1,244
	Ubungo S/S	316	2,768
	Magomeni S/S	364	3,189
	2002 total	822	7,201
2003	Mbezi S/S	31	272
	Bagamoyo S/S	27	237
	City Center S/S	246	2,155
	Mikocheni S/S	250	2,190
	Tandika S/S	1,304	11,423
	2003 total	1,853	16,277
2004	Sokoine S/S	59	517
	Tandale S/S	170	1,489
	FZ.III S/S	602	5,274
	New Oysterbay S/S	79	692
	Oysterbay S/S	177	1,551
	2004 total	1,087	9,523
Total		3,767	33,001

Note) MWh per year = Loss Reduced × 8,760 hours

Table 14.4.9 Loss Reduction in Arusha

Year	Substations	Loss Reduced (kW)	per Year (MWh)
2002	Monduli S/S	418	3,662
2003	Mt. Meru S/S	298	2,610
	Unga Ltd S/S	408	3,574
	2003 total	706	6,185
2004	Kiltex S/S	4	35
Total		1,124	9,846

Note) MWh per year = Loss Reduced × 8,760 hours

Table 14.4.10 Loss Reduction in Moshi

Year	Substations	Loss Reduced (kW)	per Year (MWh)
2002	YMCA S/S	1,402	12,282
2003	Boma Mbuzi	1,375	12,045
	Trade School S/S	103	902
	Machame S/S	30	263
	2003 total	1,508	13,210
Total		2,910	25,492

Note) MWh per year = Loss Reduced × 8,760 hours

(2) Reduction of energy loss due to power outage

It is expected that the effects of the present project, such as the reduction of power failures due to accident and the reduction of duration of power outage, will appear gradually. Although it is rather difficult to grasp those favorable effects quantitatively, the amount of electric energy that could be reduced was calculated based on the power failure data of the 18 substations in Dar es Salaam obtained during the field surveys, as follows.

(a) Average load per feeder

As shown in the following table, in 2002, the maximum power demand at the substations under consideration is 276.4 MW in total, with the maximum load per feeder being 3.89 MW.

Table 14.4.11 Max Load of Feeders (Year 2002)

Substation	Max Load (MW)	Feeders (cct)	Load/Feeder (MW)
Ubungo	12.0	4	3.00
Ilala	34.7	9	3.86
Tegeta	38.1	3	12.70
City Centre	25.0	6	4.17
Oysterbay	22.2	5	4.44
F.Zone I	15.9	3	5.30
Mikocheni	16.3	4	4.08
Mbezi	7.4	3	2.47
F.Zone III	14.3	4	3.58
Kurasini	14.0	4	3.50
F.Zone II	3.4	2	1.70
Kigamboni	2.5	2	1.25
Tandale	14.1	4	3.53
Msasani	10.8	3	3.60
Sokoine	14.3	4	3.58
Kariakoo	9.1	3	3.03
Mbagala	12.2	4	3.05
Chang'ombe	10.1	4	2.53
Total	276.4	71	3.89

After execution of the present project, 20 new feeders will have been constructed in the areas covered by the project through construction and expansion of substations. Therefore, the average load per feeder will become 3.03 MW.

(b) Average duration of power failure

According to the 1998 record on power failures shown in the following table, the average duration of power failure at the 14 substations was 1.08 hours per feeder.

Table 14.4.12 Number of Outages and Duration (Year 1998)

Substations	Nos. of Outages	Duration (h)	Feeders (cct)	Hr/Feeder (h)
Ubungo	39	53.72	4	1.38
Ilala	87	47.38	9	0.54
City Centre	66	48.85	6	0.74
Oysterbay	35	30.68	5	0.88
F.Zone I	29	34.15	3	1.18
Mikocheni	54	51.24	4	0.95
Mbezi	24	32.24	3	1.34
F.Zone III	40	49.14	4	1.23
Kurasini	67	85.87	4	1.28
F.Zone II	22	62.16	2	2.83
Kigamboni	6	19.33	2	3.22
Tandale	21	20.82	4	0.99
Msasani	17	15.79	3	0.93
Sokoine	5	0.38	4	0.08
Total	512	551.75	57	1.08

The duration of a power failure has to do with the condition of the distribution equipment, maintenance system, levels of skills of workers, etc. In order to reduce the duration of power outage, it is necessary to improve all the factors involved. Although there are a number of uncertain factors, it was assumed that the average duration of power outage could be reduced by about 10% through installation of additional line switches, reinforcement of the DAMP functions, and so on.

(c) Frequency of power outage due to accident

Power outage due to trouble with an 11 kV feeder can be caused by various factors, such as windstorm, thunderstorm, and equipment deterioration. After execution of the present project, the incidence of power failure per feeder will decrease as the feeder length is reduced. On the other hand, the number of feeders increases, hence it can hardly be expected that the incidence of power failure in the entire project area will decrease significantly.

Equipment deterioration, a factor in power failures, might become aggravated as the equipment continues to be used. However, on the premise that the planned maintenance work by TANESCO (DAMP) would be continued on a lasting basis, it was assumed that even after execution of the project, the incidence of power outage would remain at the level of 1998.

(d) Amount of fault electric energy reduced by project execution

Using the estimated values shown in (a)-(c), the amount of fault electric energy before and after execution of the project is calculated as follows. (Loss factor : 0.4)

Before project execution

Annual loss = 512 (times) x 3.89 (MW) x 0.4 x 1.08 (hrs) = 860 MWh

After project execution

Annual loss = 512 (times) x 3.03 (MW) x 0.4 x 0.97 (hrs) = 602 MWh

Loss reduction

Annual reduction = 860 – 602 = 258 (MWh)

(3) Voltage improvement

After execution of the present project, the voltage drop of every 11 kV feeder under consideration will decrease to 10% (target value) or less.

Table 14.4.13 Improvement of Voltage Drop in Dar es Salaam

Year	Substations	Feeder	Before		After	
			(V)	%	(V)	%
2002	Bahari Beach	BB4	–	–	401	3.6
		MB3	350	3.2	280	2.5
		MB4	982	8.9	442	4.0
	Ubungo	U9	–	–	499	4.5
		U8	1,453	13.2	654	5.9
	Magomeni	M01-03	–	–	318	2.9
		D13	804	7.3	434	3.9
		MG4	1,166	10.6	478	4.3
		MG5	572	5.2	337	3.1
2003	Mbezi	MB5	–	–	550	5.0
		MB2	327	3.0	196	1.8
		MB3	285	2.6	179	1.6
		MB4	813	7.4	545	5.0
	Bagamoyo	BA01	–	–	197	1.8
		BA00	563	5.1	169	1.5
	City Center	C9-C10	–	–	284	2.6
		C2-C8	1,026	9.3	647	5.9
	Mikocheni	MK5	–	–	862	7.8
		MK2	625	5.7	437	4.0
		MK3	1,389	12.6	972	8.8
		MK4	934	8.5	748	6.8
	Tandika	TK1-3	–	–	322	2.9
		MBF3	3,542	32.2	885	8.0
		KR3	1,291	11.7	813	7.4
2004	Sokoine	SK5	–	–	94	0.9
		SK1	99	0.9	30	0.3
		SK2	31	0.3	43	0.4
		SK3	45	0.4	252	2.3
		SK4	359	3.3	58	0.5

Year	Substations	Feeder	Before		After	
			(V)	%	(V)	%
2004	Tandale	MG6	—	—	55	0.5
		MG1	150	1.4	83	0.8
		MG2	452	4.1	248	2.3
		MG4	166	1.5	99	0.9
		MG5	678	6.2	407	3.7
	FZ.III	F36-37	—	—	234	2.1
		F31-34	1,638	14.9	262	2.4
	New Oysterbay	KN1-3	—	—	256	2.3
		O2	228	2.1	91	0.8
		MK1	180	1.6	69	0.6
		MK2	813	7.4	650	5.9
	Oysterbay	O7	—	—	166	1.5
		O3	237	2.2	388	3.5
		O4	555	5.0	396	3.6
		O5	566	5.1	256	2.3
		O6	366	3.3	419	3.8

Table 14.4.14 Improvement of Voltage Drop in Arusha

Year	Substations	Feeder	Before		After	
			(V)	%	(V)	%
2002	Monduli	MD1-3	—	—	31	0.3
		F03	2,596	23.6	260	2.4
2003	Mt. Meru	M01	839	7.6	545	5.0
		M02	599	5.4	389	3.5
		M03	1,364	12.4	855	7.8
		M04	225	2.0	146	1.3
	Unga Ltd.	F4	—	—	339	3.1
		F2	1,448	13.2	941	8.6
		F3	651	5.9	296	2.7
2004	Kiltex	Brew	2,025	18.4	56	0.5
		K'tex	700	6.4	19	0.2

Table 14.4.15 Improvement of Voltage Drop in Moshi

Year	Substations	Feeder	Before		After	
			(V)	%	(V)	%
2002	YMCA	Y1-3	—	—	604	5.5
		Town	2,978	27.1	894	8.1
2003	Boma Mbuzi	BM04-05	—	—	964	8.8
		Kibo	116	1.1	81	0.8
		Town	3,179	28.9	954	8.7
		Boma	332	3.0	299	2.7
	Trade School	M1	314	2.9	204	1.9
		M2	1,126	10.2	731	6.7
		M3	646	5.9	419	3.8
	Machame	SP	648	5.9	421	3.8

Table 14.4.16 Improvements for in 11kV Lines in loss-reduction and voltage conditions
Dar es Salaam 2002

Substations	Before Project				After Project				Improvements	
	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Loss (kW)	V. Drop (V)
Bahari Beach S/S	MB4	3,693	238	982	MB4	1,662	48	442	190	540
	MB3	1,915	44	350	MB3	1,532	28	280	16	70
					BB4	2,414	64	401	-64	
Subtotal			282				140		142	
Ubungo S/S	U8	5,466	521	1,453	U8	2,460	106	654	415	799
					U9	3,006	99	499	-99	
Subtotal			521				205		316	
Magomeni S/S	D13	4,399	232	804	D13	2,375	68	434	164	370
	MG4	3,480	266	1,166	MG4	1,427	45	478	221	688
	MG5	4,050	152	572	MG5	2,389	53	337	99	235
					M01-03	5,739	120	318	-120	
Subtotal			650				286		364	
2002 total			1,453				631		822	(56% Reduction)

Dar es Salaam 2003

Substations	Before Project				After Project				Improvements	
	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Loss (kW)	V. Drop (V)
Mbezi S/S	MB2	2,884	62	327	MB2	1,730	22	196	40	131
	MB3	1,742	33	285	MB3	1,097	13	179	20	106
	MB4	2,068	110	813	MB4	1,386	50	545	60	268
					MB5	2,481	89	550	-89	
Subtotal			205				174		31	
Bagamoyo S/S	BA00	1,100	41	563	BA00	330	4	169	37	394
					BA01	770	10	197	-10	
Subtotal			41				14		27	
City Center S/S						5,130	383	284	-383	
		28,500	1,919	1,026		23,370	1,290	647	629	379
Subtotal			1,919				1,673		246	
Mikocheni S/S	MK2	5,505	226	625	MK2	3,853	111	437	115	188
	MK3	5,899	537	1,389	MK3	4,129	263	972	274	417
	MK4	5,112	313	934	MK4	4,090	201	748	112	186
					MK5	4,444	251	862	-251	
Subtotal			1,076				826		250	
Tandika S/S	MBF3	5,466	1,270	3,542	MBF3	1,366	79	885	1,191	2,657
	KR3	4,616	391	1,291	KR3	2,908	155	813	236	478
					TK1-3	5,808	123	322	-123	
Subtotal			1,661				357		1,304	
2003 total			4,902			3,044			1,858	(38% Reduction)

Dar es Salaam 2004

Substations	Before Project				After Project				Improvements	
	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Loss (kW)	V. Drop (V)
Sokoine S/S	SK1	5,093	33	99	SK1	4,838	30	94	3	5
	SK2	2,271	5	31	SK2	2,157	4	30	1	1
	SK3	3,244	10	45	SK3	3,082	9	43	1	2
	SK4	5,191	122	359	SK4	3,634	60	252	62	107
					SK5	2,088	8	58	-8	
Subtotal			170				111		59	
Tandale S/S	MG1	3,393	33	150	MG1	1,866	10	83	23	67
	MG2	3,978	118	452	MG2	2,188	36	248	82	204
	MG4	1,574	17	166	MG4	944	6	99	11	67
	MG5	2,550	113	678	MG5	1,530	41	407	72	271
					MG6	4,967	18	55	-18	
Subtotal			281				111		170	
F.Z. III S/S		16,900	1,816	1,638		13,520	1,162	262	654	1,376
					F36-37	3,380	52	234	-52	
Subtotal			1,816				1,214		602	
New Oysterbay S/S	O2	3,912	58	228	O2	1,565	9	91	49	137
	MK1	2,244	27	180	MK1	853	4	69	23	111
	MK4	4,448	237	813	MK4	3,558	152	650	85	163
					KN1-3	4,629	78	256	78	
Subtotal			322				243		79	

Oysterbay S/S	O3	2,445	38	237	O3	1,711	11	166	27	71
	O4	9,537	347	555	O4	6,676	170	388	177	167
	O5	5,380	200	566	O5	3,766	98	396	102	170
	O6	3,668	88	366	O6	2,568	43	256	45	110
					O7	6,309	174	419	-174	
Subtotal			673				496		177	
2004 total			3,262				2,175		1,243	(38% Reduction)

Arusha 2002

Substations	Before Project				After Project				Improvements	
	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Loss (kW)	V. Drop (V)
Monduli S/S	F03	2,500	426	2,596	F03	250	4	260	422	
					MD1-4	2,250	4	31	-4	
Subtotal			426				8		418	(98% Reduction)

Arusha 2003

Substations	Before Project				After Project				Improvements	
	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Loss (kW)	V. Drop (V)
Mt. Meru S/S	M01	4,917	271	839	M01	4,917	176	545	95	294
	M02	2,809	110	599	M02	2,809	72	389	38	210
	M03	4,917	440	1,364	M03	4,917	286	855	154	479
	M04	2,107	31	225	M04	2,107	20	146	11	79
Subtotal			852				554		298	
Unga Ltd. S/S	F2	6,225	591	1,448	F2	4,357	290	1,014	301	434
	F3	6,356	271	651	F3	4,449	86	296	185	355
					F4	3,775	78	314	-78	
Subtotal			862				454		408	
2003 total			1,714				1,008		706	(41% Reduction)

Arusha 2004

Substations	Before Project				After Project				Improvements	
	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Loss (kW)	V. Drop (V)
Kiltex S/S	Brew	2,025	11	86	Brew	2,025	7	56	4	30
	K'tex	700	1	31	K'tex	700	1	19		12
Subtotal			12				8		4	(33% Reduction)

Moshi 2002

Substations	Before Project				After Project				Improvements	
	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Loss (kW)	V. Drop (V)
YMCA S/S	Town	9,352	1,828	2,978	Town	2,806	165	894	1,663	2,084
					Y1-3	6,546	261	604	-261	
Subtotal			1,828				426		1,402	(77% Reduction)

Moshi 2003

Substations	Before Project				After Project				Improvements	
	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Feeder	Max Load (kW)	Loss (kW)	V. Drop (V)	Loss (kW)	V. Drop (V)
Boma Mbuzi S/S	Kibo	5,001	38	116	Kibo	3,501	19	81	19	35
	Town	9,999	2,085	3,179	Town	3,000	188	954	1,897	2,225
	Boma	1,999	44	332	Boma	1,799	35	299	9	33
					BM04-05	8,700	550	964	-550	
Subtotal			2,167				792		1,375	
Trade School S/S	M1	1,216	25	314	M1	1,216	16	204	9	110
	M2	2,006	148	1,126	M2	2,006	96	731	52	395
	M3	2,857	121	646	M3	2,857	79	419	42	227
Subtotal			294				191		103	
Machame S/S	SP	2,025	86	648	SP	2,025	56	421	30	227
Subtotal			86				56		30	
2003 Total			2,547				1,039		1,508	(59% Reduction)

14.5 Economic Analysis

14.5.1 Method of Economic Analysis

The economic analysis described in this chapter was carried out by using the same method as used in the economic analysis described in Chapter 12. In this economic analysis, the amounts of benefits were assumed to be the same as those calculated for Case-A in Chapter 12. Load shedding was left out of consideration. Investment costs and operation/administration costs were calculated based on the results of discussions made in 14.1 through 14.4. As for investment costs, those of on-going projects under financial assistances of foreign donors and/or TANESCO's own funds are included in the project cost of this study, because it is difficult to distinguish benefits of on-going projects.

14.5.2 Project Costs

The calculated costs of construction are shown in Table 14.5.1. Each of the construction costs shown in the table is composed of direct construction cost and expenses, which include costs of export packing, work supervision, construction equipment/tools, and engineering. In both domestic and foreign currencies, the expense was assumed to be 46% of direct construction cost for transmission line/distribution facilities and 47% of direct construction cost for substation.

Table 14.5.1 Summary of Construction Costs (Case-B')

Dar es Salaam (Unit: Thousand US$)

	Substation			Transmission			Distribution			Total		
Year	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total
2002	0	0	0	0	0	0	1,126	6	1,132	1,126	6	1,132
2003	2,655	398	3,053	423	42	466	2,441	12	2,453	5,519	452	5,972
2004	37,012	5,552	42,564	9,986	1,311	11,297	5,564	26	5,590	52,562	6,890	59,452
2005	27,824	4,173	31,997	10,328	3,365	13,693	9,782	45	9,827	47,934	7,584	55,518
2006	8,153	1,223	9,376	1,148	159	1,307	3,595	16	3,611	12,895	1,398	14,293
2007	4,775	716	5,490	276	29	305	4,123	19	4,142	9,174	764	9,938
2008	1,177	176	1,354	0	0	0	353	1	355	1,531	178	1,709
2009	2,809	422	3,231	385	41	426	1,737	9	1,746	4,932	472	5,404
2010	3,100	465	3,565	60	6	66	431	1	432	3,591	472	4,063
Total	87,505	13,126	100,630	22,607	4,954	27,560	29,152	136	29,288	139,263	18,215	157,478

Arusha, Kilimanjaro (Unit: Thousand US$)

	Substation			Transmission			Distribution			Total		
Year	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total
2002	0	0	0	0	0	0	499	3	502	499	3	502
2003	1,840	276	2,117	0	0	0	6,332	29	6,361	8,172	306	8,478
2004	22,479	3,238	25,718	3,361	350	3,711	1,405	6	1,410	27,245	3,595	30,839
2005	4,498	675	5,173	7,690	2,473	10,163	2,578	12	2,590	14,766	3,160	17,926
2006	7,806	1,172	8,977	7,958	2,501	10,459	527	3	530	16,291	3,675	19,967
2007	1,244	185	1,429	225	23	248	1,526	7	1,533	2,994	216	3,210
2008	1,670	248	1,918	0	0	0	1,526	7	1,533	3,196	256	3,451
2009	203	31	234	0	0	0	907	4	911	1,110	35	1,145
2010	0	0	0	0	0	0	0	0	0	0	0	0
Total	39,740	5,826	45,566	19,234	5,348	24,582	15,299	72	15,371	74,273	11,245	85,518

The calculated costs of operation/administration are shown in Table 14.5.2. The operation/administration cost was assumed to be 1% of direct construction cost for substation and 0.7% for transmission facilities. For distribution facilities, the operation/administration cost was estimated separately.

Table 14.5.2 Summary of O & M Costs (Case-B')

Dar es Salaam (Unit: Thousand US$)

	Substation			Transmission			Distribution			Total		
Year	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total
2002	0	0	0	0	0	0	0	27	27	0	27	27
2003	0	0	0	0	0	0	0	86	86	0	86	86
2004	18	3	21	2	0	2	0	220	220	20	223	243
2005	270	40	310	50	6	56	0	456	456	320	503	823
2006	459	69	528	99	23	122	0	543	543	559	634	1,193
2007	515	77	592	105	23	128	0	642	642	620	743	1,362
2008	547	82	629	106	24	130	0	651	651	653	757	1,410
2009	555	83	638	106	24	130	0	693	693	661	800	1,461
2010	574	86	660	108	24	132	0	703	703	682	813	1,495
2011	595	89	685	108	24	132	0	703	703	704	816	1,520

Arusha, Kilimanjaro (Unit: Thousand US$)

	Substation			Transmission			Distribution			Total		
Year	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total
2002	0	0	0	0	0	0	0	12	12	0	12	12
2003	0	0	0	0	0	0	0	165	165	0	165	165
2004	13	2	14	0	0	0	0	199	199	13	201	213
2005	165	24	189	16	2	18	0	261	261	182	287	468
2006	196	29	225	53	14	67	0	274	274	249	316	565
2007	249	36	286	91	26	117	0	311	311	340	373	713
2008	258	38	295	92	26	118	0	348	348	350	411	761
2009	269	39	308	92	26	118	0	370	370	361	435	796
2010	270	40	310	92	26	118	0	370	370	363	435	798
2001	270	40	310	92	26	118	0	370	370	363	435	798

14.5.3 Results of Economic Analysis

As shown in the calculation sheet attached hereto, the calculated economic internal rate of return (EIRR) was 14.24% for Dar es Salaam and 5.74% for Arusha/Kilimanjaro. The results of a sensitivity analysis, in which the amount of benefit and the cost of construction were varied to evaluate their effects on EIRR, are as shown in Figures 14.5.1 and 14.5.2.

14.5.4 Summary of Economic Analysis Results

The calculated EIRR was 14.24% for Dar es Salaam and 5.74% for Arusha/Kilimanjaro. The cut-off (i.e., the EIRR value below which the planned project is abandoned) varies from country to country or according to project type. In the electric power industry, the cut-off rate is normally 10% to 12%. Using this rate as the yardstick, it can safely be said that the projects in Dar es Salaam are worthy of execution. In the case of the projects in Arusha and Kilimanjaro, the EIRR is small because only the direct benefit is taken into account. With consideration given also to the indirect benefit, including favorable effects on the tourist industry, it may be said that the projects in Arusha and Kilimanjaro are worthy of execution too.

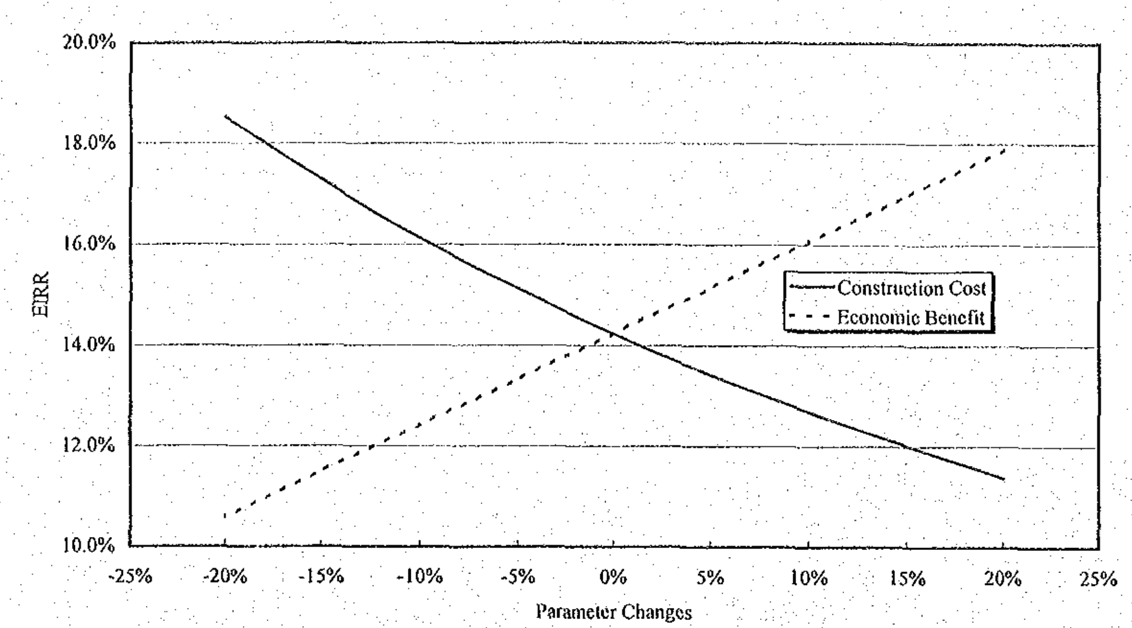


Fig. 14.5.1 Sensitivity analysis results (Dar es Salaam, Case-B')

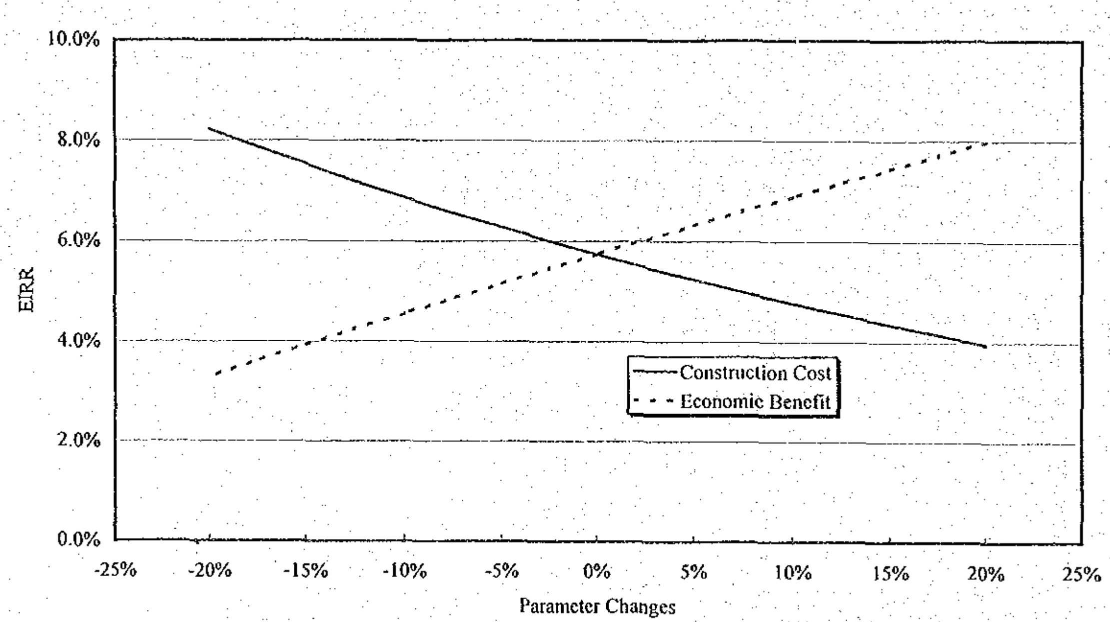


Fig. 14.5.2 Sensitivity analysis results (Arusha/Kilimanjaro, Case-B')

Dar es Salaam

EIRR= 14.24%

(Unit: Thousand US$)

Year	Economic Benefit	Economic Cost			Balance
		Capital Expenditure	Operation Expense	Total	
2002	2,720.0	3,661.5	27.0	3,688.5	▲ 968.5
2003	5,126.8	8,800.8	109.0	8,909.8	▲ 3,783.0
2004	7,704.0	56,904.3	283.3	57,187.7	▲ 49,483.7
2005	10,369.5	52,969.3	843.0	53,812.3	▲ 43,442.8
2006	13,004.8	14,293.6	1,197.1	15,490.7	▲ 2,485.9
2007	15,578.6	9,680.0	1,365.4	11,045.4	4,533.2
2008	18,259.3	1,708.2	1,411.6	3,119.8	15,139.5
2009	21,049.4	3,651.5	1,462.6	5,114.1	15,935.3
2010	23,955.9	4,062.4	1,485.7	5,548.0	18,407.8
2011	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2012	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2013	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2014	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2015	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2016	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2017	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2018	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2019	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2020	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2021	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2022	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2023	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2024	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2025	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2026	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2027	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2028	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2029	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2030	23,955.9	0.0	1,510.0	1,510.0	22,445.9
2031	23,955.9	0.0	1,510.0	1,510.0	22,445.9
Total	620,841.5	155,731.5	39,894.0	195,625.5	425,216.0

Arusha, Kilimanjaro

EIRR= 5.74%

(Unit: Thousand US$)

Year	Economic Benefit	Economic Cost			Balance
		Capital Expenditure	Operation Expense	Total	
2002	960.7	1,843.2	12.0	1,855.2	▲ 894.6
2003	1,858.2	8,477.6	174.0	8,651.6	▲ 6,793.3
2004	2,708.8	32,157.8	221.4	32,379.2	▲ 29,670.4
2005	3,518.6	17,926.0	481.6	18,407.6	▲ 14,889.0
2006	4,291.2	19,967.0	537.5	20,504.5	▲ 16,213.4
2007	5,007.5	3,210.4	725.6	3,936.0	1,071.4
2008	5,754.0	3,451.4	773.5	4,224.9	1,529.1
2009	6,530.8	1,144.9	808.6	1,953.5	4,577.3
2010	7,339.8	0.0	810.2	810.2	6,529.7
2011	7,339.8	0.0	810.2	810.2	6,529.7
2012	7,339.8	0.0	810.2	810.2	6,529.7
2013	7,339.8	0.0	810.2	810.2	6,529.7
2014	7,339.8	0.0	810.2	810.2	6,529.7
2015	7,339.8	0.0	810.2	810.2	6,529.7
2016	7,339.8	0.0	810.2	810.2	6,529.7
2017	7,339.8	0.0	810.2	810.2	6,529.7
2018	7,339.8	0.0	810.2	810.2	6,529.7
2019	7,339.8	0.0	810.2	810.2	6,529.7
2020	7,339.8	0.0	810.2	810.2	6,529.7
2021	7,339.8	0.0	810.2	810.2	6,529.7
2022	7,339.8	0.0	810.2	810.2	6,529.7
2023	7,339.8	0.0	810.2	810.2	6,529.7
2024	7,339.8	0.0	810.2	810.2	6,529.7
2025	7,339.8	0.0	810.2	810.2	6,529.7
2026	7,339.8	0.0	810.2	810.2	6,529.7
2027	7,339.8	0.0	810.2	810.2	6,529.7
2028	7,339.8	0.0	810.2	810.2	6,529.7
2029	7,339.8	0.0	810.2	810.2	6,529.7
2030	7,339.8	0.0	810.2	810.2	6,529.7
2031	7,339.8	0.0	810.2	810.2	6,529.7
Total	192,106.0	88,178.4	21,557.8	109,736.1	82,369.9