5.4 OPTIMIZED SUBSTATION PLAN (LONG TERM/SHORT TERM)

5.4.1 Optimum Power Supply System Plan

(1) Power supply reliability

1) Reliability of power distribution facilities

As for power supply reliability of distribution facilities for Dar Es Salaam district such as transmission lines, substations, and distribution lines, TANESCO is certainly very much interested in the development of it with regard to the distribution facilities located beyond the substations thus presently making great efforts to put in order, and analyze the past records of accidents and scheduled stops for maintenance work, etc. As an example, 1991 data which is supplied from TANESCO and which is arranged in order are shown in the following Table 5.4-1. These data are limited only to 33 kV and 11 kV facilities excluding that of 220 kV and 132 kV.

Table 5.4-1 Records of accidental power failure and scheduled stop for works

No.	Item	Electric Energy (MWh)			Time (hour)		
		33kV	11kV	Total	33kV	11kV	Total
1.	Overcurrent/ Grounding fault power failure	746	1,052	1,798	376.5	617.1	993.6
2.	Scheduled stop for works	380	757	1,137	145.3	498.4	643.7
	Subtotal	1,126	1,809	2,935	521.8	1,115.5	1,637.3
3.	Scheduled load shedding	637	1,282	1,919	154.5	712.4	866.9
	Subtotal	637	1,282	1,919	154.5	712.4	866.9
4.	Others						
	Subtotal						
5.	Grand total	1,763	3,091	4,854	676.3	1,827.9	2,504.2

8,760 h/year

2) Index of power supply reliability

Basic requirements for supply reliability are:

- Adequate frequency
- Adequate voltage
- Continuity of power supply

Since frequency control must be undertaken mostly by TANESCO and voltage adjustment is to be discussed in other sections of this document, only the continuity of power supply, i.e. problems of power failures, is discussed in this section.

As an index of supply reliability, MW-min. is used to measure the unit amount of lost energy due to power failure. This is one of the most convenient methods to manage the reliability if MW values can adequately be grasped at the time of accidents.

Recently, such indexes as shown below are frequently used:

- Frequency of power failure/year/consumer
- Total time of power failure/year/consumer

To use these indexes, it is necessary to improve and put facility data as well as consumer data in order so that the relation between the distribution facility and consumers is clearly known. It is also recommendable for TANESCO to study the possibility of using this method.

3) Level of power supply reliability

It is presumed that the level of reliability shown by TANESCO is rather low. This is because weather and environment differ between Japan and Tanzania as well as because of the characteristics of facilities and restoration measures against accidents during operation or maintenance.

4) Enhancement of power supply reliability

To enhance the reliability, the following countermeasures must be reviewed:

- Countermeasures to be taken to reduce occurrence of accidents
- Countermeasures to be taken to reduce power failure areas.
- Countermeasures to be taken to restore as promptly as possible.

(a) To prevent frequent occurrence of accidents, adequate number of facilities with proper quality must be constructed. Since natural conditions and load characteristics differ from district to district, it is recommended that the study should be started in respect of establishment of respective district-specific standards of reliability independently applicable to each district.

In addition, from the standpoint of reduction in accidents, it is also important to adequately conduct preventive maintenance services.

(b) To reduce power failure areas, it is basically necessary to install a large number of section switches for distribution lines and in addition interconnect the feeders.

(c) To shorten restoration period, the present state must be reviewed in detail as to the following:

- Detection of accident-outbreak section
- Urgent detection of accident-outbreak point
- Prompt restoration works by using maintenance service vehicles
- Close radio communication between service vehicles and base station

5) Establishment of respective district-specific standards of reliability

Total amount of investment in facilities varies according to the level of reliability. This needs an enormous amount of investment to cover all TANESCO service areas with such a high and uniform degree of reliability. It might be quite clear that the style of demand largely differ among the central quarters of Dar Es Salaam city, suburban districts, and farm villages.

In general, it is not realistic to conceive to keep the same level of reliability merely being bound with the word of impartiality.

Presently, TANESCO neither possess any cooperative facility standards nor flexibility to choose facility construction materials and equipment to meet the reliability. Latest density of demand of central quarters of Dar Es Salaam city is about 10,102 kVA/cm^2 which is presumed to increase many times more in the future making the difference more larger and the facilities difficult to construct on the same level of reliability. It is recommended that TANESCO establishes district-specific standards of reliability to meet various districts. An example is shown in Table 5.4-2.

To establish district-specific standards of reliability, a challenge is posed as to what index must be chosen to express important characteristics of each district. As an example, it is conceivable that population, percentage of major consumers, general standard of living, density of demand, etc. can be a candidate. From the standpoint of utility supplier, the most favorable selection is the density of demand.

It is recommendable to divide the service areas into 3 districts and establish a district-specific independent standard of reliability. On this occasion, central quarters of Dar Es Salaam city is temporarily called Area I, surrounding district of it Area II, and suburban district Area III. To determine the boundary between I, II, and III, it is necessary to fully examine the actual demand in each district.

6) Review of facility standards

As mentioned above, TANESCO does not possess any cooperative good facility standards. Because of non-existence of these standards, it is certain that in the process of expansion of the existing facilities, respective adequate facility improvement plans were not set out.

It is further anticipated that as Dar Es Salaam city advances toward a high level large city and encounters inexperienced various conditional changes, a conservative style of standards are not able to cope with the situations anymore. In order to reinforce the facilities while precluding decrease in reliability, as well as to upgrade the level, these facility standards must thoroughly be reviewed again.

First of all, it is noted that the distribution substations are presently provided with 15 MVA x 1 bank or 2 banks with each of banks consisting of 5 feeders (11 kV) or 3 feeders (33 kV). These capacities are rather small for Area I but sometimes too large for Area III. In addition, in respect of reliability, 3 banks are more advantageous than 2 banks.

Secondly, it is necessary to use such materials and equipment as with more larger capacity; hence wire size, strength of concrete pole, capacity of switch, etc. shall be reviewed.

Thirdly, the original facility standards set out in the planning stage must be modified to match the respective district-specific level of reliability. it is recommendable to adopt previous three ranking, i.e. I, II, and III districts in place of present division of networked areas and other areas.

As an example, planning standards in Japan are shown in Table 5.4-2.

Fourthly, to catch up with advanced technologies, facility standards must periodically be reviewed and therefore a technical committee should be established.

Table 5.4-2 Reliability Standard

- Sample of a Japanese utility

Basic conditions in planning power system facilities are described below:

Every facility should be planned to satisfy the condition that service interruption time should not extend beyond the following value at occurre nce of fault and at scheduled maintenance interruption.

(1) Unexpected interruption time by fault

Facility	Situation of fault	Unexpected interruption time		
		A area	B area	C area
Transmission transformer	1 bank fault	Within 15 min	Within 90 min	Within 90 min
Generator	1 unit fault	No interruption		
Transmission line	1 circuit fault	Within 2 min	Within 15 min	Early as possible
Distribution transformer(SS)	1 bank fault	Within 30 min	Within 120min	Within 480min

Notes

1. A area・・・・・・・・・・・Town area of main big city
   B area・・・・・・・・・・・Town area of other city
   C area・・・・・・・・・・・Provincial area
2. Required operation
   No interruption・・・・・Automatic recovering
   2min・・・・・・・・・・・Transfer 1 circuit by circuit breaker
   15min・・・・・・・・・・・Transfer 2 circuits by circuit breaker
   30min・・・・・・・・・・・Transfer to another bank of same substation or of adjacent substation by distribution line
   90min・・・・・・・・・・・Transfer to spare tarnsformer
   120min, 480min・・・・・・Supply by portable tarnsformer

(2) Expected interruption time by scheduled maintenance

Facility	Condition	Expected interruption time	
		A & B area	C area
Transmission transformer	1 bank out	No interruption	Within 8 hours, but important load will be transferred to another substation (once a year)
Generator	1 unit out	No interruption	
Transmission line	1 circuit out	No interruption	
Distribution transformer(SS)	1 bank out	No interruption	Within 4 hours, but important load will be transferred to another substation (once a year)

7) System voltage

As an prerequisite to meet the present load demand, voltage of TANESCO system is substantially low at 220 kV bus of Ubungo substation. Nonetheless, the voltage of transmission and distribution lines belongs to the group of very important items to be reviewed as a matter of present concern.

As a result of analysis of present and future demand forecast, it is found that the current system voltage is unnecessary to change for about 15 years from now on.

(1) To supply more power to match the load demand in the central quarters of Dar Es Salaam city, 132 kV incoming transmission system must be reinforced.

(2) To upgrade present 33 kV system for distribution substations, 132 kV system is scheduled to be used.

(3) 33 kV system is effectively expanded so that it can be used as secondary transmission lines to send power to each distribution substation.

(4) 11 kV distribution system is not necessarily be stepped up to 33 kV.

At suburban districts, it is enough to expand 11 kV distribution system as it undergoes right now.

8) IKL data and establishment of insulation level

(a) Establishment of insulation level

To establish insulation level of substation facilities in connection with determination of power supply reliability, it is indispensable to obtain IKL (Isokeraunic Level) data. It is our regret that as is known from the actual results, TANESCO has neither possessed any necessary data nor reviewed them as stated in the preliminary study report. However, it is found in the present survey that the IKL data covering 60 days out of the year is included in one of the design documents for power facilities supplied in the past through a foreign aid project. As for the lightning phenomenon directly related to the lightning-proof design for substations, a number of Japanese literature is available which state as follows:

It is extremely difficult to prevent substation electric equipment from lightning damage when they are directly struck by lightning stroke. Hence, as a rule, a shielding wire or lightning rod with sufficient lightning protection must be installed on the premises of substations to prevent these electric equipment against direct strokes. Nevertheless, certain existing substations are not yet provided with these shielding devices, and moreover, some degree of expenses are inevitably needed to actually install them. Under the circumstances, the necessity of shielding devices must first be clarified herewith by reviewing the lightning damage risk in case they are eliminated.

From the U.S. statistics, it is known that at flatlands with 30 thundery and rainy days, i.e. at IKL 30, ground discharges take place at a rate of 4 times/km2/year. Fig. 5.4-1 shows frequency of lightning strokes per year versus area of substation with IKL as a variable in a graph style for ease of calculation presuming direct strokes on the premises take place at the rate stated above.

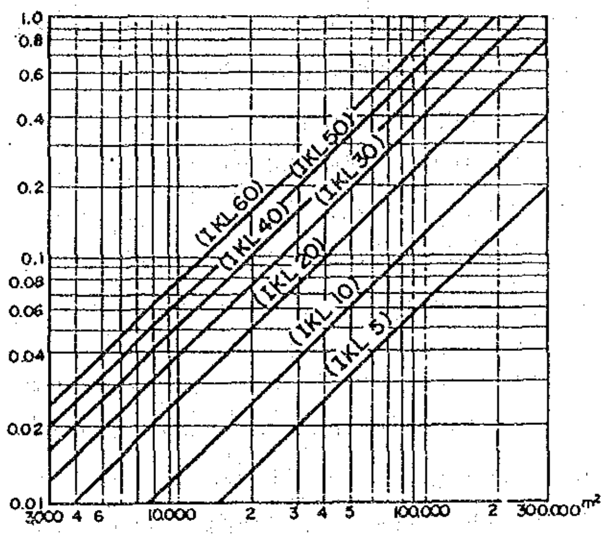
For example, a substation with an area of 33,000 m2 (10,000 tsubo) and located in IKL 30 district must be presumed that it will be struck 0.13 times per year, that is, roughly once every 8 years by lightning strokes on its premises. In case power facilities of a certain substation occupy almost half its premises and moreover no shielding devices are provided, then a serious accident due to direct lightning stroke may surely take place at a rate of once every 16 years.

It is again known from the statistics that such high buildings as a microwave steel tower or the like is apt to be struck more frequently by lightning strokes. Fig. 5.4-2 shows the above situation. In the graph, curve (I) indicates frequency of lightning strokes which strikes a high building located at IKL 30 district, and which is calculated from U.S. statistics. Be noted that frequency of lightning strokes rapidly increases almost in proportion to the increase in IKL values (or more rapidly).

Curve (II) also shows frequency of lightning strokes which strike a building under the conditions that the building should be regarded as a lightning rod with protection angle of 45° and that the ground space that is covered by this protection angle is struck by lightning strokes at the same rate as Fig. 5.4-1, i.e. 4 times/km2/year and that all these strokes are absorbed by this building. It must be noted in the graph that the curve (I) which shows frequency of lightning strokes on a high building is much more higher as compared to curve (II).

In other words, if a substation is provided with such high buildings as microwave steel tower or the like, total number of lightning strokes on it is calculated by adding number of direct strokes on high buildings as shown in Fig. 5.4-1 to that of Fig. 5.4-2. In this event, however, the balance obtained by subtracting curve (I) from curve (II) in Fig. 5.4-2 may safely be used as the number of direct strokes to be add.

Frequency of lightning
stroke per year



→ Substation area

Fig. 5.4-1 Frequency of Direct Lightning Stroke Versus Substation Area

(U.S. statistics: Calculated based on 4 times/km^2/year at IKL 30 district)

Curve (I) : Frequency of lightning stroke on high buildings (Calculated based on U.S. statistics)

(II) : Frequency of lightning stroke based on 45° of protection angle and 4 times/km^2/year

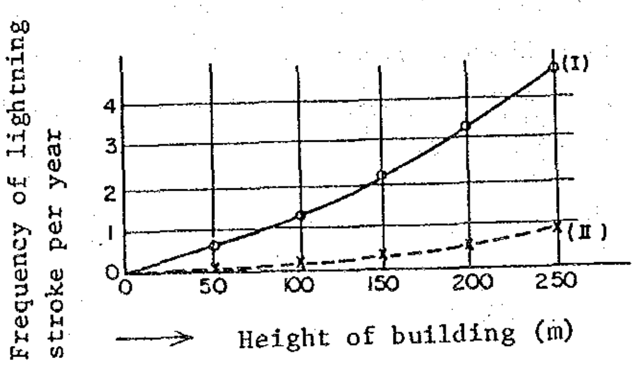


Fig. 5.4-2 Frequency of Direct Lightning Stroke on High Buildings (at IKL 30 district)

(b) Frequency of lightning discharge

An important item to be taken into account at the time of lightning-proof design is frequency of lightning attacks at the site where a substation is planned to be constructed.

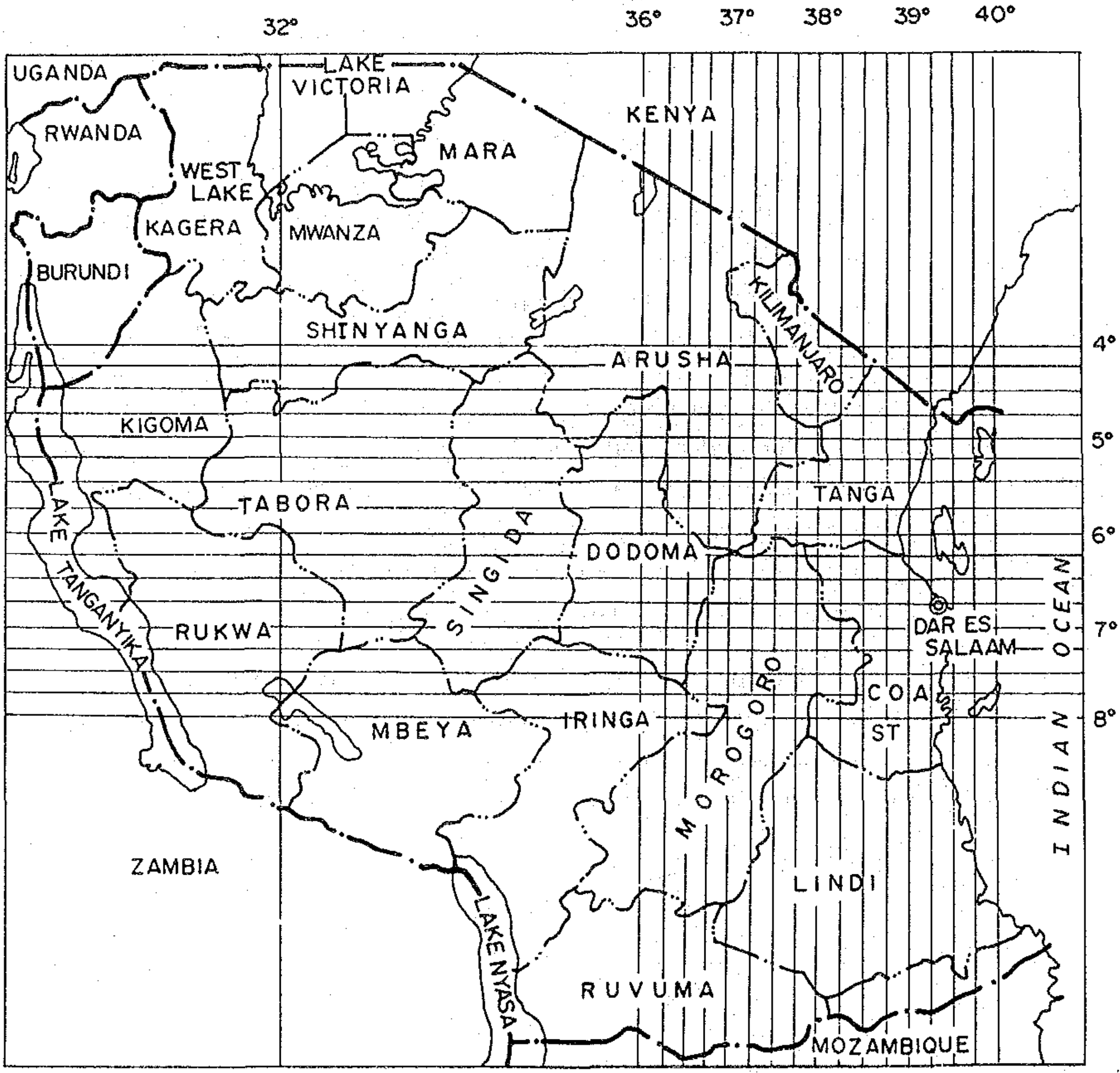
Presently, data on lightning observation are not provided in Tanzania. The lightning observation works must be planned in consideration of the future development as well.

To actually observe district-specific frequency of lightning attacks, whole Tanzania country must first be divided into square districts by parting at an interval of 15 minutes in both latitude- and longitude-wise as shown in Fig. 5.4-3 and then the isokeraunic level must be observed at each district for at least 15 years.

The isokeraunic level is called IKL which is widely known internationally. In addition, the IKL is also well known and verified in that it is well correlated with the rate of outage of facilities due to lightning damage; hence these study results can be used as a useful index at time of lightning-proof design.

It is also necessary to obtain sufficient data on landform and routes of lightning movement at construction site of substation and to analyze them since an outbreak and movement of the lightning are well affected by localized situations.

Fig. 5.4-3 Lightning observation districts



(c) IKL forecast

To forecast the isokeraunic level in the vicinity of Dar Es Salaam, following procedures shall be used.

A worldwide IKL value chart is included as IKL data in the attached technical materials as Fig. 5.4-4. Draw lines on allover the whole Tanzania country to obtain Fig. 5.4-5, from which the necessary values around Dar Es Salaam city can be found.

From the chart, it is known the value of IKL ranges from 20 to about 60 thus it is decided that IKL 60 can be used to design power facilities for the time being.

Fig. 5.4-4 World IKL chart

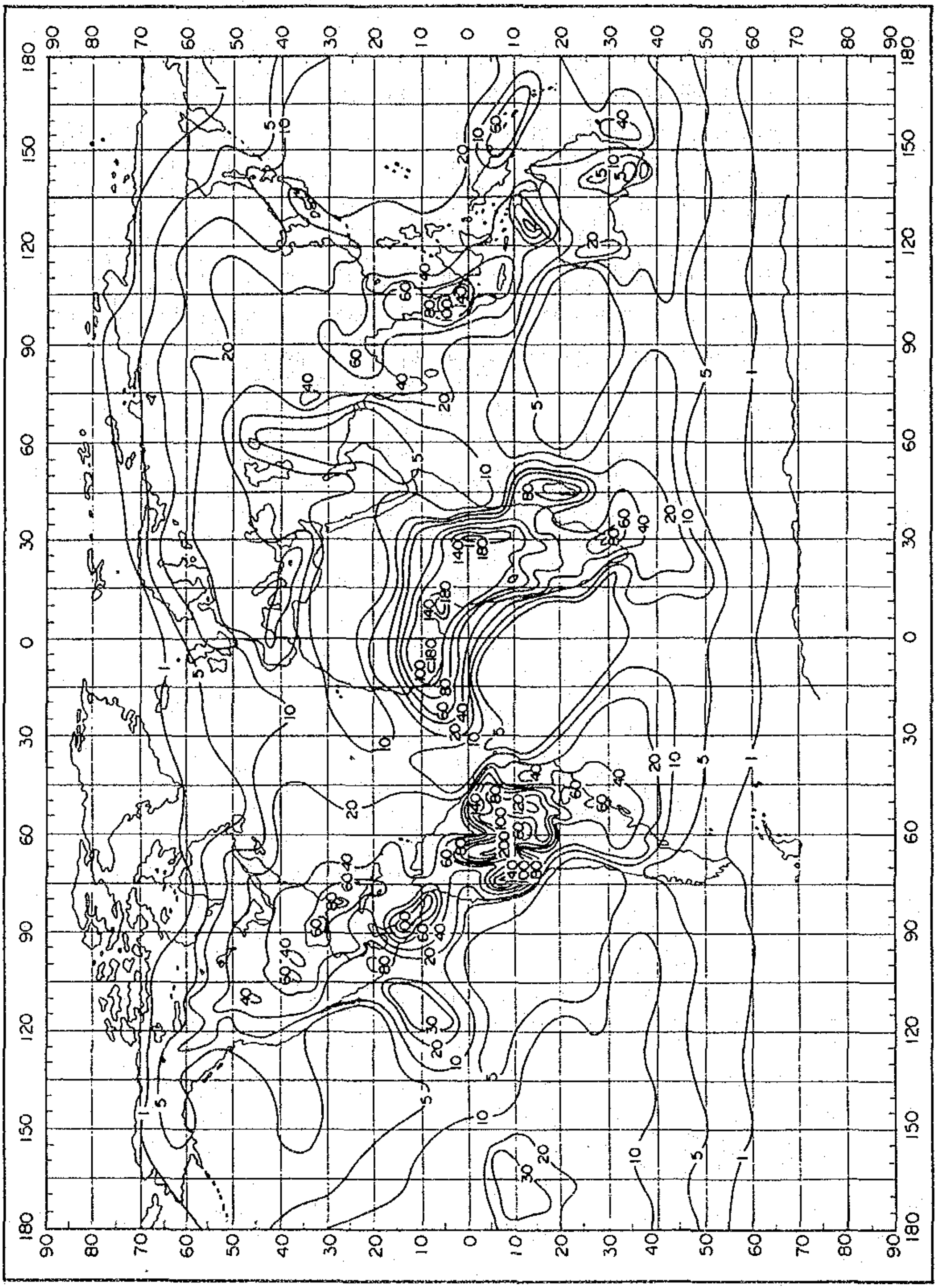
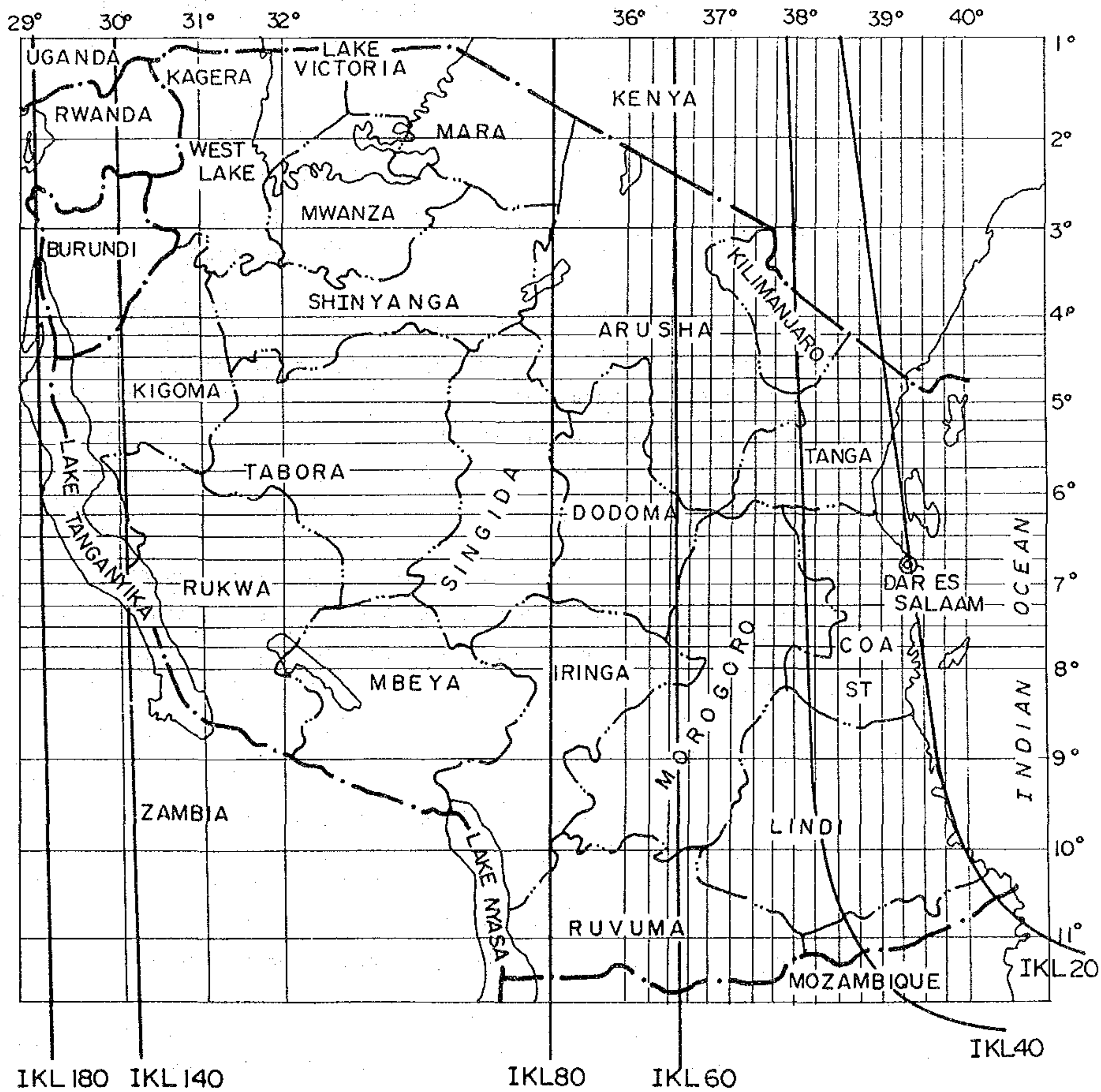


Fig. 5.4-5 IKL diagram



(d) Frequency of lightning stroke

Frequency of lightning strokes can be obtained from the graph described in the previous section by assuming the standard value of IKL in Tanzania to be 60 days/year and by presuming a site area needed for 132/33/11 kV and 33/11 kV class substations.

1) CASE 1 (132/33/11 kV)

Area: 8000 m^2	ILALA S/S
Frequency of lightning discharge:	0.05 times/year
	or 1 time/20 years

From the results obtained in the above procedure, it is known that Ilala class substations may be struck by direct lightning stroke once every 20 years. It is also inferred from the graph that distribution substations (like Factory Zone I) may be struck by direct lightning stroke once every 40 years.

These figures are not serious at all but since the substations are of valuable public facilities, all substations should be provided with overhead ground wires as well as 100% lightning shielding.

(e) Design concept for lightning arrester

As a rule, power facility equipment of substations shall be protected by an arrester.

At time of application of an arrester, major items to be taken into account in respect of lightning-proof design shall be as shown below:

a) Selection of performance and rating of arrester

b) Determination of dielectric strength of equipment and protection allowance

(i) Selection of performance and rating for lightning arrester

It is regarded that the performance of arresters is in compliance with the specification performance defined in the standards of each relevant country except for certain special occasions. However, performance of certain existing transformers are now very poor, and in particular, many of transformers which were produced before 1945 are presently posing many problems in respect of coordination of insulation. For that reason, adequate actions must be taken such as replacement with new ones after checking by using a simple type on-site verifier or the like.

Japanese standards JEC-156 was set forth in April, 1963, in which the old arrester allowable end voltage is revised into rated voltage thus enabled to be selected irrespective of system voltage, and in addition, test characteristics which are needed for switching surge countermeasures are determined.

As an example, nominal discharge current and rated voltage of arrester are shown in Table 5.4-3.

(ii) Design concept for dielectric strength of equipment and protection allowance

As for dielectric strength of equipment to be connected to the high-tension bus circuits of substations which are scheduled to be constructed hereafter, it is recommended to take into account the lightning-proof design under the basic concept as stated below:

a) One-time breakdown voltage for insulation to the earth in respect of impulsive voltage shall not be less than B.I.L during the entire service life of the equipment.

b) One-time breakdown voltage for insulation to the earth in respect of switching surge voltage shall not be less than 85% of B.I.L during the entire service life of the equipment.

c) Protection level of the lightning arrester to be taken into consideration at the time of lightning-proof design in respect of the above dielectric strength shall have such allowance as of about 20% in impulsive wave zone and about 15% in switching surge zone.

As to selection of IKL division at the time of determining the protection capacity of the arrester, A district is selected to apply to Tanzania from among A districts = 20 or more, B districts = 10 to 20, and C districts = 10 or less as shown in Table 5.4-3.

Table 5.4-3 Example of applications for nominal discharge current (JEC-156 Appendix)

Voltage ranking	Shield classification*	Lightning damage risk classification**		
		A district	B district	C district
Nominal voltage 140 kV line and extra high-tension line	Effective shielding	10,000 A arrester (Use 10 kA to check discharge voltage)	10,000 A arrester (Use 5 kA to check discharge voltage)	10,000 A arrester (Use 2.5 kA to check discharge voltage)
	Ineffective shielding	10,000 A arrester (Use 20 kA to check discharge voltage)	10,000 A arrester (Use 10 kA to check discharge voltage)	10,000 A arrester (Use 5 kA to check discharge voltage)
Nominal voltage 100 kV line or under	Effective shielding	10,000 A arrester (Use 10 kA to check discharge voltage)	5,000 A arrester (Use 5 kA to check discharge voltage)	5,000 A arrester (Use 2.5 kA to check discharge voltage)
	Ineffective shielding	10,000 A arrester (Use 20 kA to check discharge voltage)	5,000 A arrester (Use 10 kA to check discharge voltage)	5,000 A arrester (Use 5 kA to check discharge voltage)

Where:

a) See respective relevant notes for shielding class and lightning damage risk class which are marked with * and **.

b) (   ) indicates the reference current to be used at the time of determining discharge voltage.

c) If switching surge treatment is needed, 10,000A arrester should preferably be adopted.

(Note) 1) It is known from the applications shown in Table 5.4-3 above that coordination of insulation becomes generally tight in particular in case of ineffective shielding in A districts with 140 kV. In this event, the effective shielding must be used.

2) In accordance with IEC recommendations, shielding is classified into next two kinds:

(a) Ineffective shielding

(i) Power station, substation nor transmission lines is not provided with protective shielding against direct lightning stroke.

(ii) Power station and substation are provided with shielding but transmission lines are not provided with shielding.

(iii) Transmission lines are provided with shielding but Power station and substation are not provided with shielding.

(b) Effective shielding

(i) Power station, substation and transmission lines connected thereto are all provided with shielding. In this case, however, the shielding for transmission lines shall fully be applied up to a distance of at least several km from the power station or substation.

9) Preventive maintenance

Preventive maintenance of substation facilities is closely related with enhancement of reliability and hence a very important item. The daily operation and maintenance program is prepared by electric power companies in accordance with the safety standards set forth by the government. Details of the standards now generally used are as follows:

(a) Maintenance of substation

(i) General maintenance service

Maintenance service, which belongs to an indispensable sector of substation works for the purpose of smooth operation of the substation, mostly includes such facility maintenance works as inspection of equipment and devices, simple repair works, perpetual restoration works from an accident, etc.

At certain electric power companies having many substations and thus plenty of maintenance works, a dedicated organization must be set up to exclusively undertake the maintenance service. In this event, however, close communication is needed among the substations and the maintenance organization. This is needed because the maintenance service takes care of such equipment and devices as are already installed and actually in operation and moreover the operation of these equipment and devices must frequently be stopped while the inspection works are underway to allow maintenance staffs to approach hazardous points. To perform maintenance service of substations exactly and smoothly, it is also necessary to set up a very safety system in addition to the improvement of technical contents of the maintenance works; and for this purpose, therefore, it is necessary to clearly separate the maintenance service department from the operation department so that each department can surely take its share of the responsibility. On this occasion, however, special attention must be paid to the following points in order to preclude occurrence of accidents.

a) Details of the works shall be fully and thoroughly discussed and understood beforehand among the participants.

b) A responsible person shall be appointed for the works beforehand thus the communication with the operation side is limited to single route and no others.

c) If needed, a job order shall be prepared for filling in such important data as duration and range of power failure, etc. so that both departments can verify them with each other.

d) Prior to starting maintenance works, such safety measures as stopping power supply, attaching ground wire, etc. shall fully be taken, and in addition, scope of works must clearly be instructed.

   Further, during maintenance works, such measures shall also be taken as appointing a supervisor who supervises workers so that they never take independent nor insecurity action.

e) At time of completion, carefully finish the works by reversing correspondingly the procedures for initial setup.

(ii) Daily patrol, inspection, and repair

In daily patrol, inspection, and repair, substation equipment are inspected and repaired as necessary while they are in operation thus mainly visual check of equipment for any abnormalities or out of order is aimed at.

The purpose of daily inspection and repair is to check the equipment in operation for any rapid deterioration, deposit of flying foreign matter, etc., thereby precluding occurrence of any accidents, as well as to maintain facilities in order by lubricating as necessary or replace recording paper, etc. It is hereby noted that prior to starting daily patrol, inspection, and repair works, a daily check list must be prepared as to major periodic inspection items for verification of them. Nonetheless, since abnormal condition will not necessarily appear only on periodic inspection items, such careful inspections as visual, hearing, or feeling check must practically be conducted concurrently. It is noted again that to grasp variation of condition of equipment, periodic patrol and inspection should be done in such an ordinary way as is generally adopted that the patrol time and routes are fixed beforehand but nevertheless changing the routes sometimes depending on the situation is another recommendable way. Frequency of patrol may adequately be determined according to the condition of operation or facilities. As a particular case, it is known recently that the patrol is conducted only weekly at unmanned substations.

Actual daily patrol, inspection, and repair shall be conducted in such a manner that once every 6 months or so, particular consideration should be given to performance of a rather dense inspection than usual.

(iii) Periodic and temporary inspection of equipment

Periodic inspection is given much weight among maintenance works, the details of which is as shown in separate section of this paper.

To keep substation equipment operating in a stable condition, various levels of inspection are needed, of which the most simple inspection is the daily patrol and inspection which is to be conducted as a part of daily operation works. However, to smoothly operate equipment for a long time, the above mentioned daily inspection is not sufficient but further dense inspection and careful repairs are needed after a laps of predetermined time.

This inspection is so called a periodic inspection, the duration or contents of which differ depending on type of equipment or kinds but in many cases it is usual to perform at an interval of several years. During the periodic maintenance service, such adequate measures must be taken as to repair defective sections or replace the parts, the service life span of which are found to be completed. On the other hand, the temporary inspection is to be performed at time of occurrence of an accident during operation or when certain parts have reached operating duty. Accordingly, this inspection can be done mostly on a priority basis after selecting inspection points.

(iv) Maintenance of major equipment

a) Daily patrol, inspection and repairs

Pay attention to oil temperature, oil level of main body and bushing, oil leak, dirty bushing and porcelain tube, crack, overheat, abnormal temperature, offensive smell, moisture absorption of desiccant, nitrogen gas pressure, oxygen scavenger, voltage regulator operating condition, number of operation, cooling device (including cooling oil pump), and other abnormalities and clean, replace desiccant or deoxidizer with new ones, re-charge nitrogen gas, etc. as necessary.

b) Periodic inspection and repairs

(1) Overall exterior inspection: Once every 2 years

(2) Insulation resistance measurement: Once every 2 years

(3) Insulation deterioration test: Perform during periodic inspection as necessary

(4) Insulating oil performance test: Once a year for open type or once every 2 years for type with

deterioration protective device

(5) Nitrogen gas purity measurement: Once a year

(6) Protective device operation test: Once every 2 years

(7) Measuring instrument error test: Perform during periodic inspection as necessary

(8) Cooling water volume measurement: -Ditto-

(9) Cooling unit function inspection: Once every 2 years

(10) Nitrogen gas charging device function inspection: Once every 2 years

(11) Instrument protection device function inspection: Once every 2 years

(12) Cooling control device function inspection: Once every 2 years

(v) On-load tap changer

a) Periodic inspection and repairs (excluding items in common with transformers)

(1) Control device function inspection: Once every 2 years

(2) Drive unit function inspection: Once every 2 years

(3) Changeover switch function inspection: Resistance type-70,000/1 time Reactor type-20,000/1 time or once every 2 years

(4) Insulating oil performance test: Changeover switch room-20,000/1 time or once every 2 years

(vi) Oil circuit breaker (Porcelain-clad, tank type, and water circuit breakers, and oil load-break switch)

a) Daily patrol, inspection and repairs

Pay attention to oil level of main body and bushing, oil leak, dirty bushing and porcelain tube, crack, overheat, abnormal temperature, offensive smell, condition of operation mechanism, switching indicator, condition of signal lights, and other abnormalities and clean, repair contact of indicator, replace bulb, etc. as necessary.

b) Periodic inspection and repairs

(1) Overall exterior inspection: Once every 2 years

(2) Control mechanism function inspection: Once every 2 years

(3) Control circuit function inspection: Once every 2 years

(4) Insulation resistance measurement: Once every 2 years

(5) Insulating oil performance test: Perform during periodic inspection as necessary. Once every 2 years for porcelain-clad circuit breaker

(6) Trip-free operation test: Once every 2 years

(7) Minimum closing voltage and pressure test: Once every 2 years

(8) Minimum trip voltage and pressure test: Once every 2 years

(9) Switching speed test: Perform during periodic inspection as necessary Once every 2 years for circuit breaker with high speed reclosing relay

(10) Instrument error test: Perform during periodic inspection as necessary

(11) Lock pressure test: Perform during periodic inspection as necessary

(vii) Air-blast circuit breaker (excluding the same items as oil circuit breaker)

a) Daily patrol, inspection and repairs

Same procedures shall apply.
Drain of air reservoir shall be performed once a month.

b) Periodic inspection and repairs

(1) Breaker section function inspection: Once every 2 years

(2) Disconnection section function inspection: Once every 2 years

(3) Control and operation function inspection: Once every 2 years

(4) Lock pressure test: Once every 2 years

(5) Operation pressure fluctuation test: Perform during periodic inspection as necessary

(6) Disconnecting section switching error test: -Ditto-

(7) Ventilation air volume measurement: -Ditto-

(8) Breaker section resistance test: Once every 2 years

(viii) Magnetic circuit breaker

a) Daily patrol, inspection and repairs: The same procedures as oil circuit breaker shall apply.

b) Periodic inspection and repairs

(1) Breaker section function inspection: Perform during periodic inspection as necessary

(2) Arc extinguish chamber withstand voltage test: Perform during periodic inspection as necessary

(ix) Disconnector

a) Daily patrol, inspection and repairs

Pay attention to dirty insulator, crack, overheat, abnormal temperature, offensive smell, condition of operation mechanism, condition of interlock, and other abnormalities and clean, re-tighten, repair contact or indicator, etc. as necessary.

b) Periodic inspection and repairs

(1) Overall exterior inspection: Perform as necessary while item (2) or other related equipment are not in operation.

(2) Disconnecting section function inspection: Blade contact

Copper indoor: Once every 3 years
Copper outdoor: Once every 2 years
Silver indoor & outdoor: Perform during periodic inspection as necessary

(3) Control mechanism inspection: Perform as necessary while item (2) or other related equipment are not in operation.

(4) Control circuit inspection: -Ditto-

(5) Insulation resistance measurement: -Ditto-

(6) Minimum closing voltage and pressure test: Perform during periodic inspection as necessary

(7) Minimum opening voltage and pressure test: -Ditto-

(8) Switching operation test: -Ditto-

(x) Compressed air generator

a) Daily patrol, inspection and repairs

Pay attention to air pressure, overheat, leak, abnormal piping, and other abnormalities. Perform as necessary adjustment of starting pressure, minor leak repair and drain disposal, and cleaning of each section.

b) Periodic inspection and repairs

(1) Overall exterior inspection: Once a year

(2) Compressed air generator (main body and accessories) function inspection: Perform during periodic inspection as necessary

(3) Main tank, piping, valve function inspection: Once a year

(4) Control device function inspection: Perform during periodic inspection as necessary

(5) Insulation resistance measurement: Once a year

(6) Pressure indicator error test: Perform during periodic inspection as necessary

(7) Compressor air charging test: Perform as necessary whenever charging time is substantially changed.

(8) Safety valve operation test: Once a year

(9) Pressure relay operation test: Once a year

(10) Leak test: Perform during periodic inspection as necessary

(xi) Transformer for instruments

a) Daily patrol, inspection and repairs

Pay attention to oil level, oil leak, dirty bushing and porcelain tube, crack, overheat, abnormal noise, offensive smell, and other abnormalities. Perform as necessary terminal tightening, cleaning of each section, replacement of desiccant, etc.

b) Periodic inspection and repairs (Frequency of inspections of BCT shall be the same as main equipment)

(1) Overall exterior inspection: Once every 2 years

(2) Insulation resistance measurement: Once every 2 years

(3) Insulation deterioration test: Perform during periodic inspection as necessary

(4) Insulating oil performance test: Once every 2 years

(xii) Power condenser, series reactor, and discharge coil

a) Daily patrol, inspection and repairs

Pay attention to oil leak, overheat, dirty bushing and porcelain tube, crack, abnormal noise, offensive smell, and other abnormalities. Perform as necessary cleaning of each section, etc.

b) Periodic inspection and repairs

Perform overall exterior inspection and insulation resistance measurement at the time of periodic inspection of other related equipment.

(xiii) Lightning arrester

a) Daily patrol, inspection and repairs

Pay attention to dirty porcelain tube, crack, condition of discharge current recorder, abnormal noise, offensive smell, and other abnormalities. Perform as necessary cleaning and replacement of recording paper, etc.

b) Periodic inspection and repairs

(1) Overall exterior inspection: Once a year

(2) Operation indicator function inspection: Once a year

(3) Discharge current recorder: Once a year

(4) Insulation resistance measurement: Once a year

(5) Leak current measurement: Perform during periodic inspection as necessary

(6) Impulsive discharge starting voltage test: -Ditto-

(7) Power frequency discharge starting voltage test: -Ditto-

(xiv) Switchboard

a) Daily patrol, inspection and repairs

Pay attention to dirty panel face and instruments, deflection of pointer of instruments, panel back wiring, condition of each switch, operating condition of recorder and relay, and other abnormalities. Perform as necessary cleaning of each section, terminal tightening, ink filling up, and replacement of recording paper, etc.

b) Periodic inspection and repairs

(1) Exterior inspection: Once every 2 years

(2) Control and operation device function test: Once every 2 years

(3) Insulation resistance measurement: Once every 2 years

(4) Relay characteristics test: Perform during periodic inspection as necessary

(5) Switchboard (overall) coupling operation test: Once every 2 years including relay

(6) Instrument error test: Perform during periodic inspection as necessary

(b) Mobilization of maintenance service

In the era when the scale of power industry is still small and number of substations is scarce, workers of substations were doing both operation and maintenance at the same time. However, as power systems expand, reconsideration is needed in respect of adequate organization of operation and maintenance staffs. This was the challenge, however, which could successfully be solved without decreasing service level at all. This is done because of reduction in duration of maintenance service due to enhancement of reliability and practicability of equipment, as well as promotion of automation at substations through advanced automated control techniques which enabled the operation and maintenance staffs to separate out thus allowing a large number of technical personnel who are specialized in the maintenance techniques to deploy in an intensified form and in large mobilizable blocks.

Under the circumstances, the current operators of substations are able to dedicate them to only such operation works as monitoring, recording, operating, as well as daily patrol, simple inspection and repair works, while the specialized maintenance staffs can perform periodic patrol, and periodic inspection and repairs. In addition to the above, methods of maintenance are also mobilized by adopting mobile test equipment, etc., some of which are as shown below for reference:

a) Insulation diagnosis by EI detector
b) Use of hot-line temperature measuring device
c) Mobilizatin of hot-line cleaning and filtration service
d) Use of portable relay test device
e) Use of portable variable frequency power source
f) Use of portable Schering bridge
g) Use of portable withstand voltage test device

(c) Countermeasures against accidents

As stated in the previous section, such accidents as results in injury or death like an electric shock, etc. have more or less something to do with human activities.

Most of these human related causes are due to carelessness or delusion; hence careful attention of each worker is called for. In view of it, safety instructions and safety training should be reiterated at every opportunity in order to intensify worker's safety consciousness and carefulness. Nonetheless, since there is a limit for human ability to concentrate his attention on certain matter, then it is impossible to expect everything from the workers. Accordingly, it may be indispensable to take safety measures as far as practicable for the facilities, as well as for the workers so that they can form a habit to always observe the specified rules or standards to be set out in respect of working procedures or the like. As an example, preventive measures presently in use are shown as follows:

(i) Safety measures for facilities

(1) Installation of protection net and guard fence

To be provided at places with charged parts like power capacitor, lightning arrester, etc. where personnel are in danger of contact with them while patrolling or working.

(2) Locking device for disconnector

Disconnector shall not be actuated to cut load current. However, to prevent erroneous operation, it shall be interlocked with such disconnector as is connected in series.

(3) Use of grounded electric outlet

In order to ground portable type motorized appliances with voltage to the earth of 150 V or over during operation, electric outlets with earth electrodes shall be provided.

(ii) Safety measures for working space and handing over

Prior to starting maintenance works, the person responsible for the operation shall take following measures with attendance of person responsible for the maintenance works and then hand over his duties in respect of the working place.

(1) To lock open disconnector, etc.

(2) To attach grounding wire to power cut section

(3) To post a notice to show work space and enclose it by rope.

(4) To post a danger sign, overhead notice sign, up and down point sign, passage blockade sign, etc.

In addition, the duties to be handed over shall by checked one by one using a safety work order or the like.

(iii) At start of work

Prior to starting works:

(1) To fully let all workers know the purpose, details, and condition of working place, etc.

(2) To check condition of health, working wear, etc. of workers.

(3) To prepare tools, safety wear and protectors, etc. and let all workers clearly know them, as well as perform TBM in order to call all worker's attention to safety and carefulness.

In addition, works shall be conducted in accordance with Work analysis sheets (Safety and efficient behavior, position, distance, and procedure are defined in each step of the work).

(iv) Use of safety wear and protector

To conduct works, such wear as safety cap, safety belt, insulating gloves, insulating rubber boots, etc., and such protectors as insulating sheets or the like shall be used without fail for safety and security. The safety wear and protectors shall ensure to always keep normal capability; hence they shall always be maintained in a good condition.

To verify the capability of safety wear and protectors, dielectric strength test and electricity leak test shall be performed twice a year.

10) Standardization plan for power facility

(a) Standards and criteria of power facility

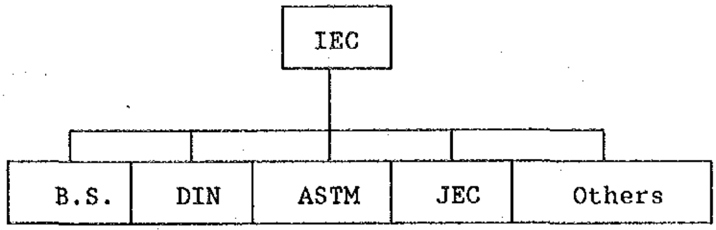
Fig. 5.4-4 shows standards and criteria based on scarce materials obtained during the local site survey which is conducted prior to setting out the standardization plan for power facilities.

Table 5.4-4 Applicable standards to TANESCO equipment

1. ISOLATOR	JEC-196-1975 BS-5253-1975 IEC-129
2. CIRCUIT BREAKER	JEC-2300-1985 BS-116 JEC-56 JEC-181-1975
3. TRANSFORMER	JEC-204-1978
4. TRANSFORMER	BS-171-1959 JEC-186-1972 BS-171-1970 IEC-76
5. FEEDER CIRCUIT BREAKER	BS-116-1952 BS-5311-1976
6. STATION TRANSFORMER	IEC-76
7. CONDUCTOR	DIN-48204 DIN-4824 IEC-209 DIN-48200 DIN-48201 ASTM B232-1974 B415-1969 B416-1969 B502-1970 B549-1971

As is shown in the study results, a number of design concepts are mixedly applied to TANESCO's substations. This is because the countries, manufacturers, and consultants, as well as applicable standards and criteria in respect of the facilities quite differ from substation to substation or from facility to facility.

It is also clear that adoption of a wide variety of international standards such as of Japan, U.S., U.K., or German will surely cause inconvenience to TANESCO in the future. For this reason, it is necessary to work out such style of standards as with IEC standards at its core and as is able to meet various standards of relevant countries.



Nonetheless, Japanese standards should basically apply to the master plan and feasibility study of this project in their review stage so that they can match the Dar Es Salaam transmission and distribution line improvement plan (Phase III), now the construction is underway.

(b) Standardization

It may perhaps be safely said that the standardization of design of substation facilities is the most important matter thus almost always often becomes the topic of the talk in every countries in the world.

In order to review the standardization with taking into account the existing TANESCO's facilities, the major relevant items are defined as follows: These specifications shall be used as the standards of optimization for substation facilities to be reviewed hereafter.

(i) Voltage

Table 5.4-5 shows standard voltage to be applied to TANESCO power facilities.

Table 5.4-5 Voltage

Nominal Voltage (kV)	Maximum Voltage (kV)	Rated Voltage (kV)	Remark
220	230	245	
132	138	144	
33	34.5	36	
11	11.5	12	
400 V			
230 V			

(ii) Capacity of transformer

As for the capacity of each transformer to be installed at substations, it shall be in compliance with the following standard values which are selected from the recommended values:

(3 phase transformer)

5,000 kVA
10,000 kVA
15,000 kVA

(iii) Insulation spacing

Capacity of each transformer to be installed at substations shall be in compliance with the following standard values which are selected from the recommended values:

Table 5.4-6 shows standard (recommended) insulation spacing of electric wires to be adopted into the design of substations.

Table 5.4-6 Standard values

Nominal Voltage (kV)	Outdoor				Remark
	Spacing to ground (mm)		Spacing between phases (mm)		
	Min.	Max.	Min.	Max.	
11	150	300	190	600	
33	350	500	480	900	
132	1,300		1,650		

(iv) Insulation design

Table 5.4-7 shows specifications and quantity of insulators which are presently in use at substations in Dar Es Salaam city.

Size of these suspension insulators is 10 inches.

Table 5.4-7 Number of insulators

Nominal Voltage (kV)	Quantity of suspension insulator (pieces)
220	13
132	9
33	3
11	2

These specifications are for lightly polluted districts (0.02 to 0.045 mg/cm2) in terms of equivalent salt deposit with regard to salt tolerant design. Quantity of these insulators are the same as that of the transmission lines, and moreover, the quantity of insulators in use at each substation in Dar Es Salaam city is the same with each other regardless of distances to the seashore. For reference, respective distances from each substation to the seashore are shown in Table 5.4-8.

Table 5.4-8 Distance to Seashore

Name of substation	Distance to seashore (km)
Ubungo	9.0
Ilala	1.8
Oysterbay	2.0
City Centre	0.8
Factory Zone I	4.4
Mikocheni	1.7
Mbezi	2.7
Factory Zone III	6.5
Kurasini	0.5
Factory Zone II	12.5
Kigamboni	1.2
Wazo Hill	4.5
Msasani	0.4
Sokoine	0.3

(v) Outgoing line from each substation

Capacity and outgoing line of each substation are as shown in Table 5.4-9, which are obtained from the survey data.

Table 5.4-9 Capacity of substation and number of outgoing circuits

Name of Substation	Capacity of Substation (kVA) (A)	Number of Outgoing Lines (B)	(A)/(B) (kVA)
Ilala	30,000	8	3,750
Oyster Bay	15,000	5	3,000
City Center	45,000	8	5,625
Factory Zone I	15,000	4	3,750
Mikocheni	15,000	5	3,000
Mbezi	7,500	3	2,500
Factory Zone III	15,000	5	3,000
Kurasini	15,000	4	3,750
Factory Zone II	5,000	4	1,250
Kigamboni	5,000	2	2,500
Wazo Hill	15,000	3	5,000
Msasani	15,000	4	3,750
Sokoine	15,000	3	5,000

As for the present state of outgoing circuits, some of the circuits are out of use due to certain reasons. Number of outgoing lines shall be selected to match the capacity of respective relevant substations. It is presumed that as capacity of TANESCO's substations increases, space to accommodate outgoing lines becomes difficult to secure since the number of circuits are very much increased if present capacity of distribution lines is kept as it is until that time. The present capacity is about 5,000 KVA but it must be further reviewed from now on.

(vi) Determination of substation size

Long-term and short-term demand forecasts for Dar Es Salaam district are as shown in other section of this paper. Starting from the reference year of 1992, short-term plan covers the period until 1997 while long-term plan until 2007 and the maximum demand is shown in kW year by year on a time series basis. From these values as well as in accordance with the facility standards previously stated, capacity of transformers can be obtained from the following:

1) Maximum power demand (kW) is in consideration of load factor, demand factor, and diversity factor.

2) Apparent power kVA or MVA is obtained at:

   (1/power factor x 1/efficiency) = 1.25

3) Table 5.4-10 indicates overload limit guidelines.

Table 5.4-10 Overload limit guidelines for substation facility

<table>
<tr><td></td><td colspan="4"><u>Planning Aspect</u></td></tr>
<tr><td rowspan="4">Transformer</td><td>Design Policy</td><td colspan="3">1. Overload operation shall be avoided in the regular operation.

2. Overload operation to an extent as shown below is allowed at the time of occurrence of an accident but it shall be limited only to a short time. Nevertheless, the load of each facility shall finally be made fallen into the normal load range of 100% or less by means of system changeover, switching to standby transformer or otherwise providing mobile transformer.

3. As a rule, the above policy shall strictly be observed. However, under certain particular circumstances, the above policy may not be applicable. In these events, respective adequate values which are determined at the time of setting out those plans may be used instead.</td></tr>
<tr><td rowspan="3">Overload Capacity</td><td rowspan="2">Transmission transformer</td><td colspan="2"><u>Distribution transformer (Single Rating)</u></td></tr>
<tr><td>Supply to:
Center of large cities

Center of medium cities</td><td>Supply to:
Other places than center of medium cities

Ordinary cities and others</td></tr>
<tr><td>150%
10 min.
120%
20 min. 100%
90% Continuous</td><td>150%
30 min.
120%
90 min. 100%
90% Continuous</td><td>130%
4 hrs. 100%
90% Continuous</td></tr>
</table>

<u>Operating Aspect</u>
1. As a rule, the overload operation shall be avoided as far as practicable in the regular operation. However, if the overload operation must inevitably be performed, it shall be done in accordance with the procedures set out with taking into account equipment characteristics, ambient temperature, load factor, etc. 2. Load of each facility shall not exceed 100% even at the time of occurrence of an accident by means of prompt system changeover, switching to standby transformer, or otherwise providing mobile transformer or the like. In this event, however, it shall still be allowed but shall be limited only to a short time that each facility may be operated in a overloaded condition to an extent that the design policy of the above planning aspect is fully met.

(2) Plans and optimum plan for substation facilities

1) Long-term and short-term plans

(a) Long-term plan

Out of the plural plans for substation facilities, i.e. Plan A, Plan B, and Plan C, which are proposed by TANESCO, inferred from the results of demand forecast, and obtained with taking into account the results of system analysis, the optimum plan is to be finally worked out.

The traditional style of review is to first prepare a number of plans with regard to possible locations of the substation and then work out after making comparison respective optimum plan for each of them. However, since the land acquisition is well underway with TANESCO and moreover location of the site of the substation for the Dar Es Salaam city power service expansion plan is almost decided by now, the above mentioned comparison will not particularly be applicable. Instead, expansion and improvement of existing substations are taken up to make a plan in such a way that the certain specific substations are added with incoming lines or GIS. Accordingly, all stations to be newly established hereafter should be provided with conventional tension bus type facilities.

According to the above concept, specifications for all substations to be constructed from the reference year of 1992 onward for 15 years are set out.

(b) Short-term plan

To establish the short-term optimum plan, 5 years are taken out of the 15 years for long-term plan, which also starts from the reference year (1992) in order to define the period of short-term, during which time a further review should be done in detail as to the scale of the substation, as well as a practical plan to facilitate a detailed site survey prior to preparation of pre-feasibility study.

2) Comparative review

(a) Grade-up introduction of 132/33 kV

As a result of demand forecast and system analysis, the incoming voltage of distribution substations is planned to be upgraded from conventional 33 kV to 132 kV.

The concept of upgrading substations is proposed this time by TANESCO as shown in Table 5.4-11. This plan aims at upgrading Tegeta first and then finally Mbagala in 2006.

Table 5.4-11

	Year	Substation	Capacity (MVA)
1.	1996	Factory Zone III	45 x 2
2.	2000	Oyster Bay	45 x 1
3.	2000	Yombo	45 x 1 depending on the Gas Project
4.	2002	Kurasini	45 x 1
5.	2004	City Centre	45 x 1
6.	2004	Mbezi	45 x 1
7.	2006	Mbagala	45 x 1

To perform comparative review of the influences of 33 kV and 132 kV power receiving types upon the distribution substations, it is necessary to study in detail a lot of items beforehand and moreover to set out a long-term power service upgrading plan beforehand aiming at improving power supply to the whole Dar Es Salaam district. As may clearly be known from the present state of existing facilities, this plan should include such measures as expansion or installation of branches in the 132 kV one circuit which extends from Ubungo grid substation to Zanzibar and Ilala secondary substations. In addition, two other measures should further be included in the above plan, which are as follows: one is to establish new distribution substations and the other is to upgrade existing 33 kV substations through modification. However, these measures should never be taken as easy matter. This is because there still remain such challenges unsolved as lack of space on the premises of substation, influences on environment and resultant effects on surrounding buildings and residents, etc.

Table 5.4-12 shows advantages and disadvantages due to upgrading of 7 substations offered by TANESCO:

Table 5.4-12 Advantages and disadvantages due to upgrading

Receiving voltage (kV)	Result of review		Remark
	Advantage	Disadvantage	
132/33 kV			
1. Factory Zone III	Voltage, improvement of loss	Negotiation of site acquisition Lack of space	
2. Oyster Bay	Voltage, improvement of loss	Lack of space	
3. Yombo	System reinforcement		
4. Kurasini	Voltage, improvement of loss		
5. City Centre	Voltage, improvement of loss	Lack of space	
6. Mbezi	Voltage, improvement of loss		
7. Mbagala	System reinforcement		

As a result of technical review, it is known that the best plan among others is to expand the facilities in such a manner that the power, which starts from Ubungo grid substation and proceeds to Yombo and Mbagala via Factory Zone III, is made finally supplied to the center quarters of Dar Es Salaam city from the southwest side of it. This plan is superior to the plan to expand the transmission line beyond Ilala secondary substation.

(b) Type of distribution substation (Tension bus type, GIS type, underground type)

All of the existing distribution substations are exclusively equipped with tension bus type. Despite it, a special review is still needed in this master plan with regard to expansion and improvement as to adoption of GIS type into City Centre and Oyster Bay substations since they are located in the center of Dar Es Salaam city thus space is limited on the premises.

There are no substations to which underground type must be applied. Hence, the previous two plans are shown in the following comparative table.

No.	Name of Substation	Comparison		Remark
		Tension bus	GIS	
1.	City Centre	Expansion and improvement are possible including 132/33 kV grading up	Not necessary	
2.	Oyster Bay	Expansion and improvement are possible including 132/33 kV grading up	Not necessary	

It is known from the table that expansion and improvement of these substations can be attained without using GIS type.

(c) Incoming line to substation (Overhead and underground lines)

Overhead incoming lines which are mostly used for the existing demand-end substations and two circuit power receiving substations should be used to lead 33 kV transmission line into the substation premises.

If, however, the overhead line is not allowed because of surrounding conditions at the substation, then underground lines to be led from a nearby pole may be used.

As for upgrading in the future, it is impossible to lead an overhead 132 kV transmission line into the substations regardless of expansion or improvement. In this event, underground lines led from such an end point as is possible to construct the transmission line should be adopted.

(d) Rehabilitation of existing facilities

Rehabilitation of existing substations shall be conducted in accordance with expansion and improvement construction plan and in such a way that the facilities of obsolete or damaged substations must be replaced with new facilities as far as practicable thereby enhancing the reliability of the relevant substations.

(e) Sites already acquired by TANESCO and possibility of further acquisition of land

As stated in the survey report, the sites which TANESCO has already acquired include a 30m x 40m plot for the Tandale, a 40m x 30m plot for the Chong'ombe, a 40m x 20m plot for the Kunduchi, a 40m x 50m plot for the Kariaoko, a 40m x 80m plot for the Mbagala, a 35m x 30m plot for the Tabata, and a 30m x 30m plot for the Mburahati substations. In addition, it is most probable that possibility of land acquisition for Kunduchi and other substations is high since TANESCO has so far been making positive efforts.

(f) Construction costs

Construction costs should be evaluated in terms of other typical construction cost.

As shown in other section of this paper, the construction costs for substation facilities included in this master plan must be calculated using the similar procedures as used in Dar Es Salaam distribution and distribution line network (Phase III) improvement plan which is now underway.

3) Optimum plan

In general, the optimum plan is consequently worked out through such evaluation processes as (1) Power demand forecast, (2) Power system expansion plan, (3) System analysis, (4) Construction costs and system losses, etc.

Taking into account the above procedures, the plan presently offered by TANESCO is fully reviewed with paying attention to various aspects. Summary of the review results in respect of each substation is as shown below.

Table 5.4-13 gives the priority order for the new construction and expansion of substations planned from 1994 and Fig. 5.4-1 shows the power grid as it will exist by 2007 under the Optimum Supply Plan.

(1) Ilala S/S (Scheduled for Expansion) 1994

The Ilala Substation is due to be expanded with the addition of one 33/11 kV 15 MVA transformer and the installation of all related equipment.

(2) Ilala S/S (Scheduled for Expansion) 1994

The 132 kV power line to be erected between Ubungo and Ilala will require the execution of expansion and improvement construction to upgrade the substation capacity, seeing that the power line is to be laid from the substation In addition, it will also be necessary to carry out expansion work on the 132/33 kV 45 MVA transformer at the same time.

(3) Ubungo S/S (to be expanded) 1994

The 132 kV power line to be erected between Ubungo and Ilala will require the execution of expansion and improvement construction to upgrade the substation capacity, seeing that the power line is to be laid from the substation In addition, it will also be necessary to install all related equipment and facilities at the same time.

(4) Tandale S/S (to be newly constructed) 1994

The Tandale region is situated in a comparatively remote location from any of the substations. It has thus experienced a number of problems such as voltage drops. The situation has been examined and the findings have already led to the decision to erect a new substation with 15 MVA transformer capacity on a 30m x 30m plot already prepared by TANESCO. The incoming 33 kV single-circuit line is run off through a T junction from an intermediate location of the Friendship line between Ubungo and Ilala and connected to the substation. To ensure the correct power supply capability for the substation, provision has also been made for the installation of five 11 kV feeder circuit lines.

(5) Chang'ombe S/S (to be newly constructed) 1994

The Chang'ombe region has a large number of factories, including National (manufacturing radios and batteries), tobacco factories, and Radio Tanzania. Demand forcasts have led to the decision to build a 15 MVA distribution substation. It is possible to secure a construction site with adequate space for the substation. The incoming 33 kV power line is run off through a π junction from an intermediate point between the Factory Zone I and Kurasini substations and connected to this substation. The substation will have for 11 kV feeder circuits.

(6) Kurasini S/S (newly constructed) 1994

The existing equipment at the Kurasini substation consists of a 33/11 kV 15 MVA transformer. In view of the poor condition of the feeder equipment for the incoming 33 kV line, repair work will be carried out on the existing feeder unit which will also be expanded with the new construction of one more bay.

(7) Mbezi S/S (newly constructed) 1994

The existing equipment at the Mbezi substation consists of a 33/11 kV 7.5 MVA transformer. In view of increased demand and as a result of the obsolescence of the existing transformer, the decision has been taken to add one more 15 MVA transformer as well as to expand and improve the equipment on site and the bus bars. The schedule also includes for the expansion of the existing substation house and the construction of new cubicles in the house and the necessary construction work for the re-siting of equipment.

(8) Oyster Bay S/S, (9) Factory Zone I S/S, (10) Msasani S/S, and (11) Sokoine S/S

The expansion and improvement construction work for the (8) Oyster Bay S/S, (9) Factory Zone I S/S, (10) Msasani S/S, and (11) Sokoine S/S is being executed under Phase III.

(12) Kunduchi S/S (to be newly constructed) 1996

Located northwest of Msasani, the Kunduchi region has some cement factories and a large number of tourist hotels along its coast. The region is also scheduled for urban development so that there will be a significant increase in power load in the future. For the region, this will entail the most serious voltage drops and losses. To improve the situation, a new distribution substation is to be built in an optimum location in close vicinity to the 132 kV Zanzibar line. The construction work at the substation will include the erection of a 15 MVA transformer, the laying of the incoming 33 kV line and all necessary equipment. The 33 kV transmission line will receive power from the 132/33 kV Tegeta substation to be built under a different project.

(13) *Factory Zone III S/S 132/33 kV (to be newly constructed)* 1996

The existing equipment capacity at the Factory Zone III substation consists of a 15 MVA transformer. In view of its potential for supplying the whole of Dar Es Salaam with electricity in the future, the program envisages the expansion of the 132 kV outer line in the southwestern direction with Ubungo S/S in the center. This line expansion work is to be carried out prior to the expansion of the substation itself. The upgrading of the substation to a 132/33 kV capacity system will involve improvement and modification work on the existing equipment and the erection of two new 45 MVA transformers for 132/33 kV operation. The incoming 132 kV line will enter the substation from the nearest tower in the form of an underground cable.

(14) Ubungo S/S (to be expanded) 1996

Construction work on the new 132 kV power transmission line between Ubungo and Ilala will involve the addition of a bay using the space available on the site of the two substations.

In connection with this study, construction is scheduled to extend and modify the related equipment.

(15) Kariakoo S/S (to be newly constructed) 1996

The Kariakoo region is that of a commercial town with a high level of power demand. The role of the substation is therefore crucial in assuring an adequate alternative power supply. In view of the need for these improvements, the decision has been made to build a new distribution substation in the Kariakoo region.

The construction work at the substation will include the erection of a 15 MVA transformer, the laying of the incoming 33 kV line and the installation of all necessary equipment. The 33 kV transmission line will receive power from the Ilala Secondary S/S.

(16) Ilala S/S (to be newly expanded) 1996

Scheduled for construction in 1994 were facilities given in No.1 and No.2 above, with additional busbars having been installed to meet the expansion of the transformer capacity and all necessary equipment modification and expansion having been completed. In connection with the new construction of the Kariakoo distribution substation which forms the study implemented next item No.15 above, work will be undertaked to expand lay the incoming 33 kV transmission line and expand the line capacity, with simultaneous expansion and modification work on all related equipment.

(17) Mbagala S/S (to be newly constructed) 1996

The Mbagala region supplies power from Kurasini to the residential areas along the Kilwa Road and to the industrial zones. The problem, however, is that the transmission distance is extremely long so that voltage drop and loss problems are at their worst. This has led to the decision to build a new distribution substation in this region.

The construction work at the substation will include the erection of a 15 MVA transformer, the laying of the incoming 33 kV line and the installation of all necessary equipment. The 33 kV transmission line will receive power from the Kurasini S/S.

(18) Kurasini S/S (to be newly erected) 1996

The construction work scheduled for 1994 and referred to in section item No. 6 above, envisages the addition of one more transmission bay for the Chang'ombe substation to provide the line equipment for the 33 kV line. The construction work to be implemented under this section (No.18) consists of the further addition of one more line bay for outgoing lines to the new Mbagala S/S. At the same time, the work will include expansion and modification work to upgrade all related equipment.

(19) Tabata S/S (to be newly constructed) 1996

The Tabata district supplies electricity from the Ubungo substation. Long-term demand forecasts suggest that this region is likely to register further increases in power demand. This has prompted the decision to build a new substation to meet increased demand in this area.

The construction work at this substation will include the erection of a 15 MVA transformer and the laying of the incoming 33 kV transmission line in conjunction with the installation of all necessary equipment. The 33 kV transmission line receives power through a π connection from the existing 33 kV transmission line between Ubungo and Factory Zone III.

(20) Mikocheni S/S 33/11 kV (to be expanded) 1998

The existing facilities at the Mikocheni S/S consist of a 33/11 kV 15 MVA transformer. Demand forecasts suggest a significant increase in demand which is to be met with the addition of one more 15 MVA transformer. The two incoming 33 kV lines connect the Ubungo and Oyster Bay substations. There are five existing 11 kV feeder circuits, and the expansion study will add another five feeder circuits.

(21) Kigamboni S/S (to be expanded) 1998

The existing equipment at the Kigamboni substation consists of a 33/11 kV 5 MVA transformer. Demand forecasts, however, entail the need for the additional construction of a 5 MVA transformer. There are two 11 kV feeder circuits. The incoming 33 kV power line will connect to the Kurasini substation.

(22) Temeke S/S (to be newly constructed) 2000

The Temeke region has public housing estates on its fringe, and demand forecasts for the region have led to the decision to build a new substation to meet increased demand.

At present, TANESCO is in the process of negotiating the acquisition of a 30m x 30m plot for the construction of a 15 MVA capacity distribution substation. The incoming 33 kV power transmission line will be connected to the Yombo substation to be built. The number of 11 kV feeder circuits will be five.

(23) Mburahati S/S 33/11 kV (to be newly constructed) 2000

The Mburahati region is a general residential zone and the demand forecasts for this region have led to the decision to build a new substation at the corner of the Elementary School Precincts. At present, TANESCO is in the process of negotiating the acquisition of a 30m x 30m plot for the construction of a 15 MVA capacity distribution substation. The incoming 33 kV power transmission line receive power through a T connection from the transmission line between the Ubungo and Ilala substations.

(24) Kitunda S/S (to be newly constructed) 2000

The Kitunda region has an oil-pipeline for oil transport to neighboring Zambia and has primarily a large number of general residential housing estates.

Demand forecasts anticipate further growth in power consumption which is to be met by construction of new 5 MVA distribution substation. The incoming 33 kV circuit line is connected to the Yombo substation which will also be constructed new. The number of 11 kV feeders is given as two.

(25) Yombo S/S 132/32 kV (to be newly constructed) 2000

The Yombo region is scheduled to have a new gas-turbine thermal power station to be built at some time in the future and is earmarked for extensive construction of public utility facilities so that it will play a major role as the base for laying an outer line for the power grid. As a secondary substation, the Yombo substation will be equipped with a 45 MVA transformer. There will be three 132 transmission lines, connected to the Factory Zone III, Kurasini, and Mbagala substations, respectively. There will be three 33 kV transmission lines, connected to the Kurasini and Mbagala, and Kitunda substations, respectively.

(26) Factory Zone III S/S (to be expanded) 2000

In connection with the erection of the new Yombo substation, the plan is to construct additional line capacity for the 132 kV transmission line in the Factory Zone III substation.

(27) Factory Zone II S/S (to be expanded) 2000

The existing equipment at the Factory Zone II substation consists of a 33/11 kV 5 MVA transformer. To meet the forecast increase in electricity demand, however, the plan envisages the additional construction of a 5 MVA capacity transformer. The 33 kV incoming transmission line connects with the Factory Zone III substation. The existing feeder capacity consists of four 11 kV feeder circuit which are to be supplemented by a further two lines.

(28) Oyster Bay S/S (to be expanded) 2000

Under the expansion program, the Oyster Bay substation is scheduled for a capacity upgrading study to achieve a 132/33 kV type substation. The 132 kV line will be run off from the Ubungo substation and brought to the Oyster Bay substation from a nearby transmission tower through an underground cable. The plan envisages the new erection of a 45 MVA transformer.

(29) Ubungo S/S (to be expanded) 2000

In conjunction with the upgrading study at the Oyster Bay substation to 132 kV, expansion will be required at the Ubungo substation with the creation of an additional outgoing line bay for the 132 kV line.

(30) Kariakoo S/S (to be expanded) 2002

The existing facilities at the Kariakoo substation consists of a 33/11 kV 15 MVA transformer. To meet forecast increases in electricity demand, the plans envisage the additional construction of a 15 MVA transformer. The 33 kV line connects to the Ilala substation. The existing 11 kV feeder capacity consists of five lines which are to be supplemented by a further five lines.

(31) Kigamboni S/S (to be expanded) 2002

The existing equipment capacity at the Kigamboni substation consists of two 33/11 kV 5 MVA transformers. As this will not be adequate to meet the anticipated increase in electricity demand, the need has arisen for an additional 5 MVA transformer to be erected.

(32) Kurasini S/S (to be expanded) 2002

In accordance with the expansion program, the Kurasini substation is earmarked for an upgrading study due to create a 132/33 kV substation. The 132 kV transmission line is to connect to the newly built Yombo substation. The plans envisage the erection of a new 45 MVA transformer.

(33) Yombo S/S (to be expanded) 2002

In conjunction with the upgrading study for the Kurasini substation to create a 132 kV line, it will be necessary to build an additional substation for the 132 kV line.

(34) Oyster Bay S/S (to be expanded) 2003

The existing facilities at the Oyster Bay substation consists of a 132/33 kV 45 MVA transformer and a 33/11 kV transformer, giving a total capacity of 25 MVA. To meet forecast increases in electricity demand, the plans envisage the additional construction of a 15 MVA transformer. There are one 132 kV and two 33 kV incoming lines. The existing 11 kV feeder capacity consists of five lines which are to be supplemented by a further three lines.

(35) Mbezi S/S (to be expanded) 1998

The existing facilities at the Mbezi substation consists of a 33/11 kV 7.5 MVA transformer. To meet forecast increases in electricity demand, the plans envisage the additional construction of a 15 MVA transformer. The two 33 kV incomming lines connect to the No.1 and No.2 of Ubungo substation. The existing feeder capacity consists of three lines which are to be supplemented by a further five lines.

(36) Mbezi S/S (to be newly constructed) 2004

*In accordance with the expansion program, the Mbezi substa*tion is earmarked for an upgrading study due to create a 132/33 kV substation. The 132 kV transmission line is to be fed from the newly built Zanzibar line through a T connection. The plans envisage the erection of a new 45 MVA transformer.

(37) Mikocheni S/S (to be expanded) 2004

The existing facilities at the Mikocheni substation consist of two 33/11 kV 15 MVA transformers. To meet forecast increases in electricity demand, the plans envisage the additional erection of a 15 MVA transformer. The two 33 kV incoming lines connect to the Ubungo and Oyster Bay substations, respectively. The existing 11 kV feeder capacity consists of ten lines which are to be supplemented by a further line.

(38) City Centre S/S (to be expanded) 2004

In connection with the expansion program, the City Centre substation is scheduled for capacity expansion with the erection of an additional 132/33 kV 45 MVA transformer and the necessary modification work to upgrade all related equipment.

(39) Ilala S/S (to be expanded) 2004

In conjunction with the upgrading scheme for the City Centre substation, additional line capacity will be constructed for the 132 kV line at the Ilala substation.

(40) Upanga S/S (to be newly constructed) 2004

The Upanga region has major power users in its bounds, and to meet the forecast increases in electricity demand, the plans envisage the construction of a new 15 MVA substation with the creation of new 11 kV feeder capacity consisting of five lines.

(41) City Centre S/S (to be expanded) 2004

The 33 kV line equipment at the City Centre substation needs additional incoming line facility for the 33 kV line in conjunction with the construction of the new Upanga substation. The expansion program also includes the erection of all necessary related equipment.

(42) Factory Zone III S/S (to be expanded) 2005

The existing facility at the Factory Zone III substation consists of one 132/33 kV 45 MVA transformer and one 33/11 kV 15 MVA transformer. To meet forecast increases in electricity demand, the plans envisage the additional erection of a 15 MVA transformer. The two 132 kV incoming lines connect to the Ubungo and Yombo substations, respectively. The existing 11 kV feeder capacity consists of five lines which are to be supplemented by a further five line.

(43) Msasani S/S (to be expanded) 2006

The existing facility at the Msasani substation consists of a 33/11 kV 15 MVA transformers. To meet forecast increases in electricity demand, the plans envisage the additional erection of a 15 MVA transformer. The 33 kV incoming line connects to the Oyster Bay substation. The existing 11 kV feeder capacity consists of four lines which are to be supplemented by a further two lines.

(44) Mbagala S/S (to be newly constructed) 2006

In accordance with the expansion program, the Mbagala substation is earmarked for a capacity upgrading study due to create a 132 kV substation. The existing installations consists of a 33/11 kV 15 MVA transformer, and to achieve the upgrading study, an additional 45 MVA transformer is to be erected. The 33 kV (11 kV operation) incoming transmission line is to be connected to the Kurasini substation. To connect the line required for the upgrading study, an additional substation will be built for connection to the Yombo substation.

(45) Yombo S/S (to be expanded) 2006

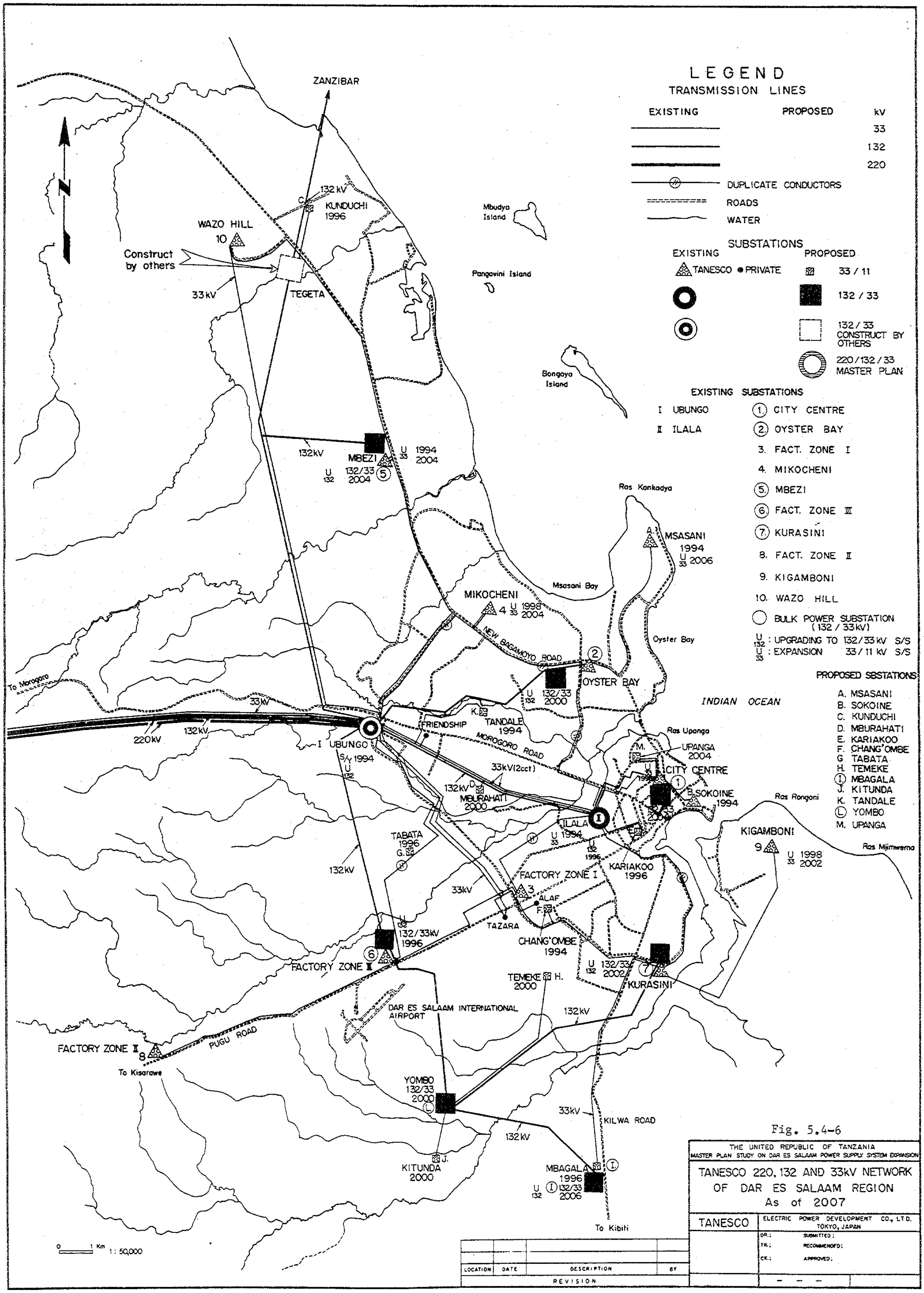
In conjunction with the upgrading of the Mbagala substation, the Yombo substation will be expanded with the construction of an additional line for incoming 132 kV line.

Figs. 5.4-8-1 through 5.4.45-2 of the revised version of Volume III show the single-line diagrams and equipment arrangement plans for the new and expansion study and the existing equipment at the substations concerned.

Fig. 5.4-6 shows the newly constructed and expanded substation under the Power Supply Expansion Program for the City of Dar Es Salaam, based on the target year 2007.

Table 5.4-13 A List of the Substations to be planned in the after 1994

No.	Year	Name of Substation		Voltage	Capacity (Newly/Expansion capacity)	Classification	Installed Capacity (MVA)	Total Capacity (MVA)	Remarks
1	1994	Ilala	Secondary Substation	33/11 kV	45 MVA (15 MVA x 1 Ex.)	Expansion	15 x 2 = 30	15 x 3 = 45	
2		Ilala	ditto	132/33 kV	135 MVA (45 MVA x 1 Ex.)	ditto	45 x 2 = 90	45 x 3 =135	
3		Ubungo	Grid Substation	132 kV	Switchyard (1 bay Ex.)	ditto	-	-	
4		Tandale	Distribution Substation	33/11 kV	15 MVA (15 MVA x 1)	Newly Installation	-	15 x 1 = 15	
5		Chang'ombe	ditto	33/11 kV	15 MVA (15 MVA x 1)	ditto	-	15 x 1 = 15	
6		Kurasini	ditto	33 kV	Switchyard (1 bay Ex.)	Expansion	-	-	
7		Mbezi	ditto	33/11 kV	22.5 MVA (15 MVA x 1 Ex.)	Expansion	7.5 x 1 = 7.5	7.5 x 1 + 15 = 22.5	
8		Oyster Bay	Distribution Substation	33/11 kV	25 MVA (15 MVA x 1 Ex.)	Expand by Phase III	5 x 3 = 15	5 x 2 + 15 = 25	-5
9		Factory Zone I	ditto	33/11 kV	25 MVA (15 MVA x 1)	ditto	5 x 3 = 15	5 x 2 + 15 = 25	-5
10		Msasani	ditto	33/11 kV	15 MVA (15 MVA x 1)	Construct by Phase III	-	15 x 1 = 15	
11		Sokoine	ditto	33/11 kV	15 MVA (15 MVA x 1)	ditto	-	15 x 1 = 15	
12	1996	Kunduchi	Distribution Substation	33/11 kV	15 MVA (15 MVA x 1)	Newly construct	-	15 x 1 = 15	
13		Factory Zone III	Secondary Substation	132/33 kV	90 MVA (45 MVA x 2)	Newly construct	-	45 x 2 = 90	
14		Ubungo	Grid Substation	132 kV	Switchyard (1 bay Ex.)	Expansion	-	-	
15		Kariakoo	Distribution Substation	33/11 kV	15 MVA (15 MVA x 1)	Newly construct	-	15 x 1 = 15	
16		Ilala	ditto	33 kV	Switchyard (1 bay Ex.)	Expansion	-	-	
17		Mbagala	ditto	33/11 kV	15 MVA (15 MVA x 1)	Newly construct	-	15 x 1 = 15	
18		Kurasini	ditto	33 kV	Switchyard (1 bay Ex.)	Expansion	-	-	
19		Tabata	ditto	33/11 kV	5 MVA (5 MVA x 1)	Newly construct	-	5 x 1 = 5	
20	1998	Mikocheni	Distribution Substation	33/11 kV	30 MVA (15 MVA x 1 Ex.)	Expansion	15 x 1 = 15	15 x 2 = 30	
21		Kigamboni	ditto	33/11 kV	10 MVA (5 MVA x 1 Ex.)	ditto	5 x 1 = 5	5 x 2 = 10	
22	2000	Temeke	Distribution Substation	33/11 kV	15 MVA (15 MVA x 1)	Newly construct	-	15 x 1 = 15	
23		Mburahati	ditto	33/11 kV	15 MVA (15 MVA x 1)	ditto	-	15 x 1 = 15	
24		Kitunda	ditto	33/11 kV	5 MVA (5 MVA x 1)	ditto	-	5 x 1 = 5	
25		Yombo	Secondary Substation	132/33 kV	45 MVA (45 MVA x 1)	ditto	-	45 x 1 = 45	
26		Factory Zone III	ditto	132 kV	Switchyard (1 bay Ex.)	Expansion		-	
27		Factory Zone II	Distribution Substation	33/11 kV	10 MVA (5 MVA x 1 Ex.)	ditto	5 x 1 = 5	5 x 2 = 10	
28		Oyster Bay	Secondary Substation	132/33 kV	45 MVA (45 MVA x 1)	Newly construct	-	45 x 1 = 45	
29		Ubungo	Grid Substation	132 kV	Switchyard (1 bay Ex.)	Expansion	-	-	
30	2002	Kariakoo	Distribution Substation	33/11 kV	30 MVA (15 MVA x 1 Ex.)	Expansion	15 x 1 = 15	15 x 2 = 30	
31		Kigamboni	ditto	33/11 kV	15 MVA (5 MVA x 1 Ex.)	ditto	5 x 2 = 10	5 x 3 = 15	
32		Kurasini	Secondary Substation	132/33 kV	45 MVA (45 MVA x 1)	Newly construct	-	45 x 1 = 45	
33		Yombo	ditto	132 kV	Switchyard (1 bay Ex.)	Expansion	-	-	
34	2003	Oyster Bay	Distribution Substation	33/11 kV	35 MVA (15 MVA x 1)	Expansion	5 x 2 + 15 x 1 = 25	5 x 1 + 15 x 2 = 35	-5
35	2004	Mbezi	Distribution Substation	33/11 kV	30 MVA (15 MVA x 1 Ex.)	Expansion	7.5 x 1 + 15 x 1 = 22.5	15 x 2 = 30	-7.5
36		Mbezi	Secondary Substation	132/33 kV	45 MVA (45 MVA x 1)	Newly construct	-	45 x 1 = 45	
37		Mikocheni	Distribution Substation	33/11 kV	45 MVA (15 MVA x 1 Ex.)	Expansion	15 x 2 = 30	15 x 3 + 5 = 45	
38		City Centre	Secondary Substation	132/33 kV	45 MVA (45 MVA x 1)	Newly construct	-	45 x 1 = 45	
39		Ilala	ditto	132 kV	Switchyard (1 bay Ex.)	Expansion	-	-	
40		Upanga	Distribution Substation	33/11 kV	15 MVA (15 MVA x 1)	Newly construct		15 x 1 = 15	
41		City Centre	ditto	33 kV	Switchyard (1 bay Ex.)	Expansion	-	-	
42	2005	Factory Zone III	Distribution Substation	33/11 kV	30 MVA (15 MVA x 1 Ex.)	Expansion	15 x 1 = 15	15 x 2 = 30	
43	2006	Msasani	Distribution Substation	33/11 kV	30 MVA (15 MVA x 1 Ex.)	Expansion	15 x 1 = 15	15 x 2 = 30	
44		Mbagala	Secondary Substation	132/33 kV	45 MVA (45 MVA x 1)	Newly construct	-	45 x 1 = 45	
45		Yombo	ditto	132 kV	Switchyard (1 bay Ex.)	Expansion	-	-	


LEGEND
TRANSMISSION LINES
EXISTING
PROPOSED
kV
33
132
220
DUPLICATE CONDUCTORS
ROADS
WATER
SUBSTATIONS
EXISTING
PROPOSED
TANESCO ● PRIVATE
33 / 11
132 / 33
132 / 33 CONSTRUCT BY OTHERS
220 / 132 / 33 MASTER PLAN
EXISTING SUBSTATIONS
I UBUNGO
II ILALA
1. CITY CENTRE
2. OYSTER BAY
3. FACT. ZONE I
4. MIKOCHENI
5. MBEZI
6. FACT. ZONE III
7. KURASINI
8. FACT. ZONE II
9. KIGAMBONI
10. WAZO HILL
BULK POWER SUBSTATION (132 / 33kV)
U 132 : UPGRADING TO 132/33kV S/S
U 33 : EXPANSION 33 / 11 kV S/S
PROPOSED SBSTATIONS
A. MSASANI
B. SOKOINE
C. KUNDUCHI
D. MBURAHATI
E. KARIAKOO
F. CHANG'OMBE
G. TABATA
H. TEMEKE
I. MBAGALA
J. KITUNDA
K. TANDALE
L. YOMBO
M. UPANGA
ZANZIBAR
132 kV
KUNDUCHI 1996
WAZO HILL 10
Construct by others
33kV
TEGETA
Mbudya Island
Pangavini Island
Bongoya Island
132kV
MBEZI
U 33 1994 2004
U 132 132/33 2004
Ras Konkadya
MSASANI 1994 U 33 2006
Msasani Bay
MIKOCHENI 4 U 33 1998 2004
NEW BAGAMOYO ROAD
Oyster Bay
OYSTER BAY
U 132 132/33 2000
INDIAN OCEAN
To Morogoro
33kV
220kV
132kV
I UBUNGO
S/Y 1994 U 132
K. TANDALE 1994
FRIENDSHIP
MOROGORO ROAD
Ras Upanga
M. UPANGA 2004
CITY CENTRE
B. SOKOINE 1994
33kV(2cct)
132kV D. MBURAHATI 2000
Ras Rongoni
ILALA U 33 1994
U 132 1996
KIGAMBONI 9 U 33 1998 2002
Ras Mjimwema
TABATA 1996 G.
132kV
KARIAKOO 1996
FACTORY ZONE I
33kV
ALAF
F.
TAZARA
CHANG'OMBE 1994
U 132 132/33kV 1996
FACTORY ZONE III
U 132 132/33 2002
KURASINI
TEMEKE H. 2000
DAR ES SALAAM INTERNATIONAL AIRPORT
132kV
FACTORY ZONE II 8
PUGU ROAD
To Kisarawe
YOMBO 132/33 2000
33kV
KILWA ROAD
132kV
KITUNDA 2000
MBAGALA 1996
U 132 132/33 2006
To Kibiti
0 1 Km 1 : 50,000
Fig. 5.4-6
THE UNITED REPUBLIC OF TANZANIA
MASTER PLAN STUDY ON DAR ES SALAAM POWER SUPPLY SYSTEM EXPANSION
TANESCO 220, 132 AND 33kV NETWORK OF DAR ES SALAAM REGION As of 2007
TANESCO
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO, JAPAN
DR.:
SUBMITTED:
TR.:
RECOMMENDED:
CK.:
APPROVED:
LOCATION
DATE
DESCRIPTION
BY
REVISION
SHEET NO.
OF

5.5 OPTIMIZED DISTRIBUTION LINE PLAN (LONG TERM/SHORT TERM)

(1) Determination of power supply reliability for long-term and short-term plans

1) Reliability of power distribution facility

Improvements on distribution lines are substantialy being promoted owing to an increase of gratuitous aid over 4 times as that from Japan in the past. However, for the most part they are still left as they are in a time-worn state and therefore, further establishment of marginal supply capability, enhancement of reliability, and promotion of safety are urgently needed.

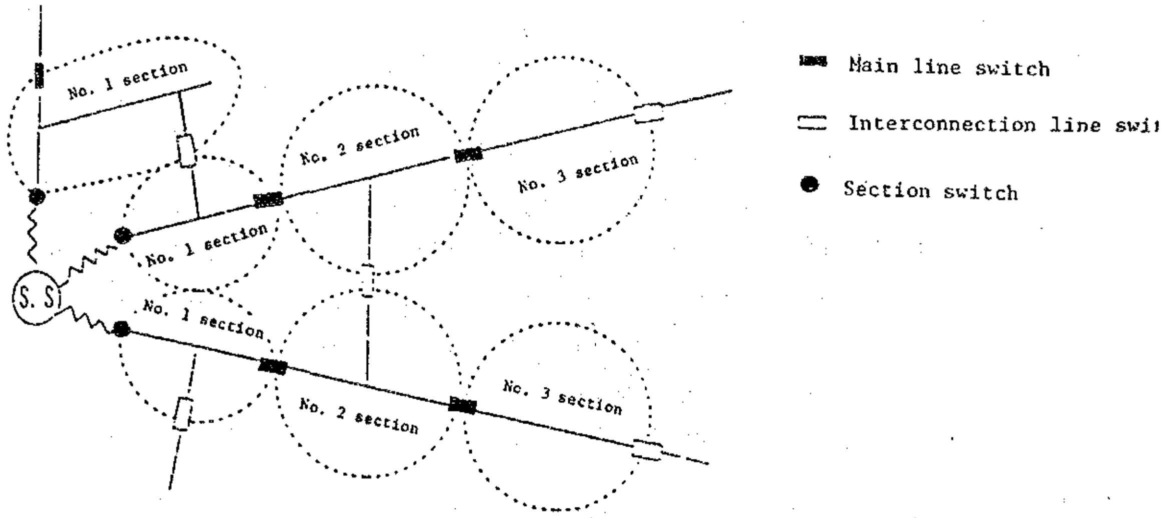
As for the actual conditions of the worn-out facilities, service level or degree of reliability of repairs which have been performed up to now in respect of distribution facilities, target points are not available yet, even now. This is because the measures have been taken on a priority basis, thus in such a style as was only urgently needed to repair certain ruined facilities.

In order to improve and expand the power supply facilities so that a stable supply is obtained hereafter, target points must first be set up in detail as to the service level and degree of reliability prior to setting out on the long-term and short-term plans.

(a) System formation of 11 kV distribution line

Formation of the system must be performed in such a manner that the system is divided into a number of sections to limit the range of power failure due to transmission lines to certain districts and interconnection lines are to be provided among these sections. The standard number of sections and interconnection lines are to be taken in 3 divisions and 3 interconnection lines in consideration of reliability, economical efficiency, and ease of maintenance service.

Example of interconnection line setup



(b) Establishment of power supply reliability standards and review thereof

Target restoration time for an accident shall be as shown in the following table:

Reliability division	Maximum duration of power failure
Service ranking A	60 minutes
Service ranking B	90 minutes
Service ranking C	150 minutes
Service ranking D	180 minutes

Note: Service ranking A: Important government and municipal offices and important installations

Service ranking B: Ordinary governmental and municipal offices and industrial parks

Service ranking C: Bustling streets and shopping quarters

Service ranking D: Residential districts and other places other than mentioned above

2) Planning of 11 kV distribution lines

Repairs must be conducted in such a way that heavily loaded or excessive voltage drop distribution lines shall be separately assigned to the feeders of newly established or reinforced substations, in short, the system must be changed over.

In addition, small size wires included in the main line sections shall be replaced with large size wires and then more switches shall be added to the 3 division and 3 interconnection line distribution system thereby enhancing reliability by effectively interchanging power and limiting the power failure areas to certain districts at the time of an accident.

Standard capacity and voltage of distribution line shall be as follows:

(a) Capacity of distribution line

Standard capacity of the distribution line shall be as shown in the following table under the conditions of:

Standard transmission capacity: Nominal 3,000 kVA/cct
Maximum 4,000 kVA/cct

	Main line capacity
Normal service capacity	200A
Short time service capacity	300A

(b) Maintenance of voltage

Voltage drop limit for 11 kV distribution line

Standard voltage drop limit for 11 kV distribution line shall be as shown in the following table:

	District division	Voltage drop limit (V)
Normal service	District A	500
	District B	1,000
At an accident	District A	900
	District B	1,900

(Notes) A districts: Important governmental and municipal offices and important installations

B districts: Other districts than mentioned above

(c) Summary of distribution facility expansion

Year	Feeder New (cct)	Overhead line distance (km) New	Overhead line distance (km) Replace	Switch New (pieces)	Under-ground wire New(km)	Remark (New/expanded substations)
1994	11	11	7	33	1.1	Newly established: 2 places Expanded: 2 places
1996	14	14	4	42	1.4	Newly established: 4 places
Short term total (For 5 years)	25	25	11	75	2.5	Newly estalished: 6 places Expanded: 2 places
1998	4	4		12	0.4	Expanded: 2 places
2000	10	10		30	1.0	Newly established: 3 places Expanded: 1 place
2002	5	5		15	0.5	Expanded: 2 places
2003	3	3		9	0.3	Expanded: 1 place
2004	9	9		27	0.9	Newly established: 1 place Expanded: 2 places
2005	3	3		9	0.3	Expanded: 1 place
2006	2	2		6	0.2	Expanded: 1 place
Total 15 years	61	61	11	183	6.1	Newly established: 10 places Expanded: 12 places

(Notes) Where;

Newly established overhead wire (distance): 1 km/cct

Replacement of overhead wire (distance): at applicable places

Newly established switches: 3 units/cct

Newly established underground wire: 0.1 km/cct

1. Details of each substation

	Newly established substation related matters		Bank additional installation/ expansion related matters	
Year	Name of substation	Distribution line under plan	Name of substation	Distribution line under plan
1994	Tandale 15MVAx1 Chan'gombe 15MVAx1	 4 cct New 4 cct New	Ilala (15MVAx2) 15MVAx1 Mbezi (7.5MVAx1) 15MVAx1	1 cct New 2 cct replacement between banks with new ones 2 cct New
1996	Kunduchi 15MVAx1 Kariakoo 15MVAx1 Mbagala 15MVAx1 Tabata 5MVAx1	 4 cct New 4 cct New 4 cct New 2 cct New		
1998			Mikocheni (15MVAx1) 15MVAx1 Kiganboni (5MVAx1) 5MVAx1	 3 cct New 1 cct New
2000	Temeke 15MVAx1 Mburahati 5MVAx1 Kitunda 5MVAx1	 4 cct New 2 cct New 2 cct New	FZ-II (5MVAx1) 5MVAx1	 2 cct New
2002			Kariakoo (15MVAx1) 15MVAx1 Kigamboni (5MVAx2) 5MVAx1	 4 cct New 1 cct New
2003			Oyster Bay (15MVAx1, 5MVAx2) 5MVAx1 Ex. to 15MVA	 3 cct New
2004	Upanga 15MVAx1	 4 cct New	Mikocheni (15MVAx2) 15MVAx1 Mbezi (7.5MVAx1, 15MVAx1) 7.5MVAx1 Ex. 15MVAx1	 3 cct New 3 cct New
2005			FZ-III (15MVAx1) 15MVAx1	 3 cct New
2006			Msasani (15MVAx1) 5MVAx1	 2 cct New

3) Low-voltage distribution line

Voltage drop and fluctuations at a customer's location is mostly due to largely widened low-voltage service areas caused by the usage of large capacity transformers and small size wires and setup over a long distance.

As a radical countermeasure, reduction in low-voltage service areas by using small capacity transformers and systematic replacement of small size wires with large ones must be urgently conducted.

In addition, in view of safety on the electric facilities and humanbody, such repairs as application of insulation to all lines including incoming line must also be conducted.

Limit of voltage drop

Standard limit of low-voltage distribution line voltage drop shall be as shown in the following table, and in addition, the voltage at service points shall be 230V±15V for lighting and 402V±40V for low-voltage power.

Classification	Voltage drop limit (V)
Lighting	15
Low-tension power	40

4) Maintenance and operation techniques

Since it is difficult to conceive that systematic maintenance services are underway now, and in consideration of the present conditions, i.e. time-worn distribution lines, an organization must be set up in respect of comprehensive maintenance service and operation.

(a) Establishment of management organization

To conduct maintenance service preciously, management organization and staff setup are needed. In addition, in order to establish perpetual countermeasures in succession to the emergency measures, a stock of construction materials and equipment and also a budgetary backing must also be secured.

(b) Implementation of periodic patrol and inspection

To preclude an accident resulting in injury or death or damage to facilities, periodic inspection and patrol must be systematized.

Classification	Applicable district	Interval	Remark
Inspection	All districts	Once a year	
Patrol	Urban district	Once a year	To be alternated with inspection

(Note) For an urban district, either inspection or patrol shall be conducted alternately at intervals of every 6 months.

(c) Execution of periodic measurement of voltage and current

To grasp and manage the voltage and condition of distribution line in operation precisely, voltage and current must be measured periodically to keep in hand adequate data.

(d) Phase control of 11 kV distribution line

A phase control chart must be prepared to secure ease of operation and safety for line changeover, adjustment of unbalanced load, etc.

(e) Improvement of accident restoration setup

To conduct prompt restoration work at the time of an accident, accident restoration procedures shall be systematized. In particular, it is indispensable to secure mobilization vehicles, mobile and portable radios, tools, and construction materials and equipment.

(2) Standardization of distribution facility

As for standards of the distribution facility, a number of standards are in use for the facility equipment such as Japanese standards (JIS) of Japan, the recent aid granting country, local standards (NS), British standards (BS), etc.

In order to expand facilities on a long-term basis, unification of specifications, a challenge to be solved in the near future, is needed.

As for the unification of specifications, it is conceivable that commonality should be made with Japanese standards at its core so that a series of aid can be continuously furnished from Japan hereafter. However, to promote it, it is necessary to review the technical assistance with attendance of relevant associated makers although there are still many problems to be solved such as commonality of specifications in respect to the locally manufactured electric wires, cables, transformers, etc.

1) 11 kV distribution line

To recommend that the accidental power failure due to contact of trees and vines with distribution lines and in consideration of the security of the facility, insulated wires must be exclusively used for the distribution lines intended part to be newly constructed or replaced with new (large size) ones.

Applicable type: OE-ACSR 120 mm2 (for main line)
OE-ACSR 32 mm2 (for minor branches)

(a) Problems to be posed by adoption of insulated wire

When struck by a lightning bolt, dielectric breakdown caused by the indirect lightning bolt surge induced in the distribution line causes a pin hole in the insulated wire covering.

If the above flashover takes place at 2 phases or more at the same time, these two phases are short-circuited via the arm to make the dynamic current start to flow from the power-frequency voltage side, which makes the insulated wire frequently fused by arc heating before operation of the substation relay.

On the other hand, the bare wires are often protected against disconnection by operation of the substation relay. This is because the points of current flow-in or flow-out do not remain the same at one point are moving for the bare wire thus giving enough time for substation relay to work.

It is known from the above disconnection mechanism for the insulated wires that the insulated wires are apt to increase occurrence of disconnection when struck by a lightning bolt. This is a disadvantageous point for the insulated wires. Nevertheless, the insulated wires are to be used. This is because the insulated wires are much more advantageous in that they can preclude power failure due to contact with trees or vines and, moreover, they are superior in various security aspects.

It is also conceivable to attach a discharge clamp to prevent disconnection, however, this method should be left as a technical challenge to be solved hereafter since the relevant research and development may take a very long time.

2) Section switches for transmission lines

The following type shall apply both to normally open and normally closed switches: Air break switch 300A

3) Countermeasures for lightning-proof and salt tolerance.

Distribution lines shall be provided with grounding wires, and in addition, all poles equipped with switches shall be provided with lightning arresters. Insulators shall be of the anti-pollution type. (Class 10A)

4) Review of insulated wire usage

As for 11 kV distribution lines (ACSR 50 mm2 and 100 mm2 bare aluminum wire with partial 25 mm2 bare hard copper), they are presenty already substantially worn out. Concerning this fact, an inception report (January, 1993) and Optimum power service plan (March, 1993) were issued to recommend usage of insulated wires from the standpoint of accident prevention.

At the time of setting out the long-term and short-term plans, usage of insulated wires must be included so that the bare wires can be replace with them gradually in addition to the establishment of new feeders to meet the added new sub-stations and replacement of small size wires with large size ones.

(a) Problems to be posed by insulated wire usage

It is conceivable that insulated wire usage are surely necessary from the point of view that they can preclude feeder power failure due to contact with foreign matter and moreover they are satisfactory in various security aspects. However, they still poses the following problems in respect to lightning bolt:

If an indirect lightning surge, which is induced when a tree or building near a distribution line is struck by a lightning surge, happens to exceed the insulation level (Class 10A), the flashover due to the dielectric break-down may sometimes cause an accident to the distribution line.

From the lightning damage generation mechanism with respect to an electric wire, it is anticipated that the frequency of accidents to the insulated wire, i.e. dis-connection of the wire may increase as compared to the bare wires, thus posing a problem.

i) Disconnection of insulated wire

a) Dielectric breakdown due to a lightning surge in insulated wire that is connected to pin insulators, causes an flashover and resultant large lightning discharge. However, since the lightning discharge takes place only for a very short time, it merely makes a pinhole in the insulated covering but does not cause disconnection of the wire.

b) During the incident mentioned in a) above, the distribution line and the earth is short-circuited to make the lightning discharge, i.e. ground fault current flow. In this event, however, since the current is not large, the wire is seldom disconnected but often recovered with insulation capability in a short time.

c) Likewise during the incident mentioned in a) above, if the flashover takes place at two phases or more concurrently, a dynamic current starts to flow at the time of b) and then continues to flow until substation relay is actuated.

On the other hand, in the case of the bare wires, the flow-in and flow-out points are moving as mentioned previously thus giving enough time for the substation relay to work. Accordingly, the bare wire is often protected against disconnection of the wire.

Since the flow-in and flow-out points in the case of insulated wires are the same as that of the pinhole, the insulated wire is often disconnected due to arc heating before the substation relay starts to work.

5.6 OPTIMIZED TELECOMMUNICATION PLAN (LONG TERM/SHORT TERM)

5.6.1 Long-term Telecommunication Plan

The power service system for Dar Es Salaam city which is a part of the planned areas, consists of 10 distribution substations with Ilala substation at its center and the telecommunication facility necessary for the system is also set up with SCADA system as its core. Since this SCADA system still has allowance in its capacity, it can cope with additional construction and expansion of substations. However, it is also clear that only 1 circuit of the present load dispatching telephone line is not at all enough as the new substations are additively constructed. The lack of circuits must therefore be coped with by an increasing number of circuits by digitizing telecommunication equipment or the like. It is again important that the operation works at Ilala load dispatching office must be upgraded, analogue information must be inputed, and measurement and recording must be automated in order to precisely grasp the power supply and demand at Ilala and Ubungo substations thereby radically improving SCADA system.

As for the mobile radio facility, the number of portable radios must be increased as well as new allocations of frequency and enhancement of supply capability must be considered since the maintenance service areas are on the increase as the new distribution lines are constructed.

5.6.2 Short-term Telecommunication Plan

From the short-term point of view, the expansion of the power service system can fully be coped with by increasing the number of seating or remodeling software by making good use of the existing SCADA system. By taking this opportunity, however, it is also important to increase the number of standby seatings and enhance the reliability of maintenance service.

As for the mobile radio facility, the existing facility can cope with the present basic system. However, the increase in the number of portable radios must also be considered to match the actual situation of the future maintenance service for the transmission line.

5.7 OPTIMIZED PROTECTION PLAN (LONG TERM/SHORT TERM)

(1) Long-term protection plan

For the expansion of existing, and the creation of new power transmission/distribution lines and transformers, the same protection methods as those which are currently being used shall be employed. The protection systems currently in use as follows:

220 kV Power Transmission Lines

Power line transportation system

Main protection: Short-circuit, remote relays, ground connection, directional relays

Rear equipment protection : Short-circuit, overcurrent relays (three-phase), ground connection, ground connection ground current relays

132 kV Power Transmission Lines

Main protection: Short-circuit, remote relays, ground connection, directional relays

Rear equipemnt protection : Short-circuit, overcurrent relays (three-phase), ground connection, ground connection ground current relays

33 kV Power Transmission Lines

Overcurrent relays (three-phase), ground connection, ground connection ground current relays

11 kV Power Transmission Lines

Overcurrent relays (two-phase), ground connection, ground connection ground current relays

Transformers

Voltage: 220/132 kV

220 kV overcurrent relays (three-phase), 132 kV overcurrent relays (three-phase)

Ratio differential relays (three-phase)

132 kV overcurrent relays (three-phase), 33 kV overcurrent relays (three-phase)

Ratio differential relays (three-phase)

Voltage: 33/11 kV, 7.5 MVA or larger capacity

11 kV overcurrent relays (three-phase), 11 kV ground connection overcurrent relays,
11 kV circuit ground connection overcurent relays (three-phase), 11 kV overcurrent relays, ratio differential relays (three-phase)

Voltage: 33/11 kV, 5 MVA or smaller capacity

11 kV overcurrent relays (two-phase), 11 kV ground connection overcurrent relays,
11 kV circuit ground connection overcurrent relays (three-phase), ratio differential relays

(2) Short-term protection plan

The above protection systems shall be used.

CHAPTER 6

POWER SYSTEM ANALYSIS

Chapter 6 Power System Analysis

CHAPTER 6 POWER SYSTEM ANALYSIS

6.1 PURPOSE AND CONDITIONS FOR CALCULATIONS

6.1.1 Purpose

(1) Power systems shall always be improved by means of addition of the electric power facilities and frequent technical reviews as the demand increases. This system analysis should be performed on a time series basis with regard to the technical review of the expansion plan (described in Chapter 5) which is set out to cope with estimated power demand for TANESCO power system over 15 years hereafter until 2007.

As for method of review, the power flow calculation is adopted to extract problems which are included latently in existing power systems (at time of 1993). In addition, in respect of medium- and long-term system expansion plans, a review was conducted with emphasis placed on supply reliability of power distribution facilities. The extracted problems are proposed as the procedure to set up optimum system plans in the near future.

6.1.2 Conditions for Power System Calculation

Various conditions necessary to carry out power system calculation are set out as shown below:

(1) Applicable year to calculation

Applicable year to calculation is selected as follows, where applicable time is the end of respective years.

1) 1993

To extract problems included latently in existing power systems and consider improvement plans.

2) 1994

To verify effectiveness of power system improvements which will be conducted after completion of the reinforcement of power distribution network in Dar es Salaam (Phase III) to be implemented in 1994.

3) 1997

Out of 15 years during which time this master plan must successfully be completed, this year is taken up to perform a review aiming at 1997 which is the final year of the recent 5 years.

4) 2002

This year is taken up to perform a review aiming at 2002 which is the 10th year of 15 years during this master plan being implemented.

5) 2007

With regard to 2007, the final year of this master plan, a review is performed aiming at setting up a long-term power system plan to match future scale of power demand. The obtained results are used for procedure at time of sett expansion plans to be promoted hereafter.

(2) Applicable systems

Applicable systems to calculation are 220 kV, 132 kV, and 33 kV. Although the main theme of this master plan is the transmission and distribution networks of Dar Es Salaam city, all power systems of the whole country comprising both 132 kV system used in Kilimanjaro district and 220 kV system in the districts beyond Kidatu power station are included in this calculation because of the fact that the Kilimanjaro and Kidatu systems exert a large influence on the Dar Es Salaam system.

(3) Details of calculation and check points

1) Power flow calculation

(a) Existence of any facilities on which overload is imposed. In other words, transmission lines and transformers are normally operated or not.

(b) Capability to maintain adequate system voltage, i.e. capability to adjust the system voltage by tap changer of transformer, generator power factor, and adequate distribution and balance of reactive power.

(c) Supply reliability of distribution facility in terms of power demand and power flow calculation is fully met or not with regard to system accidents to be taken into account.

2) Power system stability calculation

The target year of the power system stability calculation is presumed to be around 2007 in the state of that the national power grid is loaped via Ubungo, Kidatu and Killimanjaro.

3) Short-circuit current calculation

Three-phase short-circuit current is calculated aiming at the power system in arround 2007, which is helpful to designing electric power facilities.

(4) Conditions for operation of power system facilities

To verify capability of maintaining adequate system voltage, conditions for operation of power system facilities are set out as follows:

System voltage to be maintained	: 95 to 105%
Operating voltage of generator	: 100±5%
Operating power factor of generator	: 0.80 or more
Tap ratio for transformer	: 1.00±0.1
Power factor of load	: 0.95
Loading time	: At peak

In order to maintain the above voltage, static condensers (S.C) and shunt reactors (Sh.R) for voltage compensation are installed at adequate power stations.

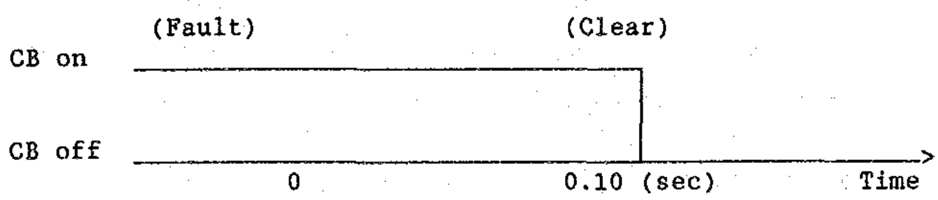
(5) Operating conditions for Ubungo power station

To review Dar Es Salaam power system as to capability to maintain system voltage, it is indispensable to know whether Ubungo power station is in operation or not. This is because the operation of this power station produces a certain amount of effective power and reactive power and hence power flow between Kidatu and Ubungo is reduced thereby restricting voltage drop of it.

In order to obtain more strict conditions for calculation of voltage maintenance, it is assumed in this study that Ubungo power station is only in operation when needed to keep demand and supply balance in respect of the output.

(6) Power system stability calculation

In power system stability calculation of the 220 kV primary network, a three-phase ground fault is applied as the system disturbance and then the fluctuations of generators are verified. In this study, the fault resistance is taken for zero, and the high-speed reclosing of the faulty transmission line is not assumed. The fault sequence to apply to these transmission lines is illustrated below. The fault clearing time is taken for 0.10 seconds assuming that the protective relays operate normally.



(7) Short-circuit current calculation

The short-circuit current is calculated in the state of that all generators of the power system, including the planned power stations in addition to the existing generators, are in operation. For

Ubungo power station, additional generators are considered for a marginal impact in the future, the total output of 150 MW (i.e 180 MVA) is presumed. Regarding a generator constant, the transient reactance (Xd') is used.

(8) Capacity of transmission line

To check overload of transmission line, allowable current (A) and transmission capacity (MW) of 220 kV, 132 kV and 33 kV transmission lines are determined as shown in Table 6-1.

Table 6-1 Allowable current and transmission capacity

Kinds of conductor (mm^2)		Allowable *1 current (A)	Transmission capacity (MW) *2		
			33 kV	132 kV	220 kV
Rabit	(53)	223.2	12	-	-
Dog	(105)	345.6	19	75	-
Wolf	(158)	453.0	25	98	-
Bison	(381)	771.9	42	168	279
Blue Jay	(564)	983.8	-	-	356
ACSR	120	383.6	21	-	-
ACSR	240	605.7	-	-	219

Notes) *1: Calculated under conditions of ambient temperature of 40°C, conductor temperature of 90°C, and wind velocity of 0.5 m/s.
See Table 5.3.1 (1) for details.

*2: Transmission capacity (P) is calculated from following formula:

$$P = \sqrt{3}\ VI\ \cos\theta \quad (MW)$$

Where; V : Transmission voltage (kV)
I : Allowable current of conductor (kA)
$\cos\theta$: Power factor of power flow (0.95 on average)

6.2 RESULTS OF ANALYSIS

6.2.1 Power Flow Calculation

(1) Summary of transition of system characteristics

Table 6-2 shows transition of characteristics of Dar Es Salaam power system which are obtained from power flow calculation. In the table, reactive power balance that exert an influence on voltage maintenance, transmission loss rate, and heavy flow compensating facility are shown.

1) Reactive power facility

Improvement of system voltage (i.e. rising of bus voltage) is characterized by operation of the S.C of 18.3 MVA, which has been installed at Ubungo and Ilala respectively in 1993. By 1997 the duplication program of Morogoro-Ubungo 220 kV line and the construction of Shingida-Arusha 220 kV line will be completed and the national power grid is linked with 220 kV and 132 kV transmission lines. These transmission line expansions will bring more improvement of the system voltage level.

In 1997 demand and supply balance of reactive power is kept by that supplied from 220 kV and 132 kV line charging capacitors and it is not necessary to operate the S.C for a few years. By the around 2002 the system voltage will be maintained at a normal level with supply of reactive power from the S.C (18.3 MVA, 2 sets) and the generators of Ubungo.

In around 2007, it is necessary to add a new S.C of of about 20 MVA for Dar Es Salaam power system. This is not owing to Dar Es Salaam power system itself but caused by heavy power flow in the 220 kV transmission line beyond Ubungo which makes Ubungo 220 kV bus voltage substantially drop.

2) Transmission loss rate

The transmission loss rate on Dar Es Salaam power system remains to be 2%. The loss rate after 1997 decreases remarkably compared with that before 1994. The reason for keeping such loss rate at low level for a longer period of time is attributable to uneven power flow occuring at present which will be caused by addition of 132 kV and 33 kV transmission lines and power stations.

As for the transmission loss rate on nationwide systems, it will drop to 2.90 in 1997 which is about half 6.50% and 6.28% in 1993 and 1994 respectively. This decrease in loss rate will be obtained by improvement on uneven power flows after the completion of Singida-Arusha 220 transmission line. In 2007 the loss rate will be increased to 7.04% caused by heavy power flow between Kidatu-Ubungo 220 kV lines.

It should be noted that the transmission loss rate described here excludes those caused by 11 kV distribution lines and 33 kV transmission lines other than that of Dar Es Salaam city.

3) Power flow of transmission line and transformer

Ubungo-Ilala 132 kV transmission line and Ilala 132/33 kV transformer are presently (1993) operated in the heavy power flow condition. In the near future, additional installation is indispensable for those facilities.

(2) Power systems in 1993 (Refer to Fig. 6-1)

Power flow calculation in 1993, Ubungo power station is stopped and Kidatu power station is operated in almost rated output. In reactive power balance, supply capability becomes 72 MVar which consists of 36 MVar received from 220 kV and 132 kV power systems, and 36 MVar from S.C. On the other hand, 47 MVar of which is for demand and 25 MVar for loss.
Secondary voltage of distribution transformers (33/11 kV) can be maintained 100% or more by supplying the above reactive power and by adjusting transformer tap changer.

Ubungo-Ilala 132 kV transmission line and Ilala 132/33 kV transformer are the facilities being operated in heavy power flow condition which reaches about 77 MW. Since capacity of 132 kV transmission line is 98 MW and that of transformer is 90 MVA (45 MVA x 2 units), failure of transmission line or any one of the transformers can cause a large scale power failure (equivalent to 35 to 40 MW demand). For that reason, additional installation is indispensable for those facilities in the near future. As for 33 kV transmission line, there are no sections in operation with heavy power flow.

(3) Power systems in 1994 (Refer to Fig. 6-2)

Judging from the power demand and supply balance in 1994, it is known that the operation of Ubungo power station is needed to avoid lack of supply capability. The operation is therefore performed to output 31 MW. In reactive power balance, supply capability becomes 69 MVar which consists of 31 MVar received from 220 kV and 132 kV power systems, and 2 MVar supplied from the generator of Ubungo. On the other hand, consumption is 74 MVar, of which 49 MVar is for demand and 25 MVar for loss.

As for Ubungo-Ilala 132 kV transmission line and Ilala 132/33 kV transformer, they are still in the state of heavy power flow condition equal to that of 1993 thereby posing a latent problem in respect of supply reliability. As for 33 kV transmission line, there are no sections in operation with heavy power flow.

(4) Power systems in 1997 (Refer to Fig. 6-3)

Judging from the power demand and supply balance in 1997, it is known that the operation of Ubungo power station is needed to avoid lack of supply capability. The operation is therefore performed to output 50 MW. In reactive power balance, supply capability becomes 75 MVar which consists of 68 MVar received from 220 kV and 132 kV power systems, and 7 MVar from the generator of Ubungo. In this case it does not need to operate the S.C. On the other hand, 59 MVar of which is for demand and 16 MVar for loss.

Since expansion of Ubungo-Ilala 132 kV transmission line and Ilala 132/33 kV transformer are scheduled to be completed until this year, the problem posed by the heavy power flow latently existing after 1993 system can be solved. In addition, Singida-Arusha 220 kV transmission line is scheduled to be newly constructed in 1995. After completion of this line, nationwide system is looped through 220 kV and 132 kV lines.

As a result, the power supplied to Kilimanjaro districts via Morogoro in the past is sent this time via Singida, thereby restricting voltage drop of Ubungo 220 kV bus and then facilitating maintenance of voltage of Dar Es Salaam system. Owing to this effect, the balance of reactive power is kept with that supplied from 220 kV and 132 kV power systems and the generators of Ubungo. As for 33 kV transmission line, there are no sections in operation with heavy power flow.

(5) Power systems in 2002 (Fig. 6-4)

Ubungo power station is operated with its output of 50 MW same as the calculation of the 1997 power system. In reactive power balance, supply capability becomes 94 MVar which consists of 49 MVar received from the power system, 36 MVar from the S.C and 91 MVar from the generators of Ubungo. On the other hand, 77 MVar of which is for demand and 17 MVar for loss.

Expansion of 132 kV transmission line of Dar Es Salaam is scheduled to be completed until this year which exerts following influences:

- Reduction in transmission loss due to improvement on uneven power flows.
- Enhancement of supply reliability in terms of facilities because of added allowance in transmission capacity.
- Reduction in voltage drop thus facilitating easy maintenance of system voltage.

(6) Power systems in 2007 (Refer to Fig. 6-5)

Judging from the power demand and supply balance in 2007, it is known that the operation of Ubungo power station can be stopped. However, if supply capability relies only on Kidatu and other hydroelectric power stations after stopping operation of Ubungo, it becomes difficult to maintain the voltage of Dar Es Salaam system at an adequate level. The operation of Ubungo is therefore performed to output 55 MW.

Reactive power receiving from the 220 kV and 132 kV power systems decreases to 20 MVar and it is impossible to expect to receive more. It is characterized by the increase in reactive power losses due to heavy power flow of Kidatu-Ubungo 220 kV lines. About 20 MVA of S.C is needed to compensate a lack of reactive power. In this calculation, 10 MVA of S.C is added to Ubungo and City Centre respectively.

Table 6-2 Transition of Characteristics of Dar Es Salaam System

Year	1993	1994	1997	2002	2007
1. Power demand (MW)					
Whole country	329.8	348.5	413.8	543.6	708.5
Dar Es Salaam	142.1	150.2	179.3	236.0	307.6
2. Reactive power balance					
(1) Supply (MVar)	72	69	75	94	137
Required S.C.	36	36	0	36	93
Line capacitor	36	31	68	49	20
Output of Ubungo Ge	0	2	7	9	24
(2) Consumption (MVar)	72	69	75	94	137
Demand	47	49	59	77	101
Losses	25	20	16	17	36
3. Transmission losses					
(1) Dar Es Salaam system					
Losses (MW)	2.6	2.7	2.6	3.0	4.7
Loss rate (%)	1.80	1.77	1.43	1.26	1.50
(2) Whole network					
Losses (MW)	23.2	23.6	12.5	23.1	54.3
Loss rate (%)	6.50	6.28	2.90	4.03	7.04
Output of Ubungo Ge (MW)	0	31	50	50	55
4. Heavy load facilities (MW)					
Ubyngo-Ilala Line (98 MW/cct)	76.5	68.3	95.1 (2 cct)	65.9 (2 cct)	85.8 (2 cct)
Ilala 132/33 kV Tr. (90 MVA/2 banks)	75.7	67.8	94.5 (3 banks)	65.7 (3 banks)	56.5 (3 banks)
Ubungo 220/132 kV Tr. (300 MVA/2 banks)	155.7	141.9	119.8	184.9	260.9
Ref. Power flow diagram	Fig. 6-1	Fig. 6-2	Fig. 6-3	Fig. 6-4	Fig. 6-5

6.2.2 Power System Stability Calculation

The results of the power system stability calculations are shown in the form of generator swing curves and voltage fluctuation curves, Fig. 6-6 through Fig. 6-9. Mode of the disturbance is that applying a 3-phase-ground fault at Kidatu - Morogoro 220 kV line closest to Kidatu and then opening one of the two circuits of the said line.

(1) Power system in 2007

Fig. 6-6 shows the generator swing curves after the disturbance. Each of the generators can maintain its stability and the generator swings are absorbed in 2 or 3 seconds after the fault is cleared.

Fig. 6-7 shows the 220 kV bus voltage fluctuations of Ubungo, Morogoro and Kidatu. It is known that the voltage drop of Ubungo and Morogoro is large, especially that of Ubungo drops by about 10% from the initial level. The large voltage drop is caused by that the major power stations are very far from the load center. It is impossible to maintain the bus voltage level at above 90% of the rating after the one of 220 kV two circuits is opened.

Power system situation in 2007 the trouble of the voltage drop will arise but the generators can maintain their stabilities.

(2) Power System after 2007

The peak power demand of Dar Es Salaam is estimated at 308 MW in 2007. Power system calculation is carried out under the condition of that the said peak power demand will increase by 100 MW reaching about 400 MW. In this power demand scale the major power stations must be operated with their rated capacities.

Fig. 6-8 shows the generator of Ubungo steps out in 3.6 seconds after the disturbance. But the rest can maintain their synchonism with each other, but their swings are spreading or not converging.

Fig. 6-9 shows the bus voltage fluctuations. Those of Ubungo and Morogoro are very large since these buses are far from the major power stations.

As the result of the calculation, transmission line expansion between Kidatu and Ubungo will be required to maintain the power system stably corresponding to the enlargement of power demand scale.

6.2.3 Short-Circuit Current Calculation

Short-circuit current in the 2007 power system is shown in Fig. 6-10. The top-three bus short-circuit currents of the substations selected from the Dar Es Salaam System are listed below.

(a) 220 kV Bus

Ubungo	2.1 kA (985 MVA)

(b) 132 kV Bus

Ubungo	3.5 kA (790 MVA)
Ilala	3.2 kA (736 MVA)
Oyster bay	3.1 kA (706 MVA)
FZ-III	3.1 kA (702 MVA)

(c) 33 kV Bus

Ubungo	14.3 kA (816 MVA)
Tabata	9.0 kA (513 MVA)
Ilala	6.6 kA (380 MVA)

(d) 11 kV Bus

Ubungo	25.2 kA (479 MVA)
Ilala	10.9 kA (208 MVA)
Mbezi	9.9 kA (189 MVA)

6.2.4 Long-term Plan for Network Formation

(1) Problem posed by present network formation

Dar Es Salaam system presently poses following two problems in respect of supply reliability:

(a) Presently, all power supply to Dar Es Salaam city and Zanzibar entirely relies on Ubungo 132 kV bus. Scale of concentration of power on this bus is 150 MW in 1994 and 180 MW in 1997 respectively. In 2007, it may reach as high as 310 MW. These power account for about 40% of total demand in Tanzania.

(b) Up to now, the reinforcement of Dar Es Salaam system has been performed in respect of supply routes of Ubungo-Ilala 132 kV transmission line. As a result, the power flow in these routes already (1993) exceeds 50% of total demand of Dar Es Salaam city.

These two points are self-explanatory that power supply capability is concentrated on Ubungo and Ilala substations and that failure of either of the buses of these substations or Ubungo-Ilala transmission line causes total loss or at least 50% loss of the power to be supplied to Dar Es Salaam city. This implies that supply reliability is substantially on the decrease.

(2) Countermeasures to be taken

As for network improvement plan to enhance supply reliability, following measures are conceivable:

(a) To reduce power flow of Ubungo-Ilala route by constructing new and separate 132 kV transmission lines from Ubungo in addition to existing Ubungo-Ilala 132 kV transmission line.

(b) To add a new bus to double each of the existing single bus of Ubungo and Ilala substations thereby avoiding risk of accidental failures inherent in the present single bus system.

(c) To establish a new substation in order to share the power coming from Kidatu power station with Ubungo substation.

Among the improvement plans shown above, first priority must be given to (a) Establishment of new transmission lines of 132 kV. Measures (b) is rather simple remodeling works of each substation thus can be taken up at any time. These works must be set to work one by one in the near future. Measures (c) is for improvement of primary system (220 kV system) but it should be considered only after improvement of the secondary system (132 kV system) since the latter is much more immature presently.

(3) Implementation plan

1) Network formation

Measures (a) above is taken up as the implementation plan to be reviewed in the following manner:

In measures (a), two routes are newly constructed to meet the demand in addition to the existing Ubungo 132 kV outgoing transmission line. One route is going in the east direction to Oyster Bay substation and second route is in the south direction to Kurasini substation via factory Zone III. Fig. 6-11 shows this long-term improvement plan and the expansion plan of Dar Es Salaam system which is scheduled to be implemented in near future.

2) Power flow

Fig. 6-12 shows power flow diagram of the system in the year of 2007 after the above mentioned improvement plan has been applied. The power flow between Ubungo-Ilala 132 kV transmission line, which was 76.5 MW (1 circuit) in the 1993 power flow diagram and which equals to 59% of total demand (excluding Zanzibar) of Dar Es Salaam city, becomes 85.8 MW (2 circuits) in the 2007 power flow diagram and the percentage is 33%, i.e. 16% per 1 circuit. The power flow of other two routes, Ubungo-Oyster Bay and Ubungo-Factory Zone III, are 37 MW (14%) and 54.6 MW (21%) respectively.

From the results, it can be said that the power flow distribution is uniformized thus risk of wide range power failure due to 132 kV transmission line is much reduced and moreover improvement of supply reliability is prominently seen.

Fig. 6-13 shows power flow diagram when loop network of Dar Es Salaam system is completed through installation of 132 kV transmission line. According to the diagram, power flow of Oyster Bay-Ilala, Ilala-Kurasini, and Yombo-Mbagala transmission lines are not heavy at all but light; hence these transmission lines