CHAPTER 5

PRESENT CONDITIONS, PROBLEMS, AND PROPOSED REHABILITATION OF TRANSMISSION, SUBSTATION,AND DISTRIBUTION FACILITIES

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5.1Dar es Salaam

5.1.1 Transmission Facilities

Concerning the existing and planned transmission facilities in Dar es Salaam, the Study Team, together with engineers of TANESCO, investigated the present conditions, problems, operation and maintenance, etc. The characteristics of transmission facilities in the individual regions are described below.

(1) Existing transmission lines

(a) 132 kV transmission lines

The existing 132 kV transmission lines were generally in good condition. Some of the steel towers do not have concrete protection but have their bottom members coated with coal tar to prevent corrosion. Since the corrosion-preventive effect of the coal tar must have declined due to aging, it is considered necessary to inspect those steel towers periodically and repair them as required. All the steel towers in Dar es Salaam are of self-supporting type.

Table 5.1.1 Specifications of 132 kV transmission lines in Dar es Salaam

Name	Length (km)	No. of CCT	Tower Type	No. of insulators (pieces/phase)	Conductor size (mm^2)	Ground wire size (mm^2)
Ubungo-FZ III	9.3	1	Vertical Self support	11	ACSR 240	ACS 55
Ubungo-Ilala #1	7.5	1	Horizontal Self support	10	ACSR 150	Steel 50
Ubungo-Ilala #2	7.5	1	Vertical Self support	11	ACSR 240	ACS 55
Ubungo-Tegeta	19.5	1	Horizontal Self support	10	ACSR 150	Steel 50
Tegeta-CTS1	3.5	1	Horizontal Self support	10	ACSR 150	Steel 50

(b) 33 kV transmission lines

There are several substations, which are not fully performing their functions due to a problematic configuration of the lines feeding distribution substations. Also, there were many superannuated lines, which require urgent repair work. Wooden poles are widely used as the support for transmission lines, although steel pipe poles are also used in some places. The number of insulators is three pieces/phase. The existing 33 kV transmission lines in Dar es Salaam and problems in the individual regions are described below.

Table 5.1.2 33 kV transmission lines in Dar es Salaam

Name	Length (km)	No. of CCT	Conductor size (mm^2)	Remarks
Ubungo-wazo	18.2	1	ACSR 100	
Wazo-Tegeta #1	2.1	1	ACSR 100	
Wazo-Tegeta #2	1.6	1	ACSR 100	
Tegeta-Mbezi	8.4	1	ACSR 100	
Mbezi-Ubungo	8.8	1	ACSR 100	
Ubungo-Mikocheni	8.3	2	ACSR 100	1cct 2conductors
Mikocheni-Oysterbay	5.3	2	ACSR 100	1cct 2conductors
Oysterbay-Msasani	5.3	1	ACSR 100	
Oysterbay-Ilala	6.3	2	ACSR 150	1cct 2conductors
Ubungo-Ilala #1	7.5	1	ACSR 150	
Ubungo-Ilala #2	7.5	1	ACSR 150	
Ubungo-Tandale branch	1	1	ACSR 100	
Tandale branch-Friendship	0.5	1	ACSR 100	
Tandale branch-Tandale	6	2	ACSR 100	
Ubungo-Friendship	1.5	1	ACSR 100	
Ilala-Kariacoo	1.3	1	ACSR 100	
Ilala-FZ I	5	2	ACSR 100	
Ilala-City Center #1	3.9	2	ACSR 150	1cct 2conductors
Ilala-City Center #2	2.8	1	ACSR 100	1cct 2conductors
City Center-Sokoine	3	1	ACSR 100	
Ilala-Kurasini	7.1	2	150/100/50	1cct 2conductors
Kurasini-Chang'ombe branch	2	1	ACSR 120	
Chang'ombe branch-FZ I	4.5	1	ACSR 120	
Chang'ombe branch-Chang'ombe	1	1	ACSR 50	
Kurasini-Kigamboni	4	1	ACSR 100	
Kigamboni-TIPER	0.9	1	ACSR 50	
Kurasini-Mbagala	9.2	1	ACSR 100	
Ubungo-TAZARA	7.8	1	ACSR 100	
Ubungo-TAZARA branch	7.5	1	ACSR 100	
TAZARA branch-ALAF	9.2	1	ACSR 100	
TAZARA branch-TAZARA	0.1	1	ACSR 100	
Ubungo-FZ III	7	2	ACSR 120	1cct 2conductor
FZ III-FZ II	10	1	ACSR 100	
FZ III-FZ I	5.9	1	ACSR 100	

(i) Kinondoni North Region

- The Ubungo-Wazo transmission line is open at the Ubungo side because of a trouble with the oil circuit breaker at the Ubungo side. Since several pole transformers are connected to this transmission line, power is transmitted from the Wazo side. There are many rotten supports (wooden poles) which need to be replaced with new ones. However, the bushes, etc. prevent vehicle access to them, making it difficult to replace them. TANESCO says that this transmission line cannot be abolished even in the future since it serves as a bypass for another transmission line.

- The Ubungo-Mikocheni transmission line has a limited transmission capacity since the 185 mm^2 outgoing cable at the Ubungo side has failed and a temporary cable (120 mm^2 or 90 mm^2) is substituted.
- The Ubungo-Mbezi S/S transmission line is not in use now.
- At present, Oysterbay and Msasani are fed from Ilala, Mikocheni from Ubungo, and Mbezi from Tegeta. In order to permit Tegeta to feed Mikocheni and Msasani so as to improve the reliability of power supply, it is necessary to effect a tap change at Mbezi, Mikocheni, and Msasani because the Tegeta-Mbezi transmission line is too small for the purpose (ACSR 100 mm^2 x 2).

(ii) Kinondoni South Region

- Rehabilitation of the Ubungo S/S that feeds distribution substations in this region over a 33 kV transmission line has been started. It seems, therefore, that repair and expansion of the 33 kV interconnecting lines and distribution lines will be carried out preferentially in the future.
- Construction of a new 33 kV interconnecting line involves difficulty in securing a line route. Therefore, we consider that TANESCO should avoid this problem (i.e., difficulty in securing a line construction site in a densely-populated area) by increasing the capacity of some existing interconnecting lines, like the Ubungo-Ilala line, by means of renewal of supports, conductors, etc.

(iii) Ilala Region

- The FZ III-FZ I transmission line has a large transmission loss due to defective conductor connection, etc. TANESCO says that it wants to double the conductor in the future. The company also wants to change part of the route of the transmission line to a route along the Nyerere road. The reason for this is that the area around the FZ I S/S is so crowded with small houses that it prevents vehicle access, making the maintenance work there difficult.
- The Ilala-FZ I transmission line is difficult to maintain because there are valleys and densely-populated areas on the route.
- The Ubungo-FZ III transmission line has many trees standing very close to the line.
- TANESCO says that it wants to double the conductor (ACSR 100 mm^2 x 2) in the FZ III-FZ I-Chang'ombe section.

(iv) Temeke Region

- The Chang'ombe is normally fed by the Ilala via the FZ I. If the FZ I is switched to the FZ III S/S that has larger supply capacity, a voltage drop occurs. This is due to a problem with the 33 kV interconnecting line between the FZ III and FZ I.
- The FZ III that was completed last year with the cooperation of the Japanese government uses 132 kV and its 33 kV feeder has sufficient supply capacity. Therefore, it is time to plan improvement/reinforcement of the 33 kV line linking the FZ III, FZ I, Chang'ombe, Kigamboni, and Mbagala Substations to increase its capacity. (Introducing ACSR 240 mm^2 should be discussed at the same time.)

(2) Planned transmission lines

(a) 132 kV transmission lines

(i) Ubungo-New Oysterbay (new line; initially single circuit, then expanded to double circuits; conductor ACSR 240 mm^2; line length 8.5 km)

In Mikocheni Region, where there are plans to construct American Embassy, hotels, and shopping centers in the future, it is expected that the demand for electric power will increase. Because of this, TANESCO has plans to construct in this region a new substation and a new 132 kV transmission line between the Ubungo and the new substation. Therefore, we conducted a survey of the Ubungo-New Oysterbay route (planned by TANESCO) and discussed problems we found with TANESCO. The outline of the route survey and discussions is given below.

(i)-1 Outline of route survey

- TANESCO plans to construct the No. 1 steel tower on the parking lot north of the Ubungo S/S and lead the transmission line out toward the Morogoro road (regional road).
- The transmission line crosses over the Morogoro road between the No. 1 and No. 2 steel towers. The crossover point is near the intersection of the Morogoro road and another main road (Sam Nujoma road) where the pedestrian and wheel traffic is brisk.
- The planned site for the No. 2 steel tower is situated in an area crowded with small houses.
- Between P46 and P45 (P: Point of survey), the transmission line crosses over the Sam Nujoma road to the east. Then, it runs along the east side of the Sam Nujoma road up to P41. On the west side of the Sam Nujoma road, the existing 33 kV and 11 kV transmission lines run in parallel with the planned 132 kV transmission line route.
- In the section between P45A and P41A, the transmission line runs over the land owned by Tanzania Telecommunications Company, a cement plant, and many residential areas.
- Between P41A and P33, the transmission line crosses over the Sam Nujoma road to the west.
- The land between near P33 and near P17 is controlled by the Tanzanian military, hence we were accompanied by a military officer during the route survey.
- Between P32 and P27, the transmission line crosses over the Bagamoyo road (regional road).
- In the area around P22, the transmission line passes over a high-grade residential district.
- Between P17 and P14A, the transmission line crosses over the Old Bagamoyo road (main road).
- In the section between P14A and P8A, the transmission line passes over a residential area.
- Then, the transmission line runs in front of the Kinondoni North Regional Office to be led into the New Oysterbay S/S.

(i)-2 Outline of discussions

Concerning the above transmission line route planned by TANESCO, the Study

Team made the following comments and presented its recommended route (see Fig. 5.1.1).

- It is necessary to relocate the existing communication antenna at the outgoing point of the Ubungo S/S.
- Considering the equipment layout of the substation, it is necessary to review the position of the No. 1 steel tower.
- On the east side of the Sam Nujoma road between P45A and P41A, there are many factories and houses, hence it is considered difficult to secure the necessary site. It is, therefore, necessary to restudy the route that passes over the grounds of the University of Dar es Salaam on the west side of the Sam Nujoma road. (TANESCO says that it received a negative reply when it asked the university if it would be possible to construct a transmission line which passes over the university's grounds. However, details are unknown.)
- In the P41A-P32 section, the transmission line should be led directly to P32. (P33 should be bypassed.)
- Since P22 is situated in a high-grade residential area, it needs to be moved near the river flowing through the east side of the area.
- Since the P12-P8A section passes through a residential area, it is necessary to restudy the alternative route on the coast side.
- The P6A-New Oysterbay S/S section should be changed to a route passing the back side of the Kinondoni North Regional Office to the New Oysterbay S/S.
- The route of this transmission line should not be decided by distance alone. It is necessary to avoid problematic points (in terms of planned sites and topography) by arranging angle towers as required.
- Concerning the route of this transmission line, it was recorded on the minutes that TANESCO would discuss it further giving consideration to the comments of the Study Team and make preparations for commencement of the construction work.

(ii) FZ III-Yombo-Mbagala-Kurasini-Ilala (new line; initially single circuit, then expanded to double circuits; conductor ACSR 240 mm^2; line length 44.5 km)

A new 132 kV FZ III-Yombo-Mbagala-Kurasini-Ilala transmission line shall be constructed and a loop shall be formed with the Ubungo-Yombo-Ilala transmission line to improve the reliability of power supply and contribute to the supply of power to the southern part of Dar es Salaam. Although a large tract of land for a substation has been secured in Yombo Region, the transmission line route has not been decided yet.

(iii) Ubungo-Ilala (addition of one circuit; conductor ACSR 240 mm^2; line length 7.5 km)

The existing Ubungo-Ilala transmission line shall be expanded to improve the reliability of power supply. Since the existing steel towers are designed to hold double circuits, only insulators and conductors need to be procured. Therefore, it is considered that the expansion work can be carried out easily.

(b) 33 kV transmission line

For the 33 kV transmission line expansion plan in Dar es Salaam, see 7.2.3 (1) (a).

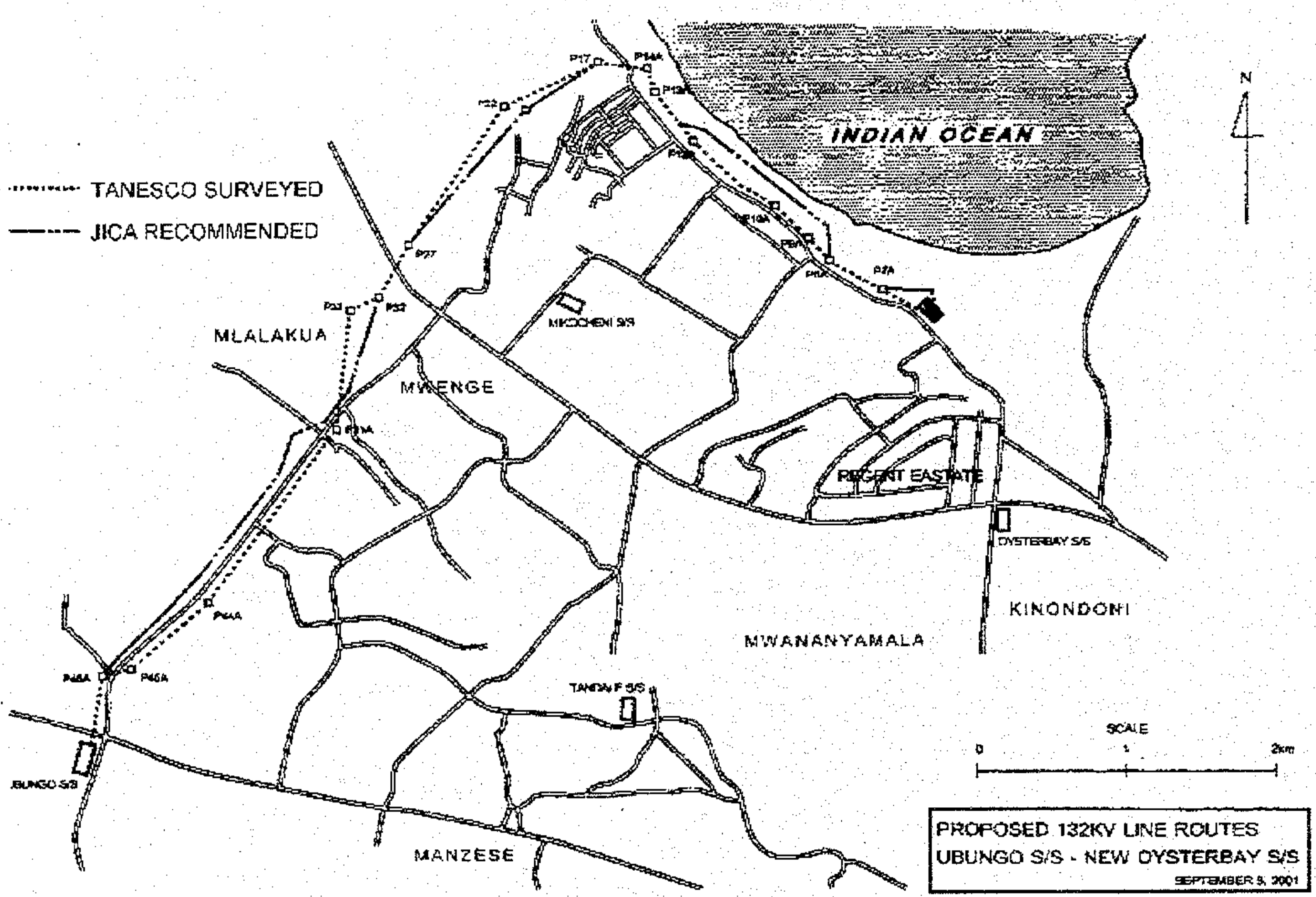


Fig.5.1.1 Proposed 132kV Line Route from Ubungo S/S to New Oysterbay S/S

5.1.2 Substation Facilities

Basically, the present conditions and problems of substations in Tanzania are nearly the same in Dar es Salaam, Arusha, and Moshi.

On the whole, substations and substation equipment which were constructed or installed before 1990 have performance problems.

In particular, quite a few of those which were constructed before 1970 have serious problems on usual daily operation to be performed smoothly.

Before making a detailed evaluation of the substation facilities in the individual regions of Dar es Salaam, we shall describe below the items, method, and bases of evaluation of equipment and the method of scoring the individual facilities.

(1) Evaluation of deterioration of substation facilities in Tanzania

In the study for rehabilitation of the distribution facilities in the principal cities of Tanzania, we shall define bases and method of evaluation of the relevant substation facilities.

In order to diagnose and evaluate the deterioration of substation facilities, it is an essential prerequisite that there exist data which indicate the trends of deterioration quantitatively. For example, the remaining life of a given device can be estimated with reasonable accuracy only as long as the device has been inspected and maintained periodically and the inspection record is well kept. However, for the substation facilities under consideration, such data are almost nonexistent. Therefore, we should say that estimating the remaining life of each individual device accurately involves considerable difficulty.

The evaluation policy and basic criteria we adopted in the present study taking the above situation into consideration are described below.

(2) Evaluation policy

On the whole, the substation facilities in Tanzania are insufficient in terms of both installed capacity and reliability. Therefore, the existing facilities should be used as effectively as possible. Namely, the substation facilities shall be evaluated on the premise that they continue to be used as long as possible.

Thus, the major premises are:

- Prevention of fires and other disasters
- Prevention of breakdown of devices
- Prevention of long-time forced outage due to shortage of spare parts or substitution parts.

And the basic evaluation policy is:

- Expecting as long a remaining life as possible.

(3) Method of deterioration evaluation and base of judgment

For each device or each type of device (if there are two or more types of device), the following base of judgment of deterioration shall be used.

(a) Transformer

(i) Method of deterioration evaluation

The transformer gradually deteriorates due to the effects of not only oxygen, moisture, etc. which reside in it in the manufacturing process but also oxygen and moisture which get into it during a long period of operation.

In addition, the transformer insulating material gradually deteriorates and ages on insulation due to the effects of mechanical vibration, temperature rise, etc. during transformer operation. Furthermore, a combustible gas generated inside the transformer accelerates the deterioration in performance, such as the deterioration of insulation and the increase in mechanical vibration.

As the transformer performance deteriorates to a certain degree, the danger of transformer breakdown caused by an abnormal voltage due to a lightning, switching surge, etc. or by an electrical/mechanical stress, such as the electromagnetic force during an external short circuit, begins to increase sharply.

Normally, the transformer life refers to the period from the time when the transformer is put into operation till the time when the above danger increases so much that the transformer no longer meets its basic performance specifications, such as the initial withstand voltage.

However, even when an overall evaluation is made of the results of periodical inspections and such data as properties of insulating oil, dissolved gas in oil, etc. collected for a long period of time, it is extremely difficult to predict the transformer life accurately unless they reveal some marked trends.

Besides, concerning the transformers under consideration, there are no data about their internal insulation, such as results of analysis of insulating oil properties, dissolved gas in oil, etc., since the time when they were put into operation, although these data are considered vitally important when it comes to estimating the transformer life. Therefore, it is impossible to evaluate transformer deterioration that compared with in light of some quantitative base of judgment.

Aside from the actual years of operation of the individual transformers, the only available information that is considered useful for the evaluation of transformer deterioration is the record of whether or not the transformers have experienced an overload operation.

In view of the above conditions, we decided to assume the transformer life to be the life that can be expected of an ordinary power transformer, consider critical matters related to the transformer internal insulation on the basis of the present condition of transformer operation at TANESCO, set a base of deterioration evaluation, evaluate the transformer deterioration on that base, and compile the results of evaluation.

Concretely, as described below, we first estimate the transformer internal deterioration from the operating environment and actual operating condition of each of the transformers under consideration, and then estimate the life expectancy of the transformer taking into consideration the transformer external condition.

- All the transformers under consideration were manufactured in accordance with the IEC or equivalent standard. Therefore, we assume that each of them has a certain life.
- In estimating the life of each transformer, we measure the difference between the operating condition specified by the standard and the actual operating condition of the transformer.
- In addition, we evaluate the actual operating condition of the transformer to determine whether or not it affects the life expectancy of the transformer.
- We make an overall evaluation of the degree of transformer deterioration from the appearances of the transformer proper and accessories.
- Then, we evaluate the deterioration in performance from the presence or absence

of oil leak from the transformer proper/accessories and discoloration of the insulating oil.

(ii) Evaluation items and base of evaluation

The oil-immersed transformer is divided largely into an internal part and an external part. The internal part consists mainly of a core, coils, lead wires, and a tap changer (diverter switch). These components are made of conductors and insulating materials, such as insulating oil, insulating paper, and pressboard. The external part consists of an iron tank and accessories.

The deterioration of each of those components shall be evaluated by the method described above, and the degree of deterioration shall be judged in light of the base of evaluation. If the degree of deterioration of a component has reached a certain limit, it is judged that the component can no longer be used for a long time.

The transformers under consideration must have been manufactured in accordance with the IEC or equivalent standard and must have passed the tests specified by the standard.

Therefore, it can reasonably be expected that these transformers will have a life of at least 25 to 30 years as long as they are operated under the specified working condition and within their ratings and given proper maintenance (e.g., purification of the insulating oil).

However, if the actual working condition has been unusually severe due to harsh weather conditions, etc. or the transformer has been subjected to an overload repeatedly, the transformer life naturally becomes shorter.

Table 5.1.3 shows the evaluation items, deterioration phenomena, contents of faults which can occur when deterioration phenomena develop, and bases of deterioration evaluation.

Table 5.1.3 Transformer evaluation items and bases of deterioration evaluation

No.	Evaluation item	Classification	Deterioration phenomenon: Type	Deterioration phenomenon: Effect	Ultimate result	Base of deterioration evaluation, etc.
1	Applicable standard in manufacture	Entire TR	———	———	———	25 to 30 years of life if TR is operated under standard operation conditions.
2	Ambient temperature	Entire TR	Thermal deterioration (if ambient temp. is higher than standard value)	-Increase in amount of dissolved gas in oil -Decrease in polymerization degree of insulating paper	Shorter life	Annual average tem. in Tanzania is 25 deg, whereas standard average annual temp. is 20 deg. However, we assume that this difference is negligible because there is a time lag between load peak and temp. peak.
3	Overload operation	Entire TR	Thermal deterioration (if ambient temp. is higher than standard value)	-Increase in amount of dissolved gas in oil -Decrease in polymerization degree of insulating paper	Shorter life	It can be considered that 30% overload lasting for about 3 hours will not affect TR life. 50% overload lasting for about 3 hours reduces TR life by about 3 days each time.
4	Core	Int. Parts	Thermal deterioration	-Increase in vibration -Local heat-up -Increase in amount of gas in oil	Shorter life	Unusual vibration/noise may indicate core anomaly.
5	Coil	Int. Parts	-Thermal deterioration -Partial discharge	-Increase in vibration -Local heat-up -Increase in amount of gas in oil	Dielectric breakdown	Coil deterioration is extremely difficult to detect by external diagnosis. It needs to be evaluated based on results of analysis of insulating oil properties and gas in oil.
6	Lead wire	Int. Parts	-Thermal deterioration -Partial discharge	-Increase in vibration -Local heat-up -Increase in amount of gas in oil	Dielectric breakdown	Coil deterioration is extremely difficult to detect by external diagnosis. It needs to be evaluated based on results of analysis of insulating oil properties and gas in oil.
7	TR insulating oil	Insulating material	Thermal deterioration Partial discharge Moisture absorption	-Decline in dielectric strength -Occurrence of partial discharge -Generation of combustible gas	Dielectric breakdown	Insulating oil deterioration is extremely difficult to detect by external analysis. It needs to be evaluated based on results of analysis of insulating oil properties, measurement of moisture in oil, and analysis of dissolved gas in oil.
8	On-load tap changer	Int. Parts	-Wear -Corrosion (silver sulfide)	-Roughening of contact surface -Increase in contact resistance -Heat-up/fusion	-Tap short circuit -Dielectric breakdown	Electrical life of tap changer is 100,000 to 200,000 operations at best, and same is true of life of auxiliary devices.
9	Tap changer insulating oil	Int. Parts	-Thermal deterioration -Partial discharge -Moisture absorption	-Decline in dielectric strength -Occurrence of partial discharge -Generation of combustible gas	Dielectric breakdown	If hot line oil filter is not installed or is inoperative, insulating oil must be replaced or cleaned. Even if oil cleaner is normal, it is necessary to check performance of oil by analyzing its withstand voltage, degree of oxidation, and moisture content.
10	Tank and gasket	Ext. Part	-Deterioration due to heat cycle -Deterioration due to aging	-Decline in elasticity -Deformation/ cracking	-Oil leak -Insulating oil deterioration	If oil is leaking, gasket life has already expired. Gasket life is normally 15 to 20 years.
11	Conservator (diaphragm type)	Accy.	-Thermal deterioration -Oxidation deterioration -Fatigue	-Decline in strength -Cracking -Oxidation of insulating oil	Deterioration of insulating oil	When appearance is normal, check insulating oil properties.
12	Bushing	Accy.	-Contamination -Damage caused by some foreign object, etc	Decline in insulation performance	Dielectric breakdown	Bushing which has been badly damaged needs to be replaced.
13	Cooling device	Accy.	-Rusting -Cracking	Temperature rise	Oil temp. rise	Cooler which has been badly damaged needs to be repaired.
14	Pressure releasing device	Accy.	-Cracking -Breakdown	Oil leak	Oil leak	If device is leaking oil, it needs to be replaced.
15	CT	Accy.	Disabled function	Inability to measure current	Inability to protect TR/monitor current	CT which is incapable of measuring current needs to be repaired.
16	Instruments	Accy.	-No operation -Inability to indicate values	-Inability to monitor -Inability to issue alarm	Inability to grasp TR operation condition	Instruments which are not functioning need to be repaired.

(iii) Scoring method

Each of the above items shall be checked by the appropriate base of evaluation, and the life expectancy of each transformer shall be ranked based on the result of an overall evaluation of those items. Then, the emergency of rehabilitation of each transformer shall be evaluated.

Table 5.1.4 Judgment of transformer deterioration

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Remarks
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	TRs which have been in operation for less than 15 years are left out of consideration.
2	Overload operation	More than 55% and/or 1hr except accident		40%-50% OL for about 3 hrs	30%-40% OL for about 3 hrs	20%-30% overload for about 3 hrs	Less than 20% OL for about 3 hrs	More than 50% OL can cause insulating paper to deteriorate markedly.
3	Unusual sound	---	---	---	Yes	---	No	Unusual sound may indicate serious int. defect.
4	Vibration	---	---	---	Unusual vibration	---	No vibration	Unusual vibration indicates serious internal defect.
5	Leak of TR insulating oil				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	No oil leak	Oil leak from TR upper part indicates strong possibility of moisture absorption.
6	Oil leak from on-load tap changer				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part		Oil leak from TR upper part indicates strong possibility of moisture absorption.
7	Properties of on-load tap changer insulating oil					Hot line oil filter is absent or in trouble, causing insulating oil deterioration Oil property test is required.		
8	Conservator condition					Conservator has been damaged or does not function.	Normal	Abnormal conservator can cause insulator oil deterioration.
9	Bushing condition				Bushing has been badly damaged.	Bushing has been partly damaged.	Normal	Abnormal bushing can cause dielectric breakdown.
10	Cooling device condition				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	Normal	Oil leak from TR upper part indicates strong possibility of moisture absorption.
11	Pressure releasing device condition				Device has been damaged.		Normal	Abnormal device can cause insulating oil deterioration.
12	CT condition				CT has been damaged or does not function.		Normal	Protective and measuring circuits fail to function and device safety cannot be secured.
13	Instrument condition					Instrument has been damaged or does not function.	Normal	Device condition cannot be grasped quantitatively.

(b) Circuit breakers

(i) Method of deterioration evaluation

The circuit breaker plays a number of critically important roles in electrical equipment operation, such as switching the load current, interrupting a fault current caused by a lightning stroke, and disconnecting a failed device from the circuit during a short-circuit fault so as to prevent breakdown of the device.

Therefore, a defective circuit breaker can cause not only a very serious trouble in equipment operation but also a breakdown of even sound equipment as a result of an accident with some device. Thus, it cannot be left unrepaired even for a short period of time.

The deterioration of a circuit breaker is mainly deterioration in electrical performance, such as a decline in the interpole insulation performance against the ground withstand voltage in a steady state or in a lightning stroke accident or against the transient recovery voltage during elimination of an accident (this is the principal role of circuit breaker) or a decline in the conducting performance caused by wear of the breaking part due mainly to a thermal stress from long-time conduction or arc energy produced during elimination of an accident.

In addition, for economical reasons, the arc-extinguishing part of a circuit breaker that consists of contacts for interruption, an arc-extinguishing chamber which controls the insulation medium by a combination of the contacts, etc. is normally made as small as the electrical performance requirement permits. Because of this, the interrupting contact operating speed is required to be very fast, and the mechanical force required of the mechanism that operates the interrupting contact instantaneously is very large. This is the principal factor in the mechanical deterioration of a circuit breaker which is used for a long period of time.

As the electrical deterioration of a circuit breaker develops, an overheat, interruption failure, dielectric breakdown, etc. can occur in the worst case, preventing the circuit breaker from functioning properly. This in turn can cause a very serious accident, such as a fire or a breakdown of sound equipment.

The mechanical deterioration of a circuit breaker may be a decline in operating speed due to insufficient mechanical force of the operating mechanism, a decrease in operating stroke, etc. In this case, the mechanical force required to operate the interrupting contact properly cannot be obtained. As a result, like the electrical deterioration, the mechanical deterioration can cause a very serious accident.

The phenomena that indicate electrical or mechanical deterioration of a circuit breaker are shown in Fig. 5.1.2.

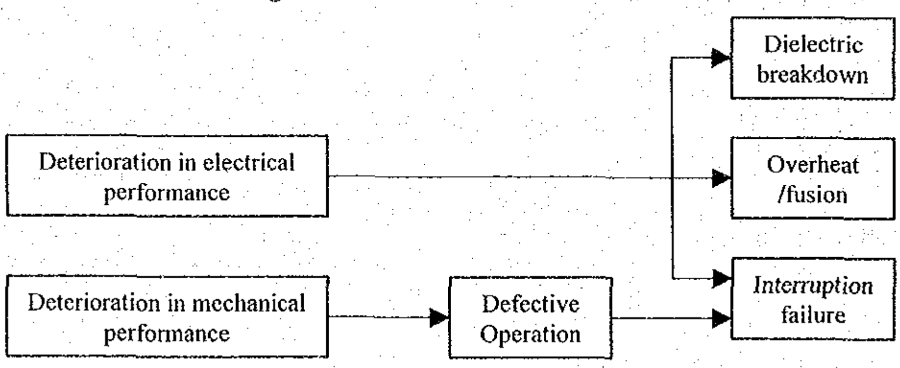


Fig. 5.1.2 Deterioration of circuit breaker

There are several types of circuit breakers: the air blast circuit breaker that uses compressed air as the insulation medium, the oil circuit breaker that uses insulating oil, the gas circuit breaker that normally uses hexavalent sulfur fluoride (SF_6), etc. In addition, there is the vacuum circuit breaker that uses a vacuum valve in the interrupting part. According to the insulation medium used, circuit breakers widely vary in interrupting method, mechanism of interrupting part, and structure. Accordingly, different types of circuit breakers show different deterioration phenomena and different deterioration rates.

In the present study, deterioration of oil circuit breakers and gas circuit breakers which are widely used in TANESCO's power supply system shall be evaluated.

During factory shipment, every circuit breaker is subjected to basic performance tests—dielectric strength test, interruption test, and conduction test. In addition, the switching operation characteristic of each circuit breaker is measured to confirm the operations of the operating circuit, drive unit, and interrupting unit. However, as circuit breakers are used for a long period of time, they are subject to aging deterioration due to the thermal stress during conduction, the wear of interrupting contacts, the mechanical deterioration of the operating mechanism, etc.

Therefore, it is necessary to routinely check the circuit breakers for abnormal conditions (appearance inspection) so as to maintain their performance. To diagnose their functions, including the function of the interrupting part, it is necessary to carry out internal inspection and operation tests every 6 years or so. Based on the results of inspections and tests, defective components must be replaced to ensure that the circuit breakers always function properly.

Nevertheless, the above inspections have not been carried out sufficiently, and records of inspection results and fault current interruptions are not kept. Therefore, whether it is safe to continue using each of the individual circuit breakers in the future shall be determined mainly from the period of use of the circuit breaker, estimated numbers of times of load switching and interruption, appearance of the circuit breaker, and condition of the operating mechanism, with consideration given to the ease of replacement/repair of interrupting contacts and the availability of replacement parts for consumable mechanical parts.

(ii) Evaluation items and bases of evaluation

The circuit breakers under consideration must have been manufactured in accordance with the IEC or equivalent standard and have passed the tests specified by the standard.

Therefore, it is safe to say that those circuit breakers have a life of at least 25 to 30 years as long as they are used in the specified working condition and within their ratings and subjected to the specified inspection and replacement of parts.

However, as the circuit breakers are used for a long period of time, their life will decrease due to: (1) contact wear caused by fault current interruption, (2) contact wear caused by load current interruption, (3) gasket fatigue caused by temperature stress, and (4) deterioration of the operating mechanism caused by aging and operation.

For each type of circuit breaker, the bases of evaluation of the above items are shown below.

<u>Contact life determined by fault current interruption</u>

It is the contact of the circuit breaker that poses a serious problem when it wears and is damaged while in use. The contact life is influenced most by the amount of its wear.

The amount of contact wear can be calculated by using the following equation. The calculated value agrees well with the measured value.

$$V = \alpha \cdot I^{\beta} \cdot t$$

where, V denotes the amount of wear; α and β, constants determined by contact materials, etc.; and t, arcing time. The value of β is approximately 1.6.

The contact life determined by contact wear varies according to the type of circuit breaker. Generally speaking, the number of times of current interruption that causes the critical amount of contact wear is as shown below. At the time when the critical amount of contact wear is reached, the contact shall be subjected to internal diagnosis and replaced as required.

Critical number of times of interruption of rated interrupting current for gas circuit breaker: 10

Critical number of times of interruption of rated interrupting current for oil circuit breaker: 4

It should be noted, however, that for the circuit breakers under consideration, the actual fault current relative to the rated interrupting current that needs to be considered is not more than 50% for a 132 kV circuit and not more than 40% for a 33 kV circuit.

Therefore, the actual critical number of times of fault current interruption is calculated as (rated interrupting current/actual interrupting current) β. Thus,

Actual critical number of times of fault current interruption for gas circuit breaker: Approx. 30

Actual critical number of times of fault current interruption for oil gas circuit breaker: Approx. 12

Contact life determined by rated current interruption

Approx. 1,000 to 2,000 times of interruption for gas circuit breaker

Approx. 500 to 1,000 times of interruption for oil circuit breaker

Gasket life

The gasket has a life of at least 20 years. It should be noted, however, that a gasket which is leaking oil needs to be replaced without delay.

Life of operating mechanism

The operating mechanism has a life of at least 5,000 times of operation as long as worn parts are replaced and the specified parts are lubricated every 3 to 6 years.

For each type of circuit breaker, the evaluation items and bases of deterioration evaluation are shown below.

Table 5.1.5 Evaluation items and bases of judgment for gas circuit breaker

No.	Evaluation item	Classification	Deterioration phenomenon		Ultimate result	Base of deterioration evaluation, etc.
			Type	Effect		
1	Applicable standard in manufacture	Entire CB	———	———	———	CB can be used for 25 to 30 years as long as it is operated under specified conditions.
2	Ambient temperature	Entire CB	Thermal deterioration	Overheat	Burnout	There are no problems under working condition of CB under consideration.
3	Overload operation	Entire CB	Thermal deterioration	Overheat	Burnout	There are no special problems since there is difference between rated current and actual operating current.
4	Interrupting unit	Int. Parts	-Wear by arcs -Wear of sliding part	-Heat-up due to defective contact -Decline in conductivity -Decline in interrupting performance	-Overheat -Decline in interrupting performance -> Interruption failure	Internal inspection is required if cumulative number of times of fault current interruption has exceeded 30. Overall inspection is required if cumulative number of times of rated load switching has exceeded 1000.
5	Operating mechanism (of interrupting unit)	Int./Ext. Parts	-Aging deterioration -Wear -Burnout -Lubricant runout	-Defective operation -Decline in interrupting performance	-Slow switching time -Operation failure	-Judge by operating speed, defective operation, and operation failure.
6	Insulating tubes	Ext. Parts	-Contamination -Damage	-Gas leak -Deterioration in insulation	Dielectric breakdown	Judge by presence or absence of damage/gas leak.
7	Tank	Ext. Parts	Corrosion	Decline in airtightness	Gas leak	Judge by presence or absence of gas leak.
8	Gaskets	Ext. Parts	Corrosion	Decline in airtightness	Gas leak	Judge by presence or absence of gas leak.
9	Operating mechanism (linking mechanism, operating air, spring, or oil compressor)	Ext. Parts	-Aging deterioration Wear -Burnout -Air/oil leak -Lubricant runout	-Defective operation -Decline in interrupting performance	-Slow switching speed -Operation failure	-Judge by presence or absence of leak of driving compressed air/operating oil. -Judge by switching speed and operating condition.
10	Control circuit	Ext. Parts	-Aging deterioration -Defective electrical circuit	-Defective operation -Decline in interrupting performance	-Slow switching speed -Operation failure	-Judge by inspection results. -Judge by operating speed and operating condition.

Table 5.1.6 Evaluation items and bases of judgment for oil circuit breaker

No.	Evaluation item	Classification	Deterioration phenomenon		Ultimate result	Base of deterioration evaluation, etc.
			Type	Effect		
1	Applicable standard in manufacture	Entire CB	———	———	———	CB can be used for 25 to 30 years as long as it is operated under specified conditions.
2	Ambient temperature	Entire CB	Thermal deterioration	Overheat	Burnout	There are no problems under working condition of CB under consideration.
3	Overload operation	Entire CB	Thermal deterioration	Overheat	Burnout	There are no special problems since there is difference between rated current and actual operating current.
4	Interrupting unit	Int. Parts	-Wear by arcs -Wear of sliding part	-Heat-up due to defective contact -Decline in conductivity -Decline in interrupting performance	-Overheat -Decline in interrupting performance -> Interruption failure	Internal inspection is required if cumulative number of times of fault current interruption has exceeded 12. Overall inspection is required if cumulative number of times of rated load switching has exceeded 500.
5	Insulating oil	Int. Parts	-Aging deterioration -Decomposition caused by arcs	-Increase in amount of moisture, degree of oxidation, and amount of sludge --> Decline in insulation performance	Dielectric breakdown	-For CB which has been used for long time or which has interrupted fault current or switched load many times, judge insulating oil deterioration by analyzing its properties.
6	Insulating tubes	Ext. Parts	-Contamination -Damage	-Gas leak -Deterioration in insulation	Dielectric breakdown	Judge by presence or absence of damage/oil leak.
7	Tank	Ext. Parts	Corrosion	Decline in airtightness	Oil leak	Judge by presence or absence of oil leak.
8	Gaskets	Ext. Parts	Corrosion	Decline in airtightness	Oil leak	Judge by presence or absence of oil leak.

No.	Evaluation item	Classification	Deterioration phenomenon		Ultimate result	Base of deterioration evaluation, etc.
			Type	Effect		
9	Operating mechanism (link mechanism, spring compressor, etc.)	Ext. Parts	-Aging deterioration -Wear -Burnout -Lubricant runout	-Defective operation -Decline in interrupting performance	-Slow switching speed -Operation failure	-Judge by spring compressor operating time. -Judge by operating speed and operating condition.
10	Control circuit	Ext. Parts	-Aging deterioration -Defective electrical circuit	-Defective operation -Decline in interrupting performance	-Slow switching speed -Operation failure	-Judge by inspection results. -Judge by operating speed and operating condition.

(iii) Scoring method

Deterioration of each of the circuit breakers under consideration shall be evaluated item by item by the bases of judgment shown above, and the life expectancy of each circuit breaker shall be ranked based on the result of overall deterioration evaluation. Then, the emergency of rehabilitation of each circuit breaker shall be evaluated.

Table 5.1.7 Judgment of deterioration of gas circuit breaker

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Remarks
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	CBs which have been in operation for less than 15 yrs are left out of consideration.
2	No.of times of fault current interruption (contact condition)	---	---	More than 40	30 to 40	11 to 30	---	Judgment based on estimated number of times of fault current interruption.
3	No. of times of load switching (contact condition)	---	---	---	More than 1,000	500 to 1,000	---	Judgment based on estimated number of times of load switching. One time of make-break operation shall be assumed as one time of load switching.
4	Switching operation	Switching operation impossible	---	Switching operation failure occurred in the past.	---	---	No defective switching operation	Switching operation failures and record thereof are important matters.
5	Conduction condition	Incomplete conduction due to defective contact	---	---	---	---	No defective switching operation	Incomplete conduction due to defective contact between fixed and movable contacts is a serial problem.
6	Internal inspection of interrupting unit	---	---	Not done in 24 yrs or more	Not done in 18 yrs or more	Not done in 12 yrs or more	---	Internal inspection needs to be done at intervals of at least 12 yrs.
7	Inspection of operating mechanism	---	---	Not done in 18 yrs or more	Not done in 12 yrs or more	Not done in 6 yrs or more	---	Lubricant needs to be replenished at intervals of at least 6 yrs.
8	Gas leak	There is gas leak.	---	---	---	Gas leaked in past.	No gas leak	Gas leak is a serious problem.
9	Control circuit	---	---	Abnormal	---	---	Normal	
10	Availability of spare parts	---	---	---	Unavailable	Available	Normal	In case of stop of production of spare parts, etc.

Table 5.1.8 Judgment of deterioration of oil circuit breaker

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Remarks
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	CBs which have been in operation for less than 15 yrs are left out of consideration.
2	No.of times of fault current interruption (contact condition)	---	---	More than 20	13 to 20	10 to 12	---	Judgment based on estimated number of times of fault current interruption.
3	No. of times of load switching (contact condition)	---	---	---	More than 500	400 to 500	---	Judgment based on estimated number of times of load switching. One time of make-break operation shall be assumed as one time of load switching.
4	Switching operation	Switching operation impossible	---	Switching operation failure occurred in the past.	---	---	No defective switching operation	Switching operation failures and record thereof are important matters.
5	Conduction condition	Incomplete conduction due to defective contact	---	---	---	---	No defective switching operation	Incomplete conduction due to defective contact between fixed and movable contacts is a serial problem.
6	Internal inspection of interrupting unit	---	---	Not done in 24 yrs or more	Not done in 18 yrs or more	Not done in 12 yrs or more	---	Internal inspection needs to be done at intervals of at least 12 yrs.
7	Inspection of operating mechanism	---	---	Not done in 18 yrs or more	Not done in 12 yrs or more	Not done in 6 yrs or more	---	Lubricant needs to be replenished at intervals of at least 6 yrs.
8	Oil leak	---	---	---	There is oil leak.	---	No oil leak	Oil leak is a serious problem.
9	Control circuit	---	---	Abnormal	---	---	Normal	
10	Availability of spare parts	---	---	---	Unavailable	Available	Normal	In case of stop of production of spare parts, etc.

(c) Instrument transformers

The instrument transformer of a substation is installed near the switching device to measure voltage, current, and electric power. Like the transformer, the current transformer with protective relay for clearing fault in power system. The instrument transformer is so constructed that its insulation is secured by insulating oil and insulating paper. However, the current transformer has a relatively simple construction and many of the troubles with it are caused by deterioration in airtightness or oil sealing.

Generally speaking, the ratings of current transformers have a comparatively large allowance for their working conditions and in many cases, their thermal deterioration that is the major factor in their internal deterioration is less severe than the thermal deterioration of transformers.

In view of the facts mentioned above, the necessity of renewing a particular instrument transformer shall be judged by evaluating the following items.

- Whether or not it has been used for more than about 25 years (Like many other electrical devices, instrument transformers manufactured in accordance with the IEC or equivalent standard can normally be used for 25 to 30 years.)
- Presence or absence of damaged insulator having, etc.
- Presence or absence of marked oil leak
- Records of accidents and faults of instrument transformers of the same type.

Many of the current transformers that have been used for a long period of time incorporate a circuit breaker. Basically, therefore, they shall be renewed at the same that their circuit breakers are renewed.

(d) Steel structures and buses

The outdoor bus consists of a steel structure, copper or aluminum wires, and tension insulators and station-post insulators which insulate the wires and fix the tension bus. These outdoor bus components normally have a semi permanent life unless they are subject to extreme salt damage and air pollution.

Namely, as long as the current capacity of the bus is not exceeded, it is possible to continue using the bus without any problem unless it is subjected to mechanical damage caused by superannuation or some other external factor. Therefore, the bases of judgment for the outdoor bus are:

- Presence or absence of some serious defect of the outdoor structure caused by natural conditions or some other external factor.
- Presence or absence of marked corrosion of the outdoor structure caused by salt damage, air pollution, etc.
- Presence or absence of wires having insufficient capacity.
- Presence or absence of wires which have deteriorated in natural environment, etc.
- Presence or absence of damaged insulators, etc.

Therefore, except when the appearance of the bus has deteriorated markedly, the bus shall be renewed at the time when some change is made to the main circuit specifications or device layout (e.g., installation of additional circuit breakers).

(e) Transmission line protection panel, device protection panel, and control panel

The transmission protection panel, device protection panel, and control panel are designed in such a way that they suit the transmission line system configuration, substation main circuit configuration, and devices installed in the main circuit.

Therefore, those panels (indoor devices) shall be renewed at the same time that the transmission line, main devices, switching devices, main circuit components of instrument transformer, etc. are renewed.

(f) Enclosed switchboard for outgoing out distribution line (11 kV cubicle)

Most of the enclosed switchboards that were installed before 1970 are of the same type as those which have frequently caused serious troubles, such as burnouts. Since the production of those switchboards has already been stopped, it is no longer possible to obtain replacement parts. It is, therefore, necessary to renew the existing switchboards as early as possible.

If a burnout occurs with an enclosed switchboard, it can spread to the adjacent switchboards and other switchboards installed in the control room, causing damage to a large extent. Unless the troubled switchboard is repaired immediately, it will have to be shut down for a long period of time.

Thus, the enclosed switchboards under consideration need to be renewed as early as possible. Since the specifications of those switchboards are closely related to those of the main outdoor equipment, it is necessary to decide specifications of the new switchboards giving consideration to those of the main outdoor equipment.

Basically, therefore, the enclosed switchboards shall be renewed at the same time that the transformer and other main devices are renewed.

(g) Power supply for control (DC power supply: battery)

The power supply for control is used mainly for control operation of outdoor circuit breakers and enclosed switchboards.

The control power supplies installed before 1970 are as old as the outdoor circuit breakers and enclosed switchboards, hence most of them have deteriorated markedly.

Therefore, the control power supplies that have long been used need to be replaced with new ones as early as possible.

However, since the output voltage and current-time capacity of a control power supply are determined by the specifications of circuit breakers, enclosed switchboard, etc. of the supply side, the control power supply shall, as a rule, be renewed at the same time that the circuit breakers, etc. are renewed.

(h) Other equipment

If there is a substation which has some unique problem, a repair plan for the substation shall be formulated with focus on that unique problem.

However, if there is the possibility that the above problem should also occur with other substations of the same type, the problem shall be solved by cooperation among the substations concerned.

(i) Relationship with expansion work

If any of the substations to be expanded has equipment which is planned to be rehabilitated, the bus configuration bus capacity, and main circuit configuration shall be planned and designed based on the number of outgoing lines, capacity, etc. required of the substation from a long-range viewpoint.

Namely, the expansion plan and the rehabilitation plan shall be well coordinated from the viewpoint of reliability, economy, and operation of the power supply system, and a rational work plan shall be formulated.

(4) Present conditions and problems of substations in Dar es Salaam

Concerning the present conditions of the substations in Dar es Salaam, the substation devices that were put into operation before 1980 are generally in the conditions described below, although they more or less differ from one substation to another.

- Most of the transformers are more or less leaking oil. Some leak a large amount of oil from several parts of the gasket, and others have the leaked oil mostly in the tap changer.
- Many of the circuit breakers, which are the most important outdoor switchgear, are not functioning as such because of defective contacts of the interrupting unit (oil circuit breaker) and a superannuated operating circuit.
- Concerning the current transformers, their present conditions are not clearly known since at the substations employing circuit breakers, the current transformer is normally built in the circuit breaker bushing. However, from the conditions of the circuit breakers proper, their operating boxes, indoor protective panels, etc., it is estimated that they have not the required precision.
- Concerning the steel structures and buses, there are several buses which are not properly maintained as substation buses (e.g., remains of dismantled facilities were found at places). However, the bus configuration and structures are simple, and none of the buses and structures need immediate rehabilitation.
- It seems that the transmission line protection panels, device protection panels, and control panels have become superannuated. There are a number of meters which are

not working accurately. Most of the panels need to be renewed as early as possible.

- Many of the substations have experienced a fire caused by electrical trouble with a 11 kV indoor cubicle. Besides, like the case of indoor circuit breakers, the interrupting units have badly worn contacts, and many of them need to be replaced. However, because of lack of the necessary spare parts, the parts of a stand-by line are used when repair becomes necessary. Those parts are also running short, preventing effective operation and maintenance of the equipment.
- Concerning the control power supplies, they are as old as the outdoor circuit breakers or 11 kV enclosed switchboards, and many of the batteries are not functioning. It looks as though the output of the charging unit were connected directly to the control power supply. There is concern that the ripple might adversely affect the device.

The study results show that the substations in Dar es Salaam that need rehabilitation are the Mbezi S/S, Oysterbay S/S, FZ II S/S, City Center S/S, Ubungo S/S, Kurasini S/S, and FZ I S/S. The results of an evaluation of these substations we made using the bases of deterioration evaluation mentioned earlier are described below. It is considered that the transformers and circuit breakers whose score is higher than 10 need immediate renewal.

(a) Mbezi S/S

(i) Bryce (made in England): 33 kV/11 kV, rated capacity 5 MVA, made in 1963

Table 5.1.9 Result of judgment of transformer deterioration in Mbezi S/S

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	5
2	Overload operation	More than 55% and/or 1hr except accident		40%-50% OL for about 3 hrs	30%-40% OL for about 3 hrs	20%-30% overload for about 3 hrs	Less than 20% OL for about 3 hrs	1(Overload operating power unknown)
3	Unusual sound	---	---	---	Yes	---	No	0
4	Vibration	---	---	---	Unusual vibration	---	No vibration	0
5	Leak of TR insulating oil				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	No oil leak	2
6	Oil leak from on-load tap changer				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part		2
7	Properties of on-load tap changer insulating oil					Hot line oil filter is absent or in trouble, causing insulating oil deterioration Oil property test is required.		1
8	Conservator condition					Conservator has been damaged or does not function.	Normal	0
9	Bushing condition				Bushing has been badly damaged.	Bushing has been partly damaged.	Normal	0
10	Cooling device condition				Large amount of oil leak from two or more points, including TR	Considerable amount of oil leak, but not from TR upper part	Normal	2

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
					upper part			
11	Pressure releasing device condition				Device has been damaged.		Normal	0
12	CT condition				CT has been damaged or does not function.		Normal	0
13	Instrument condition					Instrument has been damaged or does not function.	Normal	1
14	TOTAL							14

(ii) Hak Bridge-Hewiitic and Easun LTD (made in India): 33 kV/11 kV, rated capacity 5 MVA, made in 1972

Table 5.1.10 Result of judgment of transformer deterioration in Mbezi S/S

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	4
2	Overload operation	More than 55% and/or 1hr except accident		40%-50% OL for about 3 hrs	30%-40% OL for about 3 hrs	20%-30% overload for about 3 hrs	Less than 20% OL for about 3 hrs	1(Overload operating power unknown)
3	Unusual sound	---	---	---	Yes	---	No	0
4	Vibration	---	---	---	Unusual vibration	---	No vibration	0
5	Leak of TR insulating oil				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	No oil leak	2
6	Oil leak from on-load tap changer				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part		2
7	Properties of on-load tap changer insulating oil					Hot line oil filter is absent or in trouble, causing insulating oil deterioration Oil property test is required.		1
8	Conservator condition					Conservator has been damaged or does not function.	Normal	0
9	Bushing condition				Bushing has been badly damaged.	Bushing has been partly damaged.	Normal	0
10	Cooling device condition				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	Normal	2
11	Pressure releasing device condition				Device has been damaged.		Normal	0
12	CT condition				CT has been damaged or does not function.		Normal	0
13	Instrument condition					Instrument has been damaged or does not function.	Normal	1
14	TOTAL							13

(iii) SF_6 gas circuit breaker for 33 kV (made in England)

Table 5.1.11 Result of judgment of deterioration of gas circuit breaker in Mbezi S/S

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	4
2	No.of times of fault current interruption (contact condition)	---	---	More than 40	30 to 40	11 to 30	---	0
3	No. of times of load switching (contact condition)	---	---	---	More than 1,000	500 to 1,000	---	0
4	Switching operation	Switching operation impossible	---	Switching operation failure occurred in the past.	---	---	No defective switching operation	0
5	Conduction condition	Incomplete conduction due to defective contact	---	---	---	---	No defective switching operation	0
6	Internal inspection of interrupting unit	---	---	Not done in 24 yrs or more	Not done in 18 yrs or more	Not done in 12 yrs or more	---	3
7	Inspection of operating mechanism	---	---	Not done in 18 yrs or more	Not done in 12 yrs or more	Not done in 6 yrs or more	---	3
8	Gas leak	There is gas leak.	---	---	---	Gas leaked in past.	No gas leak	0
9	Cntr'l circuit	---	---	Abnormal	---	---	Normal	0
10	Availability of spare parts	---	---	---	Unavailable	Available	Normal	2
11	TOTAL							12

(iv) Instrument transformers

Of the instrument transformers, the current transformer is built in the gas circuit breaker. Like the circuit breaker, it has become superannuated and is not fully performing its function. Therefore, the current transformer shall be replaced with a new one when the circuit breaker is renewed.

The other instrument transformers have been used for some 30 years. With their gaskets having deteriorated in function, they also need to be renewed in the near future.

(v) Outdoor structure and bus

We consider that the mechanical performance of the outdoor structure and the electrical performance of the bus cable and disconnecting switch have no problems. However, in consideration of the change of device layout needed to cope with superannuation of the main devices, the shortage of bus capacity after equipment expansion in the future, etc., it is wise to replace them during rehabilitation of the substation.

(vi) Transmission line protection panel, device protection panel, and control panel

A fire which was apparently caused by the entry of a snake into one of the panels completely destroyed the equipment that had been installed in the building.

As a result, all the functions of the equipment were lost.

(vii) Enclosed switchboard for leading out distribution line (11 kV cubicle)

Like the transmission line protection panel, device protection panel, and control panel, the entire equipment was destroyed by the fire.

(viii) Control power supply (DC power supply: battery)

Like the transmission line protection panel, device protection panel, and control panel, the entire equipment was destroyed by the fire.

(ix) Substation transformer and lightning arrester

The substation transformer has become so superannuated that it needs to be renewed together with the main devices.

(x) Summary

Transformers: Since the transformers have become superannuated, they shall be renewed as early as possible.

Circuit breakers: Since the circuit breakers have become superannuated, they shall also be renewed as early as possible.

- Current transformer: To be renewed together with the circuit breaker.
- Instrument transformer: To be renewed together with the main devices.
- Outdoor structure and bus: To be renewed when the device layout and bus configuration are changed to adapt to new main devices.
- Transmission line/device protection panels and control panels: To be renewed together with the main devices.
- Enclosed switchboard for leading out distribution line (11 kV cubicle): To be renewed together with the main devices.
- Control power supply (DC power supply: battery): To be renewed together with the circuit breaker.
- Substation transformer and lightning arrester: To be renewed together with the main devices.

(b) Oysterbay S/S

(i) Transformers: Bryce (made in England), 33 kV/11 kV, rated capacity 5 MVA, made in 1963 and 1967

Table 5.1.12 Result of judgment of transformer deterioration in Oysterbay S/S

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	5
2	Overload operation	More than 55% and/or 1hr except accident		40%-50% OL for about 3 hrs	30%-40% OL for about 3 hrs	20%-30% overload for about 3 hrs	Less than 20% OL for about 3 hrs	1(Overload operating power unknown)
3	Unusual sound	---	---	---	Yes	---	No	0
4	Vibration	---	---	---	Unusual vibration	---	No vibration	0
5	Leak of TR insulating oil				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	No oil leak	1

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
6	Oil leak from on-*load tap* changer				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil *leak, but not from* TR upper part		1
7	Properties of on-*load tap* changer insulating oil					Hot line oil filter is absent or in trouble, causing insulating oil deterioration Oil property test is required.		1
8	Conservator condition					Conservator has been damaged or does not function.	Normal	0
9	Bushing condition				Bushing has been badly damaged.	Bushing has been partly damaged.	Normal	0
10	Cooling device condition				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	Normal	1
11	Pressure releasing device condition				Device has been damaged.		Normal	0
12	CT *condition*				CT has been damaged or does not function.		Normal	0
13	Instrument condition					Instrument has been damaged or does not function.	Normal	1
14	TOTAL							11

(ii) Oil circuit breakers: (Takaoka) made in Japan, 36 kV, 600 A, 12.5 kA, made in 1987

Table 5.1.13 Result of judgment of deterioration of oil circuit breaker in Oysterbay S/S

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	0
2	No.of times of fault current interruption (contact condition)	---	---	More than 20	13 to 20	10 to 12	---	1(Estimate from fault records)
3	No. of times of load switching (contact condition)	---	---	---	More than 500	400 to 500	---	0
4	Switching operation	Switching operation impossible	---	Switching operation failure occurred in the past.	---	---	No defective switching operation	0
5	Conduction condition	Incomplete conduction due to defective contact	---	---	---	---	No defective switching operation	0
6	Internal inspection of interrupting unit	---	---	Not done in 24 yrs or more	Not done in 18 yrs or more	Not done in 12 yrs or more	---	1
7	Inspection of operating mechanism	---	---	Not done in 18 yrs or more	Not done in 12 yrs or more	Not done in 6 yrs or more	---	1
8	Oil leak	---	---	---	There is oil leak.	---	No oil leak	2
9	Control circuit	---	---	Abnormal	---	---	Normal	0

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
10	Availability of spare parts	---	---	---	Unavailable	Available	Normal	0
11	TOTAL							5

(iii) Instrument transformers

Of the instrument transformers, the current transformer is built in the bushing of a circuit breaker. Since the current transformer has not been operated so long, it may be said that it is subject to very small stress.

We consider that it can continue to be used safely until renewal of the circuit breaker.

(iv) Outdoor structure and bus

It is considered that the mechanical performance of the outdoor structure and the electrical performance of the bus have no problems. However, the disconnecting switch has a mechanical defect. It is wise to replace the disconnecting switch when the device layout is changed to adapt to new main devices or when the equipment is subjected to reinforcement or renewal (e.g., lead-out of a new line).

(v) Transmission line protection panel, device protection panel, and control panel

The panels have become obsolescent, excepting those for the 15 MVA transformer. It is judged wise to renew the obsolescent panels at the same time that the main devices are renewed.

(vi) Enclosed switchboard for leading out distribution line (11 kV cubicle)

The 11 kV cubicle has become superannuated. Besides, the repair parts are lacking. It is judged necessary to renew it as early as possible.

(vii) Control power supply (DC power supply: battery)

The control power supply needs to be renewed when an additional outdoor circuit breaker is installed and the 11 kV cubicle is renewed.

(viii) Substation transformer

Like the other transformers, the substation transformer has become obsolescent, hence it needs to be renewed together with the main devices.

(ix) Summary

- Transformer: The two 5 MVA transformers that have become obsolescent shall be renewed as early as possible.
- Circuit breaker: The circuit breakers that are leaking oil from the oil level gauge need repair.
- Current transformer: No problems.
- Instrument transformer: Need to be renewed together with the main devices.
- Outdoor structure and bus: Need to be renewed when the device layout and bus configuration are changed to adapt to new main devices.
- Transmission line/device protection panels and control panel: Need to be renewed together with the main devices.
- Enclosed switchboard for leading out distribution line (11 kV cubicle): Needs to

be renewed together with the main devices.

- Control power supply (DC power supply: battery): Needs to be renewed together with the circuit breaker.
- Substation transformer: Needs to be renewed together with the main devices.

(c) FZ II S/S

(i) Transformer: Bryce (made in England), 33 kV/11 kV, rated capacity 5 MVA, made in 1967

Table 5.1.14 Result of judgment of transformer deterioration in FZ II S/S

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	5
2	Overload operation	More than 55% and/or 1hr except accident		40%-50% OL for about 3 hrs	30%-40% OL for about 3 hrs	20%-30% overload for about 3 hrs	Less than 20% OL for about 3 hrs	0
3	Unusual sound	---	---	---	Yes	---	No	0
4	Vibration	---	---	---	Unusual vibration	---	No vibration	0
5	Leak of TR insulating oil				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	No oil leak	2
6	Oil leak from on-load tap changer				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part		2
7	Properties of on-load tap changer insulating oil					Hot line oil filter is absent or in trouble, causing insulating oil deterioration Oil property test is required.		1
8	Conservator condition					Conservator has been damaged or does not function.	Normal	0
9	Bushing condition				Bushing has been badly damaged.	Bushing has been partly damaged.	Normal	0
10	Cooling device condition				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	Normal	1
11	Pressure releasing device condition				Device has been damaged.		Normal	0
12	CT condition				CT has been damaged or does not function.		Normal	0
13	Instrument condition					Instrument has been damaged or does not function.	Normal	1
14	TOTAL							12

(ii) Oil circuit breaker

No circuit breaker has been installed on the transformer primary side.

(iii) Instrument transformer

No current transformer has been installed in the 33 kV circuit.

(iv) Outdoor structure and bus

There is no outdoor structure that comprises a bus.

(v) Transmission line protection panel, device protection panel, and control panel

The panels are not performing their functions.

(vi) Enclosed switchboard for leading out distribution line (11 kV cubicle)

The 11 kV cubicle has become markedly obsolescent. Besides, it has experienced a fire. Furthermore, the repair parts are lacking. Because of all this, it needs to be renewed as soon as possible.

(vii) Control power supply (DC power supply: battery)

The control power supply needs to be renewed when an additional outdoor circuit breaker is installed and the 11 kV cubicle is renewed.

(viii) Substation transformer

Like the other transformers, the substation transformer has become obsolescent and needs to be renewed together with the main devices.

(ix) Summary

Transformer: It is judged necessary to renew the transformer since it has become obsolescent. However, it might be possible to put off renewing it by distributing the substation load to another substation and distribution system.

- Circuit breaker: Installing an additional circuit breaker shall be discussed.
- Current transformer: A current transformer shall be built in the circuit breaker or installed when an additional circuit breaker is installed.
- Instrument transformer: Installing an instrument transformer shall be discussed when additional main devices are installed.
- Outdoor structure and bus: Shall not be installed.
- Transmission line/device protection panels and control panel: Installing the panels shall be discussed when additional main devices are installed.
- Enclosed switchboard for leading out distribution line (11 kV cubicle): Needs immediate renewal.
- Control power supply (DC power supply: battery): To be renewed together with the circuit breaker.
- Substation transformer: Renewal of the substation transformer together with the main devices shall be discussed.

(d) City Center S/S

(i) Transformers: Product of Bonar Long & Company (England), 33 kV/11 kV, rated capacity 5 MVA, 2 units, made in 1979

Table 5.1.15 Result of judgment of transformer deterioration in City Center S/S

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	3
2	Overload operation	More than 55% and/or 1hr except accident		40%-50% OL for about 3 hrs	30%-40% OL for about 3 hrs	20%-30% overload for about 3 hrs	Less than 20% OL for about 3 hrs	1(Experience overload operation in the past)
3	Unusual sound	---	---	---	Yes	---	No	0
4	Vibration	---	---	---	Unusual vibration	---	No vibration	0
5	Leak of TR insulating oil				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	No oil leak	2
6	Oil leak from on-load tap changer				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part		2
7	Properties of on-load tap changer insulating oil					Hot line oil filter is absent or in trouble, causing insulating oil deterioration Oil property test is required.		1
8	Conservator condition					Conservator has been damaged or does not function.	Normal	0
9	Bushing condition				Bushing has been badly damaged.	Bushing has been partly damaged.	Normal	0
10	Cooling device condition				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	Normal	1
11	Pressure releasing device condition				Device has been damaged.		Normal	0
12	CT condition				CT has been damaged or does not function.		Normal	0
13	Instrument condition					Instrument has been damaged or does not function.	Normal	1
14	TOTAL							11

(ii) Oil circuit breaker: Made in South Wales, 36 kV, 600 A, 12.5 kA

Table 5.1.16 Result of judgment of deterioration of oil circuit breaker in City Center S/S

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	4
2	No.of times of fault current interruption (contact condition)	---	---	More than 20	13 to 20	10 to 12	---	1(Estimate from fault records)
3	No. of times of load switching (contact condition)	---	---	---	More than 500	400 to 500	---	0
4	Switching operation	Switching operation impossible	---	Switching operation failure occurred in the past.	---	---	No defective switching operation	0
5	Conduction condition	Incomplete conduction due to defective contact	---	---	---	---	No defective switching operation	0
6	Internal inspection of interrupting unit	---	---	Not done in 24 yrs or more	Not done in 18 yrs or more	Not done in 12 yrs or more	---	3
7	Inspection of operating mechanical	---	---	Not done in 18 yrs or more	Not done in 12 yrs or more	Not done in 6 yrs or more	---	3
8	Oil leak	---	---	---	There is oil leak.	---	No oil leak	2
9	Control circuit	---	---	Abnormal	---	---	Normal	0
10	Availability of spare parts	---	---	---	Unavailable	Available	Normal	2
11	TOTAL							15

(iii) Instrument transformers

Of the instrument transformers, the current transformer is built in the oil circuit breaker, hence it is considered that the amount of stress is small. However, any of those current transformers which have long been used and which are used with a transformer circuit breaker needs to be renewed when the circuit breaker is renewed.

(iv) Outdoor structure and bus

It is judged that the mechanical performance of the outdoor structure and the electrical performance of the bus cable have no problems. However, considering the renewal of obsolescent main devices to be carried out, it is necessary to renew the bus cable.

(v) Transmission line protection panel, device protection panel, and control panel

All the panels that are installed in the new building and one panel installed in the old building can continue to be used safely. However, the other panels have become obsolescent and are now unusable because of the effect of a fire. It is judged wise to renew these panels together with the main devices.

(vi) Enclosed switchboard for leading out distribution line (11 kV cubicle)

The 11 kV cubicle has become superannuated. Besides, it can hardly be used safely because it has been damaged by a fire caused by an electrical trouble. It is judged necessary to renew it as soon as possible.

(vii) Control power supply (DC power supply: battery)

The control power supply has been damaged by a fire. It needs to be renewed when an additional outdoor circuit breaker is installed and the 11 kV cubicle is renewed.

(viii) Substation transformer

Like the other transformers, the substation transformer has become obsolescent and needs to be renewed together with the main devices.

(ix) Summary

- Transformers: Although the transformers have not been operated for much more than 20 years, the bodies and tap changers have deteriorated badly due probably to an overload operation in the past. They need immediate renewal.
- Circuit breakers: The transformer circuit breakers need to be renewed as early as possible.
- Current transformers: Need to be renewed when the circuit breakers are renewed.
- Instrument transformers: Need to be renewed together with the main devices.
- Outdoor structure and bus: Need to be renewed when the device layout and bus configuration are changed to adapt to new main devices.
- Transmission line/device protection panels and control panels: To be renewed together with the main devices.
- Enclosed switchboard for leading out distribution line (11 kV cubicle): Need to be renewed as early as possible.
- Control power supply (DC power supply: battery): Needs to be renewed together with the circuit breaker.
- Substation transformer: Needs to be renewed together with the main devices.

(e) Ubungo S/S

The Ubungo S/S is the largest substation in Dar es Salaam. It is the only substation that leads in a 220 kV transmission line. However, since this substation has been operated for some 30 years, the main devices have deteriorated markedly. The typical examples are given below.

- The two transformers (132 kV/33 kV, 50 MVA x 2), made in India, are leaking large amounts of oil. The gasket seals have become completely ineffective, making it necessary to replenish insulating oil as it leaks.
- The contacts of the 132 kV oil circuit breaker have become loose. As a result, an explosion has occurred. The oil circuit breakers are being replaced with gas circuit breakers.
- The switches and transformers of the 33 kV circuit have deteriorated markedly, preventing stable power supply noticeably.

Under those conditions, TANESCO, with the financial aid of Sweden, is executing a major improvement work on the above transformers and 33 kV circuit.

When the work is completed, the Ubungo S/S, as the main substation in Dar es Salaam, will become capable of stable power supply again.

Since the project to improve the Ubungo S/S is already under way, rehabilitation of this substation shall be left out of consideration in the present study.

(f) Kurasini S/S

(i) Transformer: Product of Bonar Long & Company (England), 33 kV/11 kV, rated capacity 5 MVA, made in 1979

Table 5.1.17 Result of judgment of transformer deterioration in Kurasini S/S

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	3
2	Overload operation	More than 55% and/or 1hr except accident		40%-50% OL for about 3 hrs	30%-40% OL for about 3 hrs	20%-30% overload for about 3 hrs	Less than 20% OL for about 3 hrs	1(Experience overload operation in the past)
3	Unusual sound	---	---	---	Yes	---	No	0
4	Vibration	---	---	---	Unusual vibration	---	No	0
5	Leak of TR insulating oil				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	No oil leak	1
6	Oil leak from on-load tap changer				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part		1
7	Properties of on-load tap changer insulating oil					Hot line oil filter is absent or in trouble, causing insulating oil deterioration Oil property test is required.		1
8	Conservat or condition					Conservator has been damaged or does not function.	Normal	0
9	Bushing condition				Bushing has been badly damaged.	Bushing has been partly damaged.	Normal	0
10	Cooling device condition				Large amount of oil leak from two or more points, including TR upper part	Considerable amount of oil leak, but not from TR upper part	Normal	1
11	Pressure releasing device condition				Device has been damaged.		Normal	0
12	CT condition				CT has been damaged or does not function.		Normal	0
13	Instrumen t condition					Instrument has been damaged or does not function.	Normal	1
14	TOTAL							9

(ii) Oil circuit breaker: Made in South Wales, 36 kV, 600 A, 12.5 kA

Table 5.1.18 Result of judgment of deterioration of oil circuit breaker in Kurasini S/S

No.	Item	Degree of superannuation/aging deterioration/performance decline (pts)						Result of Judgment
		5	4	3	2	1	0	
1	Years in use	More than 30 years	25 to 30 years	20 to 25 years	---	---	---	4
2	No. of times of fault current interruption (contact condition)	---	---	More than 20	13 to 20	10 to 12	---	1(Estimate from fault records)
3	No. of times of load switching (contact condition)	---	---	---	More than 500	400 to 500	---	0
4	Switching operation	Switching operation impossible	---	Switching operation failure occurred in the past.	---	---	No defective switching operation	0
5	Conduction condition	Incomplete conduction due to defective contact	---	---	---	---	No defective switching operation	0
6	Internal inspection of interrupting unit	---	---	Not done in 24 yrs or more	Not done in 18 yrs or more	Not done in 12 yrs or more	---	3
7	Inspection of operating mechanism	---	---	Not done in 18 yrs or more	Not done in 12 yrs or more	Not done in 6 yrs or more	---	3
8	Oil leak	---	---	---	There is oil leak.	---	No oil leak	2
9	Control circuit	---	---	Abnormal	---	---	Normal	0
10	Availability of spare parts	---	---	---	Unavailable	Available	Normal	2
11	TOTAL							15

(iii) Instrument transformers

Of the instrument transformers, the current transformer is built in an oil circuit breaker, hence the amount of stress is considered small. However, the current transformer which has long been used and which is used with the transformer circuit breaker needs to be renewed when the circuit breaker is renewed.

(iv) Outdoor structure and bus

It is judged that the mechanical performance of the outdoor structure and the electrical performance of the bus cable have no problems.

(v) Transmission line protection panel, device protection panel, and control panel

The panels are in good condition compared with those of the other substations. Renewal of them shall be discussed when the substation voltage is raised to 132 kV in the future.

(vi) Enclosed switchboard for leading out distribution line (11 kV cubicle)

The cubicle is in good condition compared with those of the other substations. Renewal of it shall be discussed when the substation voltage is raised to 132 kV in the future.

(vii) Control power supply (DC power supply: battery)

The control power supply is in good condition compared with those of the other substations. Renewal of it shall be discussed when the substation voltage is raised to 132 kV in the future.

(viii) Substation transformer

Like the other transformers, the substation transformer has become obsolescent and needs to be renewed together with the main devices.

(ix) Summary

Transformer: Compared with the transformers of the City Center S/S that were made by the same manufacturer at the same time, the transformer of this substation is in fairly good condition probably because it has not been operated under very severe condition, although it is leaking a small amount of oil. The transformer shall be re-evaluated when the substation voltage is raised to 132 kV in the future, and renewal of it shall be discussed at that time.

- Circuit breaker: The circuit breaker is of the same type that has experienced a number of faults. Besides, spare parts are no longer available. Therefore, it is necessary to renew it as early as possible.
- Current transformer: Needs to be renewed when the circuit breaker is renewed.
- Instrument transformers: Renewal shall be discussed when the main devices are renewed or the substation voltage is raised in the future.
- Outdoor structure and bus: Renewal shall be discussed when the main devices are renewed or the substation voltage is raised in the future.
- Transmission line/device protection panels and control panel: Renewal shall be discussed when the main devices are renewed or the substation voltage is raised in the future.
- Enclosed switchboard for leading out distribution line (11 kV cubicle): Renewal shall be discussed when the main devices (transformer, etc.) are renewed or the substation voltage is raised in the future.
- Control power supply (DC power supply: battery): Renewal shall be discussed when the main devices are renewed or the substation voltage is raised in the future.
- Substation transformer: Needs to be renewed when the main devices are renewed.

(g) FZ I S/S

Many of the devices of the FZ I S/S are comparatively new since improvement of the adjacent switchyard and installation of the substation transformer have been completed recently.

However, some of the enclosed switchboards for leading out a distribution line (11 kV cubicles) burned out in an electrical accident. Since their spare parts are no longer available, they need to be renewed as early as possible.

At the same time, it is necessary to renew the control panels and control power supply.

(h) Summary of rehabilitation plan for substations in Dar es Salaam

Table 5.1.19 shows the rehabilitation plan for substations in Dar es Salaam. It reflects the results of deterioration evaluation of the existing equipment and the addition of circuit breakers, etc. which important substations must be provided with.

Table 5.1.19 Rehabilitation plan for substations in Dar es Salaam

Name of S/S	Tr	Bus	33/66kV CB	11kV CB	Protection /control panels	Control power supply
Mbezi	x	x	x	x	x	x
Oysterbay	x	x	x	x	x	x
FZ II			x	x	x	x
City Center	x	x	x	x	x	x
Ubungo*	x	x	x	x	x	x
Kurasini			x			
FZ I				x	x	x

The Ubungo S/S is left out of consideration in the present study since a project to rehabilitate the substation is already under way.

5.1.3 Distribution Facilities

(1) Current Condition and Problems of Each Office

The distribution network of Dar es Salaam is divided into four regions for the purpose of controlling it effectively. In each of the four regions, there is a TANESCO's regional office. Each of the offices is responsible for construction and maintenance of distribution facilities, collection of power bills, etc. in its region. The present conditions and problems of the distribution facilities in the individual regions are described below.

(a) Kinondoni North Region

In the Mbezi area, construction of general homes is especially active and hence, various stores have been increasing in number. Recently, therefore, the demand for electric power is increasing so rapidly that the expansion of distribution facilities to increase the supply capacity cannot catch up with the demand. As a result, the problem of voltage drops has arisen in this area. With the aim of accurately grasping this problem in the area, the Study Team installed a voltage recorder in a private house in the area where TANESCO has received many complaints about voltage drops, and measured the degrees of voltage fluctuation. The measurement results are shown in Fig. 5.1.3.

This sort of voltage problems can easily be solved by extending the 11 kV distribution line and installing a pole transformer at the load center. Actually, however, this measure has not yet been taken because the budget is insufficient to secure the materials required.

The Mikocheni S/S that was constructed in 1986 with the cooperation of the Japanese government has been operating properly without any major trouble. Recently, however, it is under an overload since more and more factories have been constructed in the neighborhood, causing the load to increase sharply. It is, therefore, necessary to plan installation of an additional main transformer in an empty space on the grounds of the substation.

In this region, the illegal act of drawing the insulating oil off from pole transformers has been committed more frequently than in any other region. This year alone, more than 30 pole transformers have already suffered damage. TANESCO welded the drain valve at the bottom of each pole transformer trying to prevent the insulating oil from being stolen. This measure turned out to be ineffective: the robbers seem really cunning - drilling a hole in the pipe at the root of the pole transformer, and so on.

The supply of power to the distribution substations by the 33 kV network is normally done this way: from the Ubungo S/S to the Mikocheni S/S, from the Ilala S/S to the Oysterbay S/S and Msasani S/S, and from the Tegeta S/S to the Mbezi S/S. When the Ilala S/S feeds the Mikocheni S/S too, the circuit breaker can trip during the peak demand. When the Tegeta S/S fed the Msasani S/S via the Mbezi S/S once, a voltage drop occurred in the Msasani area.

(b) Kinondoni South Region

In this region, many old, low-voltage distribution lines constructed in the 1960s remain, calling for immediate rehabilitation. Since the existing distribution network does not have any difficult technical problems, it should be possible to rehabilitate many of those distribution lines easily if the necessary materials can be procured. Rehabilitation of the low-voltage network should be started soon since TANESCO can do it for itself. Actually, however, the available funds are insufficient to secure the materials required for the rehabilitation.

Because of the increase in load in the Magomeni area, the Tandale S/S (15 MVA) has already recorded peak loads exceeding 14 MVA. It is, therefore, necessary to construct a new substation or install an additional main transformer before the load reaches the rated capacity of the Tandale S/S. According to TANESCO's plan, a new substation - Magomeni S/S - will be constructed in this area with the financial aid of Kfw. TANESCO expects that the new substation will dissolve the overload of the existing substation.

(c) Ilala Region

The FZ III S/S is feeding the Tabata area over the old Ubungo-FZ III line. This line has suffered a ground fault frequently. One way of solving this problem is installing an auto-recloser or sectionalizer. In the areas where construction of new houses is brisk, including the Tabata area, a voltage drop occurs very often.

The FZ I-FZ III line is incapable of operating to capacity, since part of the line has become obsolescent and there are many points of defective connection. When the FZ III S/S feeds the Chang'ombe S/S, a voltage drop occurs. The FZ III S/S introduced 132 kV last year with the cooperation of Japanese government and the 33 kV side has sufficient supply capacity. Therefore, TANESCO should plan to make existing line double-circuit so as to permit the FZ III S/S to safely feed the Chang'ombe area too.

The Ilala-FZ I line is now in such a condition that it cannot be repaired easily: houses have clustered in the area under the line, preventing vehicle access to the site. Since this line needs not only repair but also replacement of conductors, it is necessary to discuss selecting another route and using conductors of larger size to increase the line capacity.

(d) Temeke Region

The Mbagala S/S feeds the Buza and Tandika areas, as well as the Mbagala area, hence it is under an overload. Buza and Vituka, which must be fed by the Mbagala S/S, are receiving power from the F34 feeder of the FZ III S/S because the 11 kV distribution line from the Mbagala S/S does not reach those areas. If the F34 feeder is put under an excessive overload, however, those areas are severed by manual operation of pole-mounted switches. Therefore, it is necessary to construct a new distribution line which is led out from the Mbagala S/S.

In the Kigamboni area, many of the wooden poles for the distribution lines have rotted and the wire size is small. Therefore, it is necessary to rehabilitate them as soon as possible. TANESCO have a plan to introduce a 33 kV distribution line in this area. When this plan is materialized, the situation will be improved significantly since it will become unnecessary to use the obsolescent Kigamboni S/S and 11 kV line.

The low-voltage network in the Chang'ombe area has suffered a line fault often because of obsolescent equipment and incomplete repair work. Although a rehabilitation plan for the entire Chang'ombe area has been formulated, it has not yet been started since all the materials required are still unavailable.

In the Yombo area, the problem of voltage drops has arisen. The main reason for this is that the 11 kV distribution lines from the distribution substation have not been fully extended to the load center and that the number of pole transformers is insufficient for the number of consumer. As a result, TANESCO has received many complaints from the consumer. The Study Team measured voltages in this area and found that the voltage can drop below 150 V during the peak time at night. The results of the voltage measurement are shown in Fig. 5.1.3. A typical example of a low-voltage circuit which causes the low-voltage problem in the area is shown in Fig. 5.1.4

In Dar es Salaam, the Study Team measured the loads of the Mikocheni S/S and Tandale S/S. The results of the load measurements are shown in Fig.s 5.1.5 and 5.1.6.

(2) Current Condition and Problems of Distribution Equipment

The present conditions and problems of the distribution facilities in the areas under consideration are analyzed below.

(a) High-voltage distribution lines

The high-voltage distribution line is normally 11 kV, 3-phase, 3-conductor line, and the system configuration is a tree type with the loop points normally open. In some suburban areas, 33 kV is also used in case of long-distance distribution line. to prevent voltage drops.In Dar es Salaam, most of the 11 kV feeders led out from the individual distribution substations are as short as 3 to 7 km. This is a characteristic of distribution lines in urban areas.

Most of the distribution lines consist of overhead lines and underground cables are rarely used. Even in the capital city of Dar es Salaam, underground cable lines are very few. Many of the cable lines that were formerly used are found in Dar es Salaam.

Because of incomplete treatment of the underground cables as the terminations or insufficient protection, they have suffered accidents and are left unused. In those places, an overhead distribution line has been constructed to supply power. Thus, at present, cable lines are seldom used for the trunk sections of distribution lines. Underground cables are used mainly at the outlets of substations, the inlets of service lines for large consumers, the road crossings, and the points where an overhead line can hardly be branched to a load.

(i) Support and assembly

In the central part of the city of Dar es Salaam, steel poles are widely used as the supports for overhead lines. Elsewhere, wooden poles which are subjected to corrosion-preventive treatment by creosote are used.

Concerning support assembly, various methods are employed - horizontal arrangement, triangular arrangement, double horizontal arrangement, double vertical arrangement.

(ii) Insulator

For straight line poles, pin type insulator or line post insulator is used. For angle and terminal poles, the strings of two 250 mm disk insulators made of porcelain or glass are used. The same manner is applied even with 33 kV lines, except that the strings of three disk insulators are used.

(iii) Wire and cable

Most of the wires used for overhead lines are ACSR 100 mm^2. For branch lines and some of obsolescent lines, ACSR 50 mm^2 is used. However, many of the lines using ACSR 50 mm^2 are subject to a significant voltage drop.

For underground lines, various types of cables are used - 35 mm^2, 70 mm^2, 90 mm^2, 120 mm^2, 185 mm^2. The most commonly used cable-end treatment is of heat shrinkage type. A casting type is used for some obsolescent facilities. Cables are directly embedded in the ground, except under road crossings. There the cable is put in a conduit for protection since it is subjected to larger load.

(iv) Distribution transformer

The distribution transformers that TANESCO employs are of three phases, with their capacity ranging from 20 kVA to 1,000 kVA. Most of the transformers that are actually installed have a comparatively large capacity - 200 kV or more. Transformers of about 300 kVA or less are normally installed on the transformer base of an H-pole, whereas transformers having a larger capacity are installed on the ground. Most of these large-capacity transformers are of cable box type having the charged part covered.

The standard transformer protection system is open fuse cutout at the primary side, fuse cutout at the secondary side. For ground transformers, a low-voltage switch panel is installed to protect the secondary side.

(v) Section switch

In Dar es Salaam, the lines are provided with section switches. However, the number of section switches installed is insufficient to allow for efficient load interchange. Besides, those section switches are used for disconnection or load shedding during an overload, not for their primary purpose, that is, the switching operation for load interchange.

(b) Low-voltage distribution line

The distribution system is a 3-phase, 4-wire system with neutral point grounded. The voltage used is single phase 230 V or three-phase 400 V. The line type is a 3-phase, 4-wire or 1-phase, 2-wire tree.

(i) Support and assembly

In the urban areas of Dar es Salaam, steel poles are used as the supports. In the other areas, wooden poles are used. The pole assembly is vertical arrangement. Horizontal arrangement is used only at special places.

(ii) Wire and cable

PVC-covered aluminum wire is widely used. The main sizes are 100 mm^2, 50 mm^2, and 25 mm^2. However, at obsolescent facilities, various types of wire having many points of connection, including Al 25 mm^2, Al 30 mm^2, Cu 25 mm^2, and Cu 30 mm^2, are used. Many of these wires - even insulated wires - have lost their insulation performance and corroded at their connections.

Since the distribution transformers connected to the distribution network have a large capacity, there is a tendency that long low-voltage lines are used. This is the main factor in voltage drops. Besides, many accidents and extreme voltage fluctuation caused by obsolescent wires with many points of connection have been reported.

(c) Problems

(i) Wire and cable connection

In the high- and low-voltage distribution networks, the defects in wire connections and cable-end treatment are especially noticeable. Defective connection has caused such accidents as fusing of the wire and burnout of the insulator, resulting in an abnormal voltage.In addition, many of the low-voltage distribution lines have improper wire connections, such as using different wires for different phases or jointing different kinds of wires together.

Needless to say, the wires and cables used for distribution lines must be suitable ones. When it comes to connecting wires or subjecting a cable to terminal treatment, it is necessary to use a suitable method and suitable materials.

(ii) Distribution transformer

Since the distribution transformers installed have a large capacity, there is a tendency that low-voltage lines are extended too long. This has caused the problems of voltage drops and voltage fluctuation. It is considered that most of the voltage drops about which many consumers complain are due to the excessive extension of low-voltage lines through use of large-capacity distribution transformers, although some voltage drops are really ascribable to the higher-voltage power supply system.

(iii) Transformer protective devices

There are many transformers whose protective switch has been damaged or which are not provided with a fuse e.g. copper wire is substituted in the fuse link.

Those transformers show traces of overheat and burnout. Since defective protective devices can cause serious damage to the equipment and an electric shock, they should be corrected as soon as possible.

(iv) System configuration

In Dar es Salaam, the power supply system is in such a condition that it does not allow for sufficient load interchange. The reason for this is that the section switches which inter-connect the 11 kV feeders are installed in the wrong places and that the number of section switches is insufficient. As projects to construct new distribution substations and expand existing ones within the city have been carried on, the number of feeders is increasing. It is, therefore, necessary to reinforce the existing power supply system and install the section switches in the right places and thereby improve the reliability of power supply.

(v) Equipment plan

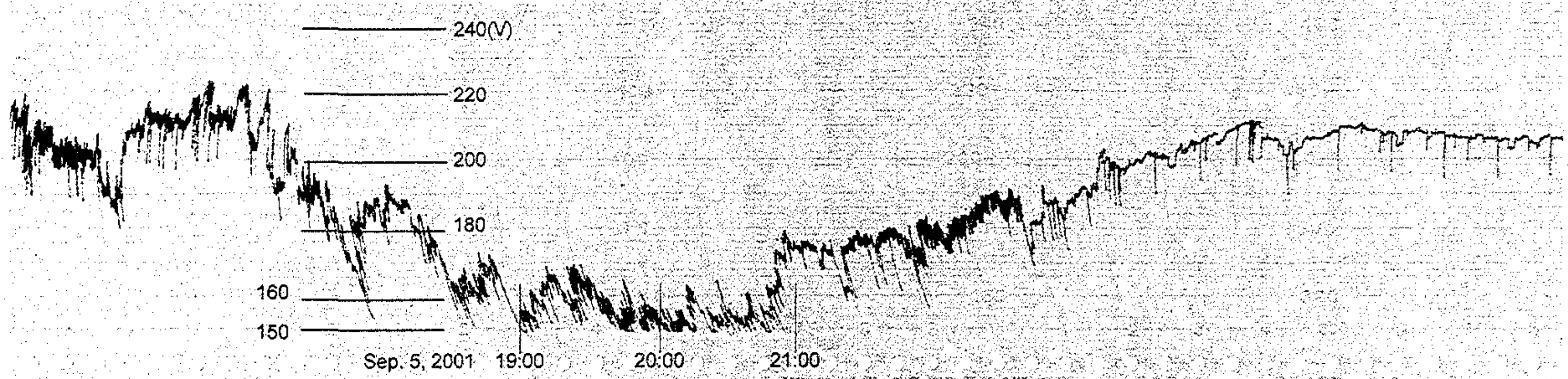
Although the distribution facilities have been expanded in a planned way, the expansion plans are not well coordinated with the plans to construct new substations and expand existing ones. Besides, neither an expansion policy nor guidelines for expansion have been established, hence the individual regional offices carry out expansion projects by their own way. At present, only a few projects are carried out as scheduled since the materials cannot always be procured as needed because of shortage of funds. As a result, some of the facilities are kept under an overload. In the worst case, devices have become useless due to overheating, burnouts, etc.

(vi) Equipment maintenance

At present, routine equipment inspection and maintenance is seldom done unless some trouble occurs with the equipment. Since the distribution facilities are normally installed in public places, it is necessary for them to assure the public safety and stable power supply. In this respect, inspection and maintenance of the distribution facilities is one of the basic requirements. The inspection and maintenance of overhead distribution lines is generally classified as shown below. It is strongly desired that TANESCO should build an organization which ensures execution of these basic types of inspection and maintenance.

- Patrol inspection for early detecting any equipment defect and eliminating it before it causes an accident
- Measurement for maintaining optimum voltage, utilizing equipment effectively, and ensuring positive operation of protective devices
- Restoration and remedial measures when an accident occurs or some dangerous factor is detected
- Supply of data/information about equipment for expansion/improvement planning
- Implementation of other matters relating to any of the above items

Voltage Record-1 (Residential house near Mbezi S/S)



Voltage Record-2 (Residential house in Yombo Vituka)

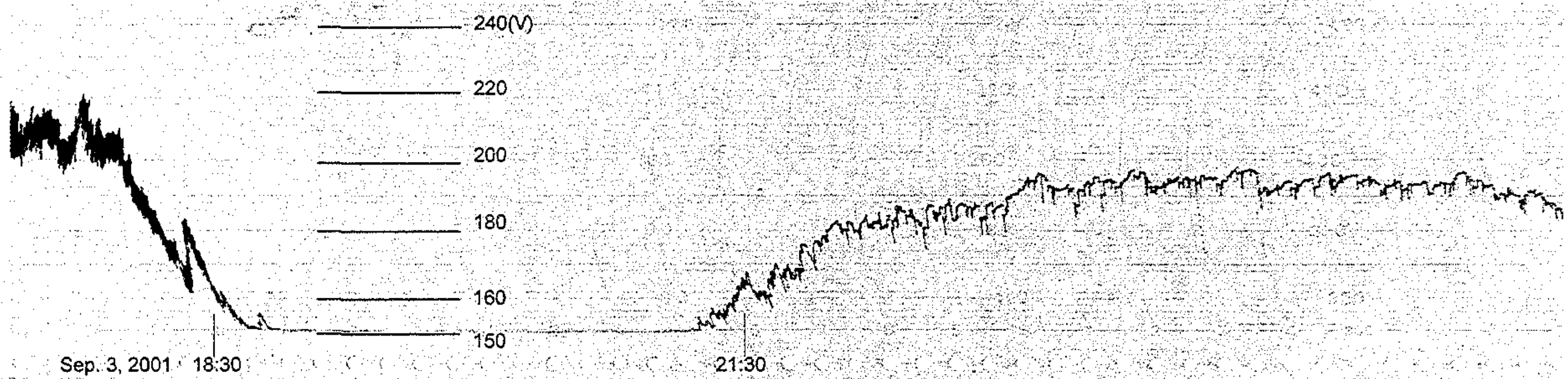


Fig. 5.1.3 Measured Voltage Records

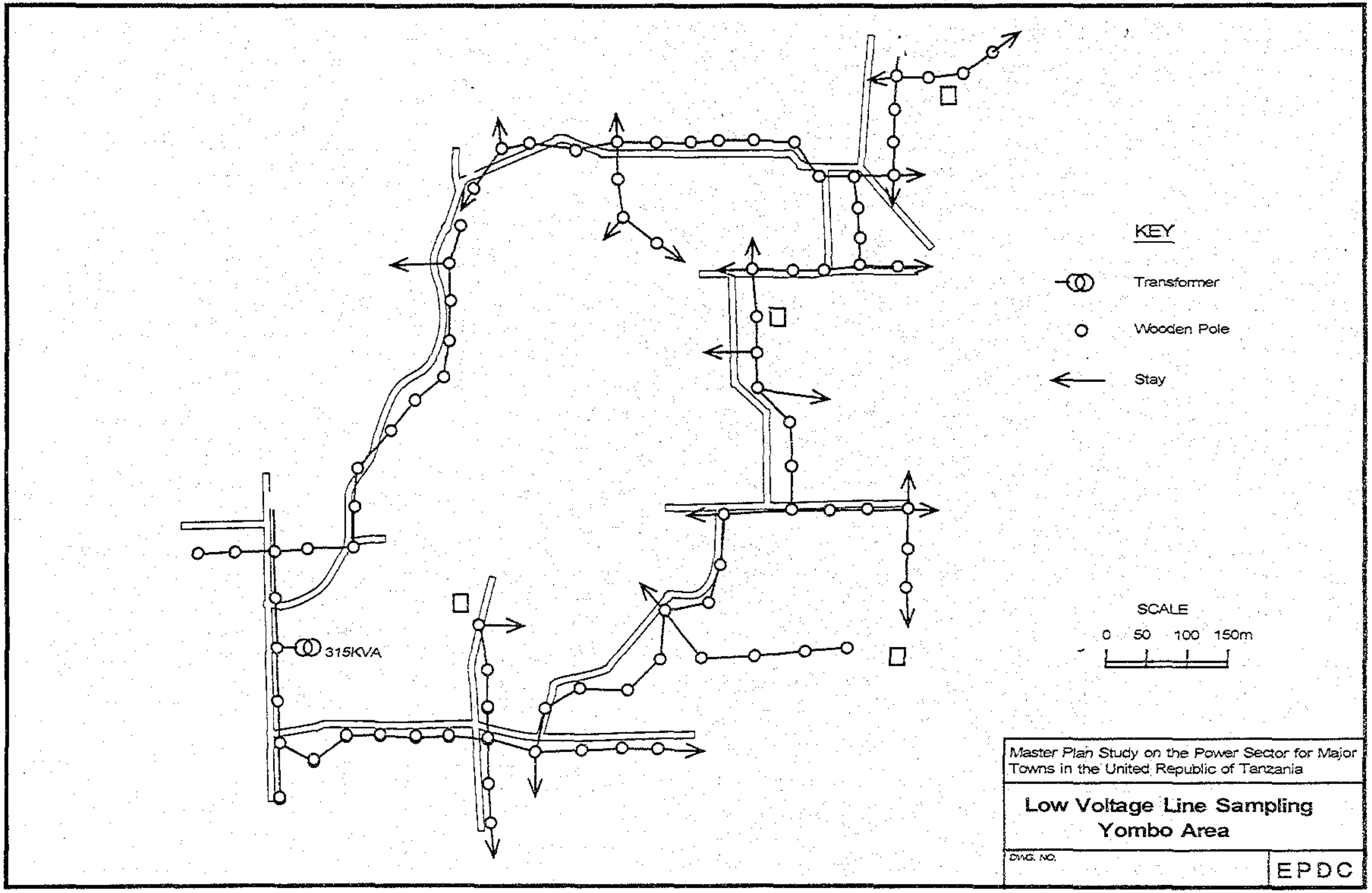


Fig.5.1.4 Mesuring point (Yombo Area Low Tension Line)

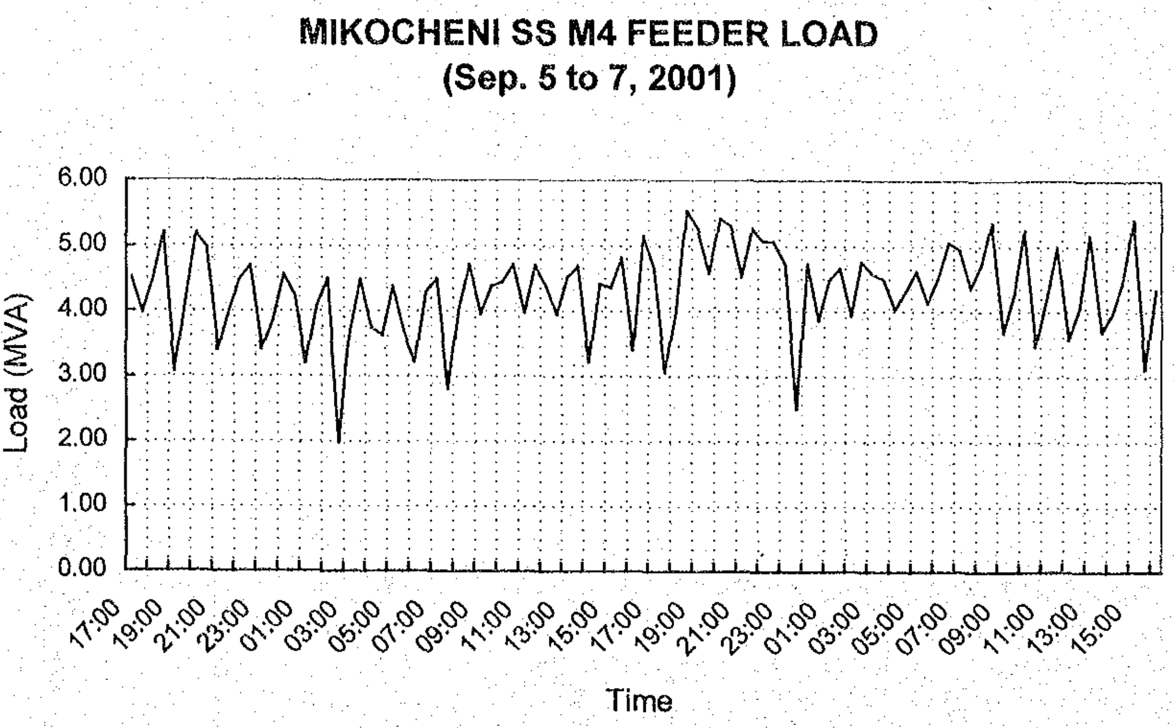


Fig.5.1.5 Measured Load Record of Mikocheni S/S M4 Feeder (11kV)

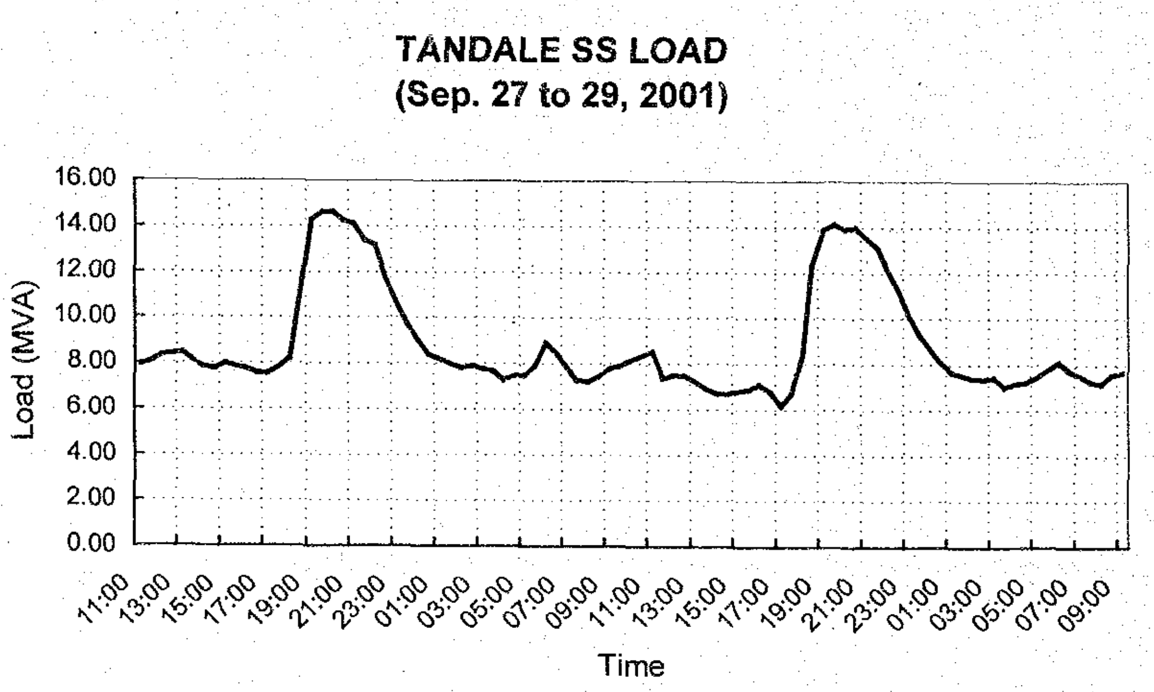


Fig.5.1.6 Measured Load Record of Tandale S/S