3.3.2 Power Subtransmission Line Facilities

(1) Outline of subtransmission line

At the end of FY 1994, the total number of existing subtransmission lines of 230 kV, 115 kV and 69 kV lines were 56 with the total line length of 875.4 ckt-km.

Subtransmission Line (at FY 1994)

Voltage	Number of Circuits	Length of Lines (ckt-km)	
		Overhead Line	Underground Cable
230 kV	2	———	15.006
115 kV	9	205.324	2.990
69 kV	45	581.687	70.393
Total	56	787.011	88.389

Outline of the subtransmission line construction in the Metropolitan area is mainly as follows:

1) 69 kV overhead subtransmission line

In case of the width of sidewalk is less than 3 m, most of the overhead lines are applied by 1 circuit. In case of the width of sidewalk is more than 3.5 m, the overhead lines are applied by 2 circuits on condition that the buildings are set back from the sidewalk.

2) 115 kV overhead subtransmission line

In case of the width of sidewalk is between 3.5 m, most of the overhead lines are applied by 1 circuit. In case of the width of sidewalk is more than 5.5 m, the overhead lines are applied by 2 circuits on condition that the buildings are set back from the sidewalk.

3) Underground subtransmission line

The underground cable system is applied in a short distance by making use of the sidewalk of road and car lane in case it is impossible to acquire sufficient electrical safety clearance and space for subtransmission line.

(a) 230 kV transmission lines

At present, there are 2 circuits starting from EGAT's Bangkapi Terminal Station which transmit power to Childlom Terminal Station.

Two more circuits are under construction by MEA connecting EGAT's South

Thonburi Terminal Station to MEA's Thanontok new Terminal Station.

(b) 115 kV subtransmission lines

The 115 kV subtransmission lines receive power from 230/115 kV terminal station and supply to the 115/24 kV distribution substation and 115 kV large customers. Those lines cover the periphery of MEA's distribution area since the distribution substation located very far from the terminal station which if supplied by 69 kV voltage system would cause problems on voltage drop and load loss.

(c) 69 kV subtransmission lines

The 69 kV subtransmission lines receive power from 230/69 kV terminal station and transmit to 69/24 kV or 69/12 kV distribution substation and 69 kV large customers. Those lines are mostly constructed in urban area.

(2) Overhead line facilities

(a) Conductor

The standard types and sizes of conductor are as follows:

1) 400 mm^2 AAC is the typical and size which is generally used. Double conductors per phase is the standard type of construction for 69 kV lines. Most of the existing 115 kV lines are single conductor per phase, however, these are being modified to double conductors per phase which will be the standard type of construction.

2) 400 mm^2 ACSR is used only for the lines which cross the Chao Phraya River at South Bangkok terminal station.

Current carrying capacity of the overhead subtransmission line is as shown in Table 3.3-1.

Table 3.3-1 Current Carrying Capacity of Overhead Subtransmission Line

Rated Voltage (kV)	Construction	Current Carrying Capacity	
		400 sq.mm. AAC.	
		Amp.	MVA
69	Single Conductor	845	101
	Double Conductor	1690	202
115	Single Conductor	845	168
	Double Conductor	1690	337
230	Double Conductor	1690	673

(b) Support structure

The majority of the support structures of subtransmission facilities consist of prestressed concrete column.

However, the angle member is used partly in the 69 kV 2 circuits section.

The cross arm made of angle member is used to support the conductor.

The 69 kV and 115 kV structures are shown in Appendix 3.3-1 to 3.3-6.

(c) Insulator string

As standard supporting devices of subtransmission line, the following suspension insulators (254 mm dia. x 146 mm) are used.

Transmission Voltage	Insulator Device	Number of One-String Insulators
230 kV	Single strain	14
115 kV	Single strain	7
69 kV	Single strain	4

Note; The arcing horn is not furnished to each insulator string for 230, 115 and 69 kV subtransmission lines.

The basic design of insulator assemblies are shown in Appendix 3.3-7 to 3.3-10.

(d) Foundation

Geologically, the area in the MEA's Region consists of soft ground, the majority of the support structure foundations of subtransmission line are of a construction supporting the prestressed concrete column of superstructure by using two concrete piles.

The structure foundation is shown in Appendix 3.3-11.

(e) Overhead ground wire

The overhead ground wire, which is grounded with earth wire/rod, is furnished to each subtransmission line.

(f) Stay

The stay made of steel wire is provided at the position of each dead-end pole exposed to eccentric load.

(g) Disconnecting switch

At the both side of branch point for large customers, the pole-mounted disconnecting switch is installed on the 115 kV and 69 kV subtransmission line to enable making and breaking of the line at the time of fault.

(h) Arrester

At the riser part of underground cable to aboveground, the following lightning arresters are provided:

Transmission Voltage	Installation of Arrester
230 kV	Yes
115 kV	Yes
69 kV	Yes

(3) Problematical points of existing overhead lines

The problematical points in the existing overhead subtransmission line clarified as a result of the First Field Investigation are as pointed out below:

(a) Branch system

Since many 69 kV subtransmission lines are T-branched in the respective distribution substations, which have only one transformer. Furthermore, only one-circuit incoming equipment is provided in many distribution substations.

(b) Clearance

As the city development projects have been promoted at a rapid tempo in the old city, the lack of clearance is raising a problem as more new buildings have to be built closer to subtransmission lines.

(c) Ground clearance

As the support structure of subtransmission line is made of concrete columns in many cases, the routes of subtransmission line requiring a sufficient ground clearance, such as speedways and elevated bridges, should be detoured.

(4) Underground cable facilities

(a) Cable

The standard types and sizes of cable are as follows:

1) 800 mm^2 XLPE cable, two conductor (Cu) per phase, is generally used.
2) 800 mm^2 oil-filled (OF) cable is used only for the 115 kV outgoing lines from South Bangkok terminal station.
3) 800 mm^2 and 1200 mm^2 OF cables are used for the 230 kV lines from Bangkapi to Chidlom terminal station.
4) 1200 mm^2 XLPE cable (Cu) will be used for the 230 kV lines of MEA in the future. Current carrying capacity of the underground subtransmission line is as shown in Table 3.3-2.

(b) Construction type

Although the underground subtransmission line is installed according to the duct bank system without special case, the duct bank is adopted in many cases of subtransmission line in city area.

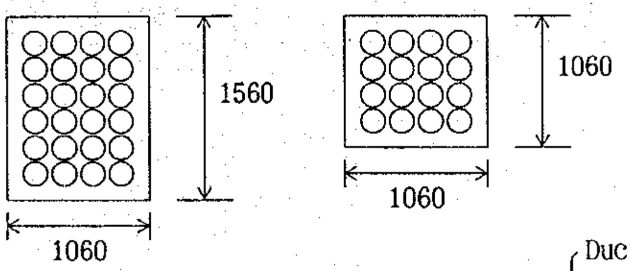
The each sectional plan is shown in Appendix 3.3-12 to 3.3-14.

(c) Pipe

The duct type is classified into asbestos cement pipe and high density polyethylene pipe. The former is of a totally banded system (the duct is reinforced with concrete over its entire length), while the latter is of a partially banded system (the pipe joint section is reinforced with concrete).

(d) Duct scale

The scale of a duct is determined for each line. In the case of 69 kV 2 circuits (2 cables/phase) for example, [Double circuits x 3 phases x 2 cables/phase + some standby ducts] = 16 ducts are provided in total. The dimensions of 24 and 16 ducts are as shown in the figure below.



(unit: mm)

a) 24 ducts   b) 16 ducts

Duct diameter : 140 mm
Pipe : Asbestos cement pipe

(e) Burying depth

The minimum direct buried depth is 1.2 m under car lane section and 0.9 m under sidewalk section and customer area. The duct bank depth is not less than 0.75 m. Moreover, a manhole is provided every between 200 and 240 meters of duct.

(f) Crossing of underground cable under or over canal

An exclusive bridge of a steel truss construction is provided generally for crossing over small river or canal. However, an under-river passing system using a propulsion system is adopted in some cases. In the case of crossing such a large river as the Chao Phraya River, a road bridge attaching system or submarine cable system are also adopted.

Table 3.3-2 Current Carrying Capacity of Underground Subtransmission Line

Type of Cable	Construction	Number of Circuits	Average Current Carrying Capacity per Circuit			
			800 sq.mm.		1200 sq.mm.	
			Amp.	MVA	Amp.	MVA
69 kV XLPE	In duct bank	1	898	107	—	—
		2	770	92	—	—
		3	709	85	—	—
	Direct burial	1	917	110	—	—
		2	860	103	—	—
115 kV XLPE	In duct bank	1	870	173	—	—
		2	741	148	—	—
		3	681	136	—	—
115 kV Low pressure oil-filled	In trench	1	1293	258	—	—
		2	1202	239	—	—
		3	1124	224	—	—
230 kV Poly-ethylene covered, oil-filled	In duct bank	1	—	—	960	382
		2	—	—	754	300
	In trough	1	862	343	—	—
		2	774	308	—	—
230 kV XLPE	In duct bank	1	—	—	N.A.	N.A.
		2	—	—	N.A.	N.A.
		3	—	—	753	300

(5) Problematical points of existing underground subtransmission line

The problematical points in the existing underground subtransmission line clarified as a result of the First Field Investigation are as pointed out below:

(a) Subtransmission line

1) Asbestos cement duct

The duct bank is bound over its entire length for reinforcement with concrete in the case of asbestos cement duct used as a duct bank for underground subtransmission line causing the duct installation work period to become longer and traffic congestion particularly when such work is carried out by an open-cut method.

Thus, it is recommended to adopt the polyester concrete fiberglass reinforced plastic pipe in order to curtail work period.

2) Combined use of overhead line and underground line

The existing underground cable is used partly among the overhead line sections in many cases. Since there is no fault section locating detector installed as an auxiliary device, it is impossible to readily judge whether a fault has occurred in the overhead section or underground section. Therefore, execution of reclosing (re-transmission) at the time of fault in the underground cable section might possibly cause spread of cable damage due to fault current.

3) Utilization of underground space

Power cable of MEA is buried as an independent work separately from the other buried works (water supply, sewage and other systems) in a same section, an environmental problem can be raised due repetition of road excavation. To avoid such a problem, therefore, Common Duct plans are under feasibility study for several routes in central part of Bangkok. In any case, early implementation of such projects is desired also for effective utilization of underground space for common uses.

Four route of Common Duct plans are shown in Fig. 3.3-1.

(b) Distribution line

1) A one-hole three cable laying system is adopted for distribution line

Instead of the existing one-hole three cable laying system adopted for distribution line, it would be advantageous to adopt the triplex type cable which can be obtained easiness of work and reduction of transmission loss.

(6) Utilization factor of subtransmission line

Utilization factor of the outgoing subtransmission lines from terminal station was checked by looking up the actual record of the peak load current on each line in September 1994, as is shown in Table 3.3-3.
Some of those lines were overloading, namely utilization factor was exceeding 100%. A suitable countermeasure, therefore, should be taken to such a heavy load line.
MEA already has a plan to reinforce, but plan has been delayed. MEA has a plan to construct a new terminal station, Teparak, in 1996. This terminal station will supply power to some of distribution substations which are supplied by South Bangkok and Bangplee terminal station at the present. Thus these heavy load lines will be reduced.
In addition, these subtransmission lines will be reinforced from cable 3c to cable 6c in the 8th power distribution system improvement and expansion plan(FY 1997-2001).

Table 3.3-3 Subtransmission Line Utilizing Factor

Terminal & Switching Station	Line	Outgoing Conductor	Assumed Capacity Amps	Peak Amps Sep. 1994	Utilizing Factor %	Practical Capacity Amps	Laying Condition and Remarks
North Bangkok	NKT-691	Cable 6c	1540	840	54.5		Trench and Duct bank
	NKT-692	Cable 6c	1540	1370	89.0		Trench and Duct bank
	NKT-697	Cable 6c	1540	670	43.5		Trench and Duct bank
	NKT-698	C.6c 500sq	1260	1475	117.1		Duct bank
	TOTAL 4		5880	4355	74.1	-	
Bangkapi	BAT-691	OH Single	845	1020	120.7		Temporary line
	BAT-692	OH Double	1690	860	50.9	-	
	BAT-693	Cable 6c	1540	1080	70.1		Trench and Duct bank
	BAT-694	OH Double	1690	1150	68.0	-	
	BAT-697	Cable 6c	1540	1090	70.8		Trench and Duct bank
	BAT-698	OH Double	1690	1450	85.8	-	
	BAT-699	OH Single	845	900	106.5		Temporary line
	TOTAL 7		9840	7550	76.7	-	
Bangkok Noi	BOT-691	C.6c 500sq	1260	600	47.6		Trench and Duct bank
	BOT-692	Cable 6c	1540	1010	65.6		Duct bank
	BOT-693	Cable 6c	1540	1235	80.2		Trench and Duct bank
	BOT-698	Cable 6c	1540	1270	82.5		Duct bank
	TOTAL 4		5880	4115	70.0	-	
Samrong	SRS-693	OH Double	1690	995	58.9	-	
	SRS-695	OH Double	1690	645	38.2	-	
	SRS-697	OH Double	1690	940	55.6	-	
	TOTAL 3		5070	2580	50.9	-	
South Bangkok	SKT-691	OH Double	1690	1200	71.0	-	
	SKT-692	OH Double	1690	1100	65.1	-	
	SKT-694	OH Double	1690	1050	62.1	-	
	SKT-695	Cable 6c	1540	1200	77.9		Duct bank
	SKT-696	Cable 6c	1540	1115	72.4		Trench and Duct bank
	SKT-699	Cable 6c	1540	805	52.3		Trench and Duct bank
	TOTAL 6		9690	6470	66.8	-	
Lard Prao	LPT-691A	Cable 6c	1540	940	61.0		Trench and Duct bank
	LPT-691B	Cable 6c	1540	1460	94.8		Trench and Duct bank
	LPT-692B	Cable 6c	1540	490	31.8		Duct bank
	LPT-693A	OH Double	1690	1360	80.5		
	LPT-693B	Cable 6c	1540	1430	92.9		Duct bank
	LPT-694A	Cable 6c	1540		0.0		Duct bank
	LPT-694B	Cable 6c	1540		0.0		Duct bank
	TOTAL 7		10930	5680	52.0	-	
Bangplee	BPT-691A	Cable 6c	1540	1250	81.2		Trench and Duct bank
	BPT-692B	Cable 3c	770	1060	137.7		Trench and Duct bank :Note 3
	BPT-693B	Cable 6c	1540		0.0		Trench and Duct bank
	TOTAL 3		3850	2310	60.0		
Klong Rangsit	KRT-691A	Cable 6c	1540	930	60.4		Trench and Duct bank
	KRT-692A	Cable 6c	1540	480	31.2		Trench and Duct bank
	KRT-692B	OH Double	1690	1320	78.1	-	
	TOTAL 3		4770	2730	57.2		
Chidlom	CLT-691A	Cable 3c	770	520	67.5		Trench and Duct bank
	CLT-691B	Cable 3c	770	820	106.5		Trench and Duct bank
	CLT-692B	Cable 3c	770	860	111.7		Trench and Duct bank
	CLT-693A	Cable 3c	770	610	79.2		Trench and Duct bank
	CLT-694A	Cable 3c	770	465	60.4		Trench and Duct bank
	CLT-694B	Cable 3c	770	560	72.7		Trench and Duct bank
	TOTAL 6		4620	3835	83.0		
South Thonburi	STT-691	Cable 6c	1540	1280	83.1		Trench and Duct bank
	STT-693	Cable 6c	1540	800	51.9		Trench and Duct bank
	STT-695	Cable 6c	1540	1130	73.4		Trench and Duct bank
	TOTAL 3		4620	3210	69.5		
Grand Total			65150	42835	65.7		

Terminal & Switching Station	Line	Outgoing Conductor	Assumed Capacity Amps	Peak Amps Sep. 1994	Utilizing Factor %	Practical Capacity Amps	Laying Condition and Remarks
South Bangkok	SKT-791	Cable 3c	741	800	108.0		Trench and Duct bank :Note 4
	SKT-793	Cable 3c	741	800	108.0		Trench and Duct bank :Note 4
	TOTAL 2		1482	1600	108.0		
Bangplee	BPT-791A	Cable 3c	741	1000	135.0		Trench and Duct bank :Note 4
	BPT-791B	Cable 3c	741		0.0		Trench and Duct bank :Note 4
	BPT-792A	Cable 3c	741	620	83.7		Trench and Duct bank :Note 4
	BPT-792B	Cable 3c	741	540	72.9		Trench and Duct bank :Note 4
	TOTAL 4		2964	2160	72.9		
Klong Langsit	KRT-791	Cable 3c	741		0.0		Duct bank
	TOTAL 1		741	0	0.0		
Nongjok	NJT-791	cable 3c	741	490	66.1		Duct bank at Minburi incoming
	NJT-792	Cable 6c	1482	620	41.8		Duct bank
	TOTAL 2		2223	1110	49.9		
Grand Total			7410	4870	65.7		

Note:

(1) Typical laying condition of subtrnsmission lines can be described that the outgoing lines are usually installed in cable trench in the terminal stations and in duct bank in public area. The assumed capacity as mentioned in the table is the average current carrying capacity of cables which are laid in duct bank.

(2) The practical capacity is set to be equal to the assumed capacity.

(3) MEA has a plan to reinforce BPT-692B from cable 3c to cable 6c in 1992 but plan has been delayed.

(4) MEA has a plan to construct a new terminal station, Teparak, in year 1996. This terminal station will supply power to some of distribution substations which are supplied by South Bangkok and Bangplee terminal stations at the present. Thus not only the load of the mentioned terminal stations but also load of their outgoing lines will be reduced. In addition, these outgoing lines will be reinforced from cable 3c to cable 6c in the 8th power distribution system improvement and expansion plan(1997-2001).

(5) Cable 3c or 6c means 3 or 6 x single core cable for single circuit transmission line.

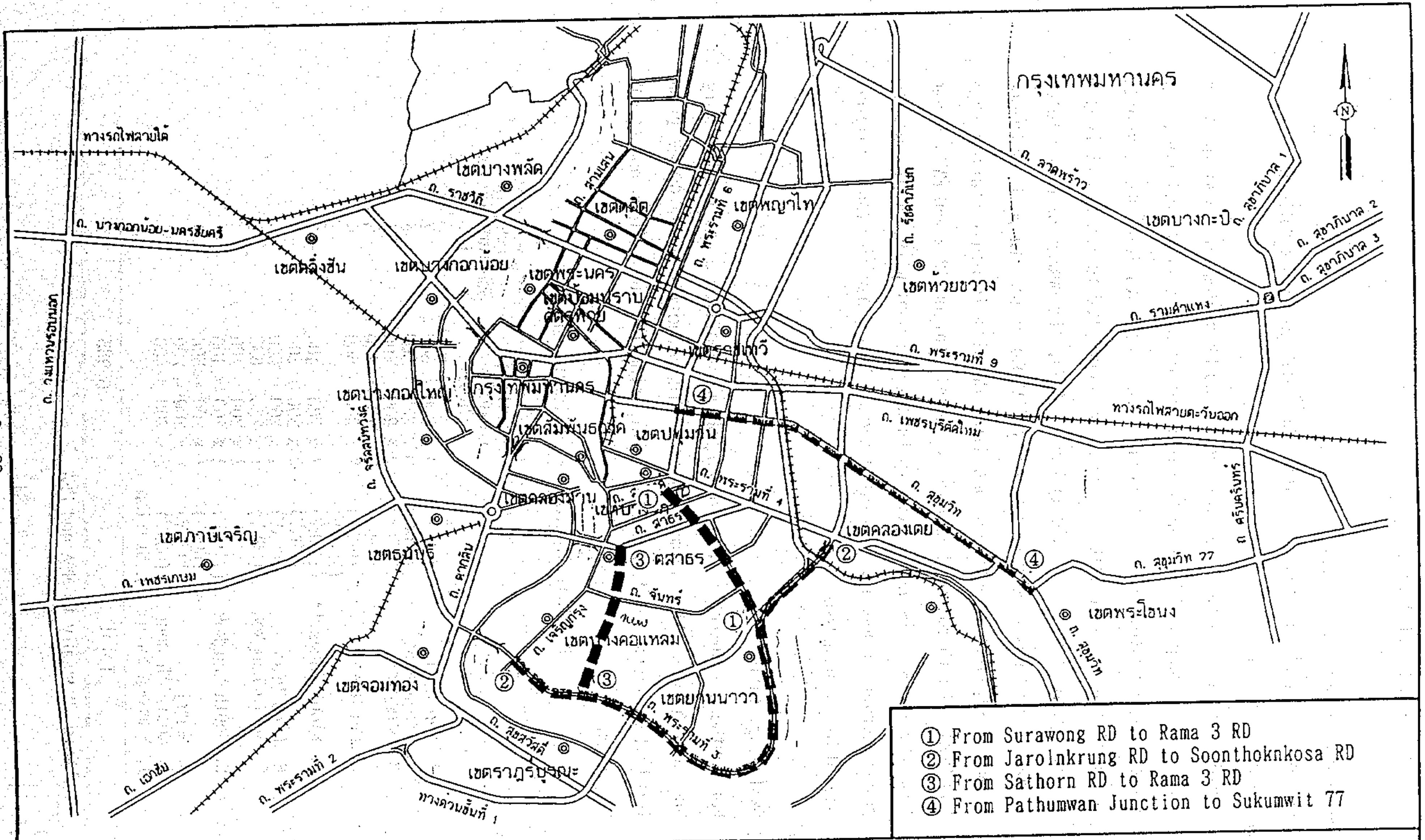


Fig. 3.3-1 Common Duct Plan in Central Part of Bangkok

3.3.3 Substation Facilities

(1) Outline of substation facilities

MEA's substations are classified into three categories as follows:

(a) Terminal station

Terminal station reduces the voltage of 230 kV system to 115 kV or 69 kV in order to supply the power to distribution substations and 115 kV or 69 kV large customers' substations. Terminal stations which supply power to the MEA's distribution area are connected to the 230 kV EGAT's transmission network. At the end of FY 1994, the number of MEA's total terminal stations receiving power from EGAT was 10. There is only one terminal station invested by MEA named Chidlom Terminal Station (2 x 250 MVA). Furthermore, Thanontok Terminal Station (2 x 250 MVA) under construction will be next one. In future, to meet with the increasing power demand in densely populated areas, MEA's new terminal stations should be constructed.

(b) Switching station

For southern industrial area in Bangkok metropolitan area, MEA has only one switching station (Samrong) receiving electric power 69 kV from terminal stations and dispatching to distribution substations and 69 kV customers.

Terminal Station and Switching Station

		Installed Capacity (MVA)	Number of Subtransmission Lines
1. Bangkapi	(69kV)	4 x 200 = 800	7
2. Bangkok Noi	(69kV)	3 x 200 = 600	4
3. Bangplee	(115kV)	2 x 200 = 400	4
	(69kV)	2 x 200 = 400	3
4. Chidlom	(69kV)	2 x 250 = 500	6
	(230kV)		2
5. Klong Rangsit*	(115kV)	2 x 200 = 400	1
	(69kV)	2 x 300 = 600	3
6. Lard Prao	(69kV)	4 x 200 = 800	6
7. North Bangkok	(69kV)	1 x 285 = 685	4
		2 x 200 = 400	
8. South Bangkok	(115kV)	2 x 200 = 400	2
	(69kV)	4 x 200 = 800	6
9. Nongjok	(115kV)	1 x 200 = 200	2
10. South Thonburi	(69kV)	2 x 200 = 400	3
11. Samrong Switching Station			3
Total		6,985	56

Note: * supply to MEA and PEA

(c) Distribution substation

At the end of FY 1994, MEA had 103 distribution substations having 8,364.78 MVA of total installed power transformers. The total number of customers which installed their own power transformer was 45, consisting three customers of 115 kV and 42 customers of 69 kV, and total capacity was 1,082.185 MVA. In the future, the total of number of 115/24 kV and 69/24 kV distribution substations will be increasing gradually by conversion from 12 kV to 24 kV.

In consideration that temporary substations with one bank configuration have been increasing rapidly for these several years, such a trend of increase is shown in the table below.

At the end of FY 1994, there were 32 substations with one bank configuration equivalent to 31% of the total number of substations. Most of these one bank substations have been constructed concentratedly since FY 1989, and out of 14 substations constructed in FY 1994, as many as 11 substations were one bank substations.

As a countermeasure for meeting rapid increase of load in recent years, it has been inevitable to construct such temporary one bank substations which can be installed within a short period of time. Such situations would have made it inevitable to consume the valuable time and labor forces uselessly for planning, design and construction of the temporary substations and could possibly cause delay in construction of permanent substations in the future. Since various problems can probably be raised in view of supply reliability as well, it is urgently required to strengthen and improve the capabilities of planning, land acquisition, design and construction work.

In addition, the one bank operation is allowed only in the case where all of the load being transmitted from the substation which has been shut down can totally be switched over to another substation and only when the utilization factor of the latter substation is sufficiently low.

Number of Distribution Substations

1) Voltage-wise

Voltage (kV)	Number of Stations	Total Capacity (MVA)
115-24	17	1,360
69-24	6	600
69-12/24	10	1,280
69-12	70	5,664.8
Total	103	8,904.8

2) Capacity-wise

Capacity (MVA)	Number of Stations	Total Capacity (MVA)
Below 60	14	540
60- 99	51	3,664.8
100-139	30	3,460
Above 139	8	1,240
Total	103	8,904.8

3) Commissioning year-wise

Commissioning Fiscal Year	Number of Substations					Total Number of Transformers
	Increment per year	Number of Transformers				
		1B	2B	3B	4B	
Before 1980	40	1	27	11	1	92
1981	1	-	-	1	-	3
1982	1	1	-	-	-	1
1983	3	-	3	-	-	6
1984	1	-	-	1	-	3
1985	4	-	3	1	-	9
1986	2	-	2	-	-	4
1987	2	-	1	1	-	5
1988	1	-	1	-	-	2
1989	4	1	2	1	-	8
1990	9	4	4	1	-	15
1991	7	3	3	1	-	12
1992	10	9	1	-	-	11
1993	4	2	2	-	-	6
1994	14	11	3	-	-	17
	103	32	52	18	1	194

Note: Total peak load 5,424.1MVA
Total capacity 8,904.8MVA
Utilization factor 60.9%

(2) Types of substations

Although MEA's substation types consist of the outdoor and semi-outdoor types, while any underground type has not been adopted so far. Recently, the semi-outdoor type substation using Gas-Insulating Switchgear (GIS) as primary circuit switching equipment has been adopted as a standard type substation.

Note: Although MEA is so called "Indoor type" for standard type substation mentioned above, it is referred to "Semi-outdoor type" in this report, because main power transformers are installed outdoor and other substation equipments are installed indoor.

The outdoor, indoor, underground and other types should be selected independently or in combination so as to attain overall efficiency depending upon the regional conditions and surrounding environment.

At present, the semi-outdoor type substation is adopted by MEA as a standard type substation as mentioned above presumably because of the following reasons:

- As substations are installed in dense residential zones in city areas in many cases, it is required to take into account preservation of urban scenery, prevention of noise, fire and other troubles.
- The substation equipment should be protected from exposure to severe natural environment (direct sun, squall, etc.) inherent to the tropical zone.
- It is difficult to acquire the premises of substation and the use of land is restricted in many cases.

Where the present standard semi-outdoor type is to be applied uniformly for any substation to be installed in the entire distribution area of MEA, many problems can possibly be raised in view of land utilization and overall efficiency in the future. Therefore, it is recommended to promote study regarding the following respective items so as to make it possible to apply the other types of substation in combination in the future:

(a) The substation capacity should be increased by adopting integrated three-phase common enclosed type GIS, one-break point type GCB, digital type protective and control devices, and other reduced-size equipment simultaneously during replacement period of aged equipment or reconstruction of substation.

(b) Although adoption of the underground type has not been planned so far because of geological conditions, flooding and other problems in Bangkok, it would become increasingly difficult to acquire land in overpopulated areas in the future. Should it become ultimately more economical to promote effective utilization of aboveground space by installing substation underground resulting from substantial rise of land price, it would be necessary to study adoption of the underground type substation.

(c) By studying adoption of gas-insulated transformer, it should be promoted to apply the underground type or indoor type wherein all of the major equipment are installed indoor.

(3) Configuration and layout of substation equipment

(a) Although the GIS have been installed and operated both indoor and outdoor not only in Japan but also throughout the world, such equipment are specified to be installed indoor according to the prevailing concept of MEA. Where the GIS are installed outdoors on the other hand, it would be possible in some cases to expand the freedom of substation layout design, ease restrictive conditions in land utilization, and attain effective substation layout. Where exposure to direct sun is to be avoided in this case, it will be sufficient to provide a simple shelter over the GIS equipment.

Therefore, it should be considered to install the GIS equipment both indoor and outdoor in the future.

(b) Although power capacitor is specified to be indoor installation according to the new standard of MEA, indoor capacitor installation is not desirable in view of fire protection since the capacitor is an oil-filled device. Therefore, it would be necessary to consider installation of the capacitor on roof top of the substation building in the future. Moreover, it is recommended to study adoption of gas-insulated capacitor as practiced already in Japan.

(c) When the electricity rate discount system is adopted for the customers executing improvement of power factor, it would be possible to expect that each customer can purchase and install a capacitor by himself. Should it be possible to eliminate the necessity to install capacitors in the MEA's distribution substations, then the overall scale of entire substation can be minimized.

(4) Acquisition of substation site and reduction of installation space

Along with densitication of city areas, acquisition of land for substation is expected to become more and more difficult. The required site area of the present standard distribution substation (60 MVA x 3 banks) of MEA is about 1,500 m² (50m x 30m), and such an area should be acquired in advance at each proposed substation location according to its short and long term plans. Nearly all of the substation site area proposed according to the Seventh Power Distribution System Improvement and Expansion Plan has been acquired. After formulation of the eighth plan, however, it will be necessary to collect and analyze the information pertaining to selection and acquisition of land including the city redevelopment, railway and road construction plans, and so forth. Then, activities should be started immediately for acquisition of the substation site areas proposed to be constructed according to the subsequent plan. At the same time, studies should be promoted for reducing the size of substation equipment to ensure easy acquisition of substation sites based on the following basic methods/policies:

a) Simplification of connection system.

b) Simplification of component equipment.

c) Simplification of auxiliary equipment.

Among the above items, Item a) is determined in view of the reliability of the power system and equipment. Item b) pertains to reduction of the sizes of main substation equipment including the primary and secondary switching equipment, transformers, power capacitor banks and so forth. For this purpose, optimum equipment should preferably be selected which sufficiently taking into account the cost, easiness of maintenance and operation, and other factors in addition to rationalization of insulation system, insulation and cooling system design.

For simplifying the auxiliary equipment in Item c), moreover, it is desirable to make effective use of valuable space by installing the main equipment and its auxiliary equipment at the same position (adjacent to each other) as well as by reviewing the equipment layout.

The basic methods and effects of reducing the equipment size are presented respectively in Fig. 3.3-2 and 3.3-3.

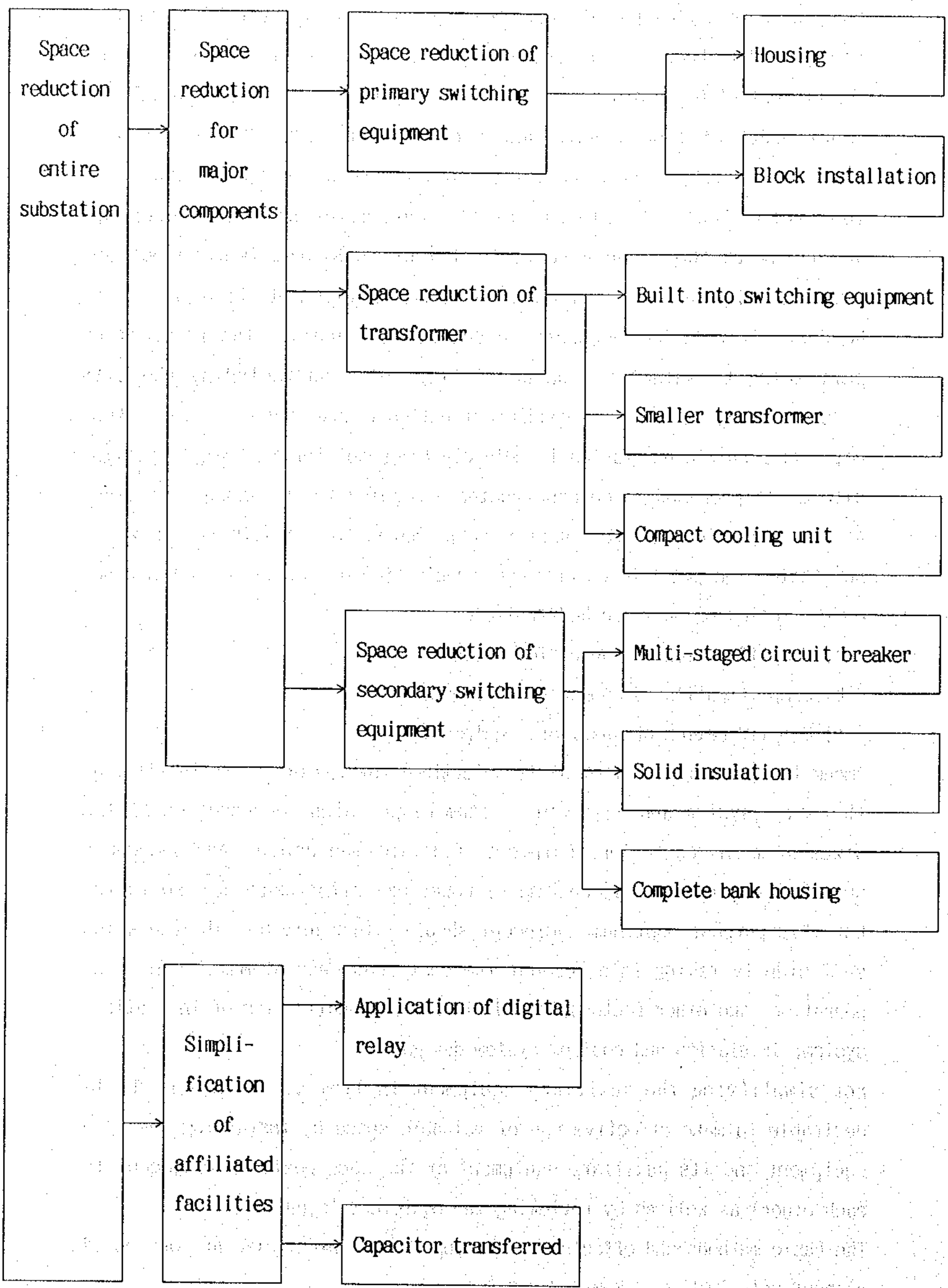


Fig. 3. 3-2 Basic Facility Reduction Methods

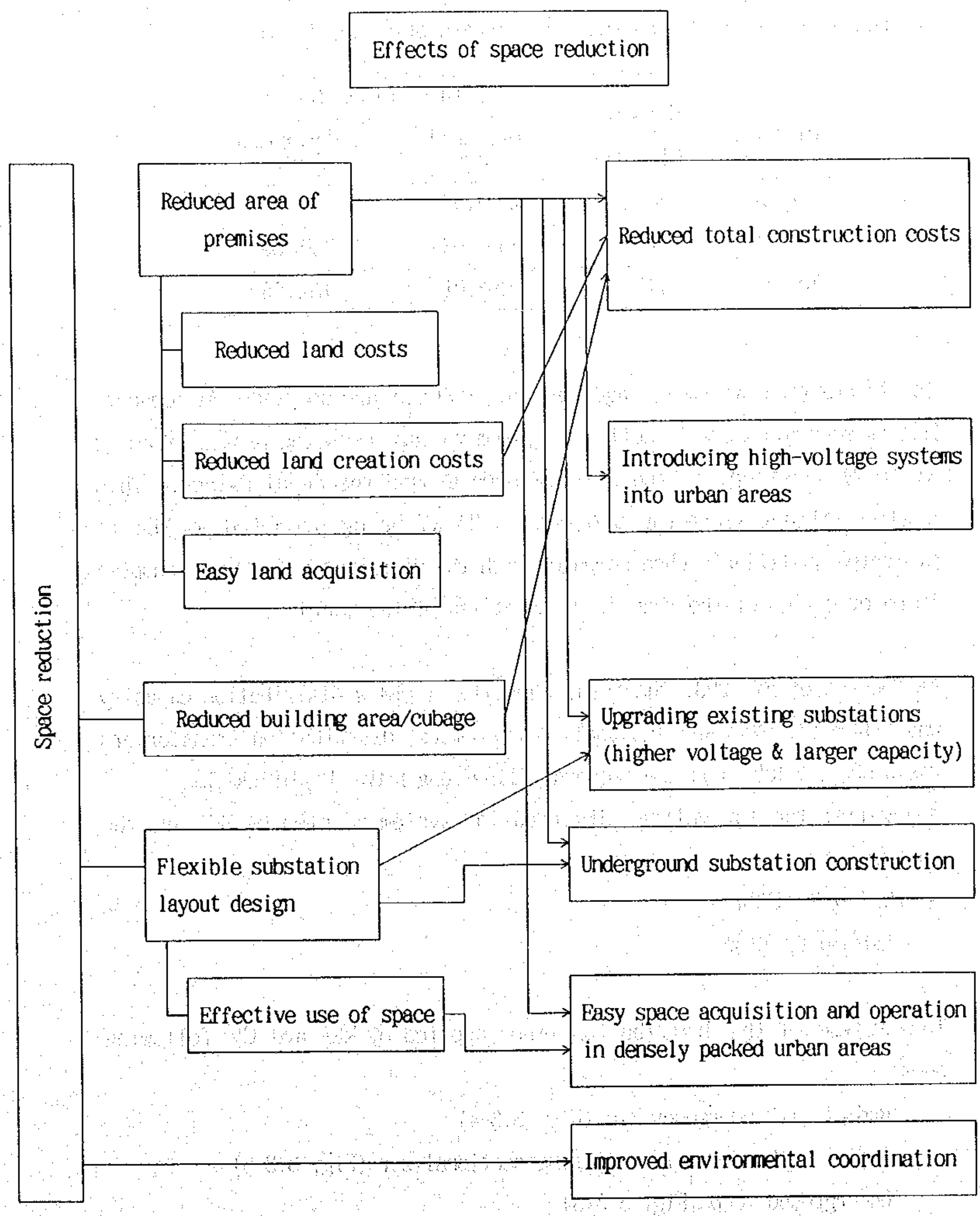


Fig. 3.3-3 Effects of Space Reduction

3.3.4 Distribution System Facilities

(1) Outline of distribution system

At the end of FY 1994, the total number of existing 24 kV and 12 kV primary lines were 981 and the total length of 8,172 ckt-km.

Voltage	Number of Circuit	Length of Lines (ckt-km)	
		Overhead Line	Underground Cable
24 kV	206	2994.99	45.96
12 kV	775	4503.02	628.59
Total	981	7498.01	674.55

As distribution system voltages of MEA, 24/12 kV are adopted. At present, MEA is schematically promoting a system voltage boosting project from 12 kV to 24 kV except in the network area around the Royal Palace. This system voltage boosting project to 24 kV being promoted by MEA is evaluated justifiable when compared with the distribution voltages adopted in major cities of the respective countries of the world.

At the end of FY 1993, the total capacity of MEA's distribution capacity was 5,608,191 kVA, whereas that of customers' distribution transformers was 3,595,257 kVA, and the secondary line length was 17,619 ckt-km. Meanwhile, the low voltage distribution system adopted by MEA are the following ones:

- 220/440 V, 1P3W
- 220/380 V, 3P4W

The systems of the distribution lines applied by MEA are the following ones:

- Radial with emergency tie (Fig. 3.3-4)
- Radial with automatic reclosing sectionalizer (Fig. 3.3-5)
- Underground loop (Fig. 3.3-6)
- Underground primary selection (Fig. 3.3-7)
- Secondary network (Fig. 3.3-8)

Furthermore, the system being studied currently for introduction is the following one:

- Underground special spare line (Fig. 3.3-9)

In the majority of MEA's area, the "radial with emergency tie" system is adopted as a standard system.

Furthermore, the underground loop system is applied by MEA as a supply system to 12/24 kV customers in high load density and over-concentrated areas.
In addition, the underground primary selection system is also adopted as a supply system to 12/24 kV customers around the Silom Street where high reliability is required in such a high load density and over-concentrated area.
With this system, it is possible to perform automatic or manual switching-over to sound circuit in case any fault has occurred in distribution line. Therefore, this system can be evaluated as a highly reliable system.
For the purpose of improving the utilization factor of equipment, study seems to have been carried out for introduction of a more advanced underground special line system than these underground distribution systems.

To introduce an optimum system for each area depending on the locational conditions by making effective use of the advantages inherent to these underground distribution systems, it is deemed to be a future task to replenish the basic criteria for system introduction.

Adopted for the secondary network system applied in the network area around the Royal Palace is a regular network system, which has also been introduced in the Tokyo Metropolitan District of Japan.
Considering that high reliability is required in the high load density area around the Royal Palace where many government agencies are located, this system is deemed to have been introduced. Consequently, this selection is evaluated justifiable.

The features of MEA's secondary network system are that only the 12 kV distribution line is installed underground, while the pole-mounted

transformers and low voltage lines are installed overhead.
Although the load around the Royal Palace is highly dense, individual customers consisting of small shops, factories and so forth are densely concentrated. In these areas, the pattern of load is predicted to undergo substantial changes in the future as a lot of construction, dismantling and other development works are extended.
In this connection, it is evaluated as a justifiable selection which meets actual situations in the area, that the low voltage lines are being applied overhead in such areas where the load is prone to fluctuate, as thereby countermeasures can be taken flexibly against load fluctuations.

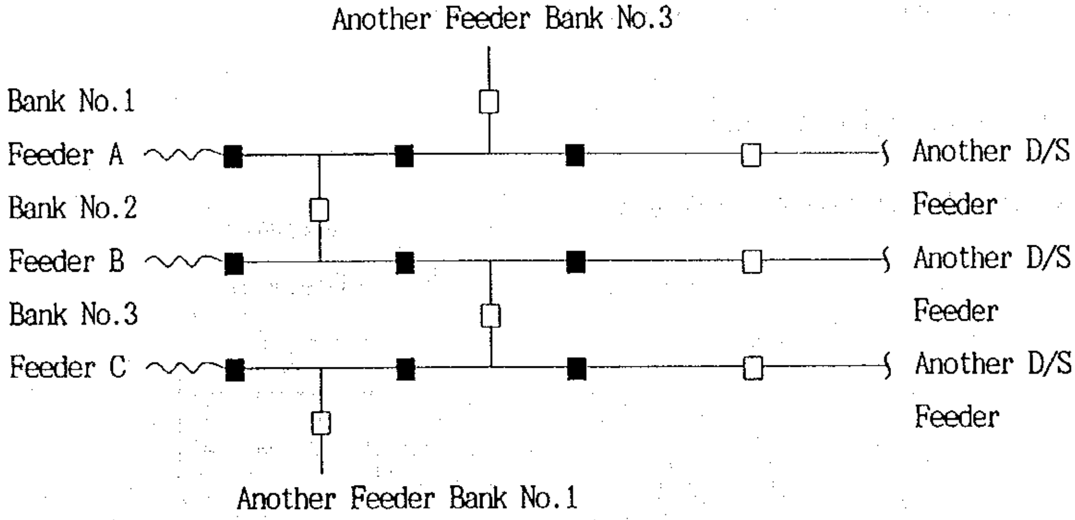
In the case of the "radial with emergency tie" system adopted by MEA, any countermeasure has not been taken into account in some aspects at the time of 1-bank fault in substation although mutual distribution lines have been interconnected to cope with any fault in distribution line.
Moreover, the overhead line and underground line have not been formed appropriately taking into account the normal and short time allowable currents inherent to the conductor and cable.

The primary point to be considered in a distribution system configuration is to design a system capable of protecting itself in time of fault in the distribution line. In this regard TEPCO adopts the multi-section and multi-interconnection modes. Besides, TEPCO normally sets the operating allowable current of the distribution systems lower than the inherent allowable current of conductors, cables and pole-mounted switches, for the sake of protection against faults which may occur in other distribution systems. Furthermore, the system configuration of distribution lines are so designed as to interconnect with those of other banks and substations, so that recovery is well enough possible with the distribution line in case of a fault in one single bank of a substation.

For reference, the systems of overhead distribution line and underground distribution cable furnished in the Tokyo Metropolitan Area are introduced below :

[Overhead Distribution Line]

Three-section three-interconnection system



■ : normally close ■ □ : 300 A —— : ACSR120 mm²

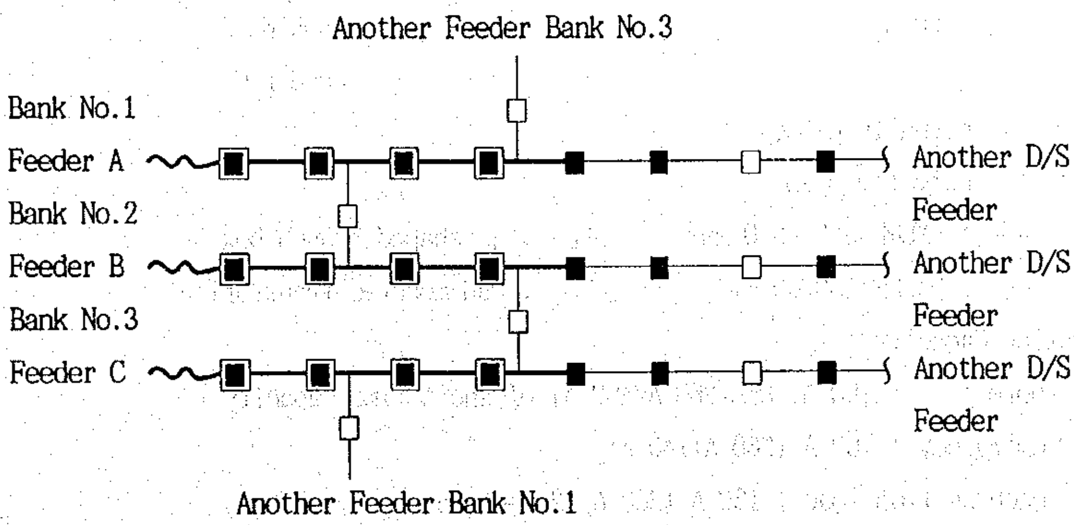
□ : normally open 〰 : XLPE 325−250 mm²

Operation Capacity

- normal : 230 A, 77%(230 A/300 A) of short-time capacity
- emergency : 300 A (230 A+70 A)

each section load : 75 A (≒230 A／3 section)

Six-section three-interconnection system



▣ ■ : normally close ▣ : 600 A ━━ : HA ℓ 240 mm² (Hard drawn Aluminum Conductor)

□ : normally open ■ □ : 300 A —— : ACSR120 mm²

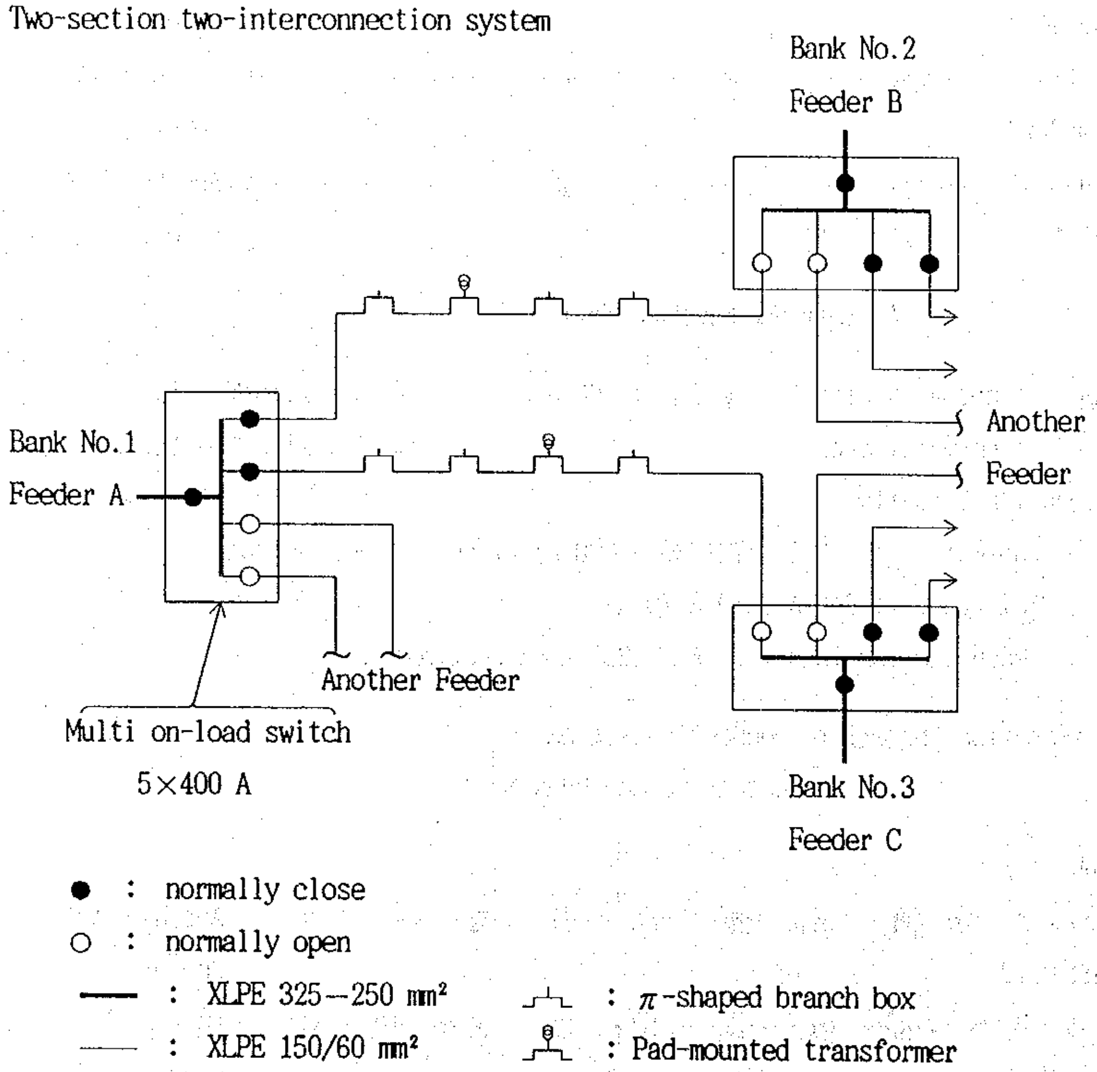
〰 : XLPE 500−325 mm²

Operation Capacity

normal : 450 A, 75%(450 A/600 A) of short-time capacity
emergency : 600 A (450 A+150 A)
each section load : 75 A (450 A/6 section)

[Underground Distribution Line]

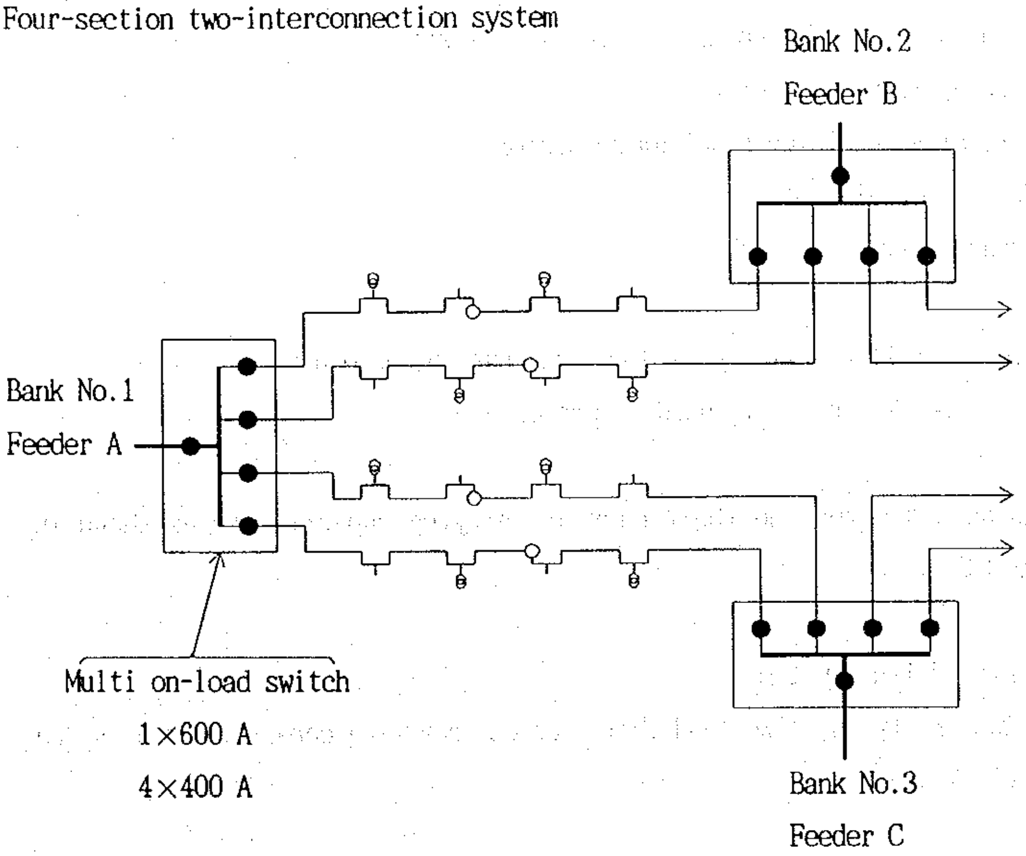
Two-section two-interconnection system



Operation Capacity

normal : 260 A, 65%(260 A/400 A) of short-time capacity
emergency : 400 A (260 A+140 A)
each section load : 130 A (260 A/2 section)

Four-section two-interconnection system



● : normally close

○ : normally open

—— : XLPE 500−325 mm²　　π-shaped branch box symbol : π-shaped branch box

—— : XLPE 150/60 mm²　　Pad-mounted transformer symbol : Pad-mounted transformer

Operation Capacity

- normal : 400 A, 67%(400 A/600 A) of short-time capacity
- emergency : 600 A (400 A+200 A)

each section load : 100 A (400 A／4 section)

(2) Overhead line system

The standard types of conductor are as follows:

1) Bare aluminum conductor.
2) Partially insulated aluminum conductor.
3) Spaced aerial cable.
4) Preassembly aerial cable.

Note Item 1) was widely used before, but not used now.
Item 2) is widely used at present.

The standard sizes and their current carrying capacity are as shown in Table 3.3-4.

(3) Underground line system

The standard types, sizes and their current carrying capacity are as shown in Table 3.3-5.

Table 3.3-4 Current Carrying Capacity of Overhead distribution line

Type of Conductor	Current Carrying Capacity			
	12 kV		24 kV	
	Amp.	MVA	Amp.	MVA
Bare Conductor				
- 35 sq.mm.	170	3.5	170	7.0
- 70 sq.mm.	270	5.6	270	11.2
- 185 sq.mm.	515	10.7	515	21.4
Partially Insulated Conductor				
- 35 sq.mm.	172	3.6	172	7.2
- 70 sq.mm.	260	5.4	260	10.8
- 185 sq.mm.	488	10.1	488	20.2
Space Aerial Cable				
- 35 sq.mm.	170	3.5	170	7.0
- 120 sq.mm.	365	7.6	365	15.2
- 185 sq.mm.	470	9.8	470	19.6
Preassembly Aerial Cable				
- 240 sq.mm.	430	8.9	430	17.8

Table 3.3-5 Current Carrying Capacity of Underground distribution line

Type of Conductor	Current Carrying Capacity			
	12 kV		24 kV	
	Amp.	MVA	Amp.	MVA
- 35 sq.mm. Cu. XLPE	161	3.3	161	6.6
- 70 sq.mm. Cu. XLPE	235	4.8	235	9.7
- 240 sq.mm. Cu. XLPE	478	9.9	478	19.8
- 400 sq.mm. Cu. XLPE	614	12.7	614	25.5

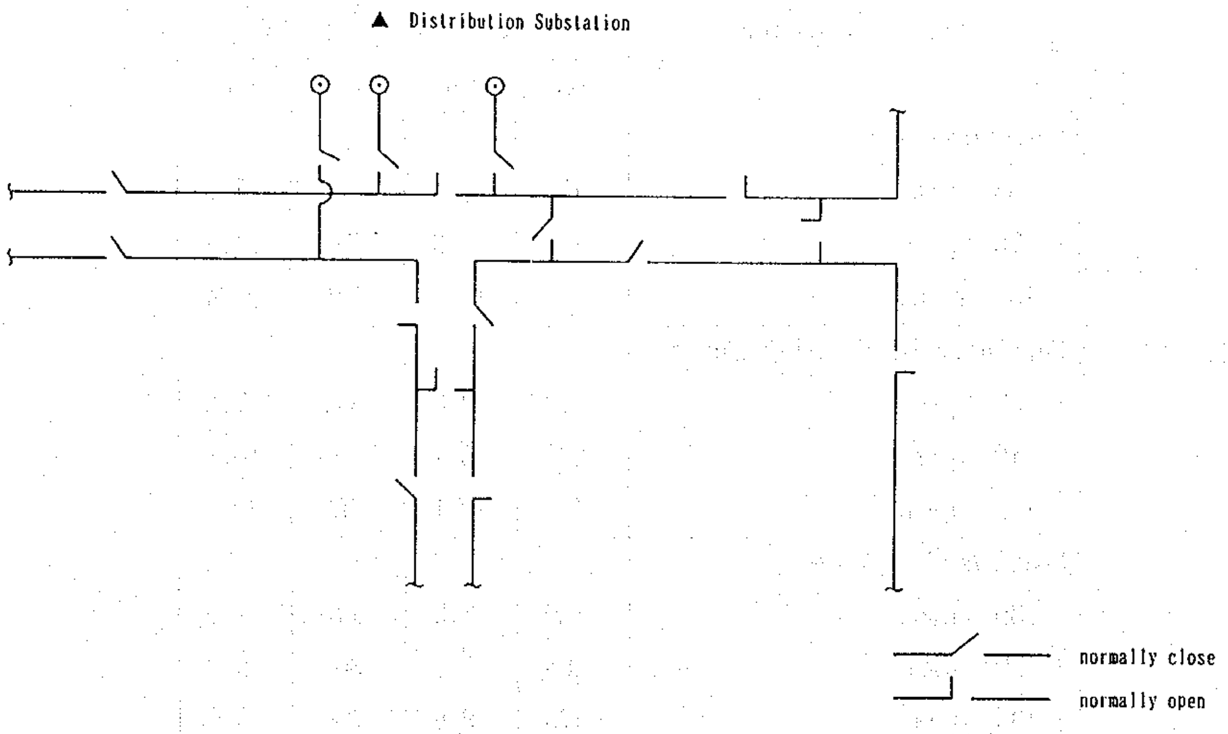


Fig.3.3-4 Radial with emergency tie

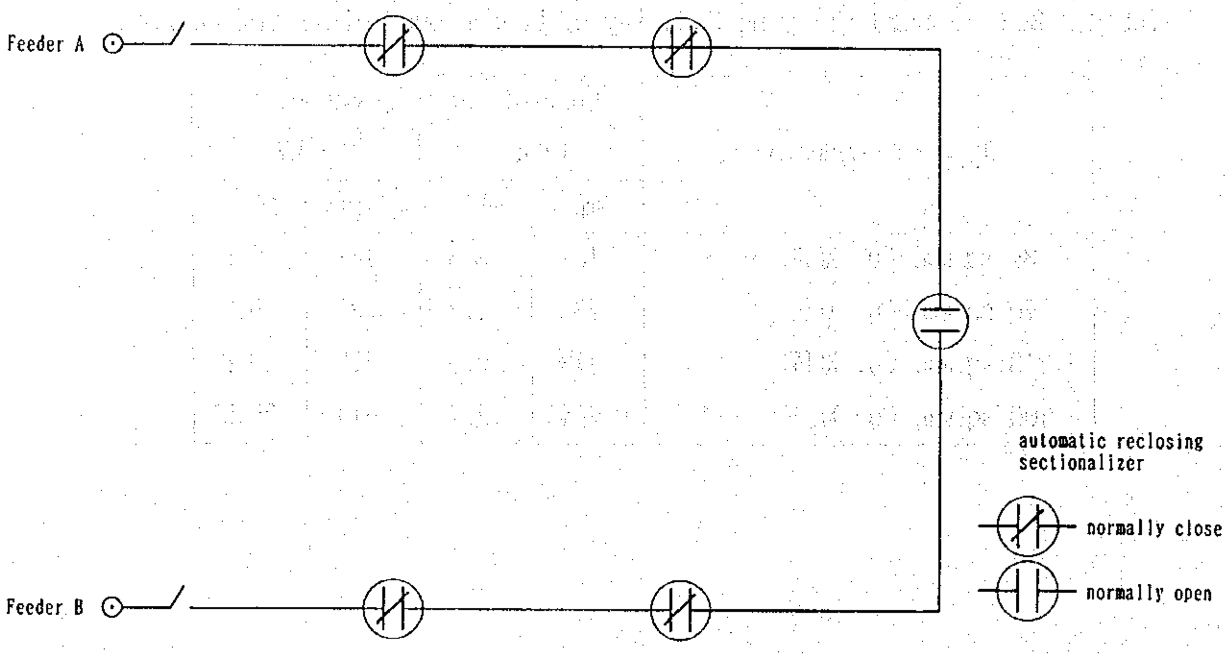


Fig.3.3-5 Radial with automatic reclosing sectionalizer

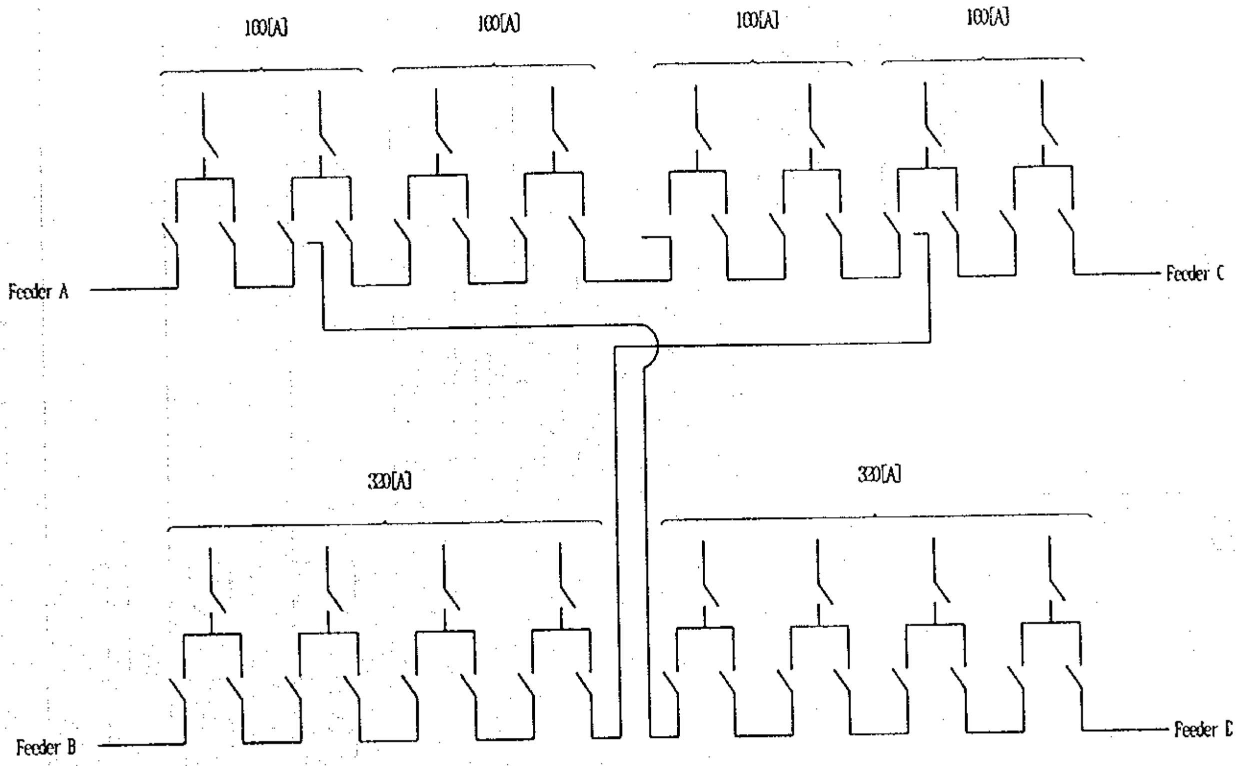


Fig.3.3-6 Underground Loop

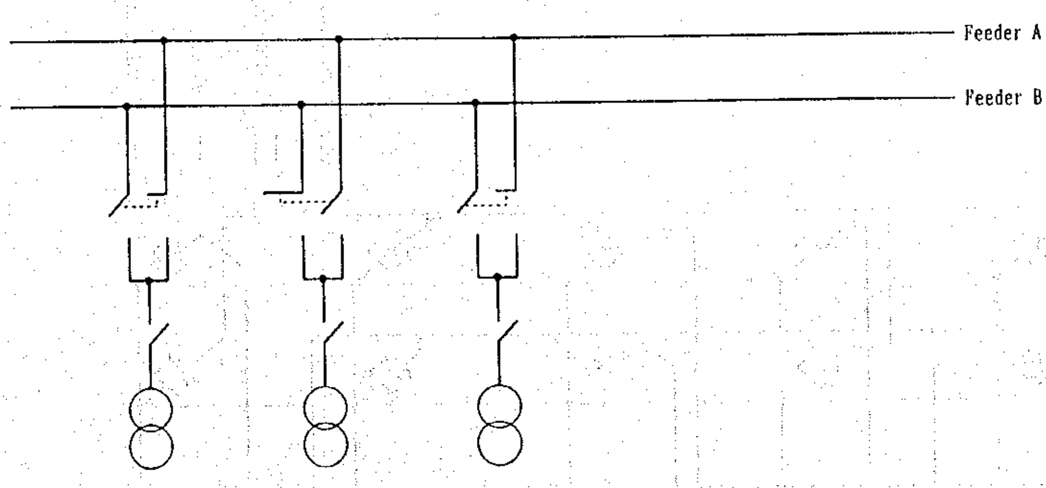


Fig.3.3-7 Undergrond Primary Selection

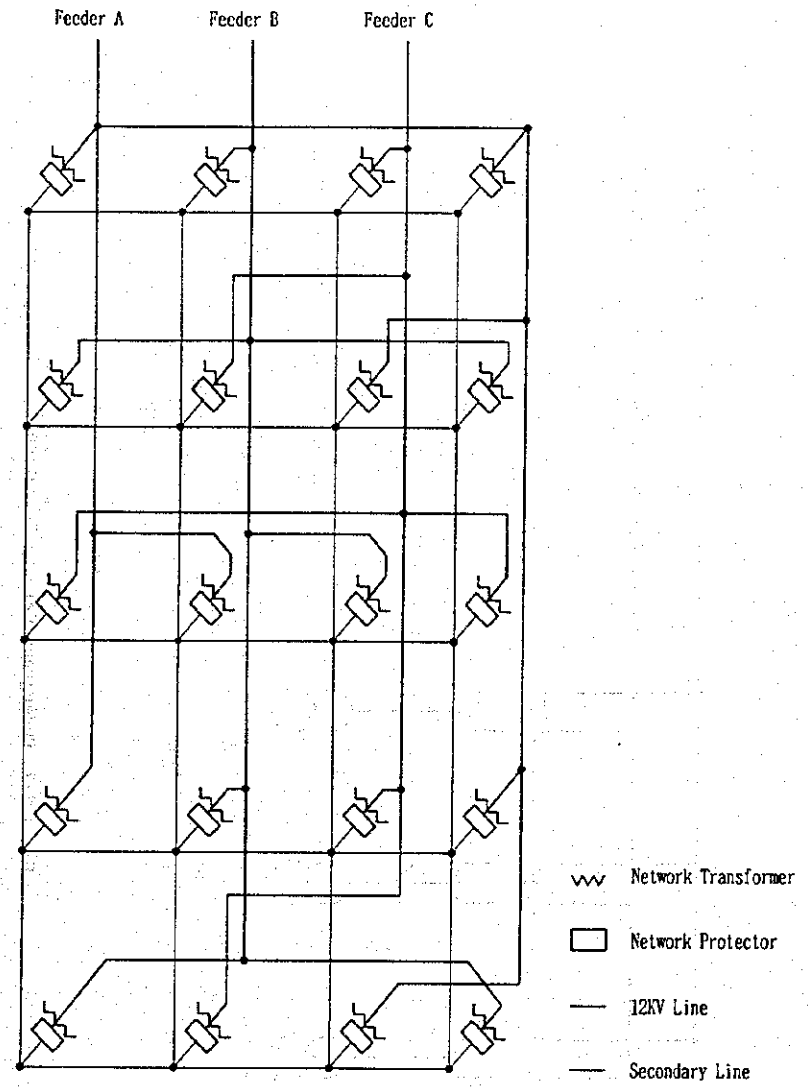


Fig.3.3-8 Secondary network

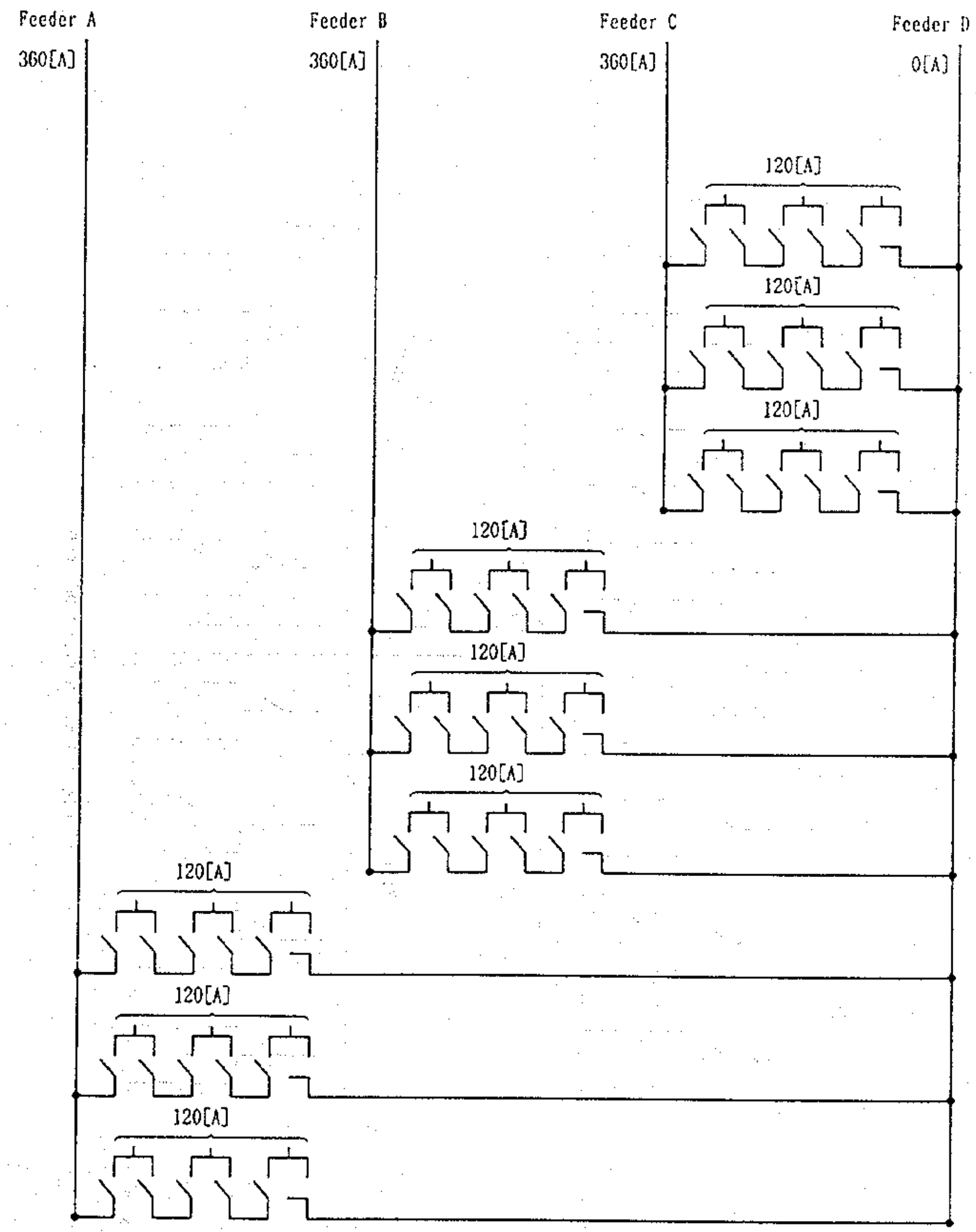


Fig.3.3-9 Underground Special Spare Line

3.3.5 Protective Relay System

(1) Automatic reclosing

To ensure early restoration from interruption of service and system stability, automatic reclosing should preferably be performed quickly after breaking of circuit breaker. Since the reclosing time is limited essentially by the following items, an optimum reclosing time is determined with comprehensively considering the said items:

- Operating duty of circuit breaker.
- Deionizing time at fault point.
- Time required until the residual voltage in large scale motor has been lowered sufficiently.
- Information updating time in case of remotely indicating ON/OFF information of circuit breaker.
- Operation time of automatic power source changeover device (line throw-over scheme) in distribution substation.
- Duration of no-voltage required by equipment arranged in series.

Whether to perform automatic reclosing of subtransmission line or not is determined taking into account whether execution of automatic reclosing causes any problem or not in view of human and equipment safety in addition to early restoration from interruption of service and assurance of system stability mentioned above.

In this sense, automatic reclosing is generally performed in case the main protective relay has been actuated, but not performed in case the backup protective relay has been actuated. Moreover, automatic reclosing is not performed in case all of the subtransmission line consists of underground cable. Likewise, in case a fault occurred in the underground portion of a subtransmission line which consists of a combination of overhead and underground lines, the automatic reclosing is normally not performed either.

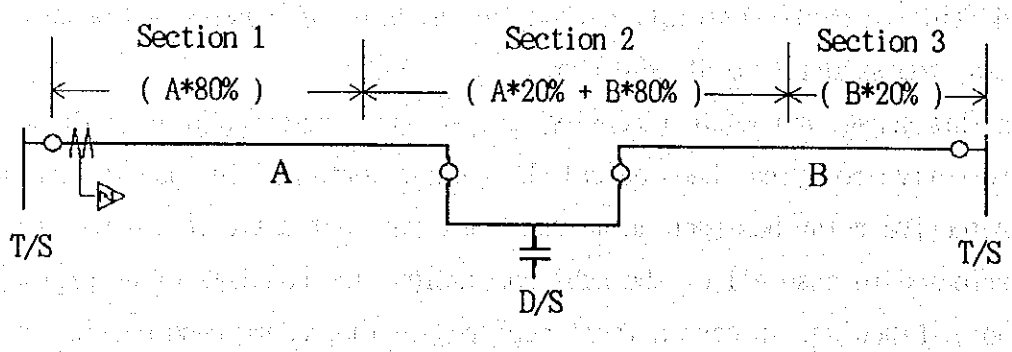
(a) Automatic reclosing of subtransmission line

Since the 115 kV and 69 kV systems are solidly grounded, the fault current is so much greater. In case a single line-to-ground fault has occurred, voltage drop will take place. The shorter the distance from the bus to the fault point in subtransmission line, the greater the fault current.

Before elapse of several seconds after the first fault current has passed in transformer subsequent to failure in automatic reclosing, a fault current will flow again. Since the circuit breaker is made while a fault is occurring continuously in the line, the fault current will flow simultaneously at the time of making. This causes a large stress to the transformer, circuit breaker and other equipment connected in series. In addition, the larger the fault current, the greater such a stress. When automatic reclosing failure has been repeated, the deterioration of circuit breaker is accelerated, and this ultimately results in the reduction of equipment reliability.

In consideration of these situations, the MEA has determined the reclosing system of subtransmission line as described below. Meanwhile, in the case of subtransmission line consisting of a combination of overhead and underground lines, automatic reclosing is executed even when a fault has occurred in the underground cable portion of the subtransmission line.

1) Protective section and automatic reclosing



Section 1	Section 2	Section 3
Main Protection (Z1; Inst.)	Back-Up Protection (Z2; 0.4 sec.)	Back-Up Protection (Z3; 0.7 sec.)
Automatic reclosing		

When the Section 2 and 3 are automatically reclosed, it naturally follows that the section would also be reclosed automatically even a backup protective relay has been actuated. This means that electricity can possibly be transmitted even before the fault point has not been eliminated. Such a reclosing system will bring about a highly probable danger of fault expanding further to equipment and human damages. Meanwhile, the Section 1 of two kilometer from the terminal station was manually switched according to the request of the EGAT to prevent an adverse effect upon transformer. The above-mentioned section has been changed to automatic reclosing since April 1995.

2) Reclosing time and frequency of automatic reclosing

Reclosing time	Frequency of automatic reclosing
2 sec.(As of Nov. '94)	1 time

At the First Field Investigation, the reclosing time has been changed from 2 sec. to 4 sec. in a part of subtransmission lines according to the request of the EGAT to prevent an adverse effect upon transformer. The reclosing time of all subtransmission lines, however, have been unified to 4 sec. since April 1995.

3) Present situations of reclosing time

Out of subtransmission line tripping (except in case of tripping caused by substation equipment) occurred in December 1993, January, April and September 1994, the reclosing time in 49 cases of short time interruption is examined. The results are presented below:

Time, %	Short time interruption					Total
Time Number %	1sec. 3 6.1%	2sec. 17 34.7%	3sec. 1 2.0%	4sec. 22 44.9%	5sec. 6 12.2%	 49 100%
Total	3 (6.1%)	18 (36.7%≒40%)		28 (57.1%≒60%)		——

From the above results, as of November 1994 the reclosing time of about 60% of subtransmission lines is estimated to be 4 sec. (Refer to Table 3.3-6).

4) Review of reclosing time

In the case of the reclosing time of subtransmission line, it is sufficient to take into account only early restoration from service interruption. Therefore, there is no need to take into consideration the system stability as in the case of bulk power transmission line. As the items to be studied in this case have already been described, MEA is recommended to take into account the following items.

a) Residual voltage in large capacity motor

In the case of large capacity motor, residual voltage is reported to exist tentatively even after service interruption. This residual voltage changes also in phase angle, and excessively large current flows due to the phase difference from power source voltage when service interruption has been restored. Thereby, the motor is exposed to a stress. The allowable value of residual voltage after motor has been exposed repeatedly to this stress is specified at 25 to 30%.

An example of the design residual voltage values in Japan are as listed below:

Design values

Induction motor (Squirrel cage)				
Residual voltage	Rated output , Time P: Pole			
	400 (kW)	1,020(kW) 2P	3,300(kW) 4P	1,800(kW) 6P
0.80 PU	0.3 sec.	1.4 sec.	2.1 sec.	0.6 sec.
0.60 〃	0.7 〃	2.2 〃	3.1 〃	0.8 〃
0.40 〃	1.3 〃	3.1 〃	4.7 〃	1.2 〃
0.25 〃	2.0 〃	4.3 〃	6.4 〃	1.7 〃
0.20 〃	2.2 〃	4.8 〃	7.2 〃	1.9 〃

Meanwhile, an example of the actual measurements of residual voltage in an industrial plant where two 15 MVA induction motors are installed are as listed below. The actual measurements have been made smaller than the design values due to the effect of other load.

Measurements

Residual voltage	0.8 PU	0.6 PU	0.4 PU	0.25 PU
Time	1.0 sec.	1.6 sec.	2.2 sec.	2.7 sec.

While the residual voltage is lowered to 25%, 2.7 sec. is required as shown in above table.

In consideration of this condition and an adverse effect of too short reclosing time exerting upon a part of transformers, it is recommended to lengthen the reclosing time to 4 sec. or over. At the Second Field Investigation, the reclosing time has been improved by changing its time to 4 sec..

(b) Automatic reclosing of distribution line

As indicated below, automatic reclosing has been executed twice. Meanwhile, such reclosing is practiced indiscriminately although most of the distribution lines are composed of a combination of overhead and underground lines.

Reclosing time	Reclosing frequency
3 sec. for 1st reclosing 60 sec. for 2nd reclosing	Twice

1) Review of reclosing time

When the information updating time and residual voltage in large capacity motor are taken into account, it is recommended to lengthen the reclosing time from 3 sec. to 4 sec. or over for raising the reclosing success ratio. For reference, the reclosing time of distribution line in the Tokyo Metropolitan Area of Japan is set at 60 sec..

(c) Success ratio of automatic reclosing

The success ratio of automatic reclosing in the fiscal year of 1994 was 28.2% for subtransmission line and 68.5% for distribution line as indicated in the table below:

Success ratio of automatic reclosing

Subtransmission lines			Feeders			
Instant. reclose	Fail to reclose	Total	Instant. reclose	Reclose in time	Fail to reclose	Total
134 (28.2%)	341 (71.8%)	475 (100.0%)	3,141 (51.3%)	1,055 (17.2%)	1,930 (31.5%)	6,126 (100.0%)

Generally, the success ratio of automatic reclosing is reported to be 90% or above for overhead subtransmission line and 70 to 80% for overhead distribution line. Although the success ratio of automatic reclosing for feeders in the case of MEA is roughly equal to the above, that of subtransmission line has been worsened substantially.

In the case of failure in automatic reclosing, not only the circuit breaker, transformer and other series equipment are exposed to excessive stresses, but also instantaneous voltage dip arises in the power system as mentioned previously. Therefore, the higher the success ratio of automatic reclosing, the better. For this purpose, it is considered necessary to investigate the causes of frequent failure in automatic reclosing of subtransmission line and take appropriate preventive countermeasures. It would also be one of the options to temporarily suspend automatic reclosing until completion of the investigations.

Meanwhile, the first and second success ratios of reclosing of distribution line are 51.3% and 17.2%, respectively. This indicates that 35.3% of distribution lines failed in the first reclosing have succeeded in the second reclosing and therefore suggests that the success ratio of the first reclosing can be raised by extending the first reclosing time from the present reclosing time of 3 sec..

(d) Causes of subtransmission line trip

The causes of 77 times of subtransmission line trip (excluding those caused by substation equipment) occurred in December 1993, January, April and September 1994 are as indicated below:

Number of interruptions

Subtransmission line					
Line severed	Flashover to 24 kV line	Aluminium rod, Ladder	Crane, Bus, Truck	Others	Fault unknown
2 (2.6%)	2 (2.6%)	2 (2.6%)	7 (9.1%)	24 (31.2%)	40 (51.9%)
13 (16.9%)				64 (83.1%)	

Out of the total number of interruption indicated above, 13 cases or 16.9% of automatic reclosing are deemed undesirable in view of public safety. In this respect, it would be one of the options to lock automatic reclosing of subtransmission line (Refer to Table 3.3-6).

(e) Automatic reclosing of transmission line consisting of a combination of overhead and underground lines

When the underground cable section has been reclosed automatically at the time of fault, there is a danger of fire and explosion, which can possibly spread into other equipment.

Considering that the majority of the MEA's transmission lines consist of overhead lines with a small portion of underground cable section, the probability of fault occurring in the underground cable section is deemed low. Even as a result of sampling and investigating the four months' portion of service interruption records in 1994, only one time of interruption was caused by underground cable out of 77 times of fault (Refer to Table 3.3-6).

Therefore, it is deemed not necessary for the MEA to lock automatic reclosing for the time being in preparation for protection from fault in the underground cable section. In other words, it would be necessary for the MEA to study locking of automatic reclosing for protecting the underground section from fault in the future when the share of the underground cable section is increased.

Presented below are examples of conditions applicable for automatic reclosing of transmission line intermingled with overhead and underground lines in the Tokyo metropolitan area of Japan:

1) 6.6 kV distribution line

Since there is no need to take into account the above-mentioned conditions because of non-grounding system, automatic reclosing is performed indiscriminately.

2) 154 kV, 66 kV and 22 kV transmission lines

(i) In the case of overhead transmission line passing over congested area and using the conductor with a cross section of less than 100 mm^2, automatic reclosing is locked to prevent public disaster.

(ii) OF cable (excluding short distance cable)

In case a fault has occurred in the underground cable section, any automatic reclosing is not performed.

(iii) XLPE cable

In case any earth fault current has occurred in the underground cable section of transmission line during fault removal time under the following conditions, automatic reclosing is not performed:

[Conditions]

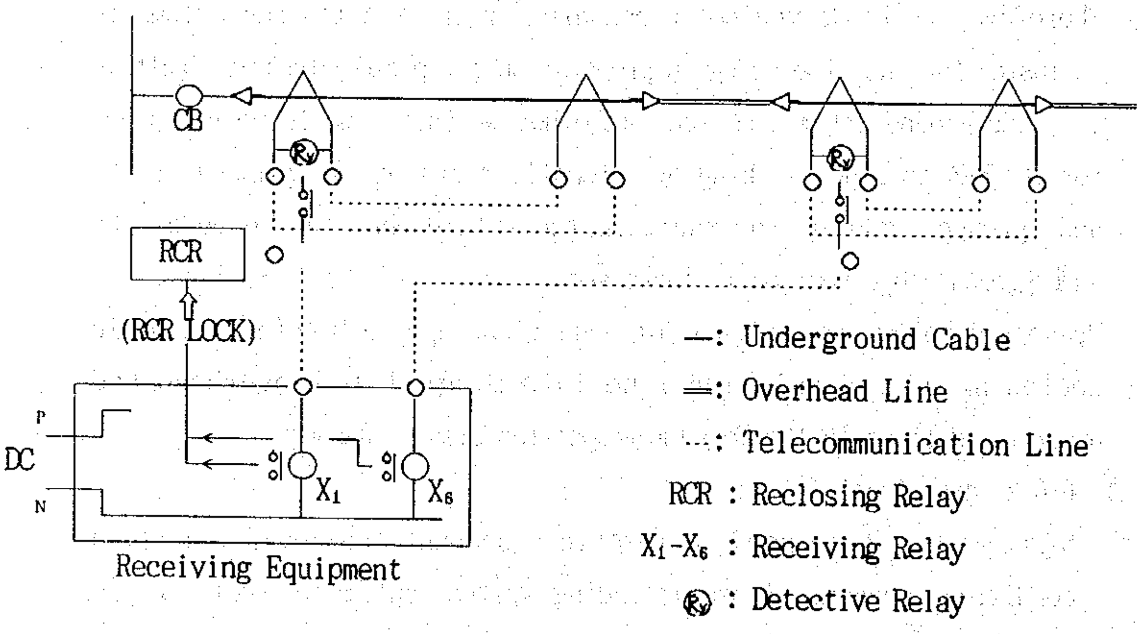
i) 154 kV and 66 kV transmission line

Earth fault current	:	Over 1,000 A
Fault removal time	:	Over 1 sec.

ii) 22 kV transmission line

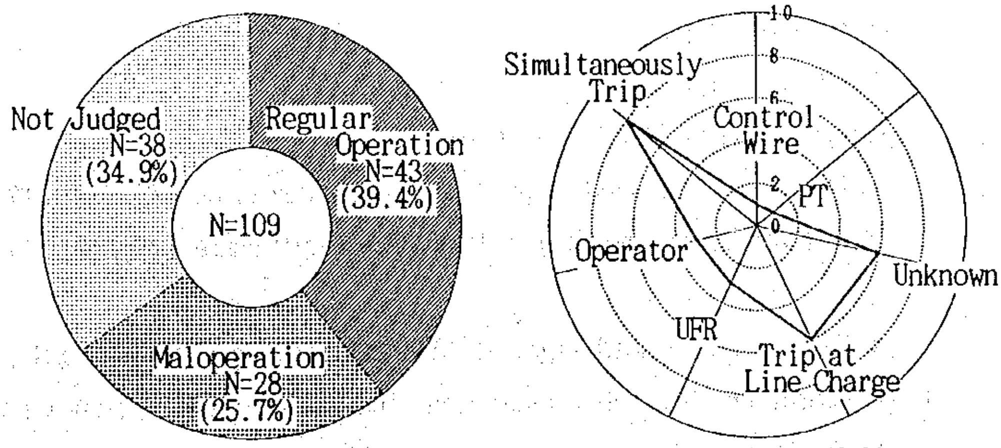
Earth fault current	:	Over 600 A
Fault removal time	:	Over 1 sec.

Meanwhile, disaster preventive countermeasures are taken in the case of both the OF and XLPE cables in Items i) and ii) above, and the devices for detecting the fault arising in the underground cable section are installed. Presented below is an example of application.



(2) Operating conditions of protective relays

With regard to 109 times of tripping of subtransmission lines, distribution lines, and transformers occurred in December 1993, January, April and September 1994, the operating conditions of protective relays have been studied as below (Refer to Table 3.3-6).



Protective Relay Operation   Maloperation N=28

The 109 times of tripping is broken down into 43 times (39.4%) of regular operation, 28 times (25.7%) of maloperation and 38 times (34.9%) of 'not judged'.

(a) Patterns of maloperation

Among 28 times of maloperation, the outstanding patterns are as indicated below:

1) Maloperation at the time of distribution line fault (seven times)

① CL 20 and CL 23 simultaneously tripped to clear a fault in CL 23 feeder

② CL 02 and CL 18 tripped due to clear a fault in CL 18 feeder

③ KS 30 and KS 34 tripped at the same time

④ BKE 10 and BKE 15 simultaneously tripped for a fault in BKE 15 feeder.

⑤ MB 420 tripped for a fault in tie feeder between MB 425 and KJ 436 feeder

⑥ WB 10 tripped after trying to reclose WB 14 for a fault in its feeder

⑦ NK 430 tripped during reclosing NK 432 to restore load after a fault in NK 432 feeder(04:52 pm., 05:47 pm. April 13, 1994)

2) Maloperation where there was not any change in the power system (five times excluding UFR)

① WA 6912 and WA 10 simultaneously tripped (April 2, 1994)

② WA 6912 and WA 10 simultaneously tripped (April 4, 1994)

③ SV 6932 and SV 30 simultaneously tripped

④ BJ 410 tripped

⑤ WB 10 tripped

3) Maloperation of UFR (three times)

① UFR worked to shed four 12 kV feeders(Prannok D/S, Dec. 17, 1993)

② UFR worked to shed three 12 kV feeders(Prannok D/S, Jan. 17, 1994)

③ UFR worked to shed eight 12 kV feeders(Klongsanpasamit D/S)

4) Maloperation when subtransmission line was charged (six times)

① RN 6912 tripped due to charging line

② SRS 6972 tripped due to closing MA 6022 to charge SRS 697 line

③ CLT 6942B tripped due to closing SY 6022 to charge LPT 693B line

④ LPT 6932B tripped while closing SM 6022 to charge LPT 693A line

⑤ LPT 6942A tripped while closing CK 6032 to charge LPT 691A line

⑥ LPT 6912B tripped while LTO worked to transfer from Chankasem D/S to LPT 691B line

(b) Features of maloperation

1) The maloperation at the time of distribution line fault (seven times) and Items ④ and ⑤ of the maloperation where there was not any change in the power system (nine times of maloperation in total) are similar to that caused by operation of LBP (local backup protection). Meanwhile, the LBP functioned effectively in the case of five times of the following operating opportunities.

① NK 20 tripped (12 kV CB failed) ⇨ regular operation

② WT 420 tripped (24 kV CB failed) ⇨ regular operation

③ BI 410 tripped (24 kV CB failed) ⇨ regular operation

④ DM 10 tripped (12 kV CB failed) ⇨ regular operation

⑤ DM 20 tripped (DM 28 protective relay failed) ⇨ regular operation

2) Out of maloperation where there was not any change in the power system, Items ①, ② and ③ are similar to that caused by operation of transformer protective relays.

3) Out of three times of maloperation of UFR, two times occurred in the same substation. Meanwhile, the UFR functioned effectively in the case of three times of the following operating opportunities.

① 21 feeders tripped by UFR at 8 D/S

(Generator tripped at EGAT, Dec. 16, 1993)

② 31 feeders tripped by UFR at 1 T/S and 6 D/S

(Incompletely-closing CB at EGAT, Sept. 1, 1994)

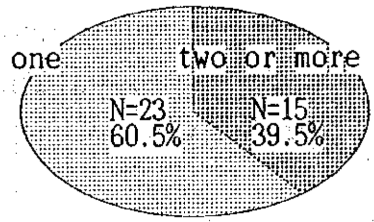
③ 207 feeders tripped by UFR at 7 T/S and 52 D/S

(Explosion of CB at EGAT, Sept. 22, 1994)

(c) Features of 'not judged' from the results of protective relay operation

Out of the 38 times of 'not judged' from the results of protective relay operation, 15 times (39.5%) correspond to two or more times of tripping.

①	Chidlom	CLT 6942C	2 times
②	Samong	SRS 6932	2 times
③	South Bangkok	SKT 6952B	2 times
④	Lardprao	LPT 6912C	2 times
⑤	Klongrangsit	KRT 6922C	3 times
⑥	Bankapi	BAT 6952B	4 times



In addition, one time of maloperation occurred respectively in the cases of CLT 6942C in Item ① and LPT 6912C in Item ④.

(d) Maloperation ratio of protective relays in subtransmission line

Among 568 times of protective relay operation in the subtransmission lines of MEA, 13 times of operation were caused by maloperation, thus the maloperation ratio is 2.29%.

When compared with 0.33% of maloperation ratio in the Tokyo Metropolitan District of Japan for example, there is a considerable difference from that of MEA (Significant level: 1%).

Rate of maloperation

	Number of protective relay operations	Number of maloperations	Rate of maloperation
JAPAN	6661 (1982-1991)	22	0.33%
MEA	568 (1994)	13	2.29%

(e) Improvement of the reliability of protective relay

1) Installation of automatic oscillograph

By the time of First Field Investigation, any automatic oscillograph was not installed in the MEA's terminal station and distribution substation. The MEA intends to install such an automatic oscillograph in its terminal station. The automatic oscillograph ensures easy analysis of the relationship between the electrical phenomena in subtransmission line fault and reaction of protective relays. Although about 60% of protective relay operation has so far occurred by unknown causes and maloperation, but this value will be reduced substantially and the reliability of protective relays be improved remarkably through appropriate countermeasures after promoting analysis of the above relationship. Therefore, it is preferable to install such automatic oscillograph not only in the terminal stations but also in some typical distribution substations.

2) Prevention of recurrence of maloperation

Should many similar maloperation phenomena be observed, it will be necessary to take appropriate countermeasures after investigating and clarifying the causes of such maloperation. In the case of maloperation occurring at the time of charging subtransmission line, maloperation of DZR and OCGR due to inrush current can also be considered. Meanwhile, the automatic oscillograph also ensures easy analysis of inrush current.

3) The relay configuration should be modified to a combination of instantaneously acting relay and timer.

The standard protective relay being applied by MEA has an inverse time lag characteristics. This relay does not allow appropriate timely coordination with the other relays and can possibly cause maloperation of protective relays. By modifying the configuration of protective relay into a combination of instantaneously acting relay and timer, it will be possible to ensure easy timely coordination with other relays and expect reduction of maloperation.

Date	No	Substation	Tripped CB	Cause	Operation state	Others
1993. 12. 2	1	Pathumwan D/S	PM 6012 tripped.	PM 6012 tripped due to flashover during disconnecting 6063 LP disconnecting switch.	Regular Operation	・69kV disconnecting switch 3 feeders were interrupted 4 minutes.
1993. 12. 3	2.2	Lardprao T/S	LPT 6912B and LPT 6912C simultaneously tripped.	LPT 6912B tripped while LTO worked to transfer load from Chankasem D/S to LPT 691B subtransmission line.	Maloperation	23 feeders and 3 customers were interrupted 5 minutes.
1993. 12. 3	2.3	South Bangkok T/S	SKT 6912A disruption resulted in the following electrical failures. (It means SKT 6912A tripped or disrupted ?)	Phase R 69kV SKT subtransmission line severed at riser pole leading to tower within South Bangkok T/S.	Regular Operation	・69kV line served 24 feeders and 1 customer were interrupted 7 to 92 minutes.
1993. 12. 3	2.3	Rasburana D/S	RN 6912 tripped.	RN 6912 tripped due to charging line after SKT 691 subtransmission line tripped.	Maloperation	19 feeders were interrupted 2 minutes.
1993. 12. 4	3.1	Chidlom T/S	CLT 6942A, CLT 6942B and CLT 6942C simultaneously tripped.	Unknown	Not judged	25 feeders and 1 customer were interrupted 5 minutes.
1993. 12. 4	3.3	South Bangkok T/S	SKT 6952B tripped.	Unknown	Not judged	5 feeders and 4 customers were interrupted 2 minutes.
1993. 12. 4	3.4	South Bangkok T/S	SKT 6992A tripped.	SKT 699 subtransmission line, phase R 69kV lightning arrester damaged at riser pole within South Bangkok T/S	Regular Operation	・69kV line lightning arrester 21 feeders and 1 customer were interrupted 6 to 506 minutes.
1993. 12. 6	4	Bangkok Noi T/S	BOT 6932 tripped.	Unknown	Not judged	Dip in voltage
1993. 12. 9	5.2	Samrong S/S	As a result of SRS 6972 interruption the following electrical failures occurred. (It means SRS 6972 tripped or disrupted ?)	SRS 6972 tripped due to closing MA 6022 to charge SRS 697 subtransmission line.	Maloperation	Dip in voltage
1993. 12. 9	5.4	Klongsanpasamit D/S	At 01:30 am under frequency relay worked to shed eight 12kV feeders.	Unknown	Maloperation	・UFR missed 8 feeders were interrupted 3 to 6 minutes.
1993. 12. 11	6.1	Lardprao T/S	LPT 6932B and LPT 6932C simultaneously tripped.	A boom of crane was inadvertently lifted to sever phase B 69kV subtransmission line (LPT 693B).	Regular Operation	・Crane 3 feeders were interrupted 4 minutes.
1993. 12. 11	6.2	Chidlom T/S	CLT 6942B and CLT 6942C simultaneously tripped.	CLT 6942B tripped due to closing SY 6022 to charge LPT 693B subtransmission line.	Maloperation	29 feeders and 1 customer were interrupted 2 minutes.
1993. 12. 11	6.3	North Bangkok T/S	NK 20 tripped.	NK 24 circuit breaker failed to clear a fault in its feeder ; therefore NK 20 tripped as back up protection.	Regular Operation	・12kV CB failed 3 feeders were interrupted 3 to 7 minutes.
1993. 12. 15	7	Chidlom T/S	As a result of CL 20 disruption six feeders were interrupted and CL 23 was disrupted.	CL 20 and CL 23 simultaneously tripped to clear a fault in CL 23 feeder.	Maloperation	・Failure to trip(CL 23 relay) 6 feeders were interrupted 2 minutes.
1993. 12. 16	8.1	8 D/S	21 feeders tripped by UF. relay at 8 D/S.	Caused the frequency to be dropped down until UF. relay worked to shed the following load.	Regular Operation	・UFR(Generator tripped at EGAT) 21 feeders were interrupted 6 or 7 minutes.
1993. 12. 16	8.2	Lardprao T/S	LPT 6932A and LPT 6932C simultaneously tripped.	Unknown	Not judged	13 feeders and 1 customer were interrupted 3 minutes.

Date	No	Substation	Tripped CB	Cause	Operation state	Others
1993. 12. 17	9	Prannok D/S	At 09:08 am under frequency relay worked to shed 4 12kV feeders.	Unknown	Maloperation	· UFR missed 4 feeders were interrupted 3 minutes.
1993. 12. 22	11	Bangkok Noi T/S	BOT 6912 tripped.	Flashover took place at 69kV pole #108 of BOT 691 R subtransmission line owing to a snake slithering upon the line.	Regular Operation	· Snake Dip in voltage
1993. 12. 23	12	Bangnamjued D/S	BI 410 tripped.	BJ 413 circuit breaker failed to clear a fault in its feeder : therefore BJ 410 tripped as back up protection.	Regular Operation	· 24kV CB failed 4 feeders were interrupted 8 or 28 minutes.
1993. 12. 24	13	Bangkapi D/S	BAT 6932B tripped two times : at 10:47 am and 10:55 am.	An aluminium rod was accidentally lifted to contact with BAT 693B subtransmission line between pole #97 and pole #98.	Regular Operation	· Aluminium rod 7 feeders and 1 customer were interrupted 3 or 17 minutes.
1993. 12. 25	14	South Bangkok T/S	SKT 6912A tripped.	A boom of crane was accidentally lifted close to phase B SKT 691A subtransmission line and flashover took place.	Regular Operation	· Crane 24 feeders and 1 customer were interrupted 2 minutes.
1993. 12. 26	15. 1	South Bangkok T/S	SK 01 tripped.	Power transformer KT-4A and KT-5A tripped at South Bangkok T/S of EGAT.	Regular Operation	31 feeders and 7 customers were interrupted 4 or 24 minutes
1993. 12. 26	15. 2	Nonthaburi D/S	BTO worked to trip.	BTO worked to function under its test.	Maloperation	· Worker Dip in voltage
1993. 12. 30	17	Klongrangsit T/S	KRT 7912B tripped.	Unknown	Not judged	Dip in voltage

Source ; MEA monthly report Dec. 1993

(1994.1)

Date	No	Substation	Tripped CB	Cause	Operation state	Others
1994. 1. 6	1	Nonthaburi D/S	NR 6022 and NR 6032 simultaneously tripped.	Unknown	not judged	17 feeders were interrupted 4 or 14 minutes.
1994. 1. 9	2	Surawong D/S	SU 6012 and SU 30 simultaneously tripped.	They simultaneously tripped while testing protective relay of the transformer	Maloperation	・Worker 14 feeders were interrupted 26 minutes.
1994. 1. 11	3	Klongrangsit T/S	KRT 6922B and KRT 6922C simultaneously tripped.	Unknown	not judged	4 feeders and 1 customer were interrupted 2 minutes.
1994. 1. 12	4. 1	Prasanmit D/S	PA 6922 and PA 20 simultaneously tripped.	Unknown	Maloperation	Dip in voltage
1994. 1. 12	4. 2	Mai-Ad D/S	MA 6022 tripped.	Unknown	not judged	1 customer was interrupted 2 minutes.
1994. 1. 13	5	Nonthaburi D/S	NR 6912, NR 6922, NR 6932, NR 10, NR 20 and NR 30 simultaneously tripped.	Two capacitor cells damaged while closing NR 34-C capacitor bank.	Regular Operation	・Capacitor 13 feeders were interrupted 11 or 15 minutes.
1994. 1. 17	7	Prannok D/S	Under frequency worked.	Unknown	Maloperation	・UFR missed. 3 feeders were interrupted 15 minutes.
1994. 1. 20	9	Bangping D/S	Automatic function worked to trip BI 410, BI 410, BI 7012, BI 7022, BI 7913, causing seven feeders to be interrupted about 6 seconds.	The potential transformer of BTO of the first power transformer damaged.	Maloperation	・Potential transformer Dip in voltage
1994. 1. 22	9	Bangkapi T/S	BAT 6972 tripped.	Unknown	not judged	Dip in voltage
1994. 1. 24	10	Paknam D/S Prakasa D/S	PN 7012 and PR 7022 simultaneously tripped.	Unknown	not judged	1 customer was interrupted 2 minutes.
1994. 1. 25	11	Chidlom T/S	CLT 8022, CLT 8002, CLT 6932B, CLT 6932C, CL 20R and CL 20 simultaneously tripped.	At Chidlom T/S CL 20R switchgear exploded and fire occurred.	Regular Operation	・Switchgear Dip in voltage
1994. 1. 27	12. 1	Bangplakod D/S	BK 6022 tripped two times: at 07:53 am and at 08:05 am.	Unknown	not judged	Dip in voltage
1994. 1. 27	12. 2	Bangkapi T/S	BAT 6972B tripped.	Unknown	not judged	Dip in voltage
1994. 1. 31	13. 1	Muangmai D/S Prakasa D/S	MG 7022 and PR 7032 simultaneously tripped at 05:48 am and MG 7012 tripped at 05:50 am.	Phase Y 69kV porcelain insulator in BPT 791A subtransmission line damaged.	Regular Operation	・Porcelain insulator 16 feeders and 1 customer were interrupted 4 minutes.
1994. 1. 31	13. 2	Klongrangsit T/S	KRT 6912A and KRT 6912C simultaneously tripped.	The static wire of KRT 6912A subtransmission line severed and fell down upon of 22kV feeder of PEA.	Regular Operation	・Static wire served 10 feeders and 2 customers were interrupted 131 minutes.
1994. 1. 31	13. 3	Lardprao T/S	LPT 6912A and LPT 6912C simultaneously tripped.	Phase Y and B 69kV porcelain insulator damaged at pole #16.	Regular Operation	・Porcelain insulator 2 customers were interrupted 2 minutes.
1994. 1. 31	13. 4	North Bangkok T/S	NKT 6982A tripped.	The 69kV cross arm of NKT subtransmission line broke and phase B line fell down to contact with pole.	Regular Operation	・Cross arm 35 feeders and 1 customer were interrupted 6 to 38 minutes.

Source ; MEA monthly report Jan. 1994

(1994. 4)

Date	No	Substation	Tripped CB	Cause	Operation state	others
1994. 4. 2	2.1	Chidlom T/S	CL 02 tripped.	CL 02 and CL 18 tripped due to a fault in CL 18 feeder.	Maloperation	・Failure to trip (CL 18 relay) Caused 3 feeders to be interr-upted 11 or 52 minutes.
1994. 4. 2	2.2	Lardprao T/S	LPT 6932A and LPT 6932C simultaneously tripped.	A pulley of power crane severed accid-entally phase Y and B LPT 693A subtrans-mission line.	Regular Operation	・Crane 10 feeders and 2 customers were interrupted 11 to 63 minutes.
1994. 4. 2	2.3	Bangkapi T/S	BAT 6992B tripped.	Unknown	Not judged	12 feeders and 1 customer were interrupted 5 minutes.
1994. 4. 2	2.4	Watklang D/S	WA 6912 and WA 10 simultaneously tripped.	Unknown	Maloperation	Caused 4 feeders to be interr-upted 7 minutes.
1994. 4. 3	3	Lardprao T/S	LPT 6932A and LPT 6932C simultaneously tripped.	Unknown	Not judged	Dip in voltage
1994. 4. 4	4.1	Watklang D/S	WA 6912 and WA 10 simultaneously tripped.	Unknown	Maloperation	Caused 4 feeders to be interr-upted 4 minutes.
1994. 4. 10	5.1	North Bangkok T/S	NKT 6952B and NK 20 simultaneously tripped.	The control wire of the second power transformer damaged during excavating to strengthen #1 base.	Maloperation	・Control wire damaged Caused 3 feeders to be interr-upted 5 minutes.
1994. 4. 10	5.2	Bangyeekhan D/S	BY 6922 tripped.	Unknown	Not judged	Caused 3 feeders to be interr-upted 1 minute.
1994. 4. 11	6	Bangplee T/S	BPT 6912A, BPT 6912C, BPT 6922B and BPT 6922C tripped at 01:32 am.	(1)Unknown(BPT 691A subtransmission line) (2)A truck crashed into 69kV pole #106 of BPT 692B subtransmission line.	Not judged Regular Operation	・Truck Dip in voltage
1994. 4. 13	7.1	North Bangkok T/S	LBP worked to open NK 430 two times; at 04:52 pm and at 05:47 pm.	LBP worked to function during reclosi-ng NK 432 to restore load after a fault in NK 432 feeder.	Maloperation	・Failure to trip (NK 432 relay) Caused 2 feeders to be interr-upted 2 or 3 minutes.
1994. 4. 13	7.2	Bangkapi T/S	BAT 6972B tripped two times; at 04:57 pm and at 05:24 pm.	The advertisement cloth string severed and fell down to contact with 69kV BAT 697 subtransmission line.	Regular Operation	・Advertisement cloth string Dip in voltage
1994. 4. 13	7.3	Bangkapi T/S	BAT 6932B tripped.	Unknown	Not judged	Dip in voltage
1994. 4. 15	8.1	Lardprao T/S	LPT 6932A tripped.	The cloth was blown to contact with 69kV LPT 693A subtransmission line.	Regular Operation	・Cloth 11 feeders and 2 customers were interrupted 3 to 131 minutes.
1994. 4. 15	8.2	Lardprao T/S	LPT 6932B tripped.	LPT 6932B tripped while closig SM 6022 to charge LPT 693A subtransmission line.	Maloperation	14 feeders were interrupted 2 min-utes.
1994. 4. 15	8.3	Lardprao T/S	LPT 6912B and LPT 6912C tripped.	Unknown	Not judged	11 feeders and 1 customer were interrupted 6 minutes.
1994. 4. 15	8.4	South Bangkok T/S	SKT 6952B tripped.	Unknown	Not judged	5 feeders and 3 customers were interrupted 2 minutes.

Date	No	Substation	Tripped CB	Cause	Operation state	others
1994. 4.15	8.5	South Thonburi T/S	STT 6912 tripped.	Unknown	Not judged	Dip in voltage
1994. 4.15	8.6	Bangkapi T/S	BAT 6972B tripped.	Unknown	Not judged	Dip in voltage
1994. 4.16	9.1	Chidlom T/S	CLT 8012 and CLT 8022 tripped at 01:40 am. CLT 6912A and CLT 6912C tripped at 01:46 am. CLT 8012 and CLT 6912A tripped at 01:52 am.	(1) CLT 8012 and CLT 8022 simultaneously tripped for fault in CLT 691A S/L. (2) The collapsed advertisement board contacted with R 69kV S/L(CLT 691A).	Maloperation Regular Operation	・Collapsed advertisement board 57 feeders and 2 customers were interrupted 6 to 22 minutes.
1994. 4.16	9.2	South Bangkok T/S	SKT 6962A tripped.	At South Bangkok T/S, the porcelain insulator of phase B SKT 696 subtransmission line damaged at the terminator	Regular Operation	・Porcelain insulator 10 feeders and 3 customers were interrupted 4 to 155 minutes.
1994. 4.19	11	Chidlom T/S	CLT 6912A and CLT 6912C simultaneously tripped.	The pruned branch of a tree fell down upon phase B CLT 691A subtransmission line.	Regular Operation	・Pruned branch of a tree Caused 9 feeders to be interrupted 7 to 54 minutes.
1994. 4.22	13	Samrong S/S	SRS 6932 tripped.	Unknown	Not judged	Dip in voltage
1994. 4.26	15	South Bangkok T/S Prakasa D/S Paknam D/S	NKT 7912, PR 7022 and PN 7012 simultaneously tripped.	Unknown	Not judged	1 customer was interrupted 2 minutes.
1994. 4.27	16	North Bangkok T/S	NKT 6982A tripped.	Unknown	Not judged	Dip in voltage
1994. 4.29	17	Bangkapi T/S	BAT 6952A, BA 10 and BA 20 simultaneously tripped.	BA 10 tripped during closing BAT 6955 by pass switch causing the current following to BAT 694 S/L via BAT 6952.	Not judged	Caused 14 feeders to be interrupted 1 or 3 minutes.

Source ; MEA monthly report April 1994

Date	No	Substation	Tripped CB	Cause	Operation state	Others
1994. 9. 1	1.1	Bangnamjued D/S	BJ 410 tripped.	Unknown	Maloperation	Caused interruption lasting 6 minutes to 5 feeders.
1994. 9. 1	1.2	North Bangkok T/S and 6 D/S	31 feeders tripped by UF. relay at 1 T/S and 6 D/S.	caused the frequency to be dropped down until UF. relay worked to shed the following load.	Regular Operation	・UFR (Incompletely-closing CB) 31 feeders were interrupted 29 to 70 minutes.
1994. 9. 3	2	Bangplee T/S	BPT 6912A and BPT 6912C simultaneously tripped.	Flashover due to a fault in TP 422 under built feeder occurred to contact with phase B 69kV BPT 691A S/L.	Regular Operation	・Flashover between 24kV line and 69kV line. Dip in voltage
1994. 9. 4	3.1	Chidlom T/S	CLT 6922B and CLT 6922C simultaneously tripped.	SF_6 gas low pressure condition occurred in compartment S. T of CLT 6922B.	Regular Operation	・GIS Dip in voltage
1994. 9. 4	3.2	Bangkae D/S	LBP worked to open BKE 10.	BKE 10 and BKE 15 simultaneously tripped for a fault in BKE 15 feeder.	Maloperation	・Failure to trip(BKE 15 relay) 5 feeders were interrupted 22 to 78 minutes.
1994. 9. 4	3.3	Romklao D/S	RK 7022 tripped.	RK 7022 tripped due to instantaneous voltage dip caused by interruption of the second circuit 230 kV. tie line.	Maloperation	There was no electrical failure
1994. 9. 5	4.1	Wangthonglang D/S	WT 420 tripped.	WT 421 failed to clear a fault in its feeder, hence WT 420 tripped as back up protection.	Regular Operation	・24kV CB failed 6 feeders were interrupted 7 or 62 minutes.
1994. 9. 5	4.2	Klongjan D/S	KJ 6012 tripped.	Unknown	Not judged	There was no electrical failure
1994. 9. 7	5.1	South Thonburi T/S	STT 6932 tripped.	A sling of a crane was taken to contact with phase B 69kV subtransmission line (STT 693) close to the tel. exchange.	Regular Operation	・Crane 7 feeders and 1 customer were interrupted 3 minutes.
1994. 9. 7	5.2	Donmuang D/S	LBP worked to open DM 10.	DM 16 failed to clear a fault in its feeder, hence LBP worked to open DM 10.	Regular Operation	・12kV CB failed 4 feeders were interrupted 14 to 76 minutes.
1994. 9.10	6.1	Donmuang D/S	LBP worked to open DM 20.	LBP worked for a fault in DM 28 feeder by unknown cause.	Regular Operation	・Failure to trip(DM 28 relay) Caused interruption lasting 4 minutes to 5 feeders.
1994. 9.10	6.2	Klongrangsit T/S	KRT 6922B and KRT 6922C simultaneously tripped.	Unknown	Not judged	Dip in voltage
1994. 9.10	6.3	South Bangkok T/S	NKT 6912A tripped.	Unknown	Not judged	Dip in voltage
1994. 9.10	6.4	Lardprao T/S	LPT 7912B and LPT 7912C simultaneously tripped at 09:57 pm.	Phase Y 69kV UG. cable of LPT 691B subtransmission line at the terminator pole damaged.	Regular Operation	・Terminator pole 19 feeders were interrupted 1 minute.
1994. 9.10	6.4	Lardprao T/S	LPT 6942A tripped at 10:01 pm.	LPT 6942A tripped while closing CK 6032 to charge LPT 691B subtransmission line.	Maloperation	2 customers were interrupted 44 minutes.
1994. 9.11	7	Klongrangsit T/S	KRT 6922A and KRT 6922C simultaneously tripped.	Unknown	Not judged	Dip in voltage

Date	No	Substation	Tripped CB	Cause	Operation state	Others
1994. 9.12	8	Klongsanpasamit D/S	LBT worked to open KS 30.	LBT worked to open KS 30 and KS 34 tripped at the same time.	Maloperation	・Failure to trip(KS 34 relay) Caused disruption lasting 11 minutes to 3 feeders.
1994. 9.14	9	Bangnamjued D/S	BJ 410 tripped eight times as follows: at 04:23, 05:05, 05:09, 05:37, 05:45, 05:53, 06:05 and 11:41	The interlock control wire of tripping circuit of BJ 410 short-circuited.	Maloperation	・Control wire Caused 5 feeders to be interrupted 1 to 50 minutes.
1994. 9.17	10	South Thonburi T/S	STT 6952 tripped.	Phase B lead wire at the load side of 6027 ST disconnect switch severed.	Regular Operation	・Disconnect switch Dip in voltage
1994. 9.18	11	Chidlom T/S	CLT 6912A and CLT 6912C simultaneously tripped.	Unknown	Not judged	Dip in voltage
1994. 9.21	12	South Bangkok T/S	SKT 6922A tripped.	The bus crashed into and collapsed the 69kV pole.	Regular Operation	・Bus 1 customer was interrupted 218 minutes.
1994. 9.22	13.1	Klongrangsit T/S	KRT 6922B and KRT 6922C simultaneously tripped.	A steel ladder was accidentally slipped and fell to contact with phase B 69kV subtransmission line.	Regular Operation	・Steel ladder 8 feeders were interrupted 3 or 10 minutes.
1994. 9.22	13.2	52 D/S, 7 T/S and 1 S/S.	207 feeders tripped by UF. relay at 7 T/S and 52 D/S.	caused the frequency to be dropped down until UF. relay worked to shed the following load.	Regular Operation	・UFR (Explosion of CB at EGAT) 207 feeders were interrupted 3 to 126 minutes.
1994. 9.23	14	Bangplee T/S	BPT 6922 and BPT 6922C simultaneously tripped.	Lead wire phase B terminator severed.	Regular Operation	・Lead wire of terminator 1 feeder was interrupted 134 minutes.
1994. 9.26	15.1	Bangkapi T/S	BAT 6992B tripped.	Flashover occurred due to phase B 69kV BAT 699 subtransmission line sagging close to the top of 12kV pole.	Regular Operation	・Flashover between 12kV pole and 69kV line. (sagging) 13 feeders were interrupted
1994. 9.26	15.2	Soonvijai D/S	SV 6932 and SV 30 simultaneously tripped.	Unknown	Maloperation	5 feeders were interrupted 37 to 77 minutes.
1994. 9.28	16.1	Chalongkrung D/S	CG 410 tripped at 04:23 am and CG 7912 tripped at 04:38 am.	At Chalongkrung D/S fault occurred causing damage to bus bar due to the rat inside the switchgear cubicle.	Regular Operation	・Rat 5 feeders were interrupted 48 to 57 minutes.
1994. 9.28	16.2	Wangpetchaboon D/S	WB 10 tripped.	WB 10 tripped after trying to reclose WB 14 for a fault in its feeder.	Maloperation	・Failure to trip(WB 14 relay) 5 feeders were interrupted 15 to 41 minutes.
1994. 9.28	16.3	Bangkapi T/S	BAT 6982A tripped.	Unknown	Not judged	18 feeders were interrupted 3 minutes.
1994. 9.28	16.4	Bangplee T/S Muangmai D/S	BPT 7912C, BPT 7912A and MG 7012 simultaneously tripped.	Unknown	Not judged	Dip in voltage
1994. 9.28	16.5	Chidlom T/S	CLT 6942C and BPT 6942A simultaneously tripped.	Unknown	Not judged	Dip in voltage

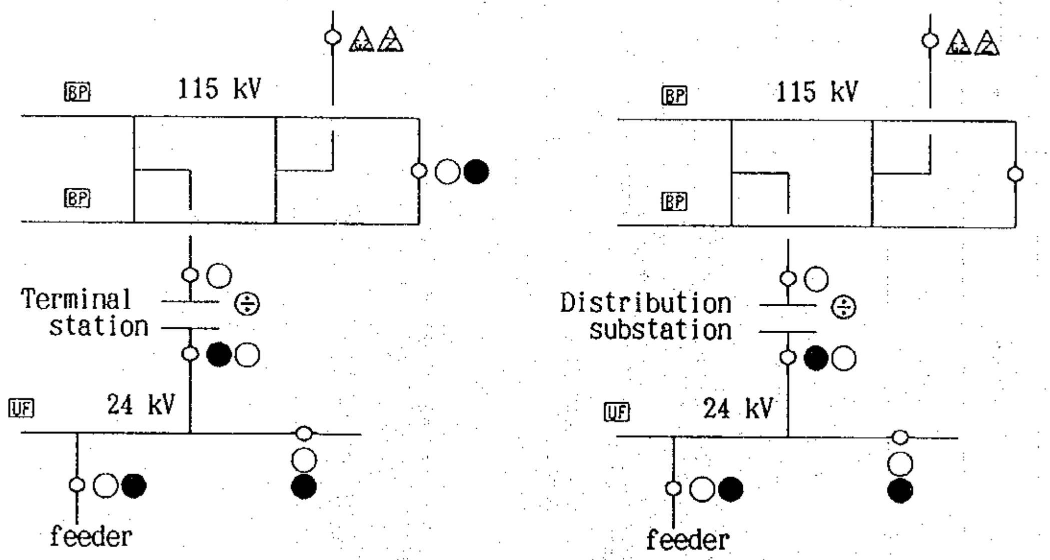
Date	No	Substation	Tripped CB	Cause	Operation state	Others
1994. 9.28	16.6	Muangmai D/S Prakasa D/S	MG 7022 and PR 7032 simultaneously tripped.	Unknown	Not judged	5 feeders were interrupted 1 minute.
1994. 9.28	16.7	Bangplee T/S South Bangkok T/S Prakasa D/S	BPT 7922A, BPT 7922C, SKT 7912 and PR 7012 simultaneously tripped.	Unknown	Not judged	Dip in voltage
1994. 9.28	16.8	Samrong S/S	SRS 6932 tripped.	Unknown	Not judged	Dip in voltage
1994. 9.29	17.1	Lardprao T/S	LPT 6912A and LPT 6912C simultaneously tripped.	Unknown	Not judged	There was no electrical failure
1994. 9.29	17.2	Lardprao T/S	LPT 6912B tripped.	The static wire severed to contact with 69kV LPT 691B subtransmission line and its phase R, Y were tied together.	Regular Operation	· Static wire severed 1 customer was interrupted 55 minutes.
1994. 9.29	17.3	Bangkapi T/S	BAT 6982A tripped.	The sling of a crane was moved to contact and sever phase A 69kV BAT subtransmission line.	Regular Operation	· Crane 18 feeders were interrupted 15 to 99 minutes.
1994. 9.29	17.4	Samrong S/S	SRS 6932 tripped.	Phase A, Y 69kV SRS subtransmission line severed.	Regular Operation	· 69kV line severed 6 customers were interrupted 105 to 780 minutes.
1994. 9.29	17.5	Wangthong D/S	WT 6012 tripped.	Unknown	Not judged	28 feeders were interrupted 2 or 3 minutes.
1994. 9.29	17.6	Minburi D/S	MB 420 tripped.	At Minburi D/S, MB 420 and KJ 436 tripped for a fault in tie feeder between MB425 and KJ 436 feeder.	Maloperation	· Failure to trip 4 feeders were interrupted 8 or 9 minutes.
1994. 9.30	18	Bangkapi T/S	BAT 6942B tripped.	Phase B porcelain insulator of 69kV BAT 694 subtransmission line damaged.	Regular Operation	· Porcelain insulator 15 feeders were interrupted 2 minutes.

Source ; MEA monthly report Sept. 1994

(3) Applying condition of protective relays

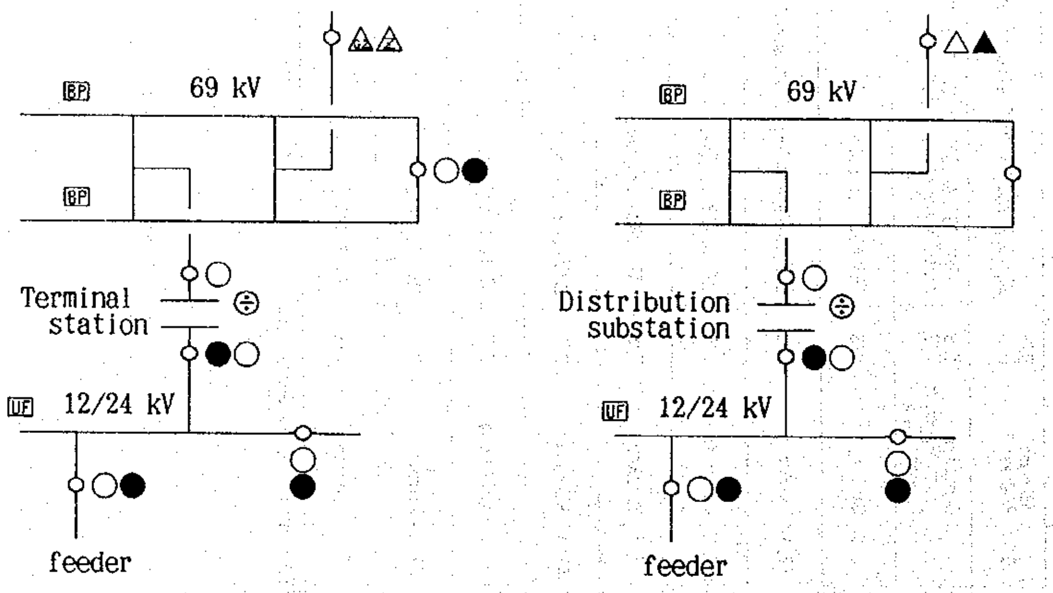
Applying condition of normal protective relays on the MEA system are shown in figures below. OCR, OCGR, DOCR, DGR are applied as a relay which has inverse time lag characteristics.

(a) Protective relay for 115 kV system



△△ ; Distance relay (DZR)
⊕ ; Transformer differential relay
BP ; Bus differential relay
UF ; Under frequency relay(UFR)
○ ; Overcurrent relay(OCR)
● ; Earth fault relay(OCGR)

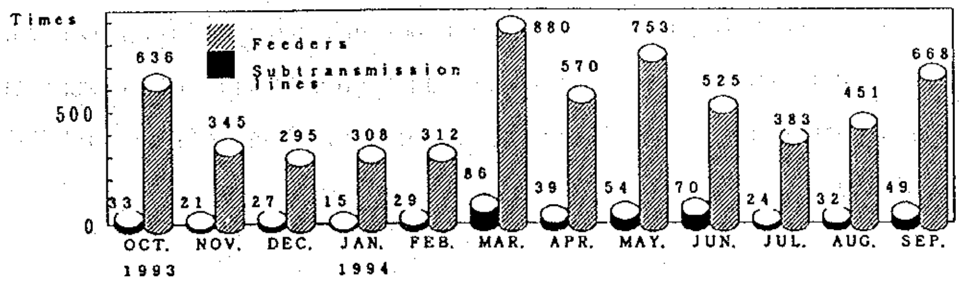
(b) Protective relay for 69 kV system



△ ; Directional overcurrent relay (DOCR)
▲ ; Directional earth fault relay (DGR)

(4) Power outage and restoration equipment

(a) The situations of power outage in subtransmission and distribution lines occurred in October 1993 through to September 1994 are as indicated in the diagram below:



As countermeasures for minimizing the effect of such power outage, the MEA installed the following equipment:

(b) Automatic line changeover equipment: LTO (Line throw-over scheme)

This equipment, which is designed for automatic changeover (throw-over) to standby line when any power source line has been shut down in any distribution substation, has been installed in each distribution substation of MEA as standard equipment.

[Changeover sequence]

Step 1: Power outage in the corresponding distribution substation resulting from power source failure.

Step 2: Breaking of line circuit breaker in outage in case any power has not been sent even after elapse of reclosing time (4 seconds).

Step 3: Making of standby line circuit breaker.

Step 4: Restarting of power supply.

(c) Automatic bus changeover equipment: BTO (Bus throw-over scheme)

This equipment, which is designed for automatically making the bus coupler when transformer has been shut down in distribution substation resulting from tripping of transformer secondary circuit, has been installed in each distribution substation of MEA as standard equipment.

[Changeover sequence]

Step 1: Shutdown of the corresponding transformer due to tripping of transformer secondary circuit.

Step 2: Automatic making of bus coupler.

3.3.6 Telecommunication Equipment

The existing telecommunication network of MEA consists of radio telecommunication system based on the VHF and UHF bands. These are largely classified into the voice telecommunication network and substation monitor and control network (SCADA system). Moreover, an optical fiber telecommunication network has been established between the Poenchit head office and Watlieb district office.

(1) Voice telecommunication radio network

The voice telecommunication network of MEA consists of the privately-owned VHF radio system (160 MHz band, 4 channels) based on the Chidlom Substation as a master station and the trunk radio system (800 MHz, 15 channels) in addition to public telephone network. This voice radio telecommunication system is used for the following purposes:

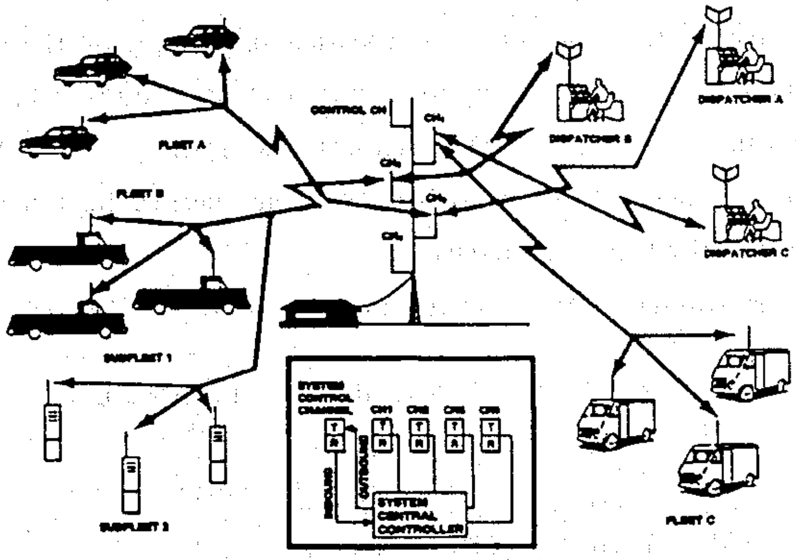
(a) Restoration of power supply at the time of power outage.

(b) Control, operation and maintenance of substation facilities.

(c) Proceedings for application for electricity supply from customers between district offices.

(d) Proceedings for claiming and payment of electricity rate to and from customers between district offices.

In the case of the VHF radio system among the above systems, the number of channels has become insufficient when compared with the number of accommodated stations after elapse of two decades (20 years) subsequent to starting this system. Therefore, MEA has been promoting installation of trunk radio system since 1994. Thereby, only the trunk radio system will be operated by dismantling the VHF radio system since 1997. The trunk radio system is outlined in the diagram below:



System configuration of trunk radio system

Moreover, the subscriber units of this system is installed in substations, district offices, maintenance vehicles (service cars), etc. The number of installed subscriber units by types is indicated in the table below:

Number of subscriber units

ITEM	EXISTING		FUTURE(1997～)	Note
	VHF	TRUNK	TRUNK ONLY	
Handhold	325	20	540	Voice
Mobile	505	66	780	Voice
Base	310	16	420	Voice
DAS	-	7	80	Data
Total	1,140	109	1,820	

Note; DAS(Distribution automation system)

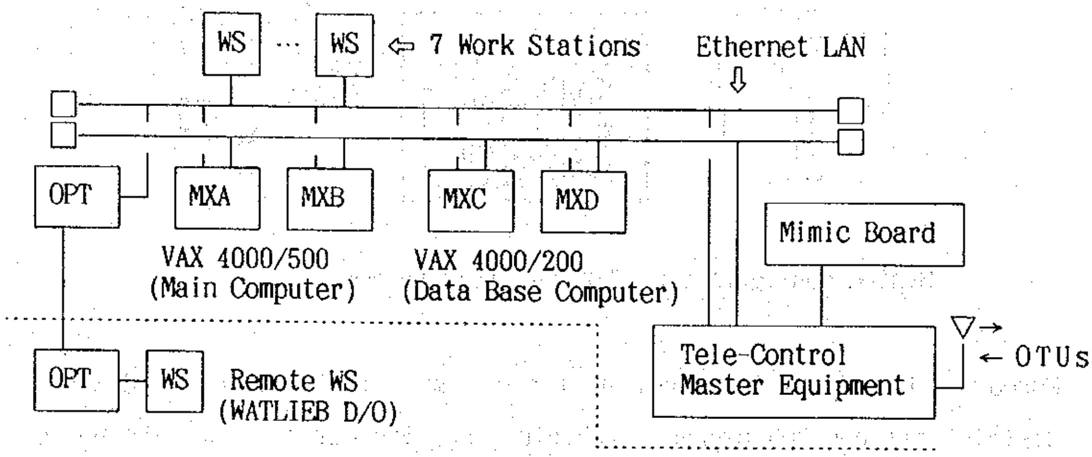
(2) Supervisory Control And Data Acquisition (SCADA) system of substations and telecommunication circuits of the SCADA system

(a) Outline of SCADA system

The load dispatching center of MEA located within the compound of Childom Substation is used to undertake operation of subtransmission lines, distribution lines and distribution substations within the territory of MEA.

Equipped with the mimic system board, load dispatching desk and load dispatching radio equipment in Item 3.3.6(1) above, the load dispatching center is undertaking constant monitoring of the conditions of circuit breakers, as well as voltage, current, etc. of subtransmission lines and substation buses according to the SCADA system regarding 67 substations excluding temporary substations among all of the 107 distribution substations.

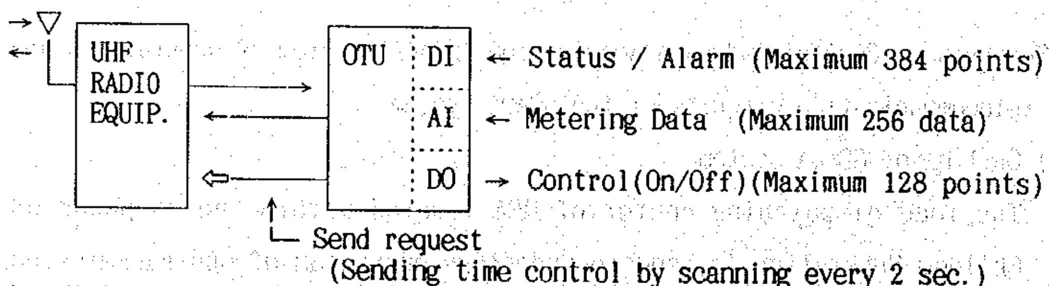
The master station of SCADA system is outlined in the diagram below:



SCADA system master station (Chidlom Load Dispatching Center)

The SCADA telecommunication system between the load dispatching center and respective substations consists of 24 UHF channels in total including 800 MHz band (16 channels) and 2,200 MHz band (8 channels), and the polling system, wherein one channel is used commonly for five substations in maximum, is adopted.

As SCADA equipment, the UHF radio equipment and RTU (Remote Terminal Unit) are installed on the substation side. The substation side equipment of SCADA system is outlined in the diagram below:



Note: Modulation Type: FSK (Frequency Shift Keying), 1,400bps for 800MHz
PSK (Phase Shift Keying), 1,200bps for 2,200MHz
(subcarrier frequency: 1,700Hz ; and interface: V.23)

SCADA system substation facilities

(b) Installation conditions of RTU

The present installation conditions of the SCADA system of MEA are as described below:

1) Terminal and switching stations

The RTUs have been installed in all of the 10 terminal stations and one switching station.

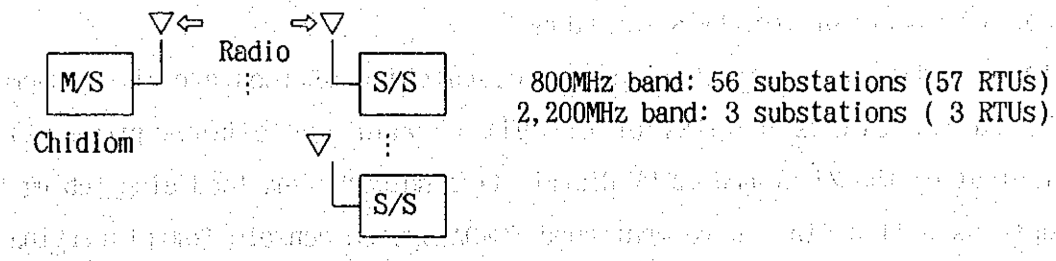
2) Distribution substations

The RTUs have been installed in 67 distribution substations (The RTUs are used commonly for terminal stations and switching station in nine substations among such distribution substations) out of 103 distribution substations. Meanwhile, most of the substations where any RTU has not been installed are so-called small (temporary) substations of one bank configuration.

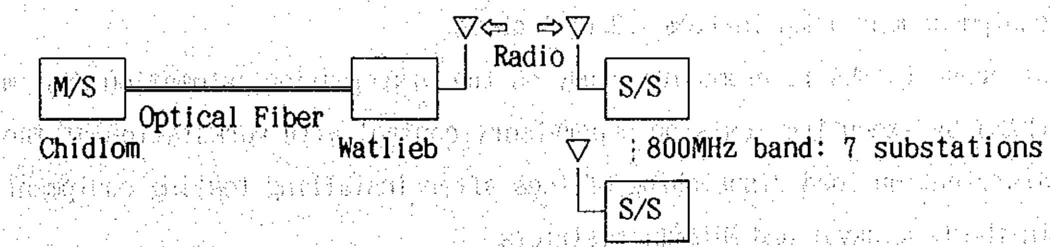
(c) Configuration system of SCADA telecommunication channels

Such systems as described below are applied for the SCADA telecommunication channel configuration. Out of such systems, those in Items 2) ~ 4) below are applied as countermeasures for preventing UHF radio channel wave interference resulting from increased high-rise buildings in the city center in recent years.

1) Link with radio directly from Chidlom master station

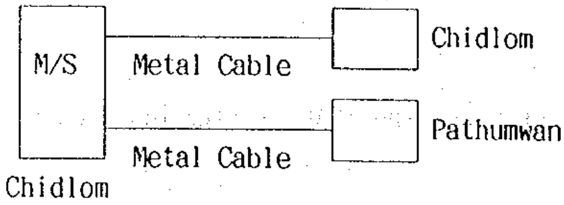


2) Link with optical fiber cable between Childom master station and Watlieb, and link with radio between Watlieb and respective substations

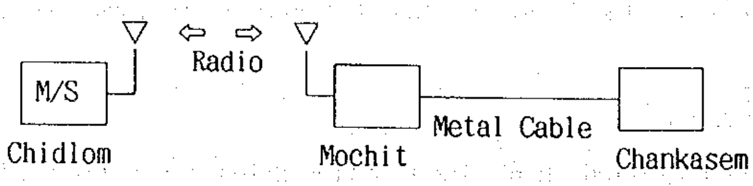


3) Use of metal wire

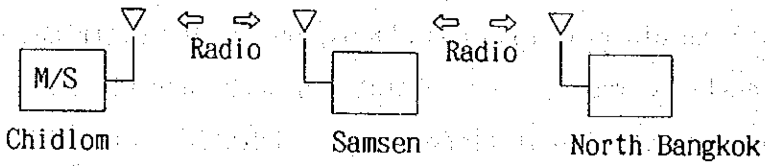
a) Link with metal cable directly from master station



b) Link with radio from master station and further with metal cable



4) Radio relay



(3) Outline of telecommunication equipment for distribution load dispatching office

For executing supervision and operation of 24 kV or lower voltage distribution lines as well as instruction for restoration at the time of power outage, two distribution load dispatching offices are located within the compound of Chidlom Substation (on the same first floor adjacent to the load dispatching center) to cover the southern and northern parts of the MEA's territory.

Installed in the distribution load dispatching offices are the system board (no status display of circuit breaker and other equipment) indicating the 24 kV and 12 kV distribution networks and load dispatching desk as well as the above-mentioned SCADA system console for clarifying the states of higher level power system to undertake telecommunication with patrol cars and service cars through dispatching VHF and UHF radio equipment mentioned in Item 3.3.6(1) above.

At present, MEA is promoting study on the Distribution Automation System (DAS) by executing tests on supervisory control with workstation at the distribution load dispatching offices after installing testing equipment in the Bangrakyai and Minburi Districts.

In the future, this Distribution Automation System (DAS) is scheduled to be introduced to all of the district offices successively according to the following schedule:

Present : Bangrakyai and Minburi (6 RTUs and one Master Station)

1995 : Rasburana (20 RTUs, Samsen (20 RTUs) and Klongtoey (20 RTUs)

1996 : Samut Prakarn, Yannawa and Bangkapi

1997 : (Next three district offices)

1998 : (Next three district offices)

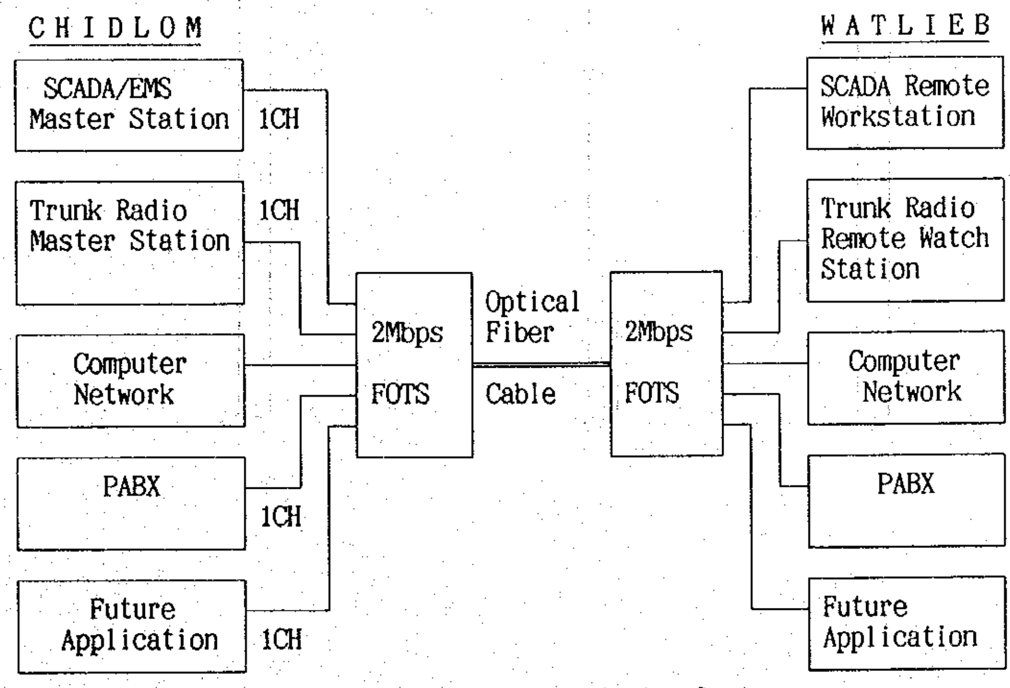
Meanwhile, the telecommunications channels for DAS are scheduled to be operated by using three talking groups of the trunk radio system in 1995, fiber optic transmission system in 1996 and both trunk radio system and fiber optic transmission system in combination after 1997.

The Distribution Automation System (DAS) is outlined in Figs. 3.3-4 and 3.3-5.

(4) Optical fiber cable telecommunication system

So far, the MEA has established the telecommunication channels for SCADA, trunk radio, computer network and telephone exchanges by means of an optical fiber cable telecommunication system of 2.048 Mbps between the Head Office at Ploenchit and Watlieb District Office.

This optical fiber cable telecommunication system is outlined in the diagram below:



FOTS: Fiber Optic Transmission System

Configuration of 2 Mbps optical fiber cable telecommunication system

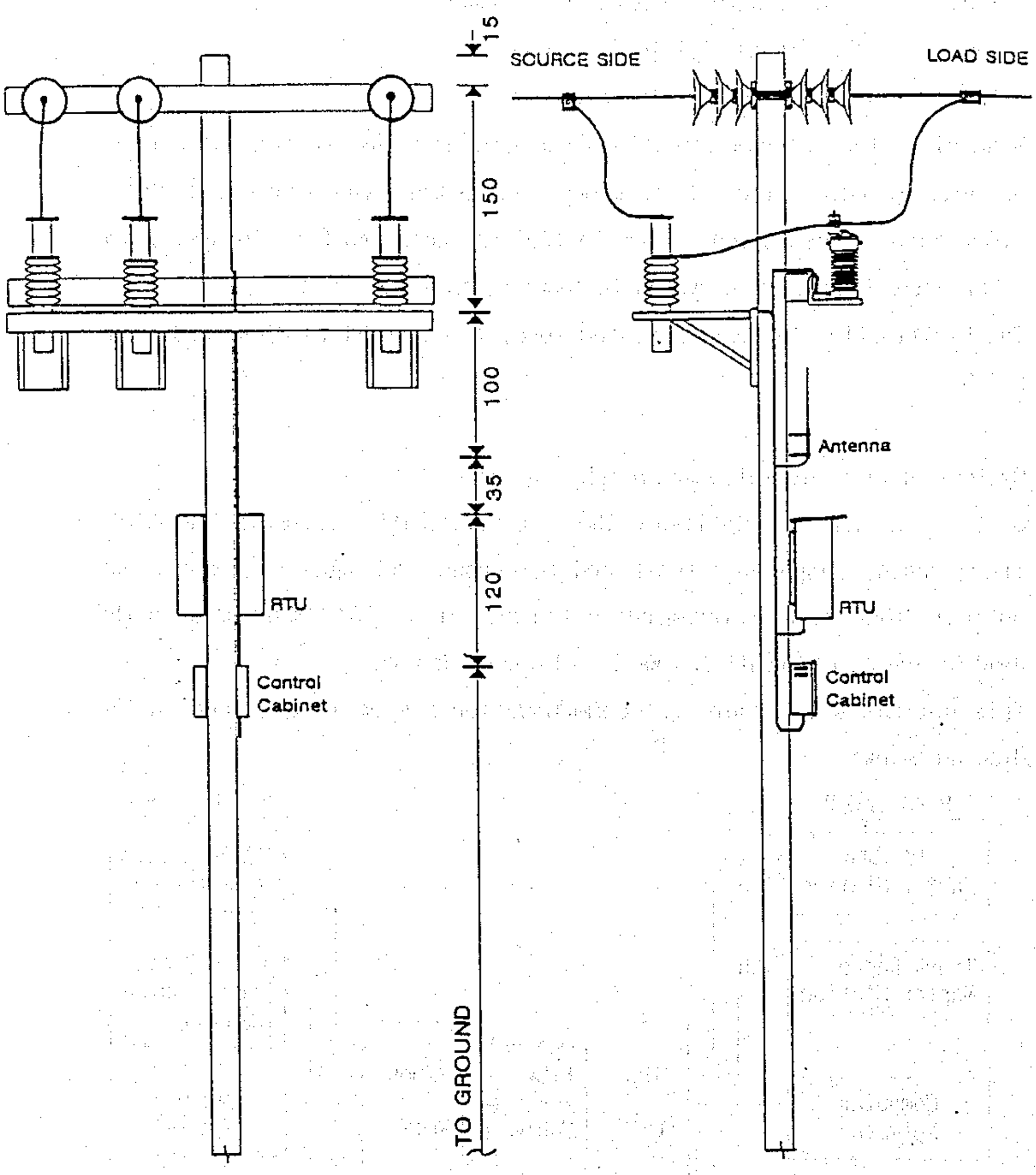


Fig. 3.3-10 Outline of DAS (Distribution Automation System)
Pole-Top RTU Installation Diagram

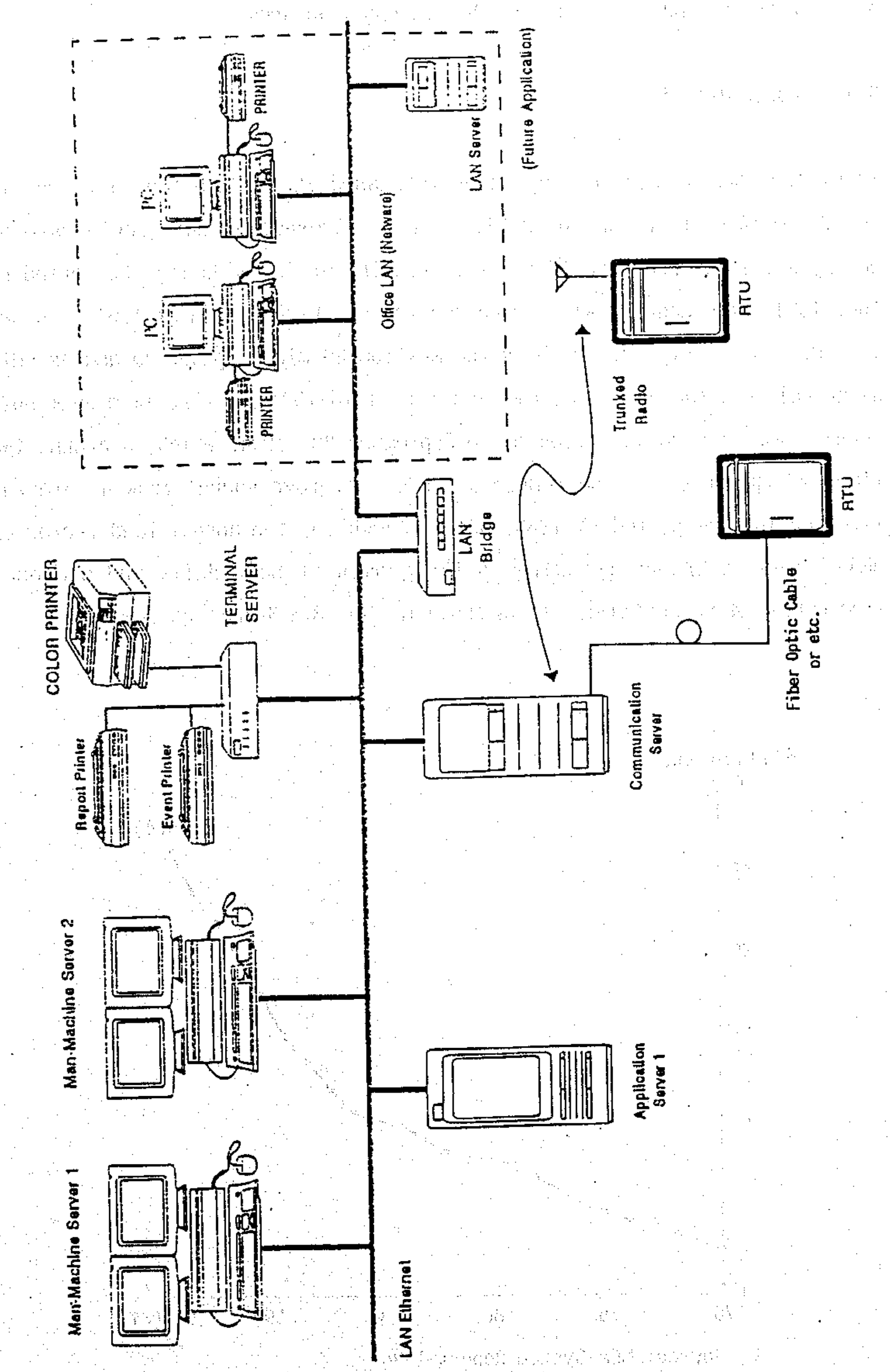
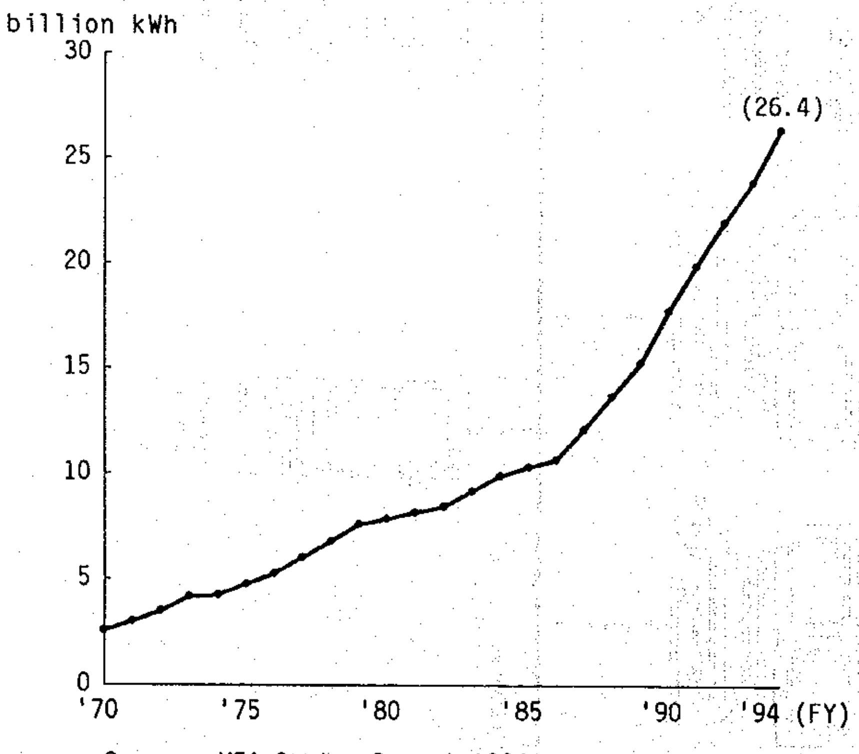


Fig. 3.3-11 Outline of DAS (Distribution Automation System) Hardware Configuration

3.4 Power Demand and Supply in the Metropolitan Area

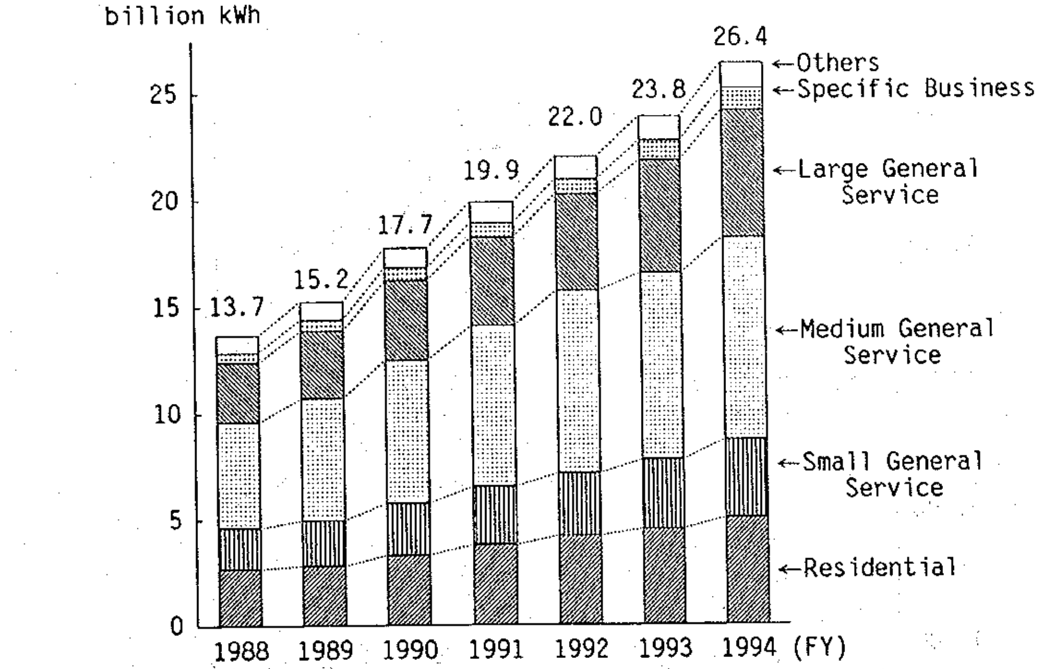
3.4.1 Power Demand

In FY 1994 MEA's total energy sales increased 10.6% from the last year to 26,369.83 GWh, as is shown in Fig. 3.4-1. Average annual growth rate of energy sales has been considerably increasing or 12.0% during the period FY 1987-1994. The energy sales by categories of customers in FY 1994 is shown in Fig. 3.4-2. Fig. 3.4-3 shows the maximum 30-minute power demand as well as annual load factor during the period FY 1970-1994. The maximum 30-minute power demand record was 4,755 MW on September 23, 1994, which is around two times of the record on September 5, 1988. Average annual growth rate was 11.8% during the period FY 1988-1994. Meanwhile, the annual load factor of MEA decreased gradually owing to the growth of both daily and seasonal fluctuation of power demand, as is shown in Fig. 3.4-4 and Fig. 3.4-5.



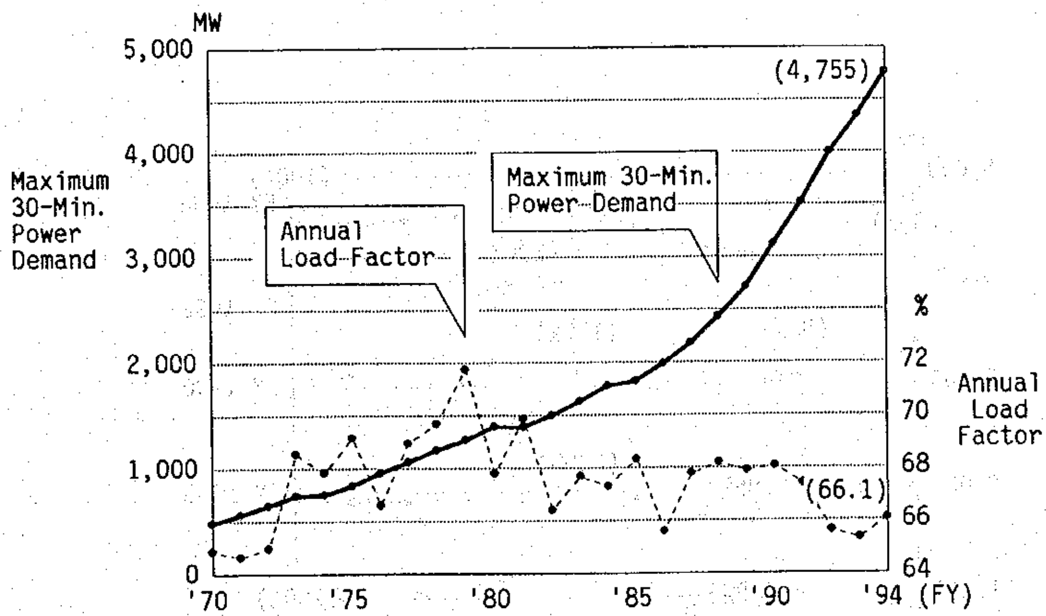
Source: MEA System Report 1994

Fig. 3.4-1 Trend of kWh Sales



Source: MEA Annual Report 1992-1994

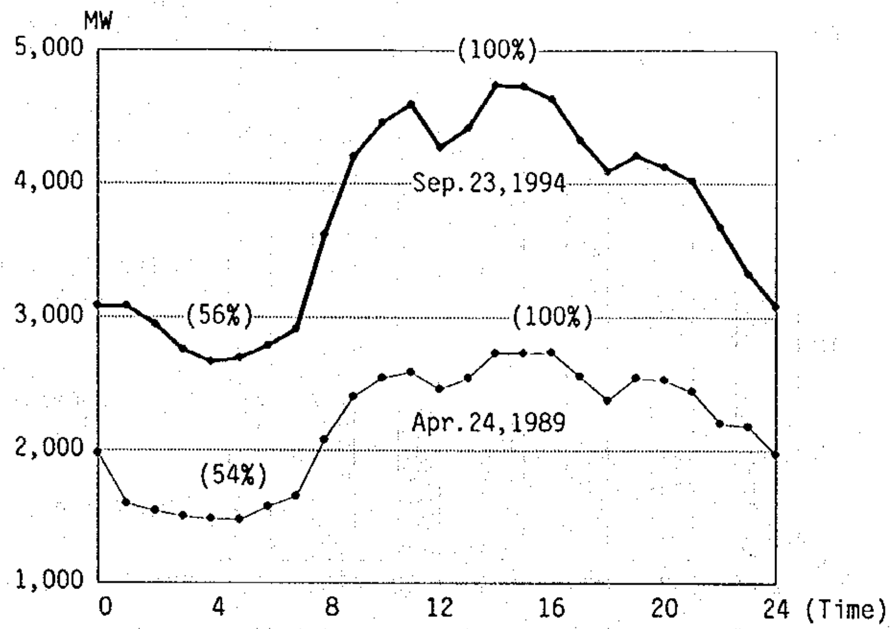
Fig. 3.4-2 Energy Sales by Customer Classification



$$\text{Annual Load Factor: } \frac{\text{Annual Electric Power Consumption}}{\text{Maximum 30-Minute Power Demand} \times 24(h) \times 365(d)}$$

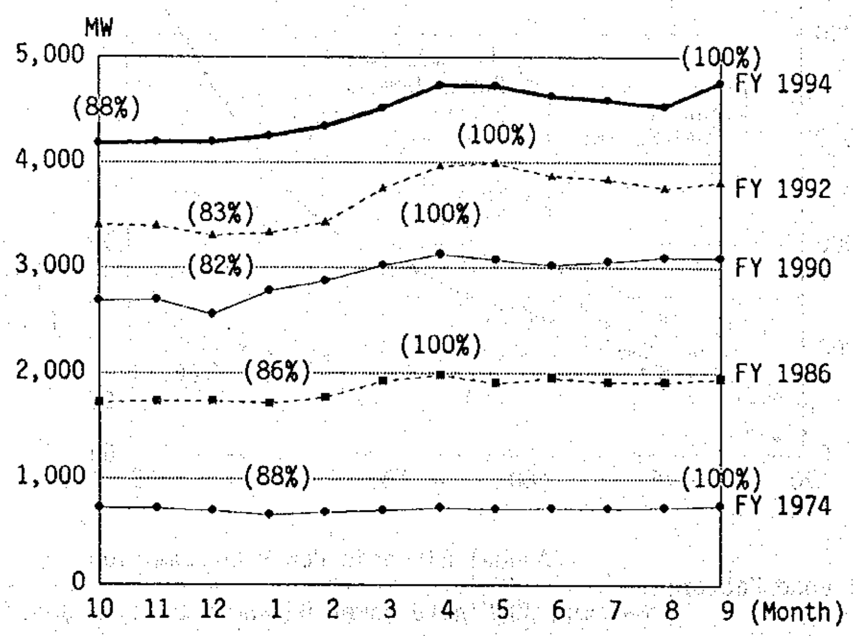
Source: MEA System Report 1994

Fig. 3.4-3 Maximum 30-Minute Power Demand and Annual Load Factor



Source: MEA System Report 1993,
MEA Monthly Report Sep.1994, etc.

Fig. 3.4-4 Daily Load Curves on Peak Day



Source: MEA Monthly Report Sep.1994

Fig. 3.4-5 Monthly System Peak Load

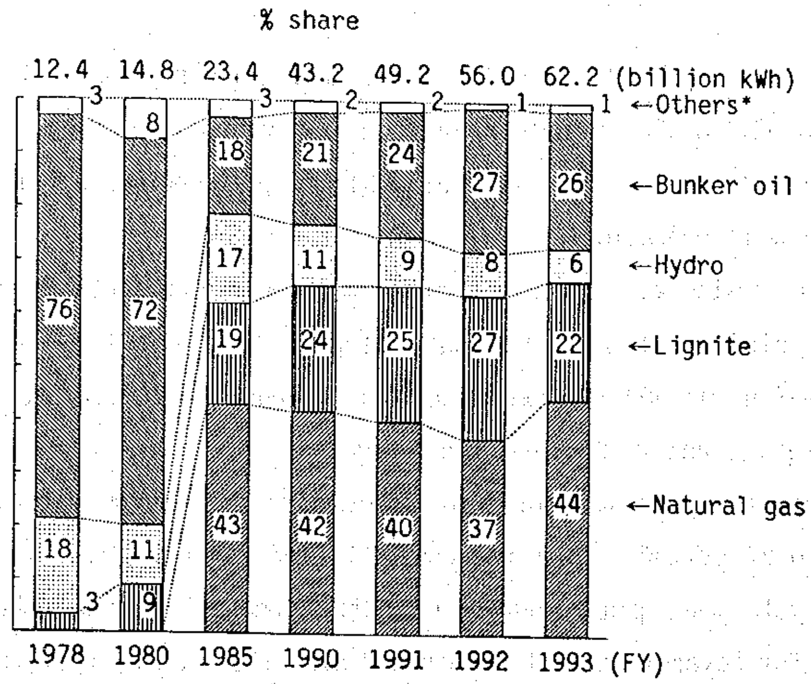
3.4.2 Power Supply

As is shown in Fig. 3.4-6, EGAT's total energy production in FY 1993 rose further to 62,181 GWh or 11% up over the previous year. Domestic energy resources namely natural gas, lignite and hydro provided approximately 72% of the total power generation.

The largest portion was obtained from thermal power plants utilizing different fuels comprising 44% from the natural gas, 22% from lignite, 26% from imported bunker oil and 1% from diesel oil. Minor shares were provided by 6% from hydro power and 1% from power purchase.

Significant escalation was noted for the energy share from natural gas which grew 33% to 27,523 GWh. This was caused by the commissioning of several new combined cycle power plants during FY 1993. Generation from bunker oil, the main fuel for several thermal plants and also the standby fuel for the gas-firing units, was also on a rise, yielding 15,921 GWh or 5% more than FY 1992. Unlike many past years, lignite-based generation dropped considerably by 8% to 13,831 GWh. The slowdown in this power source seems to be a result of the air quality problem.

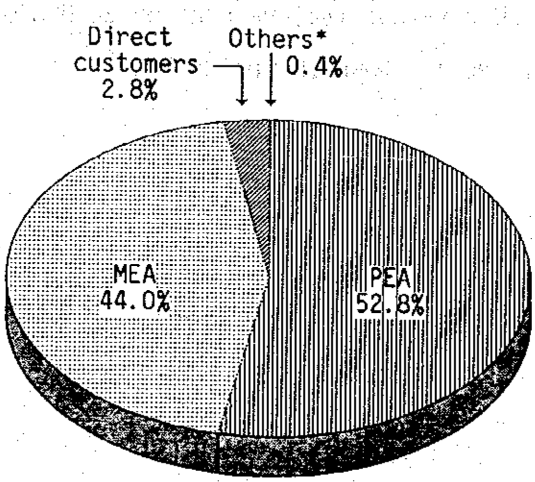
Incidentally, total electric energy sales for FY 1993 grew 11% from FY 1992 to 56,558 GWh following the fast growing demand. Nearly most of the energy sales was to MEA and PEA. Forty-four (44) percent or 24,873 GWh was sold to MEA, 8% more than last year, as is shown in Fig. 3.4-7.



Note : * Including Purchased, Diesel Oil and Alternative energy

Source: EGAT PDP 92-01(1)
EGAT Annual Report 1993

Fig. 3.4-6 EGAT Energy Generation by Type of Fuel



Note : * Including Electicite du Laos (EDL) and TNB - Malaysia

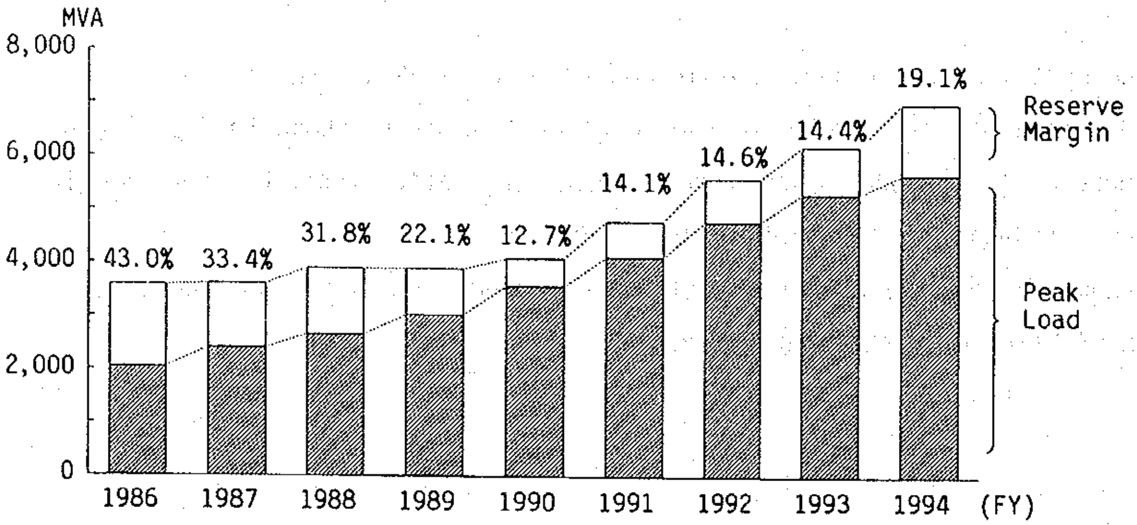
Source: EGAT Annual Report 1993

Fig. 3.4-7 EGAT Energy Sales for FY 1993

3.4.3 Power Demand and Supply Balance

The system annual reserve margin continued to go down year by year till FY 1990 from 43% in FY 1986 to the level of 12%, as is shown in Fig. 3.4-8, because of slowdown of new terminal station. After that, however, margin level recovered to the level of 19% in FY 1994.

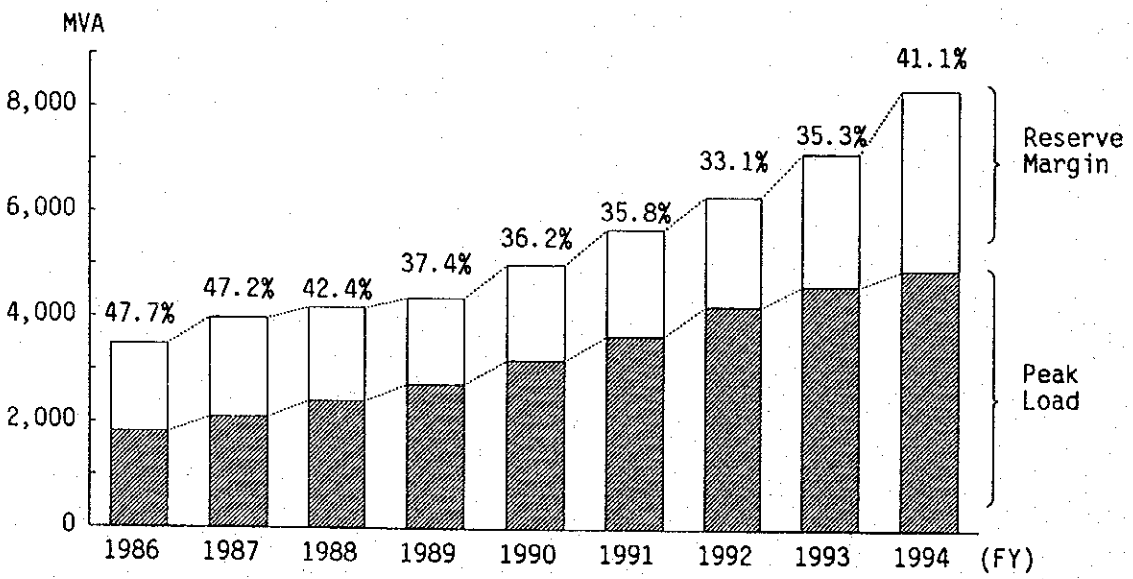
Meanwhile, reserve margin of distribution substations was 3,436 MVA or 41.1% in FY 1994, as is shown in Fig. 3.4-9.



$$\text{Reserve Margin} = \left(\frac{\text{T/S Capacity (MVA)}}{\text{Maximum System Load (MVA)}} - 1 \right) \times 100\ (\%)$$

Source: MEA System Report 1994

Fig. 3.4-8 System Annual Reserve Margin (at the time of load peak)



$$\text{Reserve Margin} = \left(\frac{\text{D/S Capacity (MVA)}}{\text{Maximum D/S Load (MVA)}} - 1 \right) \times 100\ (\%)$$

Source: MEA System Report 1994

Fig. 3.4-9 Distribution Substation Annual Reserve Margin (on the maximum demand peak day)

3.5 Electric Rate in the Metropolitan Area

The present MEA's electric rate applying to general household has been effective from December 1, 1991, same as those of PEA. The energy charge for residential and small general service is step-up and gradual increase system. Therefore, the more customer's energy consumption increases, the higher electric rate is.

Meanwhile, time zone rate system is applied to medium general service, large general service and specific business for the purpose of reducing peak demand and improving load factor.

MEA's electric rate system is shown as follows:

(1) Residential

(a) Consumption not exceeding 150kWh per month

Energy Charge:

First	5kWh or less	5.00 Baht
Next	10kWh (6kWh - 15kWh)	0.70 Baht/kWh
Next	10kWh (16kWh - 25kWh)	0.90 Baht/kWh
Next	10kWh (26kWh - 35kWh)	1.17 Baht/kWh
Next	65kWh (36kWh - 100kWh)	1.58 Baht/kWh
Next	50kWh (101kWh - 150kWh)	1.68 Baht/kWh
Next	250kWh (151kWh - 400kWh)	2.22 Baht/kWh
Over	400kWh	2.53 Baht/kWh

(b) Consumption exceeding 150kWh per month

Energy Charge:

First	35kWh or less	89.00 Baht
Next	115kWh (36kWh - 150kWh)	1.14 Baht/kWh
Next	250kWh (151kWh - 400kWh)	2.22 Baht/kWh
Over	400kWh	2.53 Baht/kWh

(2) Small General Service

Energy Charge:

First	35kWh or less	94.00 Baht
Next	115kWh (36kWh - 150kWh)	1.14 Baht/kWh
Next	250kWh (151kWh - 400kWh)	2.22 Baht/kWh

Over 400kWh 2.53 Baht/kWh

(3) Medium General Service

(a) Average consumption of the last 3 consecutive months does not exceed 355,000kWh per month ending with the current month.

1) 69kV and Over

Demand Charge: 188.00 Baht/kW

Energy Charge: 1.03 Baht/kWh

2) 12-24kV

Demand Charge: 210.00 Baht/kW

Energy Charge: 1.07 Baht/kWh

3) Below 12kV

Demand Charge: 237.00 Baht/kW

Energy Charge: 1.10 Baht/kWh

(b) Average consumption of the last 3 consecutive months ending with the current month exceeds 355,000kWh per month.

1) 69kV and Over

Demand Charge:

Peak	(06.30 PM - 09.30 PM)	240.00 Baht/kW
Partial Peak	(08.00 AM - 06.30 PM)	32.00 Baht/kW
Off-Peak	(09.30 PM - 08.00 AM)	-

Energy Charge: 1.03 Baht/kWh

2) 12-24kV

Demand Charge:

Peak	(06.30 PM - 09.30 PM)	305.00 Baht/kW
Partial Peak	(08.00 AM - 06.30 PM)	63.00 Baht/kW
Off-Peak	(09.30 PM - 08.00 AM)	-

Energy Charge: 1.07 Bhat/kWh

3) Below 12kV

Demand Charge:

Peak	(06.30 PM - 09.30 PM)	356.00 Baht/kW
Partial Peak	(08.00 AM - 06.30 PM)	73.00 Baht/kW
Off-Peak	(09.30 PM - 08.00 AM)	-

Energy Charge: 1.10 Bhat/kWh

(4) Large General Service

(a) 69kV and Over

Demand Charge:

Peak	(06.30 PM - 09.30 PM)	240.00 Baht/kW
Partial Peak	(08.00 AM - 06.30 PM)	32.00 Baht/kW
Off-Peak	(09.30 PM - 08.00 AM)	–

Energy Charge: 1.03 Bhat/kWh

(b) 12-24kV

Demand Charge:

Peak	(06.30 PM - 09.30 PM)	305.00 Baht/kW
Partial Peak	(08.00 AM - 06.30 PM)	63.00 Baht/kW
Off-Peak	(09.30 PM - 08.00 AM)	–

Energy Charge: 1.07 Bhat/kWh

(5) Specific Business

(a) Normal Rate

1) 69kV and Over

Demand Charge: 236.00 Baht/kW

Energy Charge: 1.03 Baht/kWh

2) 12-24kV

Demand Charge: 274.00 Baht/kW

Energy Charge: 1.07 Baht/kWh

3) Below 12kV

Demand Charge: 296.00 Baht/kW

Energy Charge: 1.10 Baht/kWh

(b) Time of Day Rate

1) 69kV and Over

Demand Charge:

Peak	(06.30 PM - 09.30 PM)	240.00 Baht/kW
Partial Peak	(08.00 AM - 06.30 PM)	32.00 Baht/kW
Off-Peak	(09.30 PM - 08.00 AM)	–

Energy Charge: 1.03 Baht/kWh

2) 12-24kV

Demand Charge:

Peak	(06.30 PM - 09.30 PM)	305.00 Baht/kW

Partial Peak (08.00 AM - 06.30 PM) 63.00 Baht/kW

Off-Peak (09.30 PM - 08.00 AM) —

Energy Charge: 1.07 Baht/kWh

3) Below 12kV

Demand Charge:

Peak	(06.30 PM - 09.30 PM)	356.00 Baht/kW
Partial Peak	(08.00 AM - 06.30 PM)	73.00 Baht/kW
Off-Peak	(09.30 PM - 08.00 AM)	—

Energy Charge: 1.10 Baht/kWh

(6) Government Institutions and Non-Profit Organizations

(a) 69kV and Over

Energy Charge:

First 10,000kWh or less	14,800.00 Baht
Over 10,000kWh	1.48 Baht/kWh

(b) 12-24kV

Energy Charge:

First 300kWh or less	495.00 Baht
Over 300kWh	1.65 Baht/kWh

(c) Below 12kV

Energy Charge:

First 10kWh or less	18.70 Baht
Over 10kWh	1.87 Baht/kWh

(7) Agricultural Pumping

Energy Charge:

First 100kWh or less	117.00 Baht
Over 100kWh	1.17 Baht/kWh

Incidentally, automatic adjustment clause can be charged in addition to the above mentioned rate from September, 1992. If there should be any change in expenses beyond control by the public utility such as the fluctuation of fuel cost etc., adjustment will be made automatically and customers will be asked for payment in the electric bill.

Concerning this adjustment rate, the Energy Adjustment Subcommittee (EASC), which is set up in Energy Policy Committee (EPC) situated in the National Energy Policy Committee (NEPC) is held every month, making evaluation based on the index of three months ago. EASC evaluates PEA's electric rate and adjustment amount of purchasing price from EGAT simultaneously.

Automatic Adjustment Rate for MEA

Year/Month		MEA-Customers (Baht/kWh)	EGAT-MEA (Baht/kWh)
1992	Sep	0.0617	0.0587
	Oct	0.0617	0.1182
	Nov	0.0617	0.0914
	Dec	0.0617	0.1064
1993	Jan	0.0839	0.0951
	Feb	0.0839	0.0912
	Mar	0.0839	0.1133
	Apr	0.0532	0.0930
	May	0.0532	0.1128
	Jun	0.0532	0.1119
	Jul	0.0324	0.0618
	Aug	-0.0186	0.0760
	Sep	-0.0186	0.0353
	Oct	-0.0186	0.0265
	Nov	-0.0186	0.0271
	Dec	-0.0186	0.0258
1994	Jan	0.0691	0.0890
	Feb	0.0691	0.0859
	Mar	0.0356	0.0746
	Apr	0.0036	0.0469
	May	0.0953	0.1270
	Jun	0.0280	0.1102
	Jul	0.0280	0.0615
	Aug	-0.0053	0.0849
	Sep	0.0750	0.0125
	Oct	0.0750	0.1058
	Nov	0.0750	0.1128

Rate adjustment between MEA and customers will be made if and only if the difference between the applied rate of last month and evaluated rate of this month is over 0.02 Baht per kWh. The same rate applies to PEA.

With regard to between MEA and EGAT, payment will be made adding the whole adjustment rate to 1.4682 Baht per kWh. Incidentally, adjustment rate between PEA and EGAT is evaluated independent of the above table.

The average purchasing price from EGAT was 1.4460 Baht/kWh in FY 1994 against 1.4637 Baht/kWh FY 1993 and decrease of 1.77 Stang (100 Stang are equivalent to 1 Baht) or 1.21%. The average selling price of MEA for customer in FY 1994 was 177.20 Stang/kWh. The figures decreased from 177.66 Stang/kWh in FY 1993 by around 0.46 Baht/kWh or 0.26%.