7.2 Substation Facility Plan

7.2.1 Current Status of Substation Facilities

The current status, progress of construction, and the current utilization factors of the substations in the Project Area are presented in Table 7-5, Table 7-6 and Table 7-7 respectively.

The standard voltage classes adopted by ANDE are 220 kV, 66 kV and 23 kV, and the power systems are operated at 50 Hz.

(1) As of the end of 1988, there are 9 substations in the Project Area. These substations consist of three, 220 kV substations (to be termed the primary substations) and six, 66 kV substations (to be termed the secondary substations). Distribution transformers are also installed in all primary substations.

The construction works for 220 kV Limpio Substation and Puerto Botanico Substation are under progress, and these substations are expected to be completed by 1990.

As of the end of 1988, there are 19 transformer banks, with the total installed capacity of 661.5 MVA in these substations in the Project Area.

The total supply capabilities of these substations are 277.5 MVA on the 66 kV side and 384 MVA on the 23 kV side.

The content of these facilities is presented in the table below.

Voltage (kV)	Number of Banks	Installed Capacity (MVA)	Supply Capacity (MVA)	
			66 kV	23 kV
220/66/23	2	240/120/120	120.0	120.0
220/66	3	157.5	157.5	
220/23	1	40.0		40.0
66/23	13	224.0		224.0
Total	19	661.5	277.5	384.0

The unit capacity of transformer bank is standardized to 37.5, 60 and 120 MVA for the 220 kV system transformers, and 10, 12, 20, 40 and 60 MVA for the distribution transformers. The 120 MVA banks (for system transformers) and 20 MVA banks (for distribution transformers) are most commonly used. Most of the system transformer banks consist of single phase transformers.

The system transformers are standardized to have Y-Y connection. For distribution transformers, the transformers at San Lorenzo and Jardin Botanico Substations have Y-Y connection, those at Lambare Substation have Y-Y-Δ connection, and those in other substations have Δ-Y connection.

(2) The average utilization factor of substations in the Project Area in 1988 was 62.8% for 220 kV transformers, and 73.3% for distribution transformers.

Most of the substations in the Project Area were constructed in 1968, and the additional supply capacity thereafter has been created by expanding these substations. Therefore, all secondary substation inside the City have 2 transformer banks, and their utilization factors are high. Recently, Centro Substation was constructed in the urban center, and large distribution transformers were installed at Lambare Substation. Although this helped to reduce the average utilization factor, the current status is such that certain substations in urban center are overloaded, while the utilization factor of Lambare Substation is low.

(3) The average power factor of substations in the Project Area in 1988 was 92.9% on the 66 kV side and 89.4% on the 23 kV side.

The phase compensation capacitors are installed in 6 substations out of 9 substations in the Project Area. The total installed capacity of these capacitors is 178 MVAR, composed of 100 MVAR (25 MVAR x 4) at 66 kV busses and 78 MVAR (12 MVAR x 2, 6 MVAR x 8 and 3 MVAR x 2) on the 23 kV busses.

(4) The configuration of 220 kV busses in substations in the Project Area, including those under construction, are double bus system with one bus tie, with the exception of Lambare Substation which has a single bus design.

The 66 kV bus configuration is double bus system with one bus tie at all of 6 substations. 23 kV bus configuration is single bus system, with the exception of San Miguel Substation and a part of Puerto Sajonia Substation, where the double bus system is adopted.

The 220 kV and 66 kV circuit breakers have been replaced recently to gas circuit breakers, although some old oil circuit breakers are still in use. Gas circuit breakers are used in substations which have been newly constructed or expanded.

The rupturing capacity of circuit breakers is standardized to 31.5 kA for 220 kV, 12.5 kA for 66 kV, and 8 kA for 23 kV breakers. Some old circuit breakers do not meet these standard values.

For power system protection, distant relay systems (LZ32 and LI41a of BBC Corporation) are used for 220 kV and 66 kV transmission lines and the ground overcurrent relay systems are used for distribution line protection. For transformer protection, electrical protection systems, such as ratio differential relays and overcurrent relays, are provided in addition to mechanical protection systems.

(5) All substations in the Project Area are attended by operators, and they are constantly monitored and controlled by three shift

crews. The records of voltage, current, power, etc. are registered in every hour to the operation logs.

7.2.2 Basic Plan

The electric energy consumption in the Project Area is expected to grow to approximately 2,776 GWh by year 2000, with the maximum demand of approximately 674 MW, which will be around 3 times the values in 1988.

In dealing with this expected growth of power demand in the Project Area, it is required to expand and improve the existing primary and secondary substations, and implement a comprehensive power system expansion program for the Project Area including construction of new primary and secondary substations.

The JICA Study Team had formulated two alternative plans and hold reviews and discussions with ANDE. In Alternative-1, it was conceived to introduce the 220 kV transmission lines to the centers of the Metropolitan Area, to supply power to the secondary substations from primary substations through 220/66/23 kV transformer banks, and also to provide direct power distribution from the primary substations in urban center. In Alternative-2, it was conceived to expand and strengthen the 66 kV transmission line to supply power to the center of Metropolitan Area and assure demand/supply balance in the substations systems of Metropolitan Area.

These two alternatives were presented to ANDE in the interim report, and it was decided in the meeting with ANDE to revise Alternative-1 and continue the study based on this revised plan. (Alternative-3)

The study and analysis conducted on Alternative-3 are presented in Section 5.2.6 of Chapter 5.

7.2.3 Basic Provisions

The following provisions have been set down in developing the substation expansion/construction plan based on the power demand projection for the year 2000 in the Project Area.

(1) The substations are to be designed according to the facility operation standard of ANDE.

(2) The bus system of the new substations, both primary and secondary substations (except for 66 kV side of A substation and K substation for which compact system is adopted), shall be the double bus with one bus tie system.

(3) The adoption of SF6 gas insulated, compact substation has been considered in view of site constraint and urban scenery.

However, conventional substation design has been selected, except for the K substation and the 66 kV side of A Substation, in view of ANDE's request and the high investment cost required for the gas insulation system.

(4) In designing the insulation coordination, it was first attempted to provide lightning protection on all sections of busses with limited number of lightning arresters which are located rationally on the busses and with top priority placed on transformer protection. However, it was found out that the lightning stroke frequency (IKL) is very high (about 60), and the equipments in transmission line bays are most vulnerable to incoming surges. Therefore, it was decided to provide lightening arresters on all 220 kV and 66 kV incoming lines.

(5) As the substations are not located in polluting areas, the industrial pollution, atmospheric pollution and salt pollution on the substation equipments in the Project Area are not considered.

(6) The main transformer capacity and the main transformer specification shall be standardized to those installed in existing substations, to facilitate utilization of spare transformers.

When 220/66/23 kV, three-winding transformers are used in primary substations, the transportation limit on the weight must be taken into account. In view of the fact that the largest unloading equipment owned by ANDE for the transportation on Rio de Paraguay is a 50 ton crane, the maximum transportation weight was set at 50 tons.

(7) The control systems used in the secondary substation shall be such that they can be converted to un-manned substations in future and remotely operated.

7.2.4 Substation Conceptual Designs

The new substations are standardized in accordance with the power facility standard of ANDE. It has been estimated that a minimum horizontal space of 150 m x 120 m = 18,000 m^2 is required for the primary substation, and a minimum space of 60 m x 60 m = 3,600 m^2 for the secondary substation. Candidate sites for substations were looked for in the Project Area based on these minimum spaces, and conceptual designs were developed.

The new substations to be constructed up to 2000 is given in Table 7-8, and the expansion plan up to 2000 is given in Table 7-9.

The plan for construction of substation has been developed as described below.

(1) Primary Substation-A

This substation is planned at the old soccer field at Barrio Obrero of Asuncion City.

The site area is 120 m x 90 m = 10,800 m^2, which is smaller than the minimum land area of 18,000 m^2. Since it was impossible to adopt the conventional design of with 220 kV double bus and 66 kV double bus configuration, the SF6 gas insulated compact substation was adopted for the 66 kV bus only. It was also decided to adopt a special three phase design for the 220/66/23 kV transformers (a design by which the transformer can be divided into three sections for transportation) instead of the standard, single phase design.

The general arrangement plan of this substation is presented in Figure 7-11, general arrangement section in Figure 7-12, and the single line diagram in Figure 7-13.

(2) Primary Substation-B

This substation has been planned on a part of land space available at a park (Parque Caballero) at San Blas of Asuncion City. The land area that can be obtained exceeds 150 m x 120 m = 18,000 m^2, and the substation can be designed with conventional 220 kV and 66 kV bus configurations.

The special three phase transformers (divided into three during transportation) have been adopted to reduce the size.

The general arrangement plan of this substation is presented in Figure 7-14, the general arrangement section in Figure 7-15, and the single line diagram in Figure 7-16.

(3) Secondary Substation-E

This substation is planned at a site available at Villa Aurelia in Asuncion City.

There is no problem with equipment layout because a land area of 97 m x 78 m = 7,566 m^2 can be secured.

The general arrangement plan of this substation is presented in Figure 7-17, the general arrangement section in Figure 7-18, and the single line diagram in Figure 7-19.

(4) Secondary Substation-F

This substation is planned at a site at Hipodrome in Asuncion City.

There is no problem with equipment layout because a land area of 150 m x 72m = 10,800 m^2 can be secured.

The general arrangement plan of this substation is presented in Figure 7-20, the general arrangement section in Figure 7-21, and the single line diagram in Figure 7-22.

(5) Secondary Substation-G

This substation planned on the land at Dr. Francia of Asuncion City which will become vacant after ANDE's Distribution Dispatching Center and Distribution Equipment Test Center move out.

The facility of this substation will be constructed from January, 1995. The Distribution Dispatching Center and Distribution Equipment Test Center of ANDE must move out by the end of 1994.

The land area available will be 5,251 m^2. There is difference of land level in the site, requiring land preparation work. This, however, does not present problem against equipment layout of the substation.

The general arrangement plan of this substation is presented in Figure 7-23, the general arrangement section in Figure 7-24, and the single line diagram in Figure 7-25.

(6) Secondary Substation-K

This substation is planned on a land at Catedral of Asuncion City.

The land area available is 57 m x 42 m = 2,394 m^2, which is short of 3,600 m^2. It is not possible to design a conventional substation with 66 kV double bus configuration.

This substation is planned with a compact design employing SF6 gas insulation system, although a substation of a conventional design may be constructed if an alternative site, with 60 m x 60 m land area or more, is found by ANDE. In the current design, the 66 kV bus is designed with a single bus configuration in order to reduce the construction cost.

The general arrangement plan and section of this substation is presented in Figure 7-26, and the single line diagram in Figure 7-27.

(7) Secondary Substation-L

This substation is planned on a land available at Pinoza of Asuncion City.

There is no constraint on the equipment layout since a land, 73 m x 64 m = 4,672 m^2 in area, will be secured.

The general arrangement plan of this substation is presented in Figure 7-28, the general arrangement section in Figure 7-29, and the single line diagram in Figure 7-30.

(8) Expansion of Existing Substations

As illustrated in Table 7-9, a total of 7 substations, including the primary substations of Limpio, Puerto Botanico, Guarambare, San Lorenzo, and the secondary substations of Puerto Sajonia, San Miguel, Barrio Parque and Centro, will be expanded.

The equipment specifications and equipment layouts are selected similarly to the existing substations.

The general arrangement plan, general arrangement section, and the single line diagram of expansion work of each substation are presented in Figure 7-31 through Figure 7-47.

7.2.5 Substation Buildings

The substation buildings will be constructed with reinforced concrete structures, their walls being covered with bricks, and the building foundations will be supported by piles if required by the result of soil survey at the sites. The roof slabs will be performed asphalt water proof, and provided with metal plate non-structural roofs to protect the building from sunshine heat.

The windows exposed to sunshine shall be provided with movable vertical louvers or movable horizontal louvers, or other devices to evade the sunshine, as appropriate, fixed on the outside of windows.

The building dimensions shall be appropriately decided in reference to the attached drawings (Fig. 7-48 and Fig. 7-49), and the

Table 7-5 Main Substations in the Project Area

System		Substation		Transformer			Capacity		23 kV Line of Circuit	Year of Completion
				Voltage (kV)	Unit Capacity x Bank (MVA)	Component (Phase x Amount)	220kV	23kV		
Metro-politan Area	Project Area	San Lorenzo	SLO	220/66 220/23	60 x 2 40 x 1	1 x 3 x 2 3 x 1	120 40	40	8	1968
		Lambare	LAM	220/66/23	120/60/60 x 2	1 x 3 x 2	240	120	9	1968
		Guarambare	GUA	220/66 66/23	37.5 x 1 20 x 1	1 x 3 x 1 3 x 1	37.5	20	4	1981
		Puerto Sajonia	PSA	66/23	20 x 2	3 x 2		40	5	1968
		San Miguel	SMI	66/23	20 x 2	3 x 2		40	5	1968
		Barrio Parque	BPA	66/23	20 x 2	3 x 2		40	7	1968
		Jardin Botanico	JBO	66/23	12 x 2	3 x 2		24	5	1968
		Tres Bocas	TBO	66/23	10 x 2	3 x 2		20	4	1979
		Centro	CEN	66/23	20 x 2	3 x 2		40	4	1987
		Sub-Total			661.5			384	51	
	Other Area	Itaugua	ITG	66/23	20 x 1	3 x 1		20		1973
		Caacupe	CAE	66/23	12 x 1	3 x 1		12		1973
		Paraguari	PAR	66/23	9 x 1	3 x 1		9		1973
		Caapucu	CAU	66/23	5 x 1	3 x 1		5		1973
		Quiindy	QUI	66/23	5 x 1	3 x 1		5		1987
		Sub-Total		66/23	51.0			51		
		Total			712.5		437.5	435		

Table 7-6 Substations under Construction

System	Substation	Transformer		Capacity (MVA)		23 kV Line of Circuit	Expected Year of Completion
		Voltage (kV)	Unit Capacity x Bank (MVA)	220 kV	23 kV		
Metropolitan System	Limpio	220/66 66/23	37.5 x 1 20 x 1	37.5	20	4	1990
	Puerto Botanico	220/66/23	120/60/60 x 1	120	60	7	1990
Southern System	Paranambu	220/23	10 x 1	10	10	3	1990
	Natario	220/23	10 x 1	10	10	3	1990
Eastern System	Itakuyry	220/66/23	25/15/15 x 1	25	15	3	1990

Table 7-7 Rate of Utilization of Substations (1988)

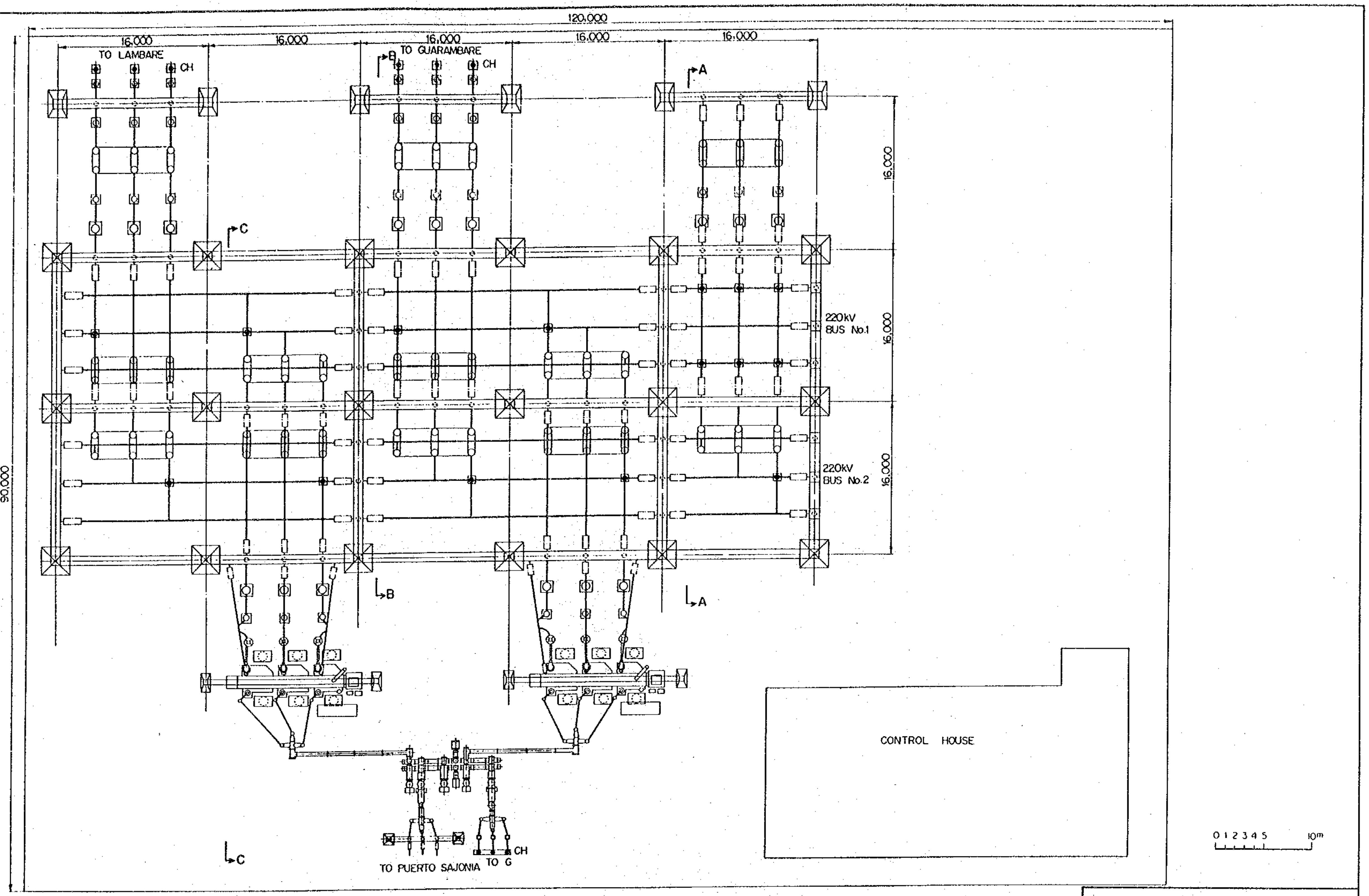
System		Substation		Capacity (MVA)		Maximum Power (MW)		Maximum Power (MVA)		Rate of Utilization (%)		Power Factor (%)	
				220kV	23kV	220kV	23kV	220kV	23kV	220kV	23kV	220kV	23kV
Metro-politan Area	Project Area	San Lorenzo	SLO	160	40	134.3	33.0	146.0	34.7	91.3	86.8	92.0	95.1
		Lambare	LAM	240	120	108.0	42.0	113.7	45.2	47.4	37.7	95.0	92.9
		Guarambare	GUA	37.5	20	13.1	13.1	15.2	15.2	40.5	76.0	86.2	86.2
		Puerto Sajonia	PSA		40		27.1		29.8		74.5		90.9
		San Miguel	SMI		40		32.9		38.7		96.8		85.0
		Barrio Parque	BPA		40		34.7		37.7		94.3		92.0
		Jardin Botanico	JBO		24		22.4		27.7		115.4		80.9
		Tres Bocas	TBO		20		22.2		23.1		115.5		96.1
		Centro	CEN		40		24.3		29.3		73.3		82.9
	Sub Total				384		251.7		281.4		73.3		
	Other Area	Itaugua	ITG		20		15.8		18.6		93.0		84.9
		Caacupe	CAE		12		7.1		8.4		70.0		84.5
		Paraguari	PAR		9		4.2		4.9		54.4		85.7
		Caapucu	CAU		5		1.7		2.0		40.0		85.0
		Quiindy			5		3.8		4.5		90.0		84.4
	Sub Total				51		32.6		38.4		75.3		
Total				437.5	435	255.4	284.3	274.9	319.8	62.8	73.5		

Table 7-8 Installment Plan of New Substations Equipment in 2000

Substation			Installment Plan	
	Site	Name or Place	Transformer Capacity	Line Equipment
New	A	Barrio Obrero ($10,800\ m^2$)	220/66/23 kV 99/60/39 MVA x 2	220 kV, 2 cct 66 kV, 2 cct
New	B	San Blas (Parque Caballero) ($18,000\ m^2$)	220/66/23 kV 99/60/39 MVA x 2	220 kV, 2 cct 66 kV, 2 cct
New	E	Villa Aurelia ($7,566\ m^2$)	66/23 kV 20/20 MVA x 2	66 kV, 2 cct
New	F	Hipodromo ($10,800\ m^2$)	66/23 kV 20/20 MVA x 2	66 kV, 2 cct
New	G	DR. Francia ($5,251\ m^2$)	66/23 kV 20/20 MVA x 3	66 kV, 3 cct
New	K	Catedral ($2,394\ m^2$)	66/23 kV 20/20 MVA x 3	66 kV, 2 cct
New	L	Pinoza ($4,672\ m^2$)	66/23 kV 20/20 MVA x 3	66 kV, 2 cct

Table 7-9 Expansion Plan of Existing Substation Equipment in 2000

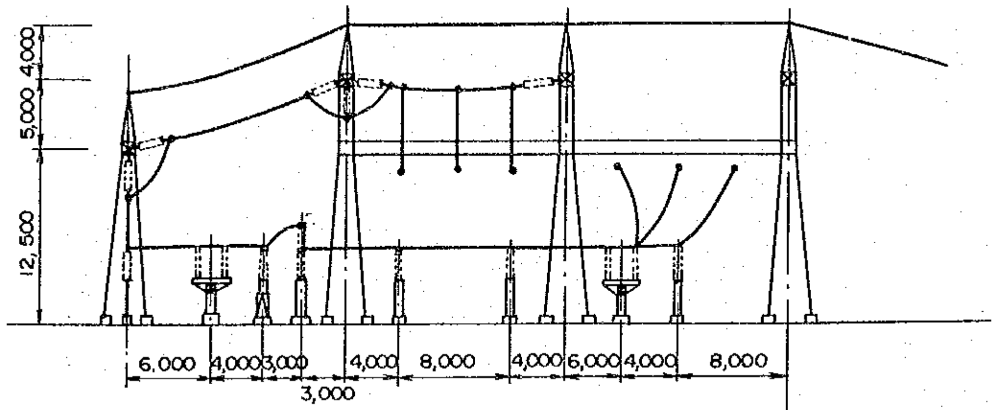
Substation			Installment Plan	
	Site	Name or Place	Transformer Capacity	Line Equipment
Existing	PBO	Puerto Botanico	220/66/23 kV 120/60/60 MVA x 1	220 kV, 3 cct 66 kV, 1 cct
Existing	PSA	Puerto Sajonia	66/23 kV 20/20 MVA x 1	-
Existing	SMI	San Miguel	66/23 kV 20/20 MVA x 1	-
Existing	BPA	Barrio Parque	66/23 kV 20/20 MVA x 1	66 kV, 2 cct
Existing	GRA	Guarambare	220/66 kV 37.5/37.5 MVA x 1 66/23 kV 20/20 MVA x 1	-
Existing	LIM	Limpio		220 kV, 1 cct
Existing	SLO	San Lorenzo	220/23 kV 40/40 MVA x 1	-



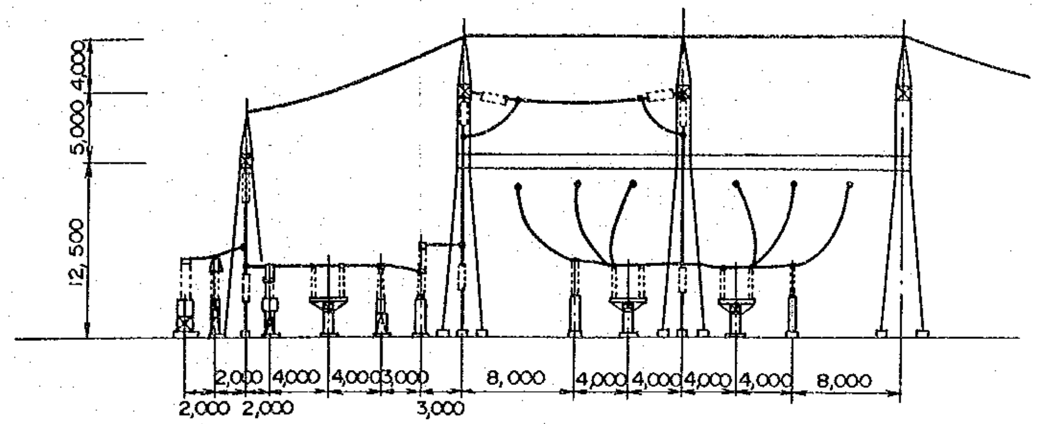
POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRAGEMENT PLAN
(A. SUBSTATION)

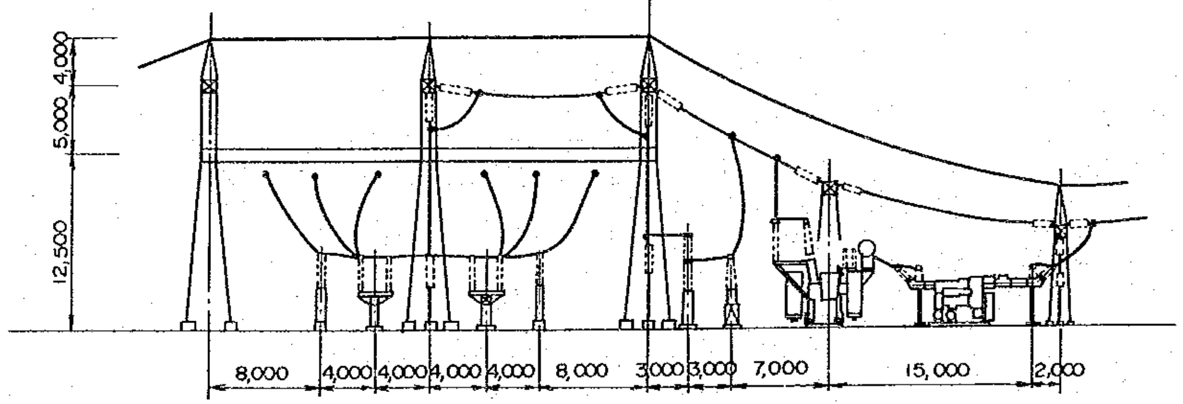
Fig. 7 - 11



SECTION A – A



SECTION B – B



SECTION C – C

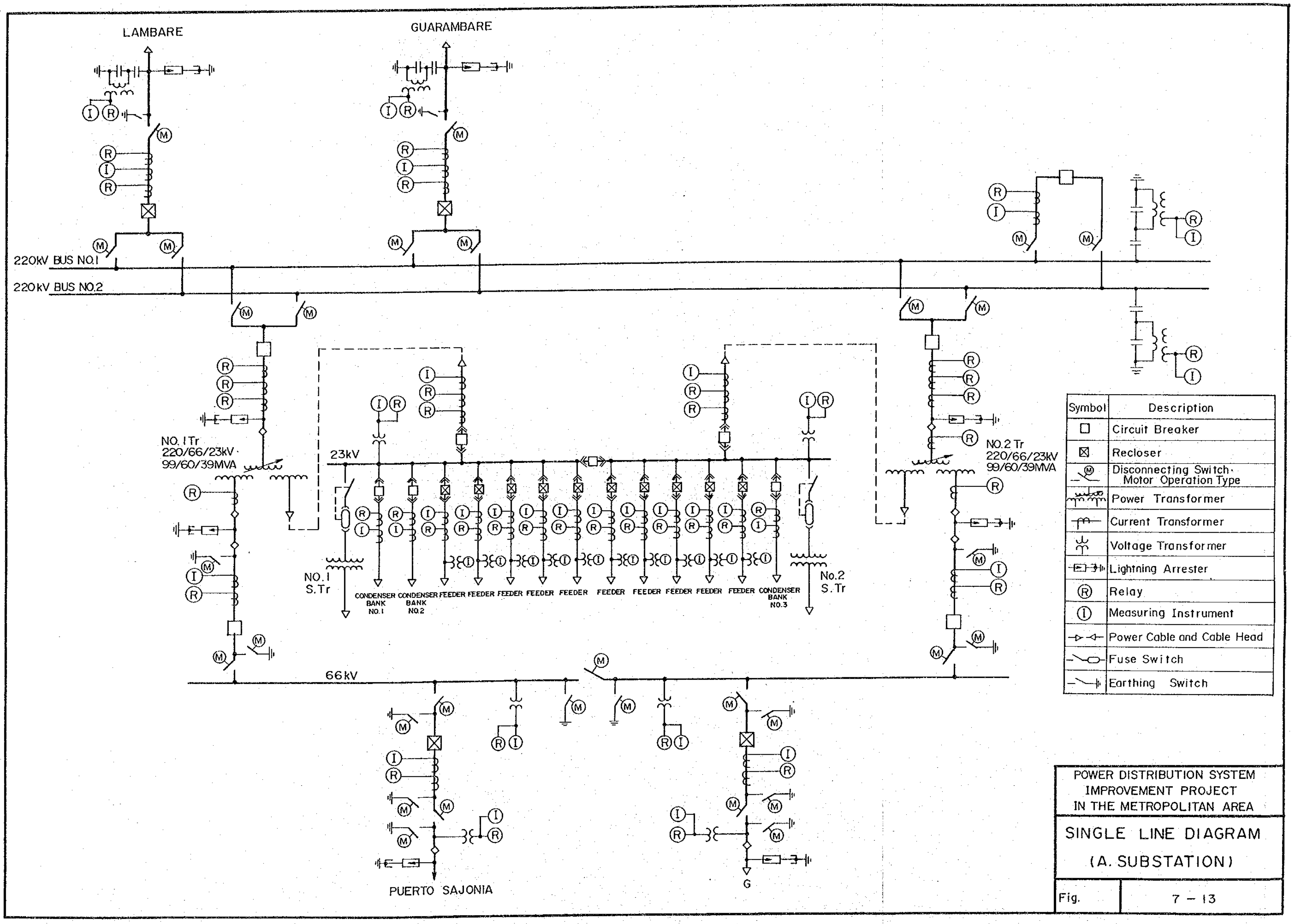
0 5 10 20m

POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT SECTION

(A. SUBSTATION)

Fig.	7 – 12

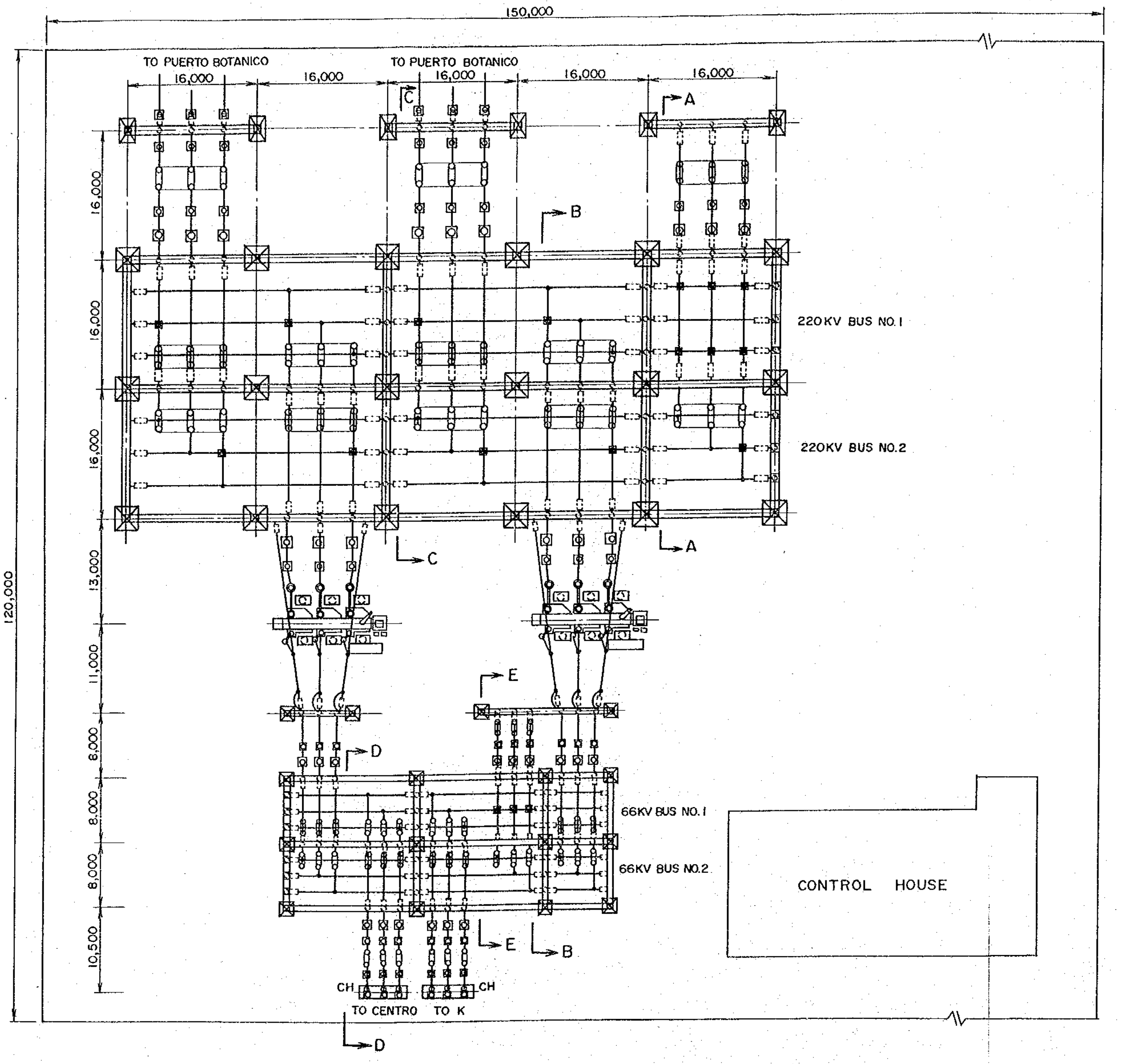


Symbol	Description
	Circuit Breaker
	Recloser
	Disconnecting Switch· Motor Operation Type
	Power Transformer
	Current Transformer
	Voltage Transformer
	Lightning Arrester
	Relay
	Measuring Instrument
	Power Cable and Cable Head
	Fuse Switch
	Earthing Switch

POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM
(A. SUBSTATION)

Fig. 7 - 13

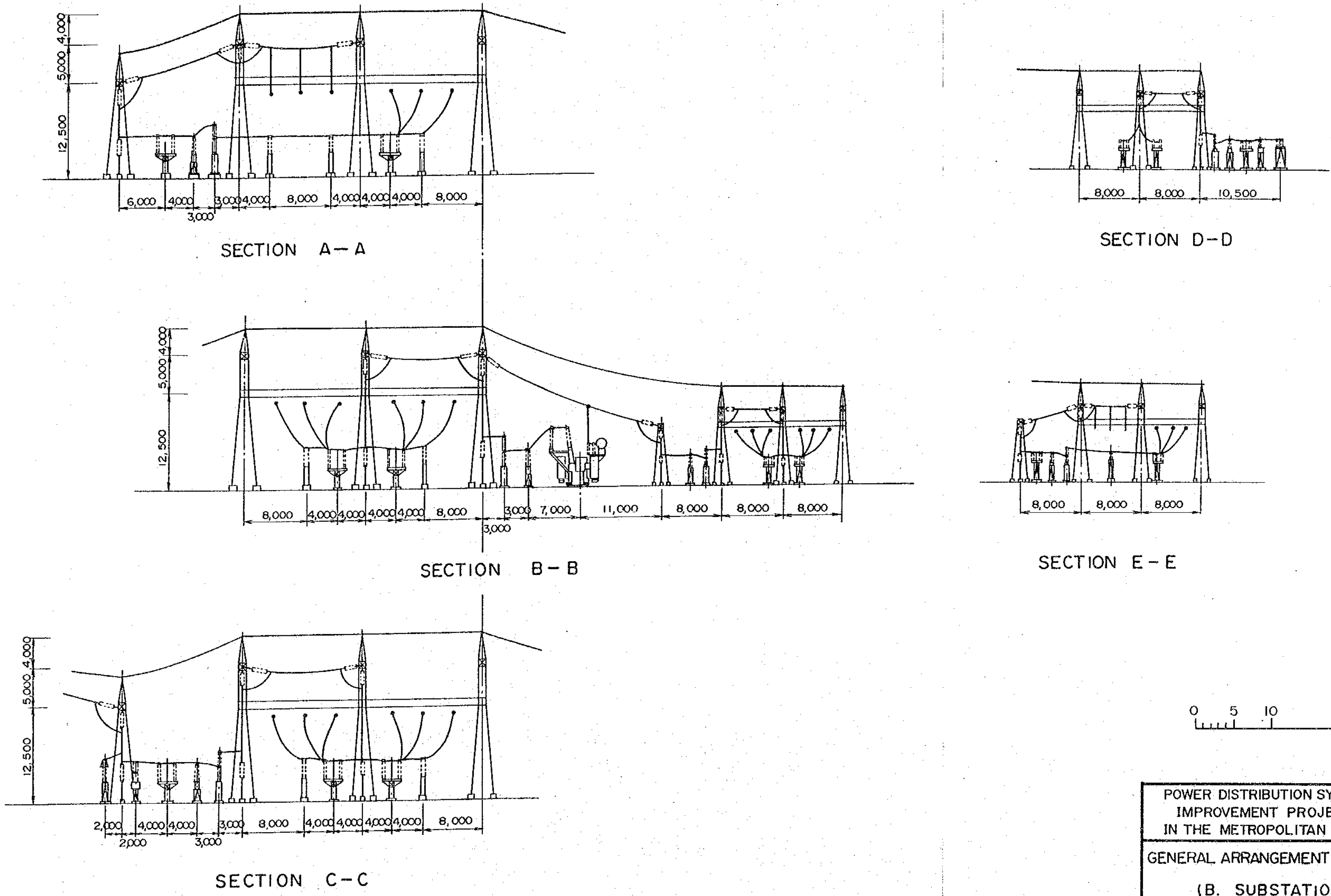


POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT PLAN

(B. SUBSTATION)

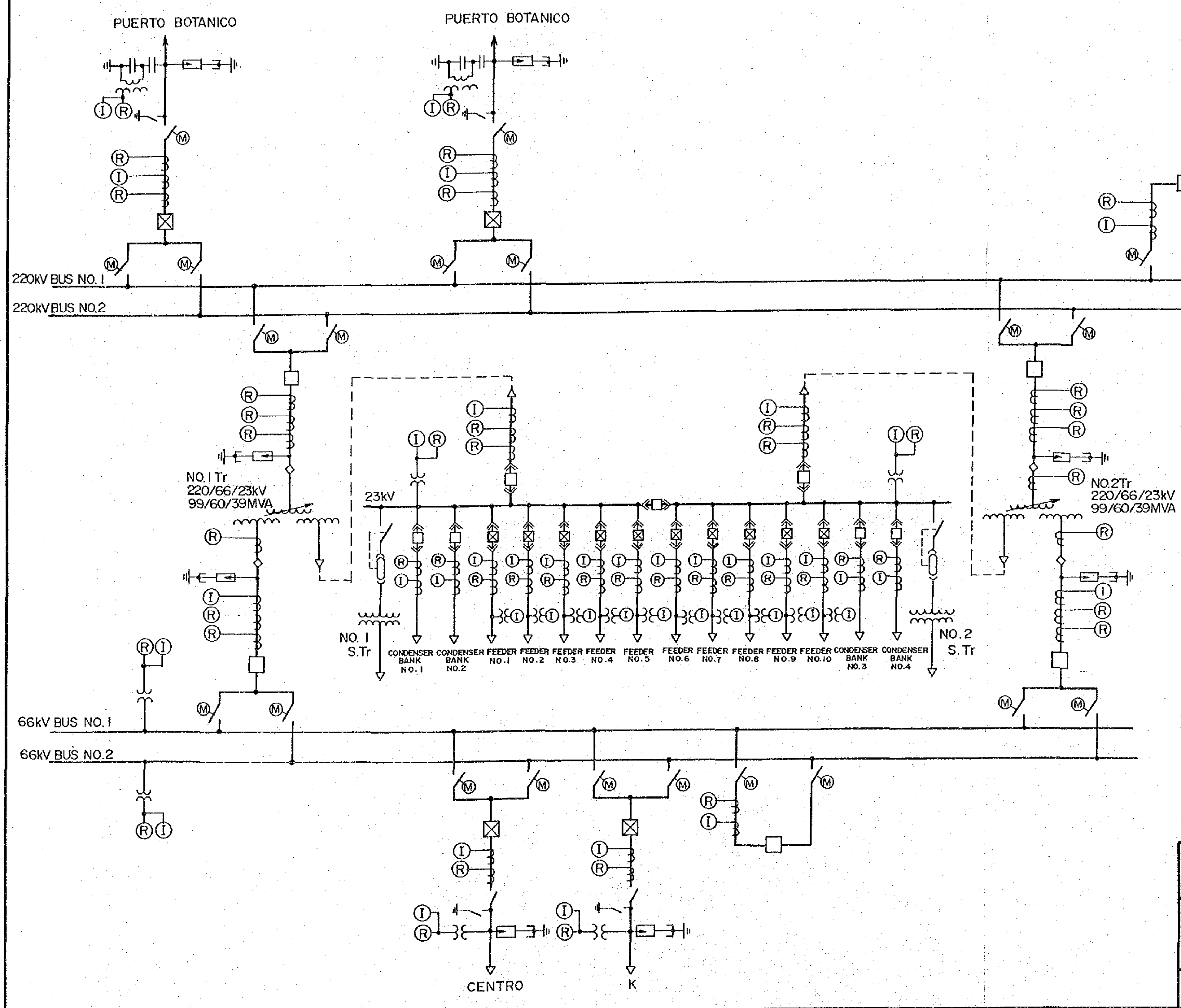
Fig. 7 - 14



POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT SECTION
(B. SUBSTATION)

Fig.	7－15

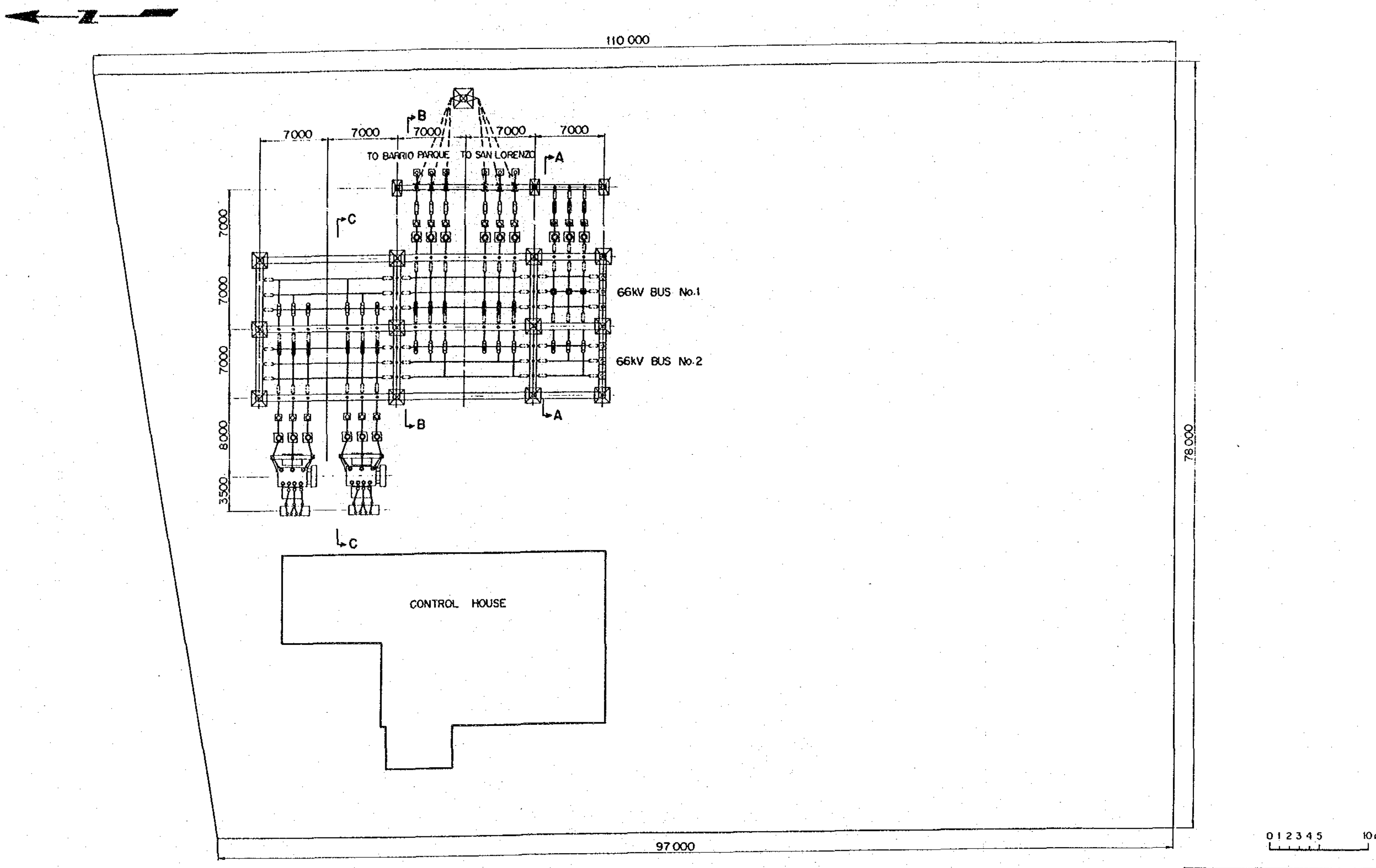


Symbol	Description
□	Circuit Breaker
⊠	Recloser
	Disconnecting Switch Motor Operation Type
	Power Transformer
	Current Transformer
	Voltage Transformer
	Lightning Arrester
Ⓡ	Relay
Ⓘ	Measuring Instrument
	Power Cable and Cable Head
	Fuse Switch

POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM
(B. SUBSTATION)

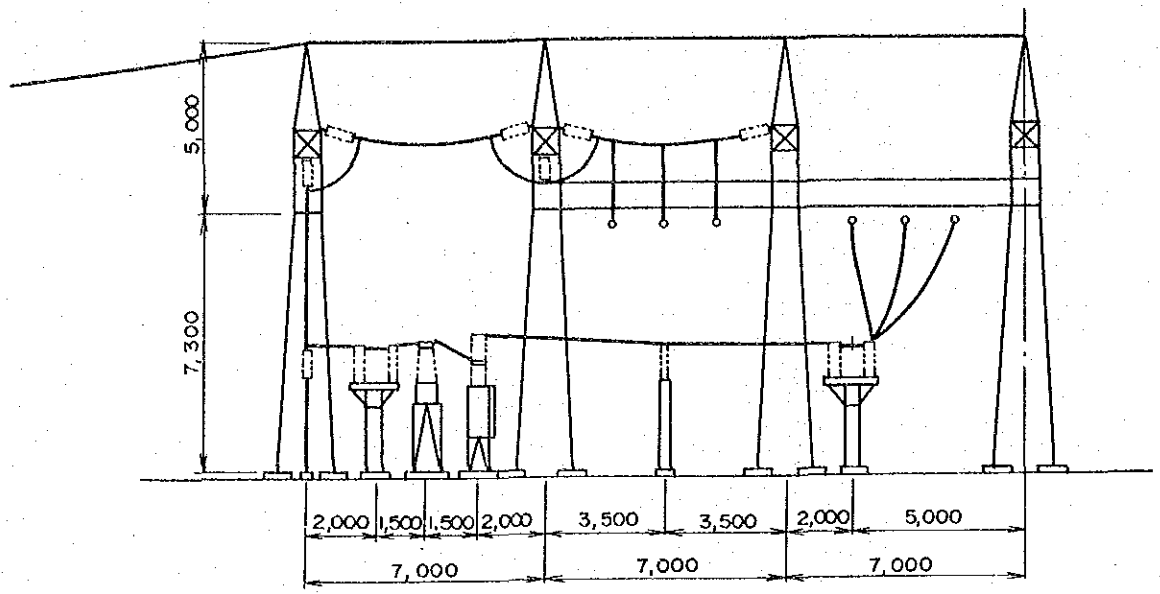
Fig. 7 - 16



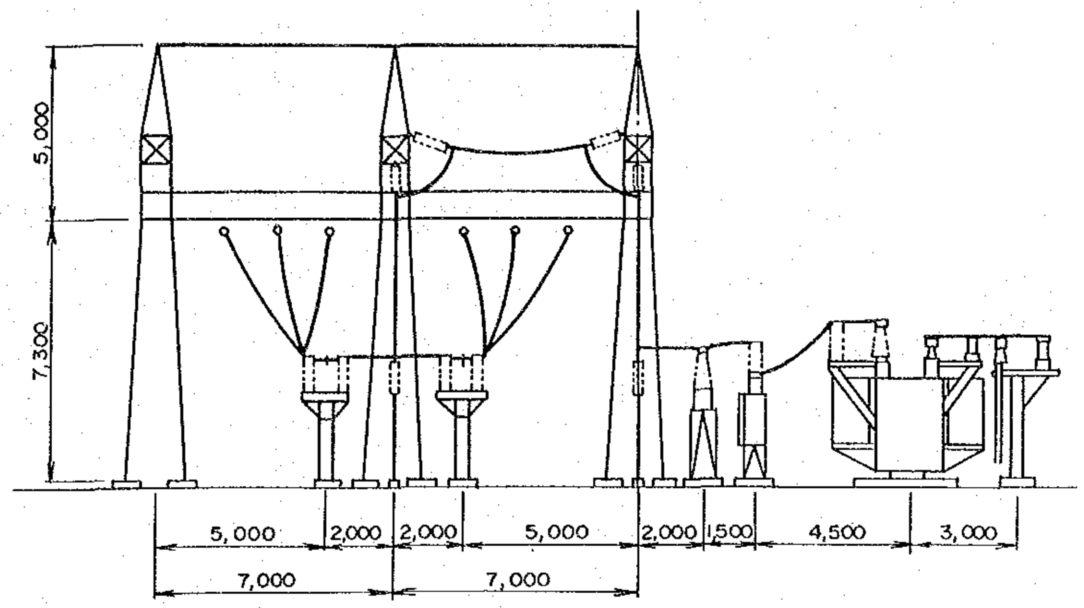
POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRAGEMENT PLAN
(E. SUBSTATION)

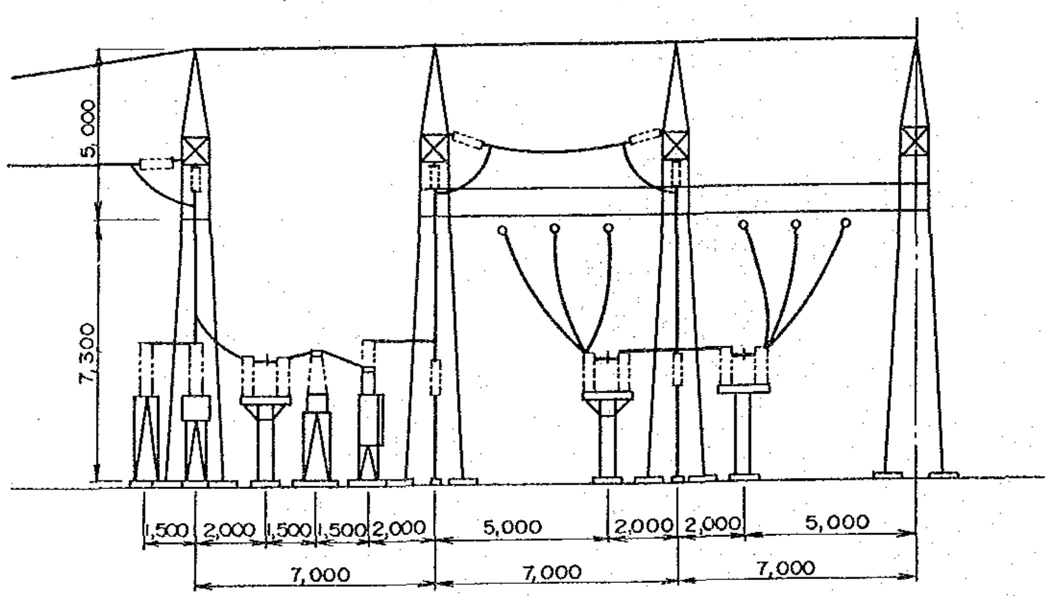
Fig. 7 - 17



SECTION A－A



SECTION C－C



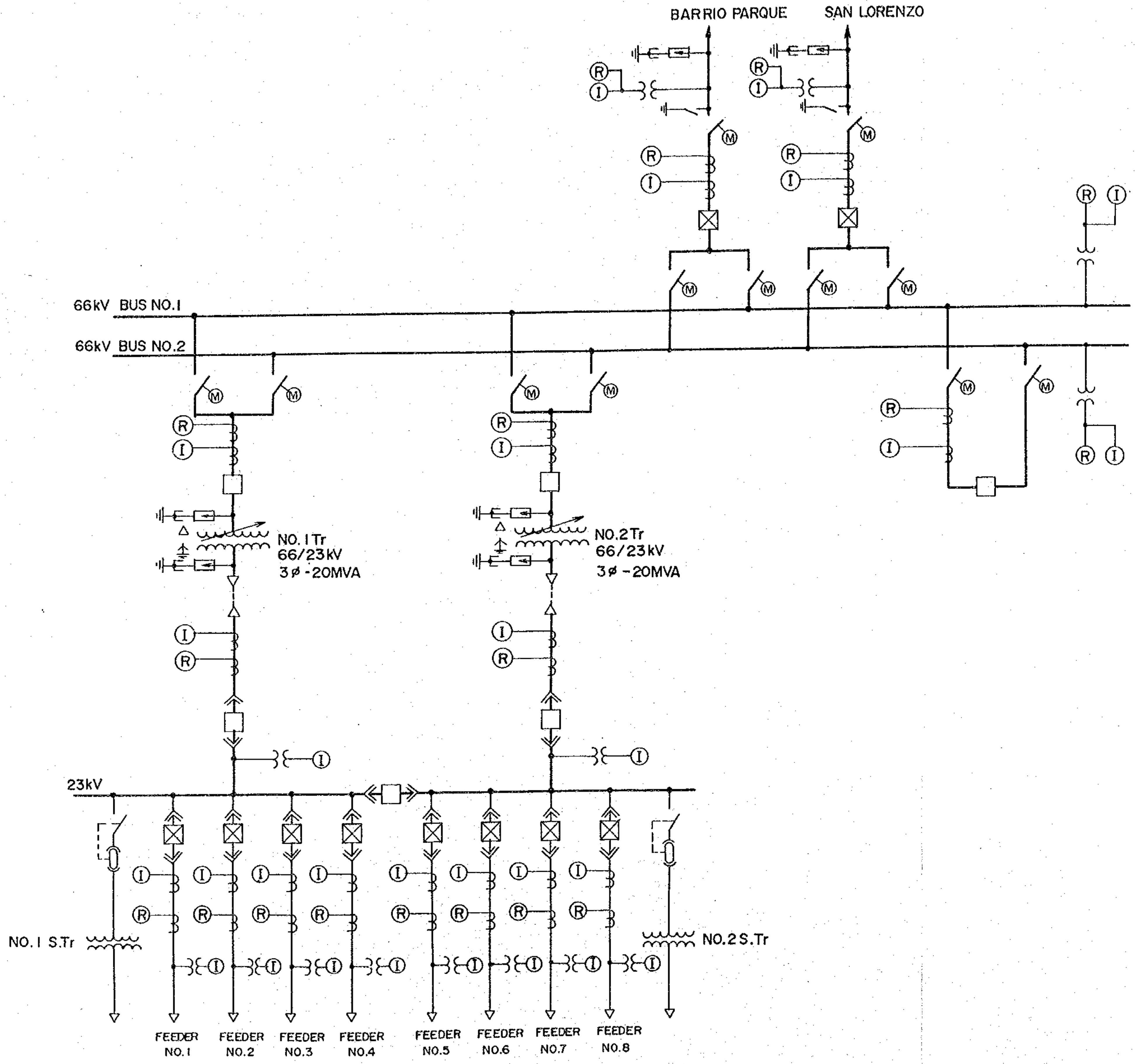
SECTION B－B

0 1 2 3 4 5 10m

POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT SECTION
(E. SUBSTATION)

Fig. 7－18

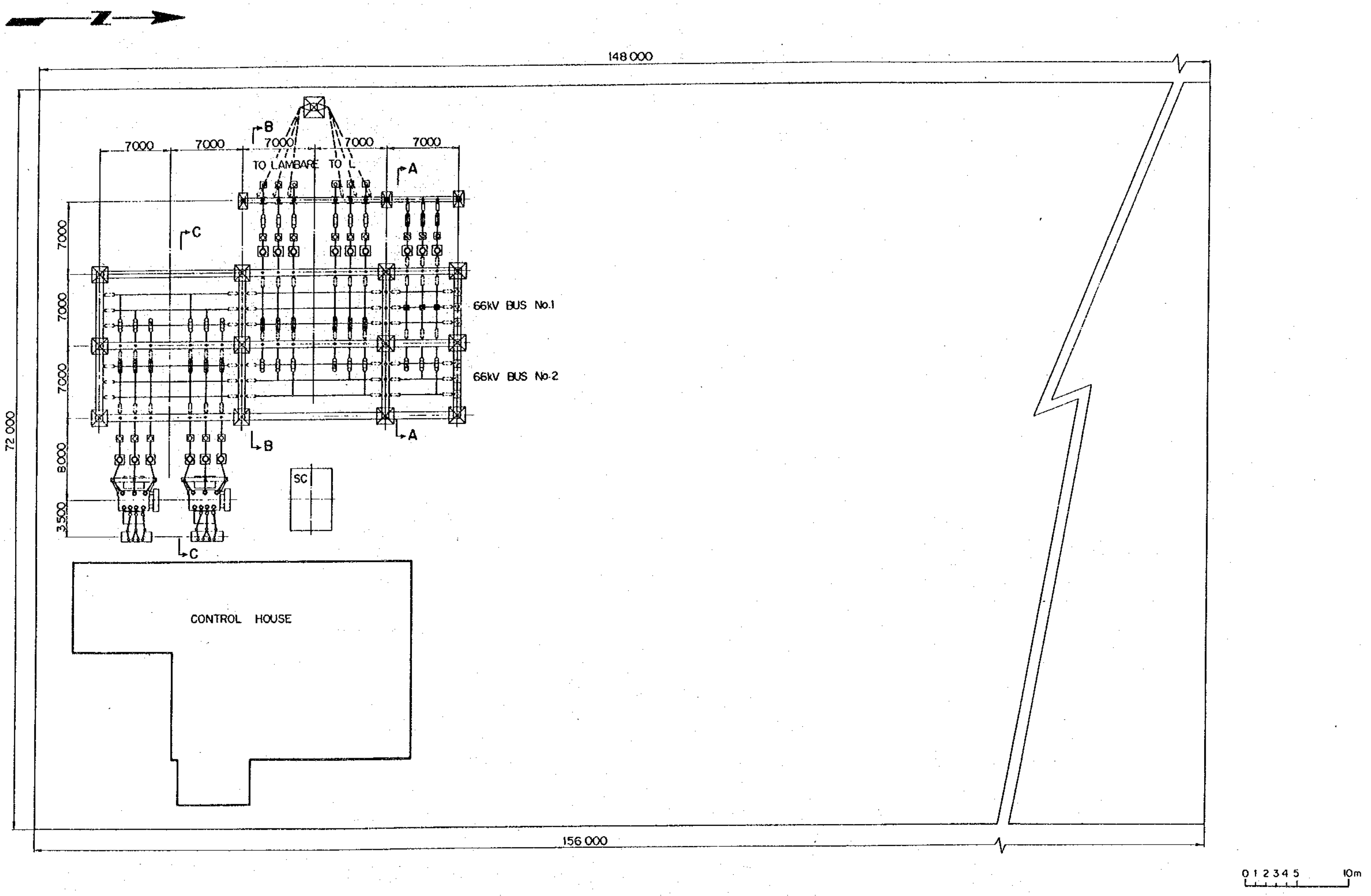


Symbol	Description
□	Circuit Breaker
⊠	Recloser
	Disconnecting Switch Motor Operation Type
	Power Transformer
	Current Transformer
	Voltage Transformer
	Lightning Arrester
Ⓡ	Relay
Ⓘ	Measuring Instrument
	Power Cable and Cable Head
	Fuse Switch

POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM (E. SUBSTATION)

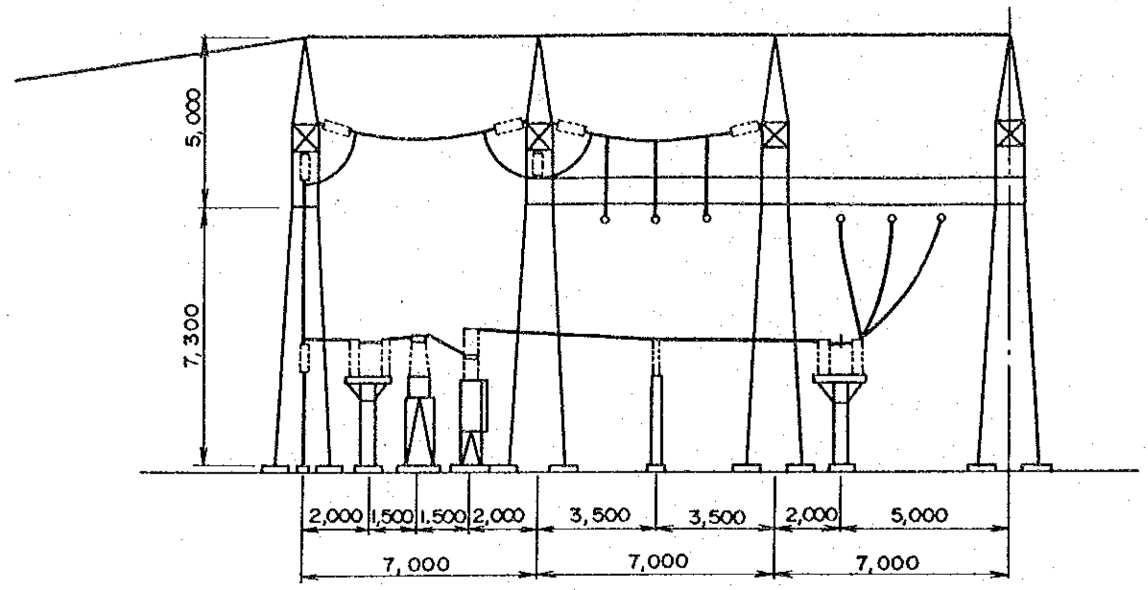
Fig. 7 – 19



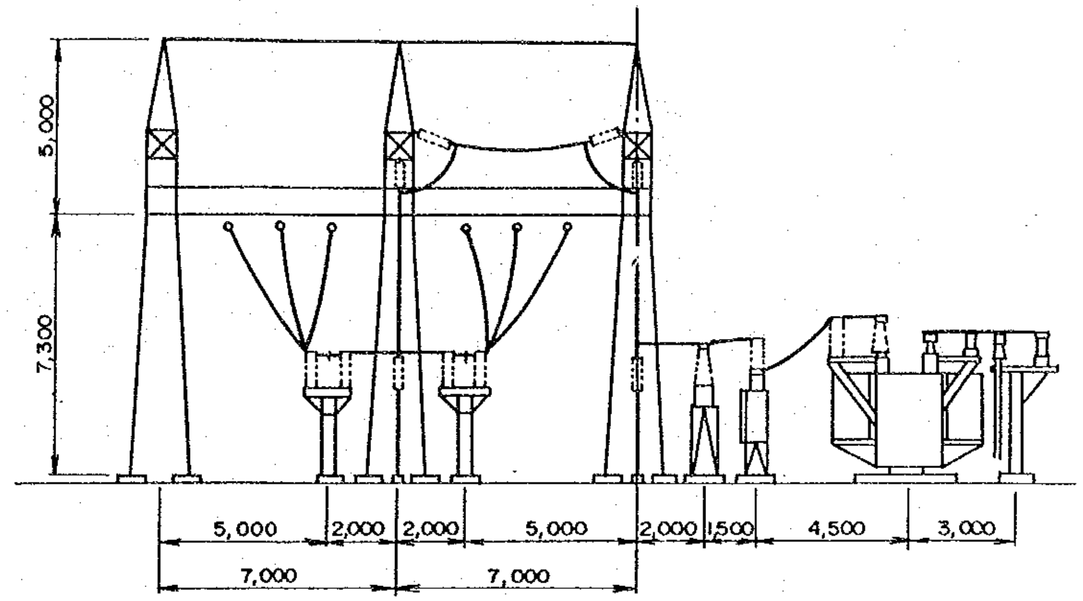
POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRAGEMENT PLAN
(F. SUBSTATION)

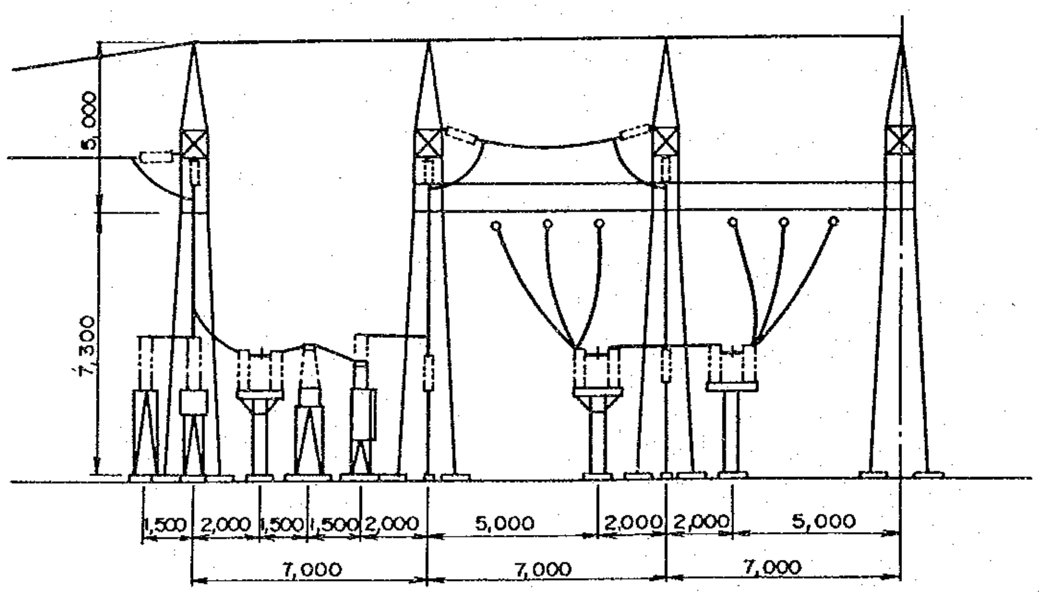
Fig.	7 - 20



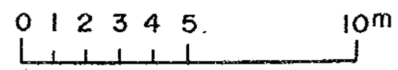
SECTION A－A



SECTION C－C



SECTION B－B

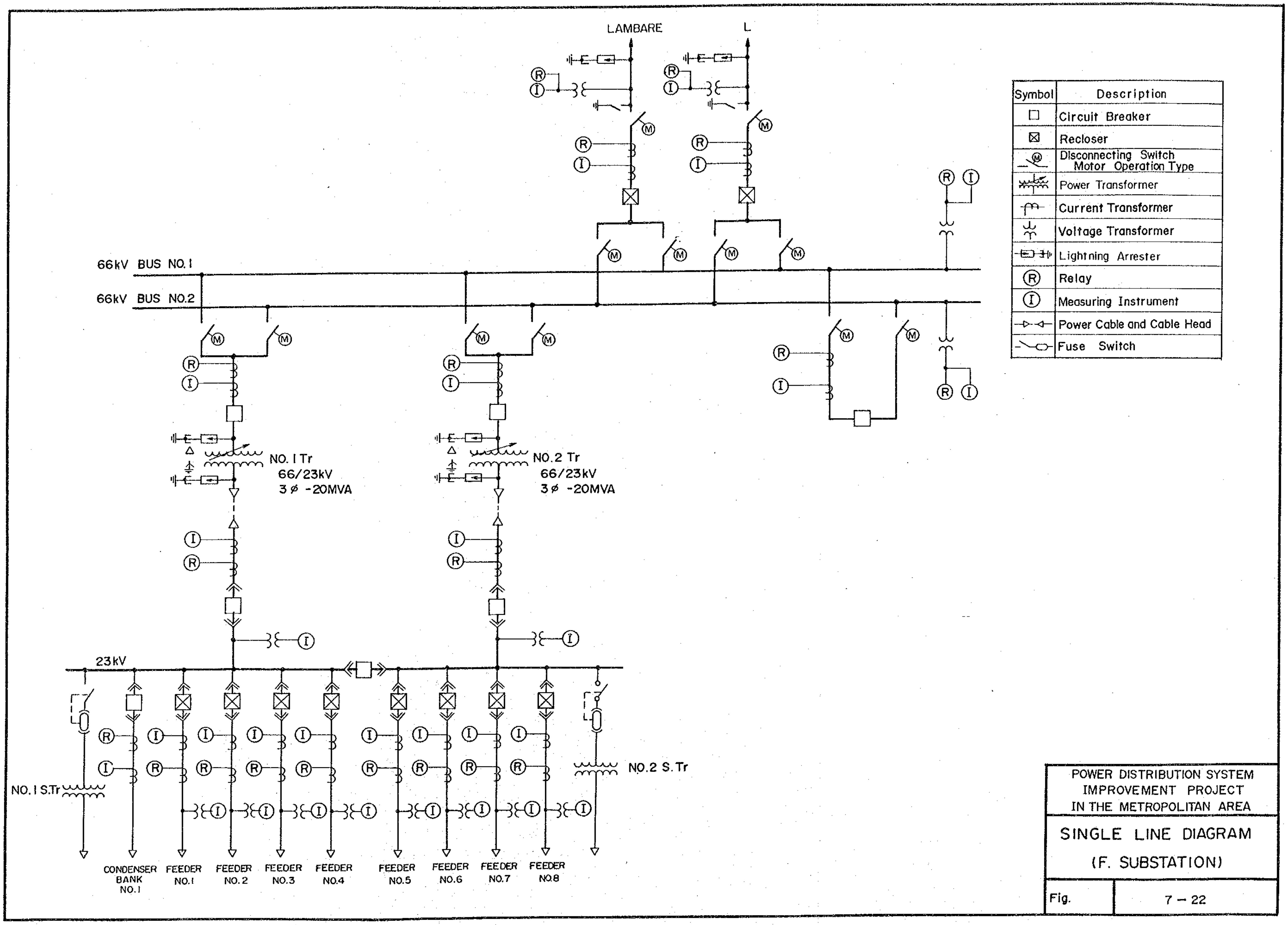


POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT SECTION

(F. SUBSTATION)

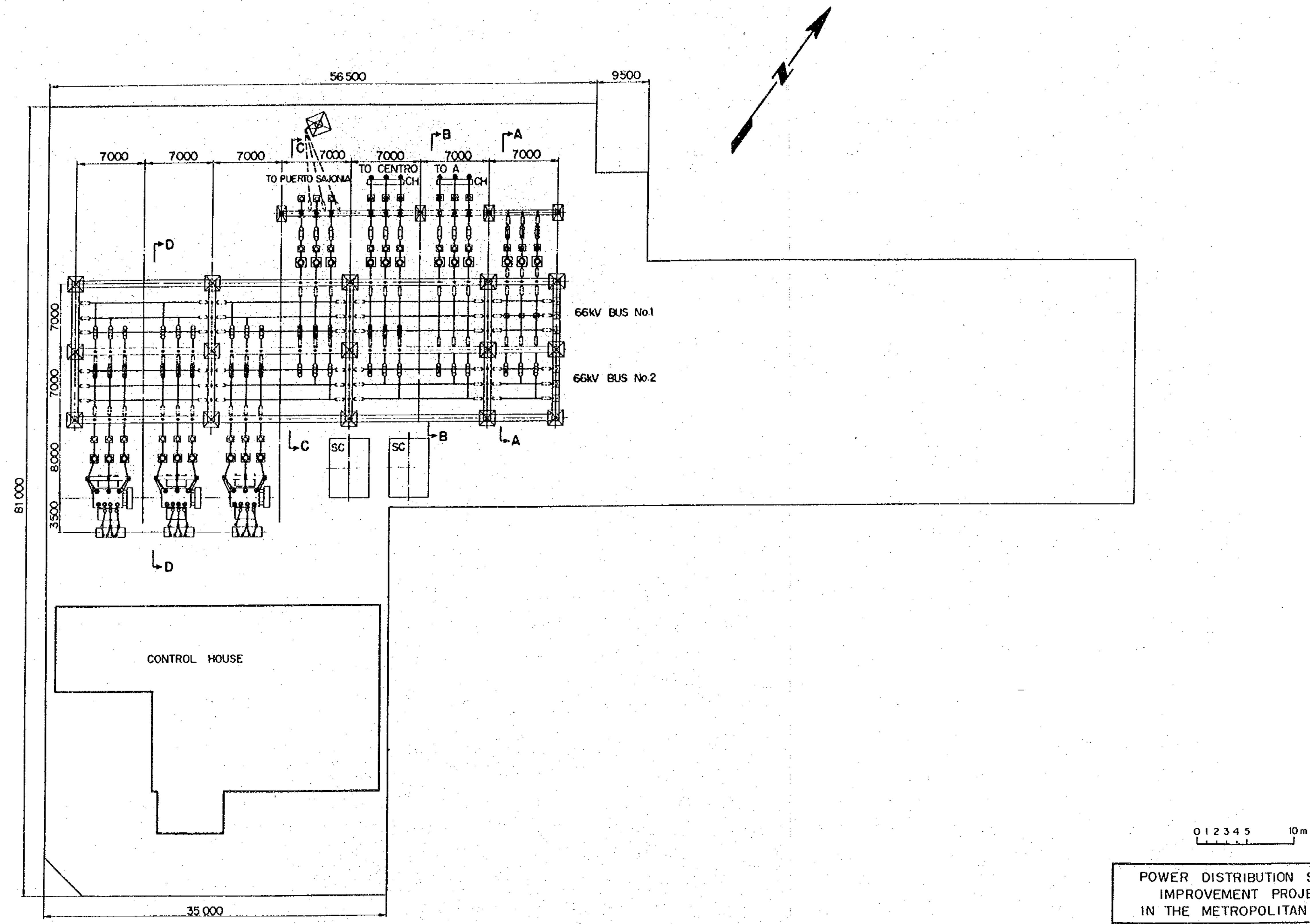
Fig. 7－21



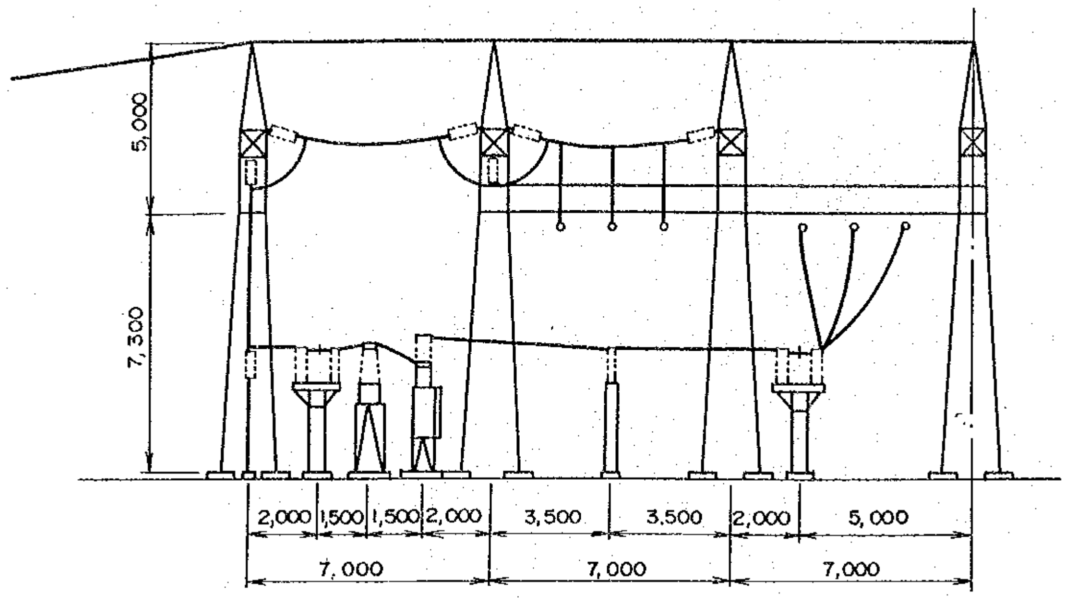
POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM (F. SUBSTATION)

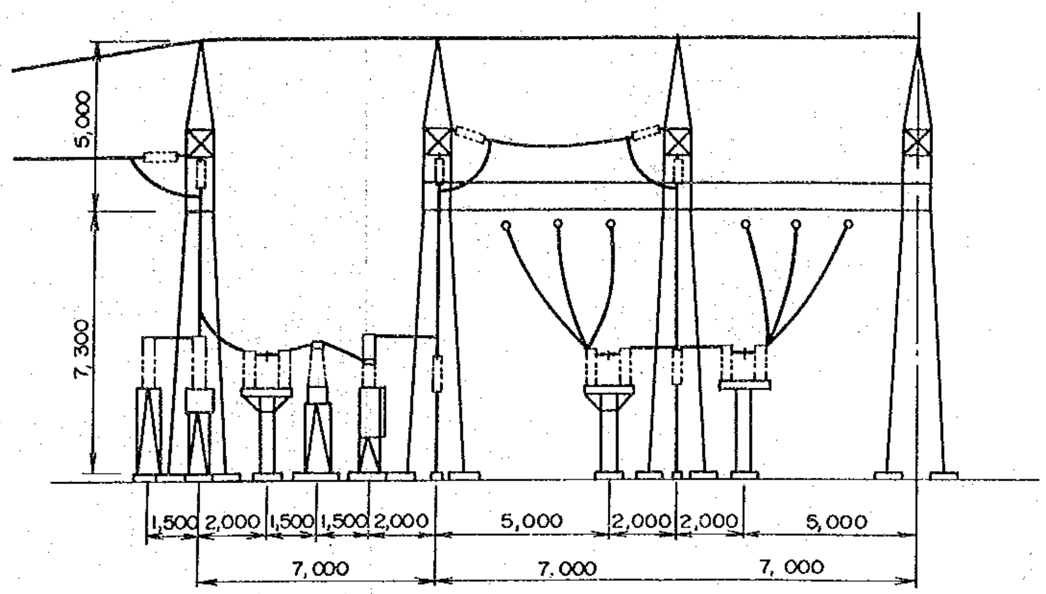
Fig. 7 – 22



POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA	
GENERAL ARRAGEMENT PLAN (G. SUBSTATION)	
Fig.	7 - 23



SECTION A – A



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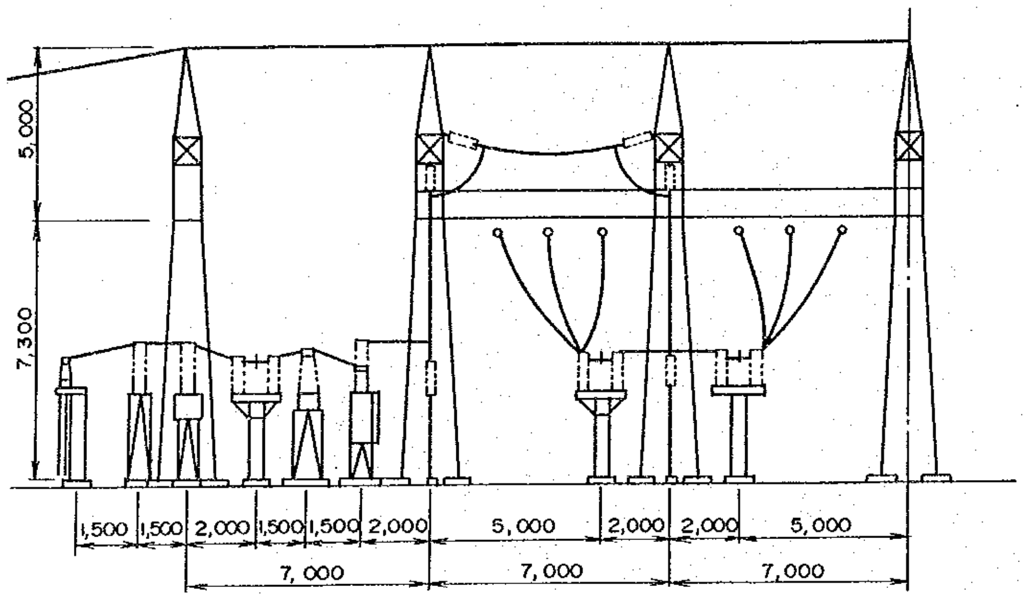
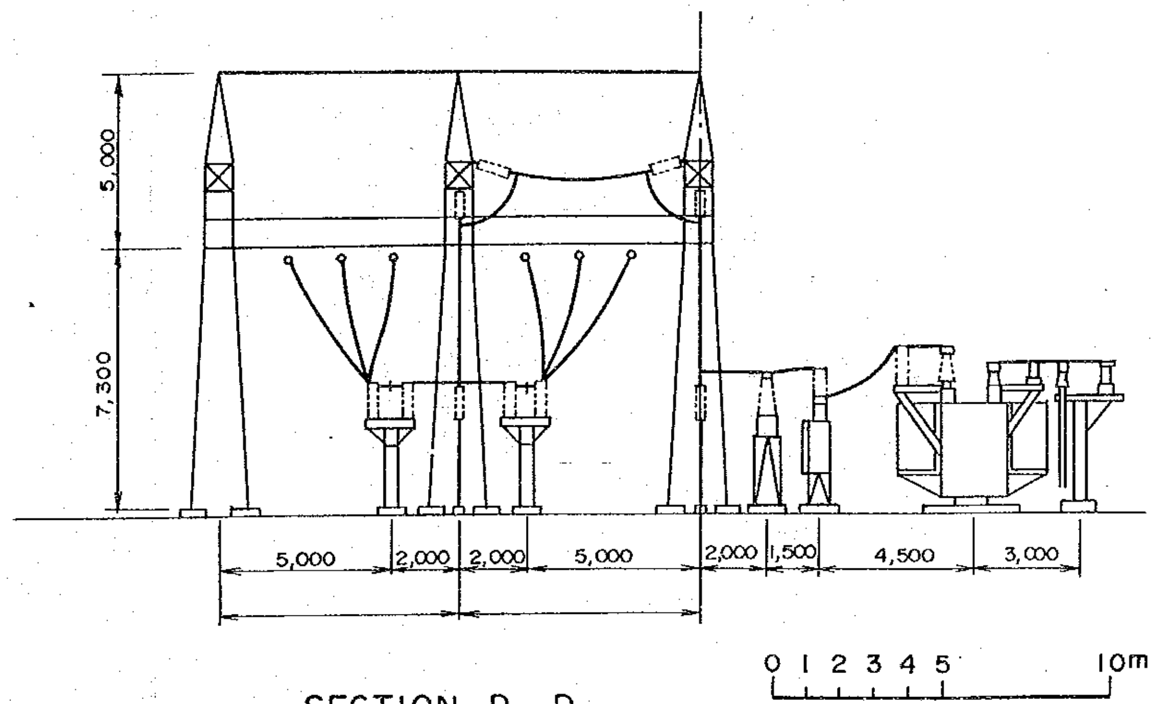
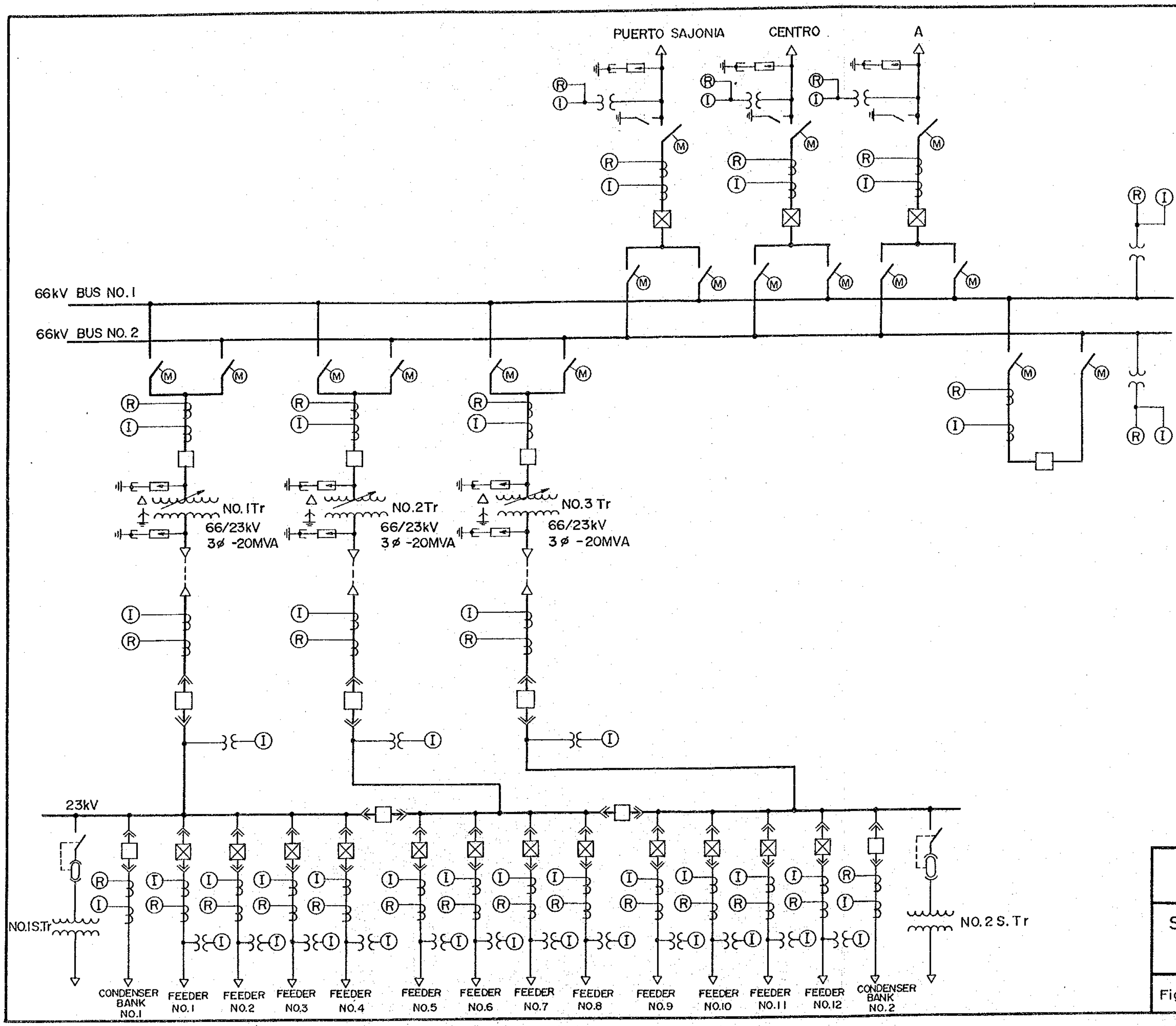


SECTION B – B



SECTION D – D

POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA	
GENERAL ARRANGEMENT SECTION (G. SUBSTATION)	
Fig.	7 – 24

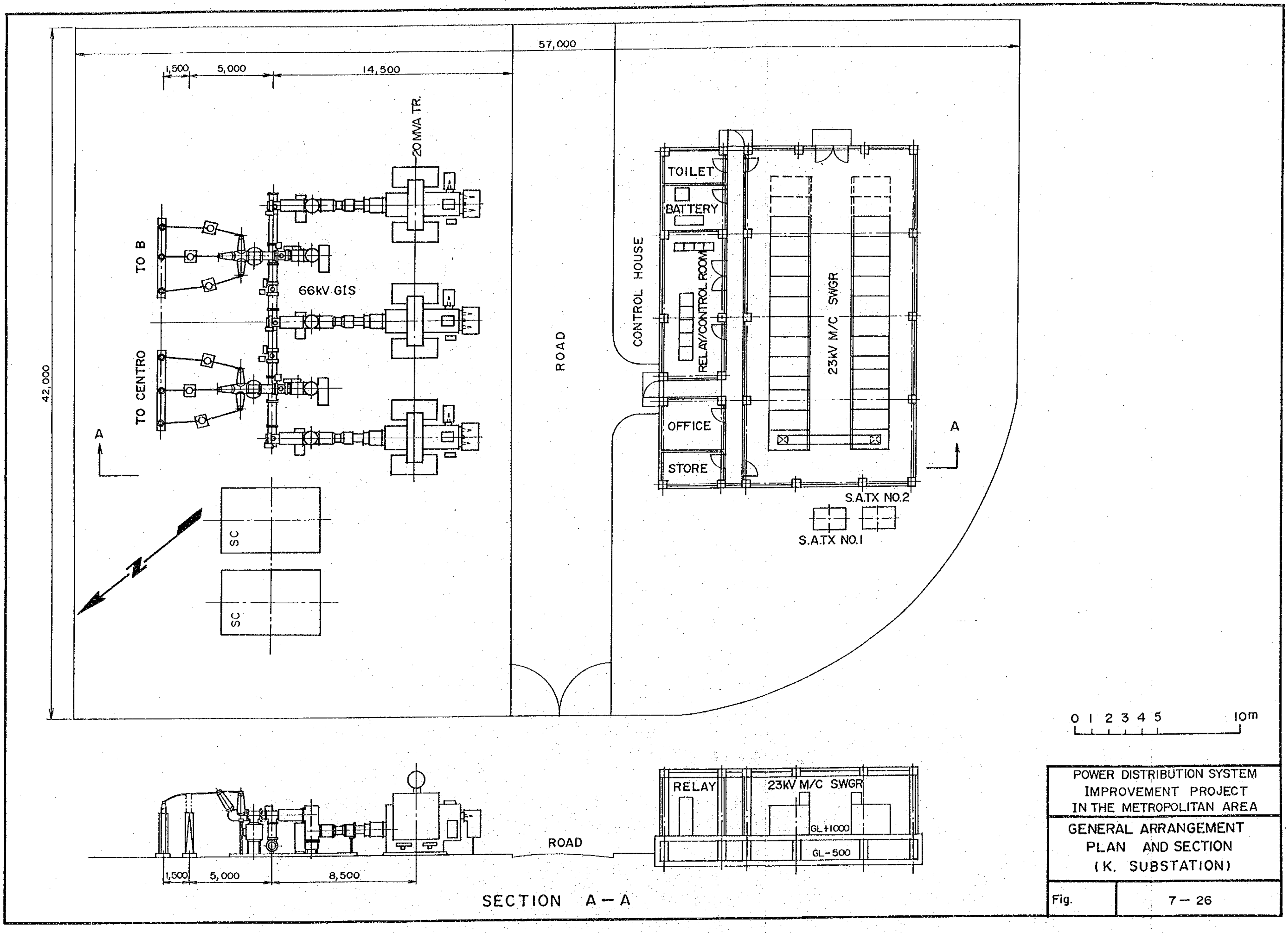


Symbol	Description
□	Circuit Breaker
⊠	Recloser
	Disconnecting Switch Motor Operation Type
	Power Transformer
	Current Transformer
	Voltage Transformer
	Lightning Arrester
Ⓡ	Relay
Ⓘ	Measuring Instrument
	Power Cable and Cable Head
	Fuse Switch

POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM
(G. SUBSTATION)

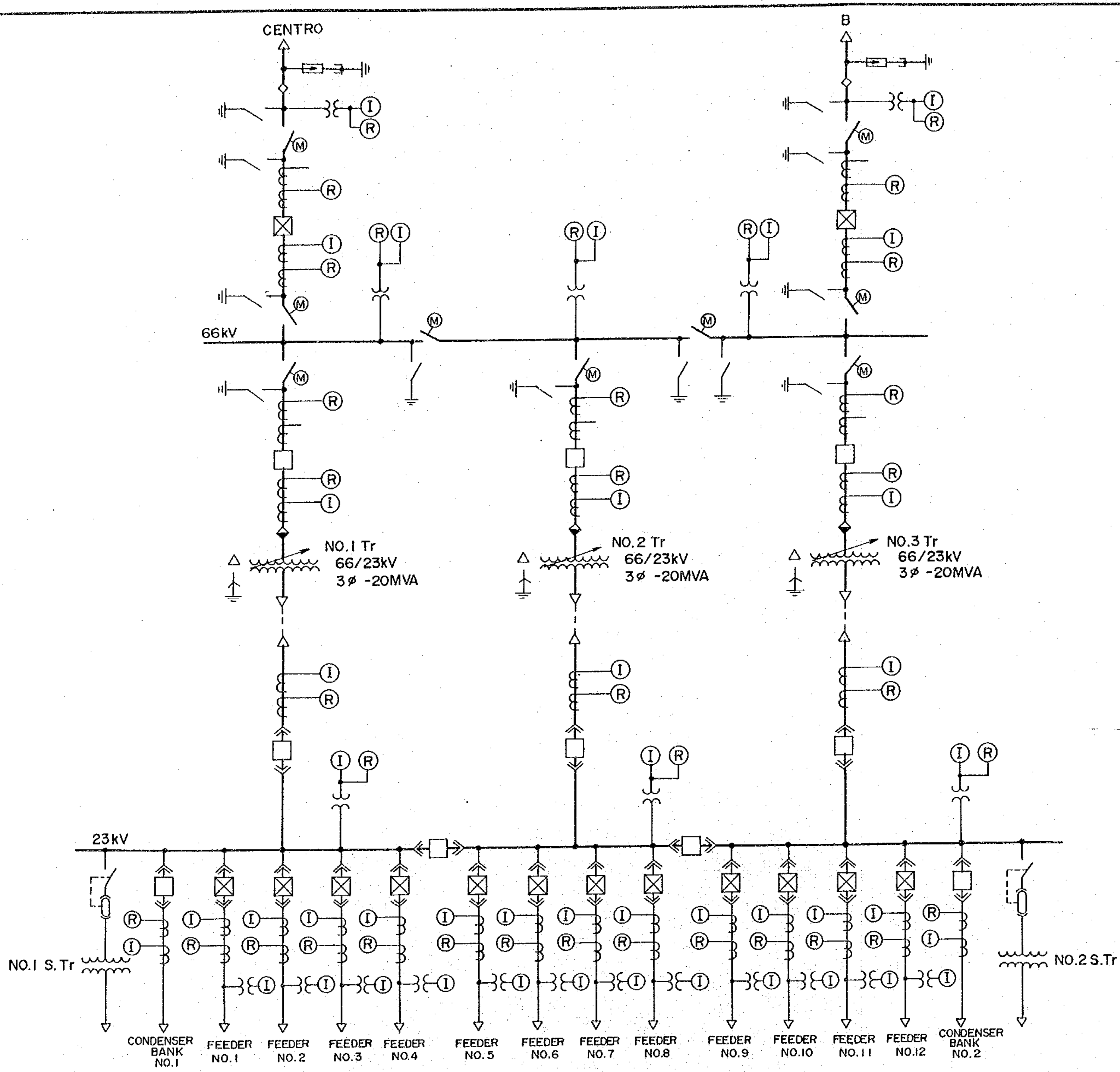
Fig. 7 − 25



POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT PLAN AND SECTION (K. SUBSTATION)

Fig. 7 — 26

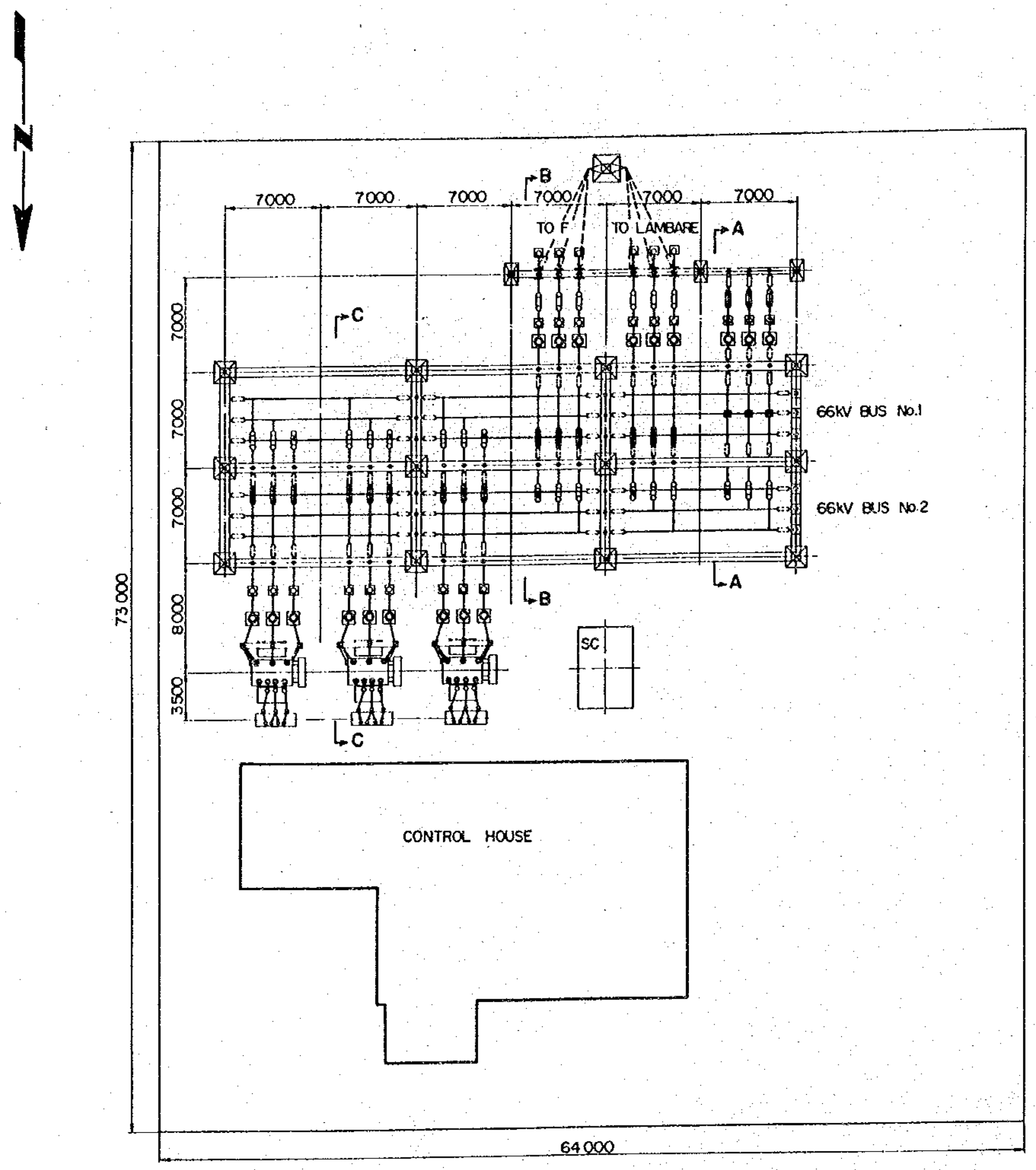


Symbol	Description
□	Circuit Breaker
⊠	Recloser
	Disconnecting Switch Motor Operation Type
	Power Transformer
	Current Transformer
	Voltage Transformer
	Lightning Arrester
Ⓡ	Relay
Ⓘ	Measuring Instrument
	Power Cable and Cable Head
	Power Fuse Switch
	Eeathing Switch

POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM (K. SUBSTATION)

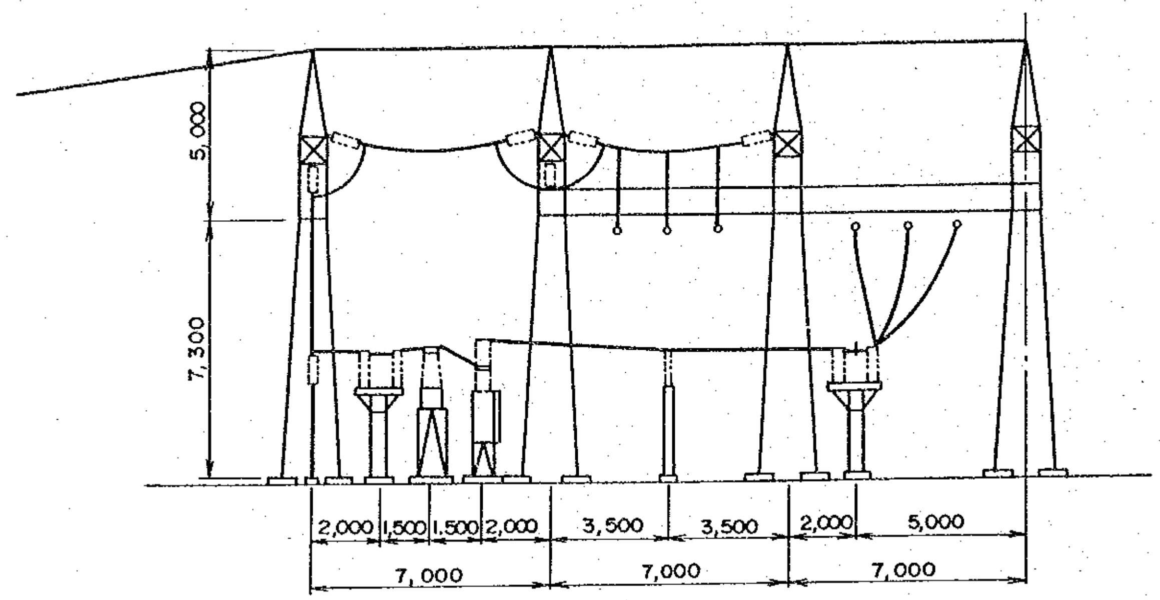
Fig. 7-27



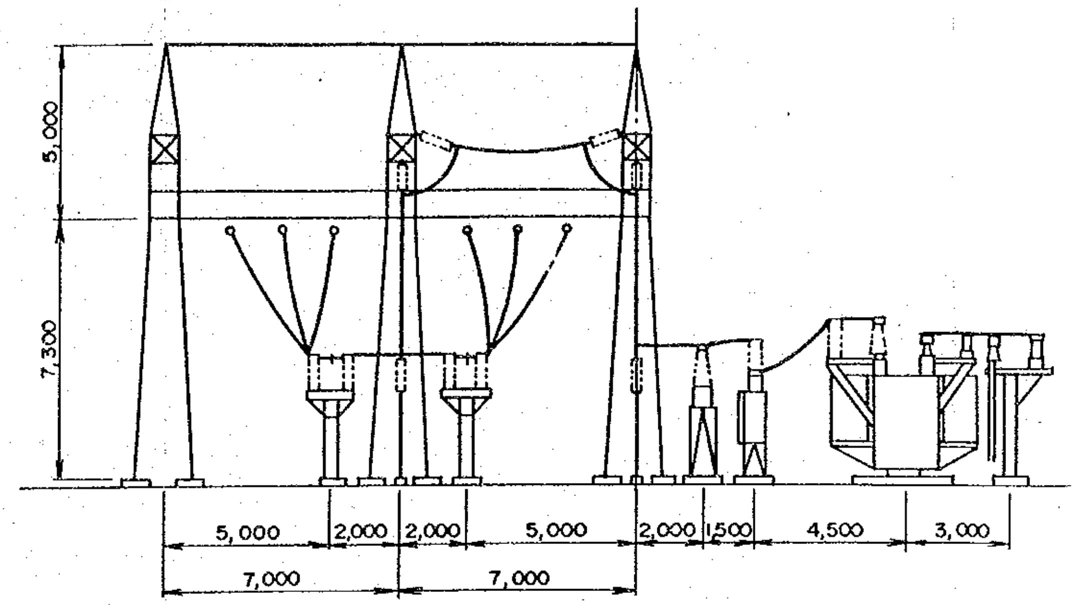
POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRAGEMENT PLAN
(L. SUBSTATION)

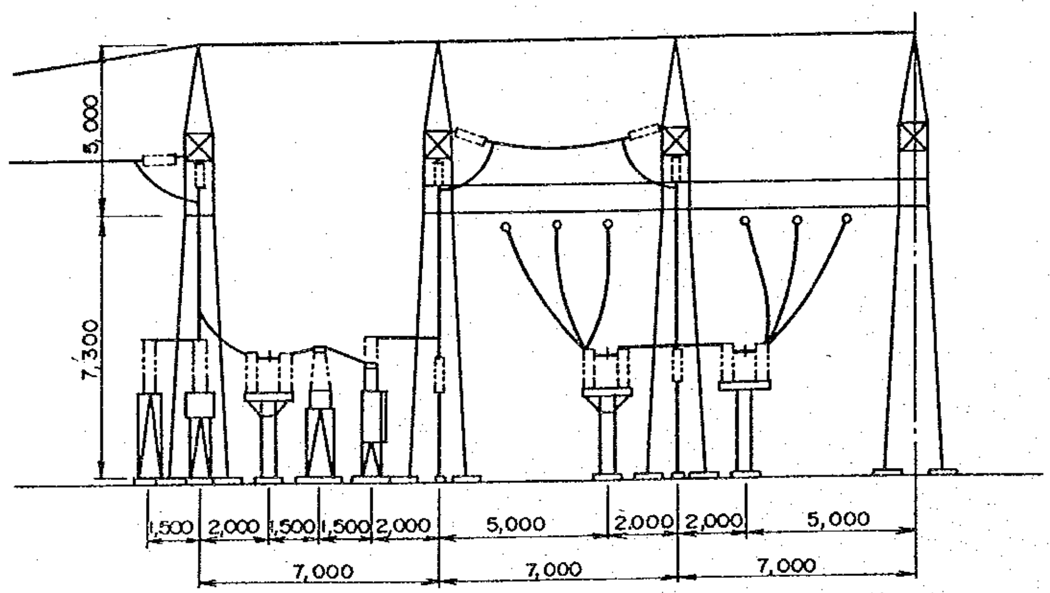
Fig. 7-28



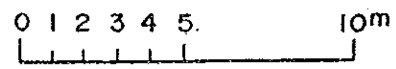
SECTION A－A



SECTION C－C



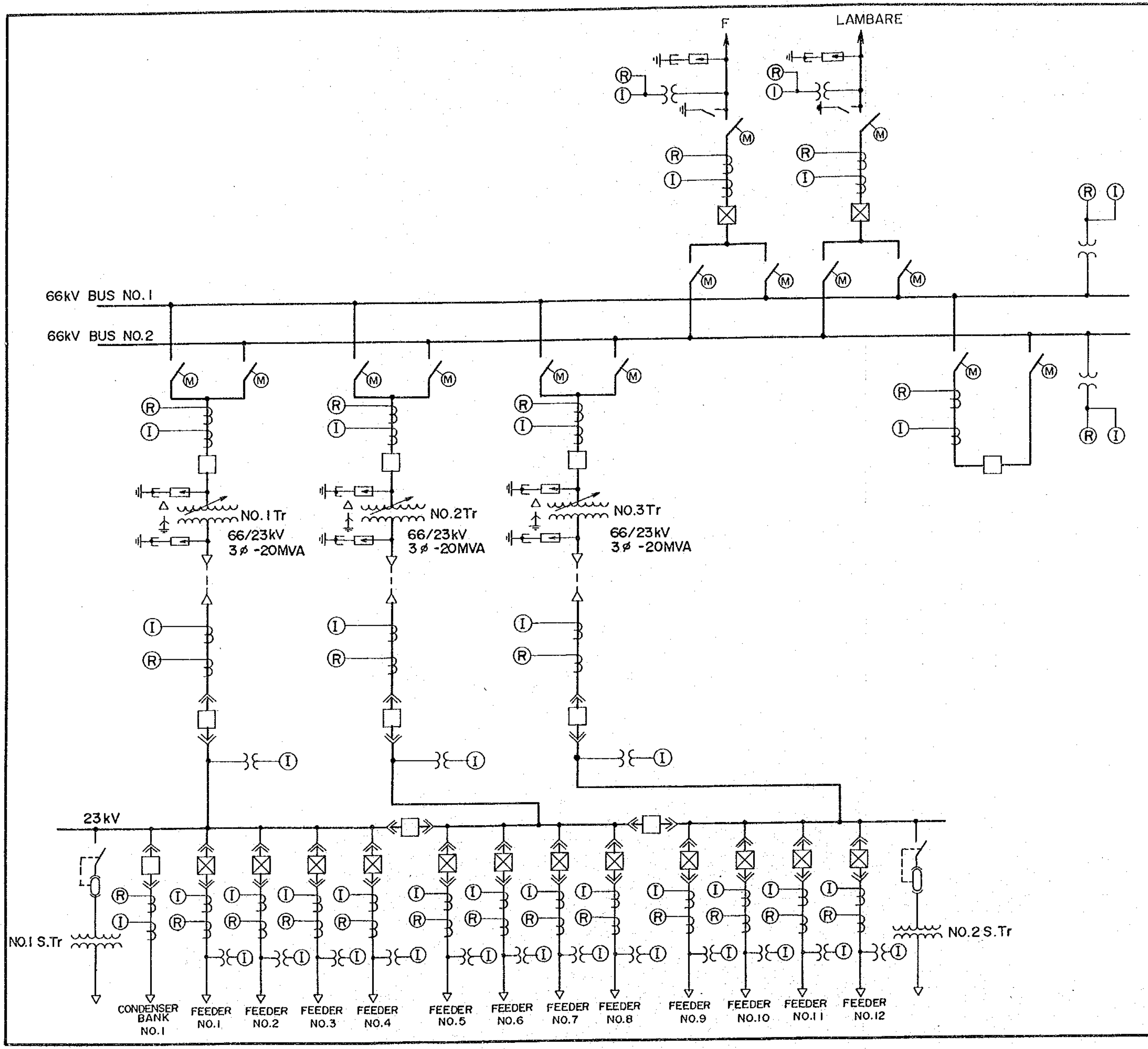
SECTION B－B



POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT SECTION
(L. SUBSTATION)

Fig. 7－29



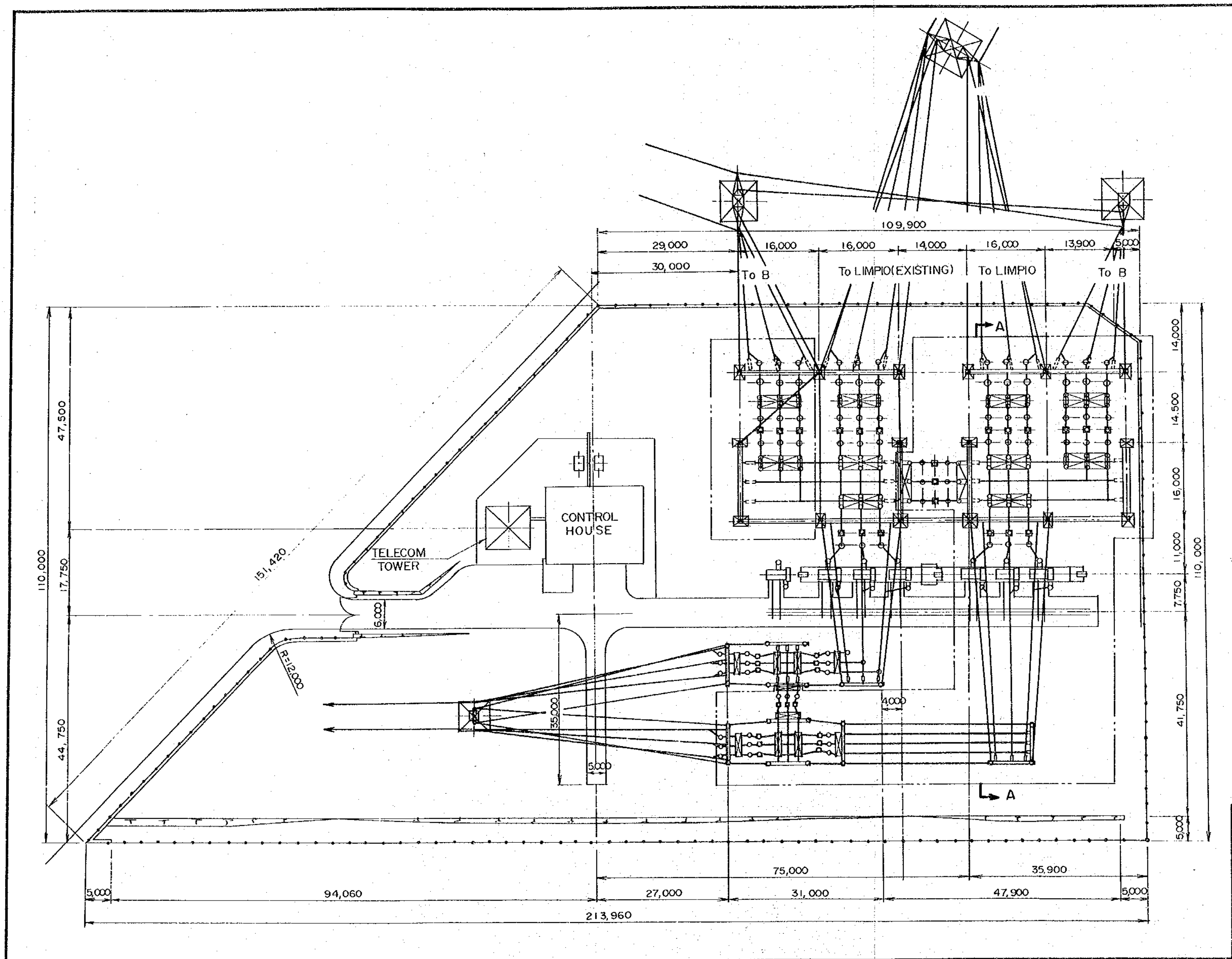
Symbol	Description
□	Circuit Breaker
⊠	Recloser
	Disconnecting Switch Motor Operation Type
	Power Transformer
	Current Transformer
	Voltage Transformer
	Lightning Arrester
(R)	Relay
(I)	Measuring Instrument
	Power Cable and Cable Head
	Fuse Switch
	Earthing Switch

POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM

(L. SUBSTATION)

Fig. 7 – 30

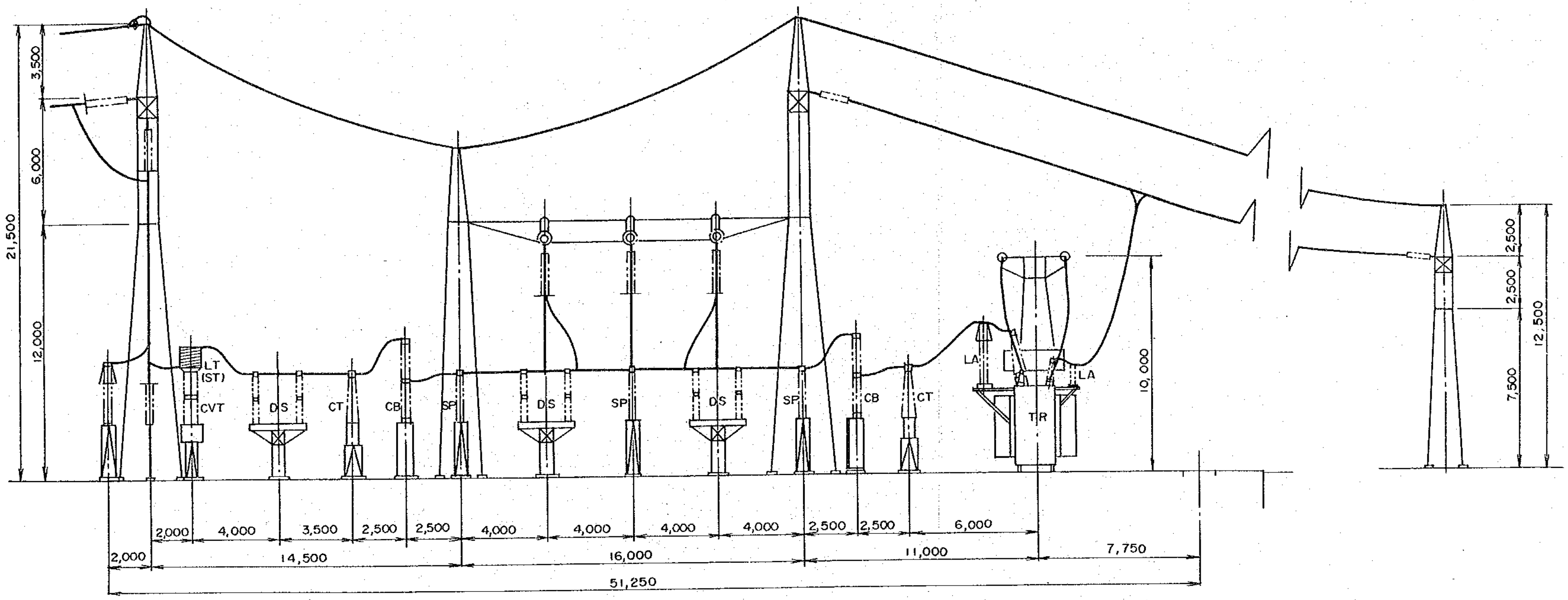


POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT PLAN

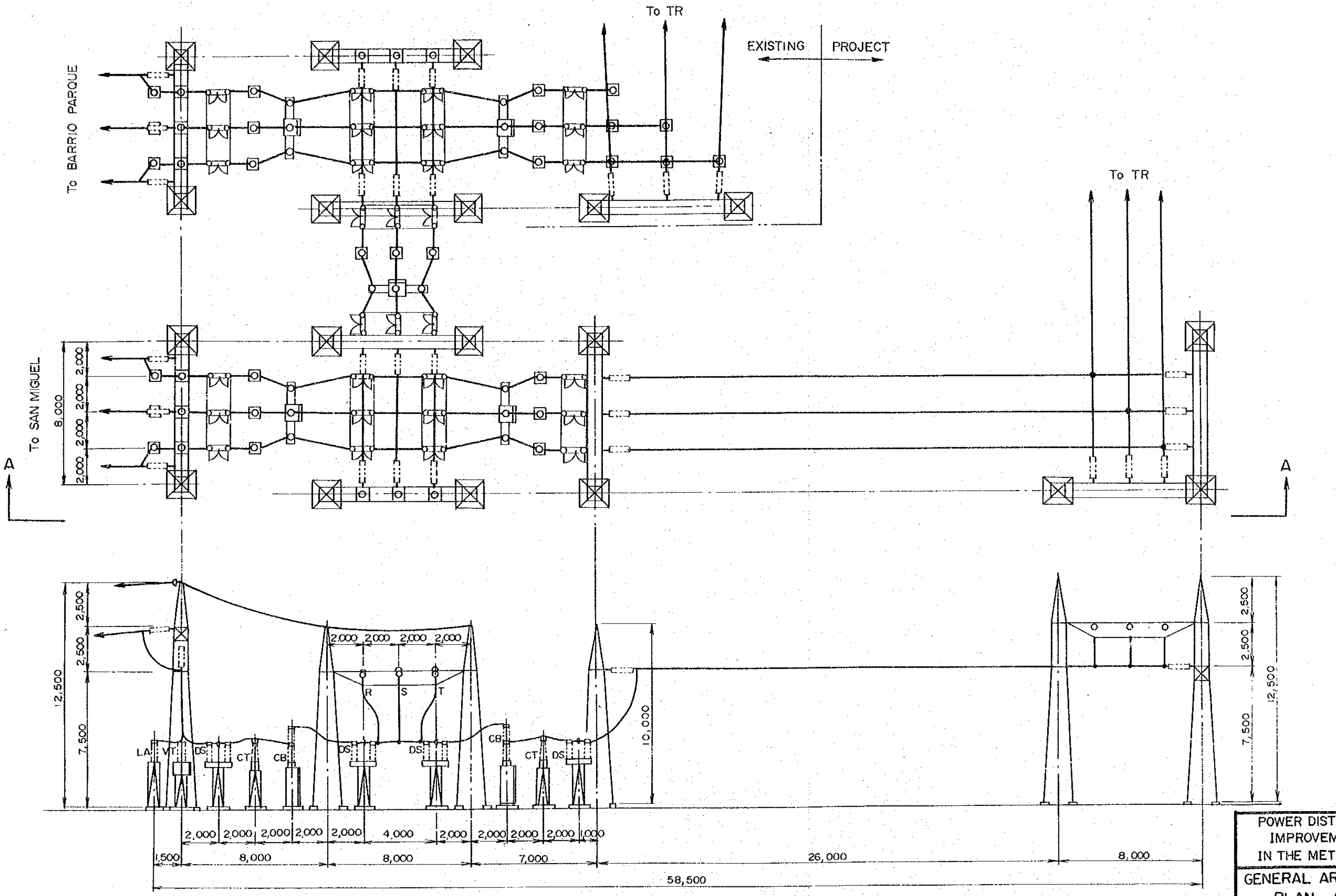
(EXISTING PUERTO BOTANICO SUBSTATION)

Fig. 7 - 31



SECTION A – A

POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA	
GENERAL ARRANGEMENT 220kV SECTION (EXISTING PUERTO BOTANICO SUBSTATION)	
Fig.	7 – 32

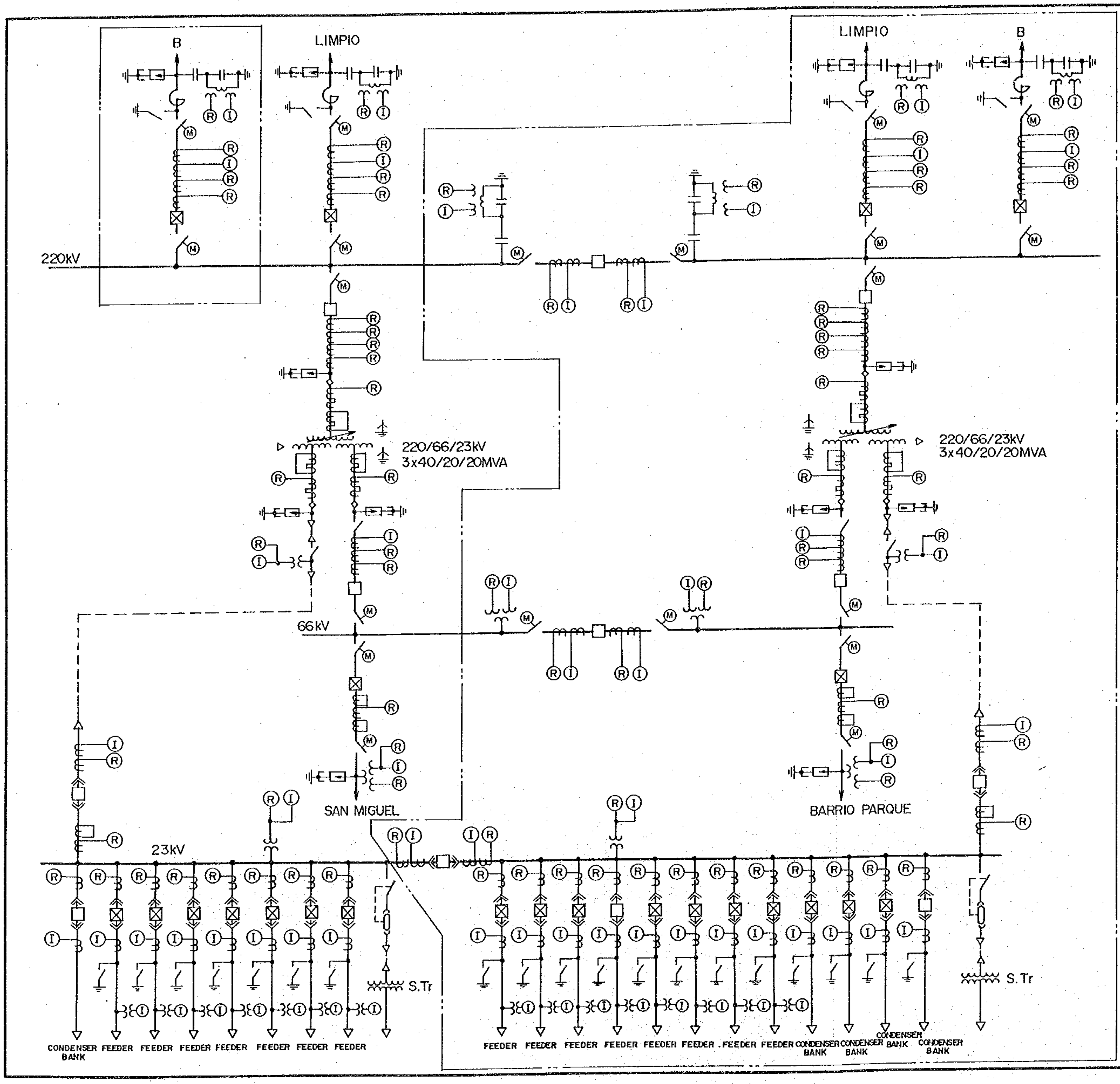


SECTION B-B

POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT 66kV
PLAN AND SECTION
(EXISTING PUERTO BOTANICO SUBSTATION)

Fig. 7 - 33



Symbol	Description
	Circuit Breaker
	Recloser
	Disconnecting Switch Motor Operation Type
	Power Transformer
	Current Transformer
	Voltage Transformer
	Lightning Arrester
Ⓡ	Relay
Ⓘ	Measuring Instrument
	Power Cable and Cable Head
	Power Fuse Switch
	Earthing Switch

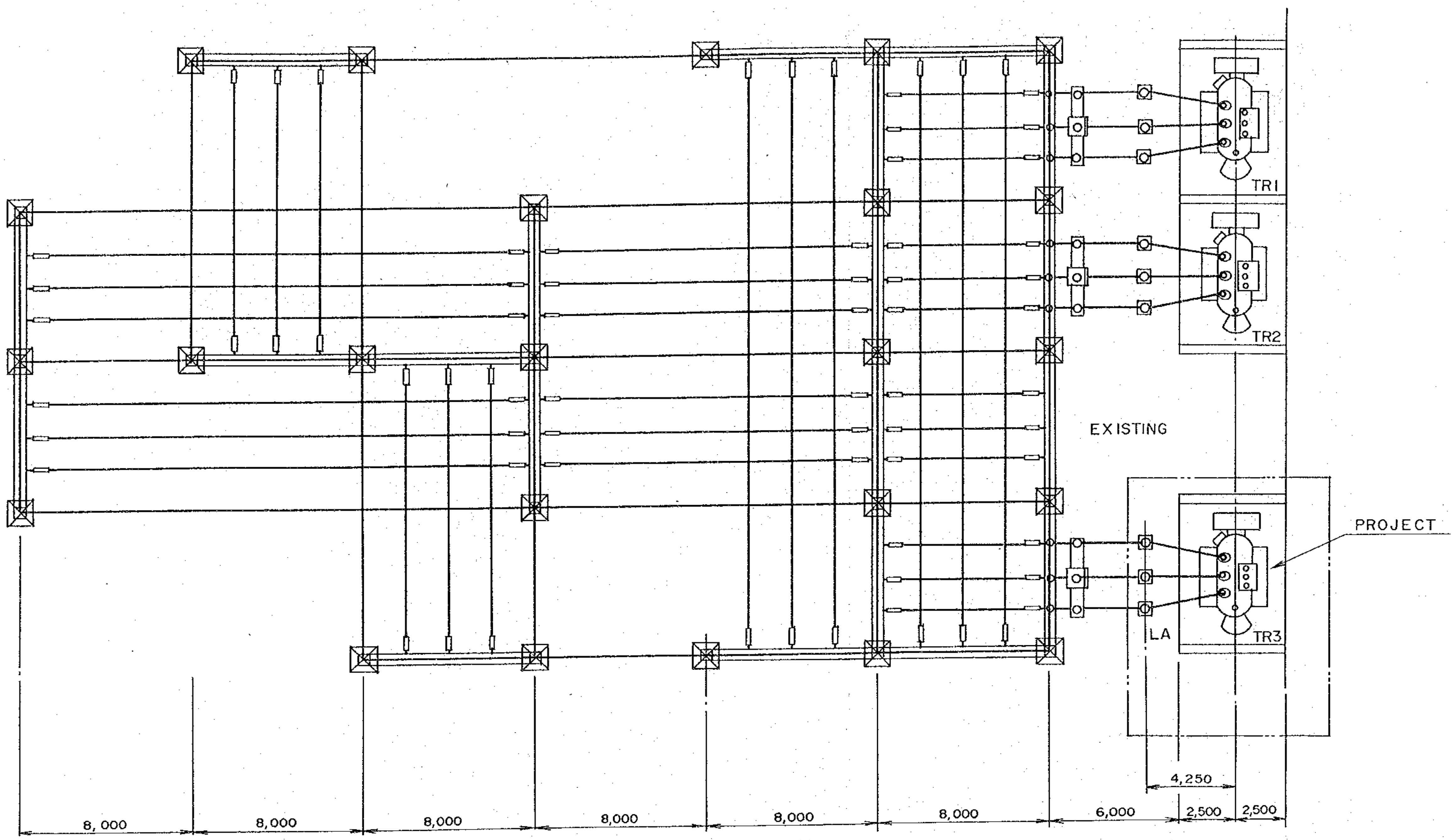
PROJECT

POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM

(EXISTING PUERTO BOTANICO SUBSTATION)

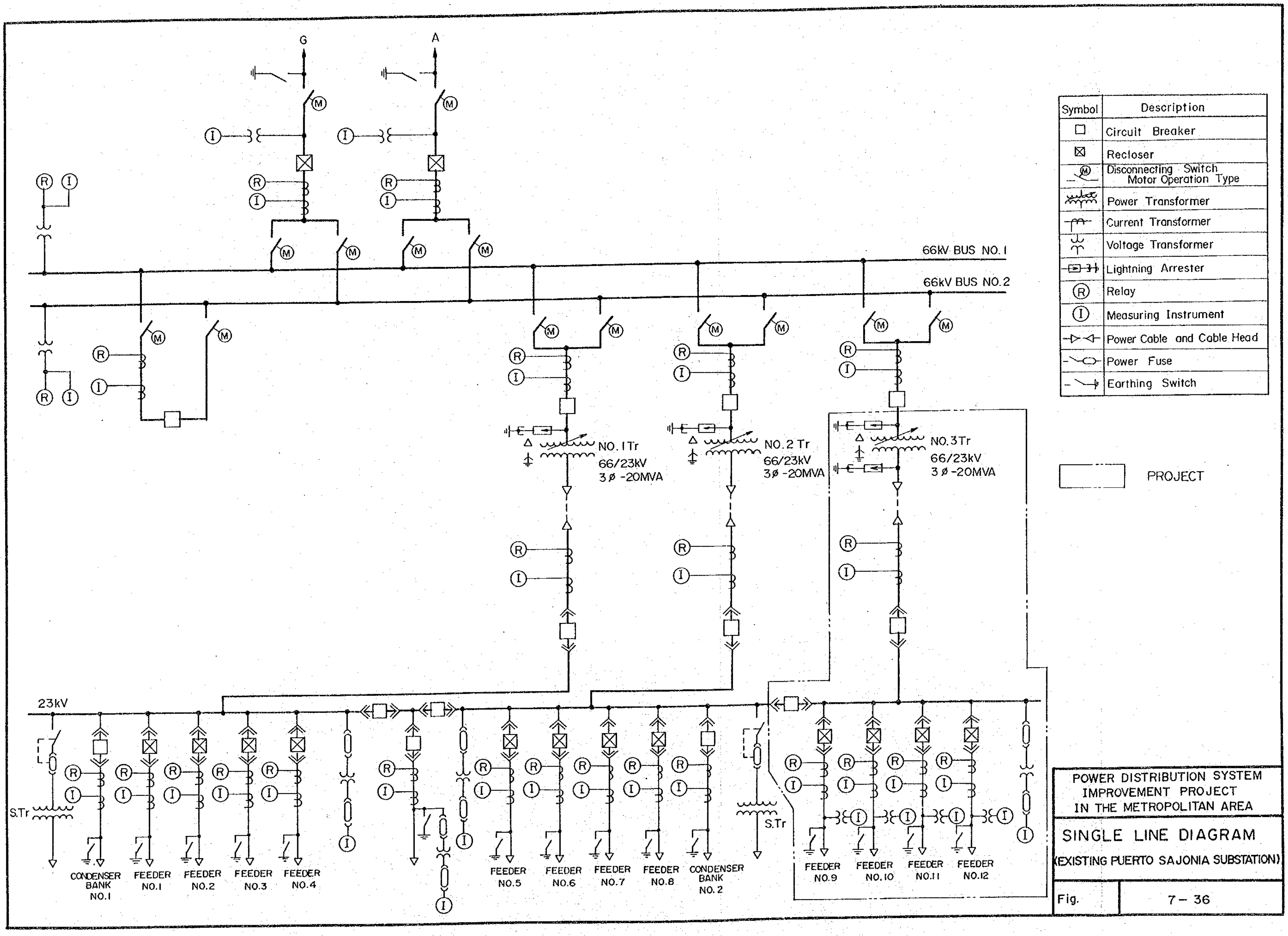
Fig. 7 - 34



POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT PLAN
(EXISTING PUERTO SAJONIA SUBSTATION)

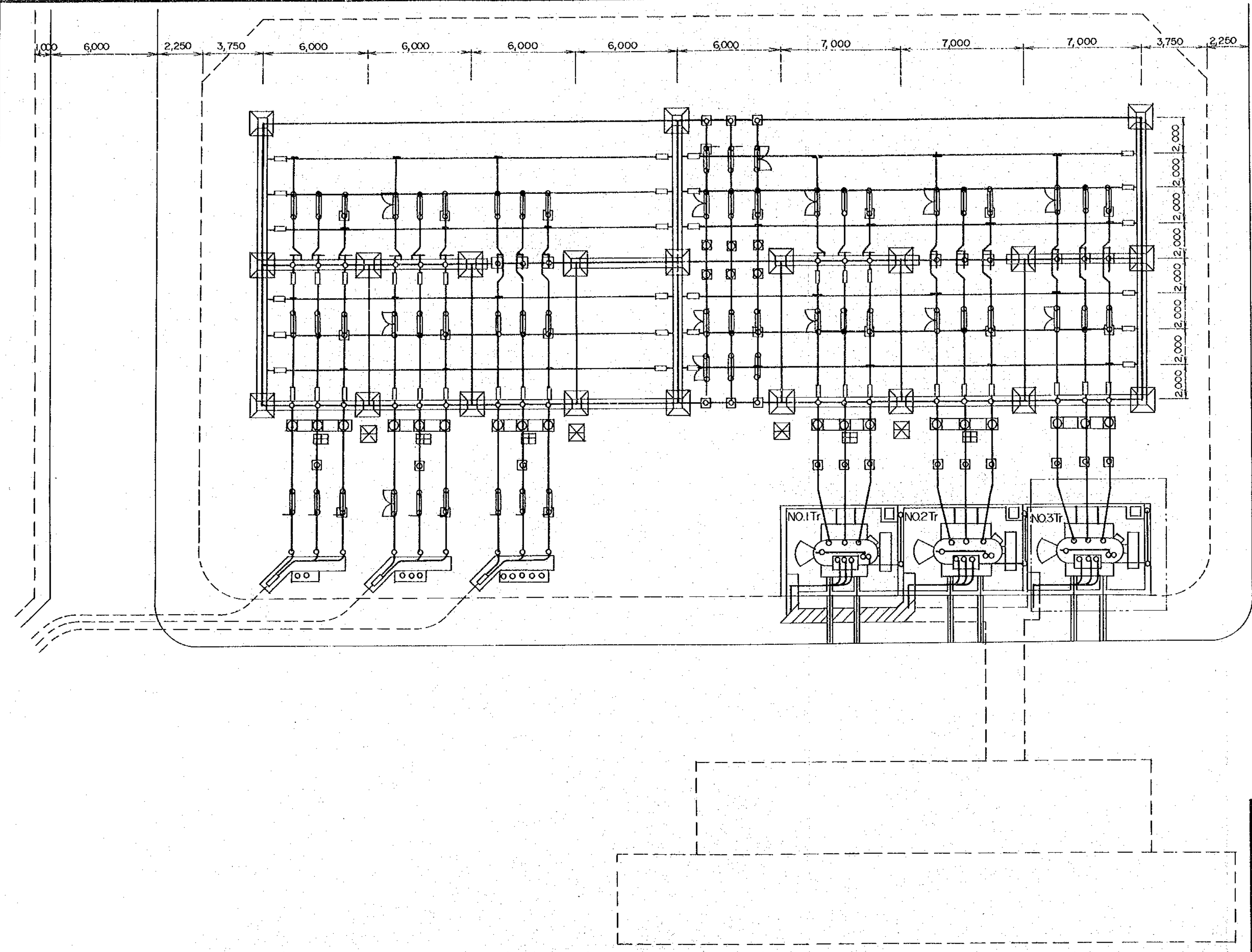
Fig.	7 - 35



POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM (EXISTING PUERTO SAJONIA SUBSTATION)

Fig. 7- 36

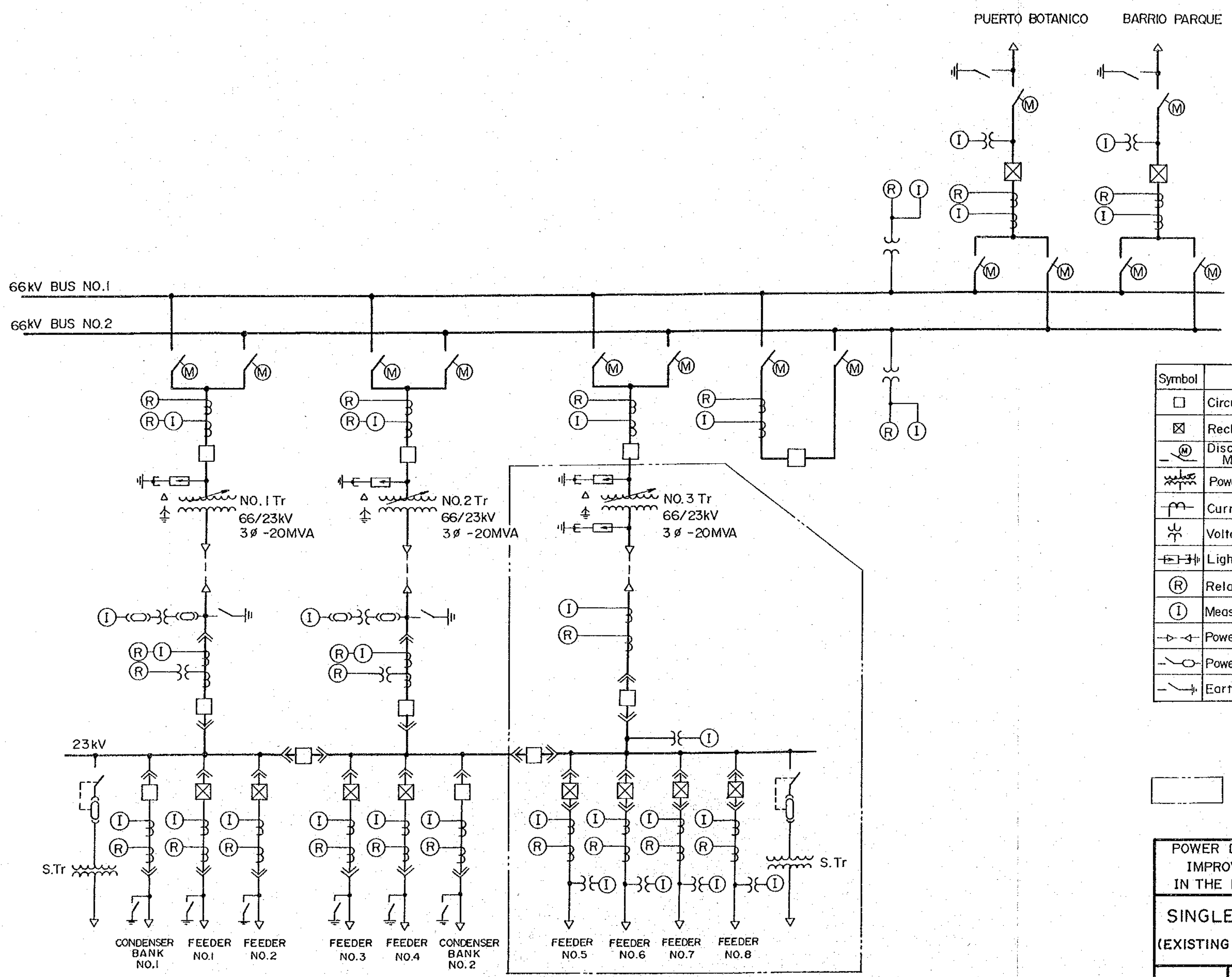


PROJECT

POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT PLAN
(EXISTING SAN MIGUEL SUBSTATION)

Fig. 7 – 37

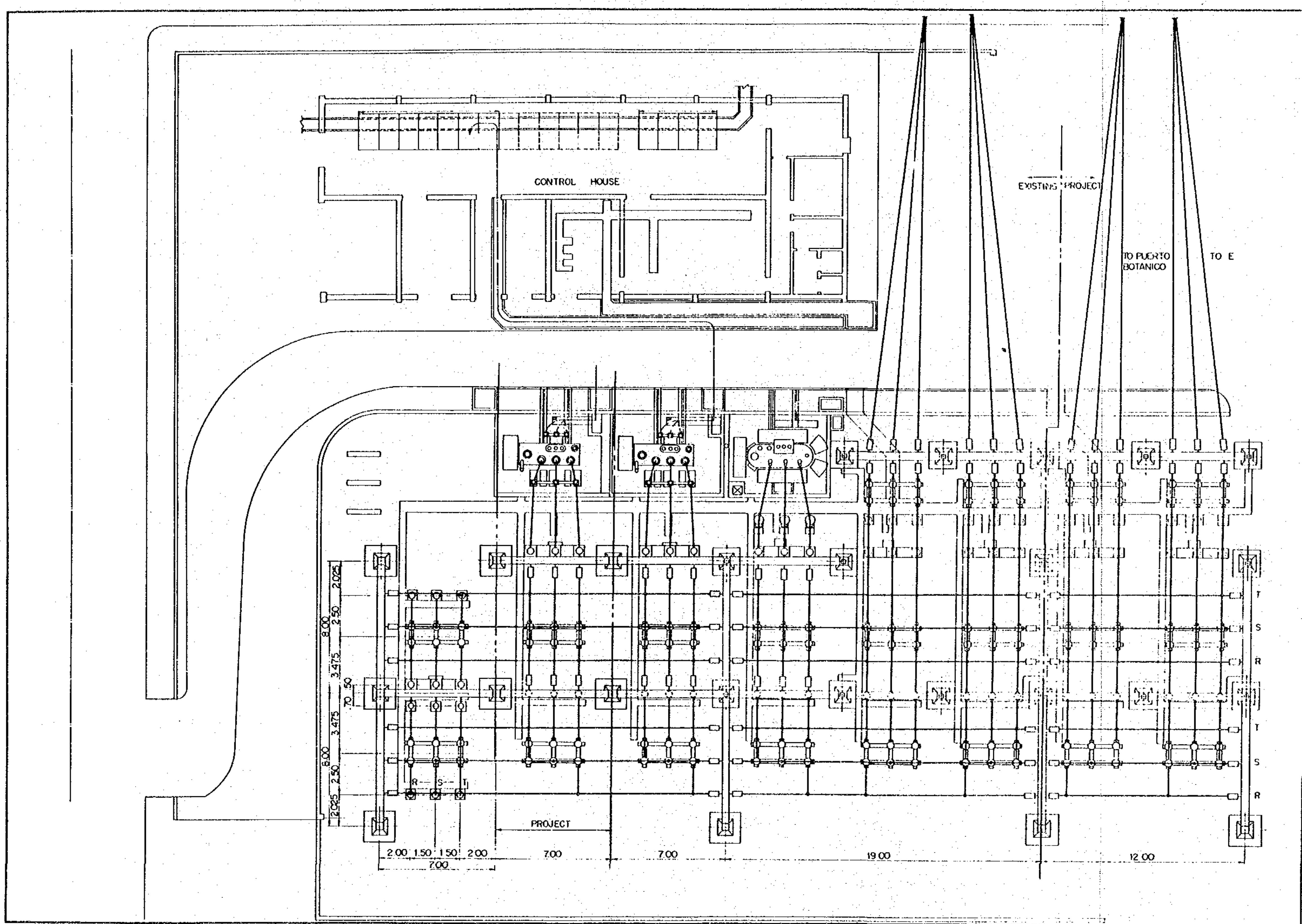


Symbol	Description
□	Circuit Breaker
⊠	Recloser
	Disconnecting Switch Motor Operation Type
	Power Transformer
	Current Transformer
	Voltage Transformer
	Lightning Arrester
(R)	Relay
(I)	Measuring Instrument
	Power Cable and Cable Head
	Power Fuse Switch
	Earthing Switch

POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM (EXISTING SAN MIGUEL SUBSTATION)

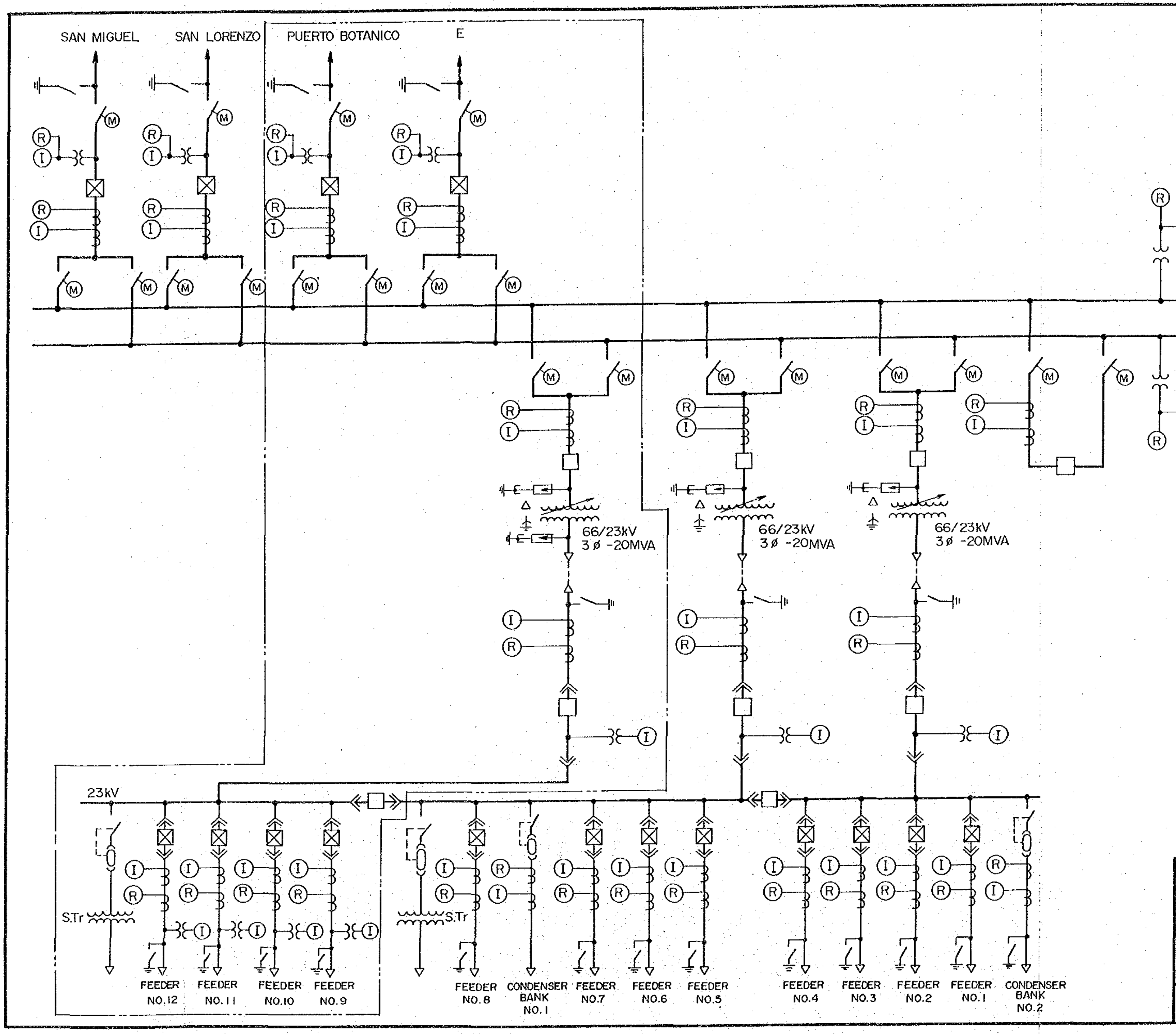
Fig. 7 - 38



POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

GENERAL ARRAGEMENT PLAN (EXISTING. BARRIOPARQUE SUBSTATION)

Fig. 7 - 39



Symbol	Description
□	Circuit Breaker
⊠	Recloser
	Disconnecting Switch Motor Operation Type
	Power Transformer
	Current Transformer
	Voltage Transformer
	Lightning Arrester
Ⓡ	Relay
Ⓘ	Measuring Instrument
	Power Cable and Cable Head
	Power Fuse Switch
	Earthing Switch

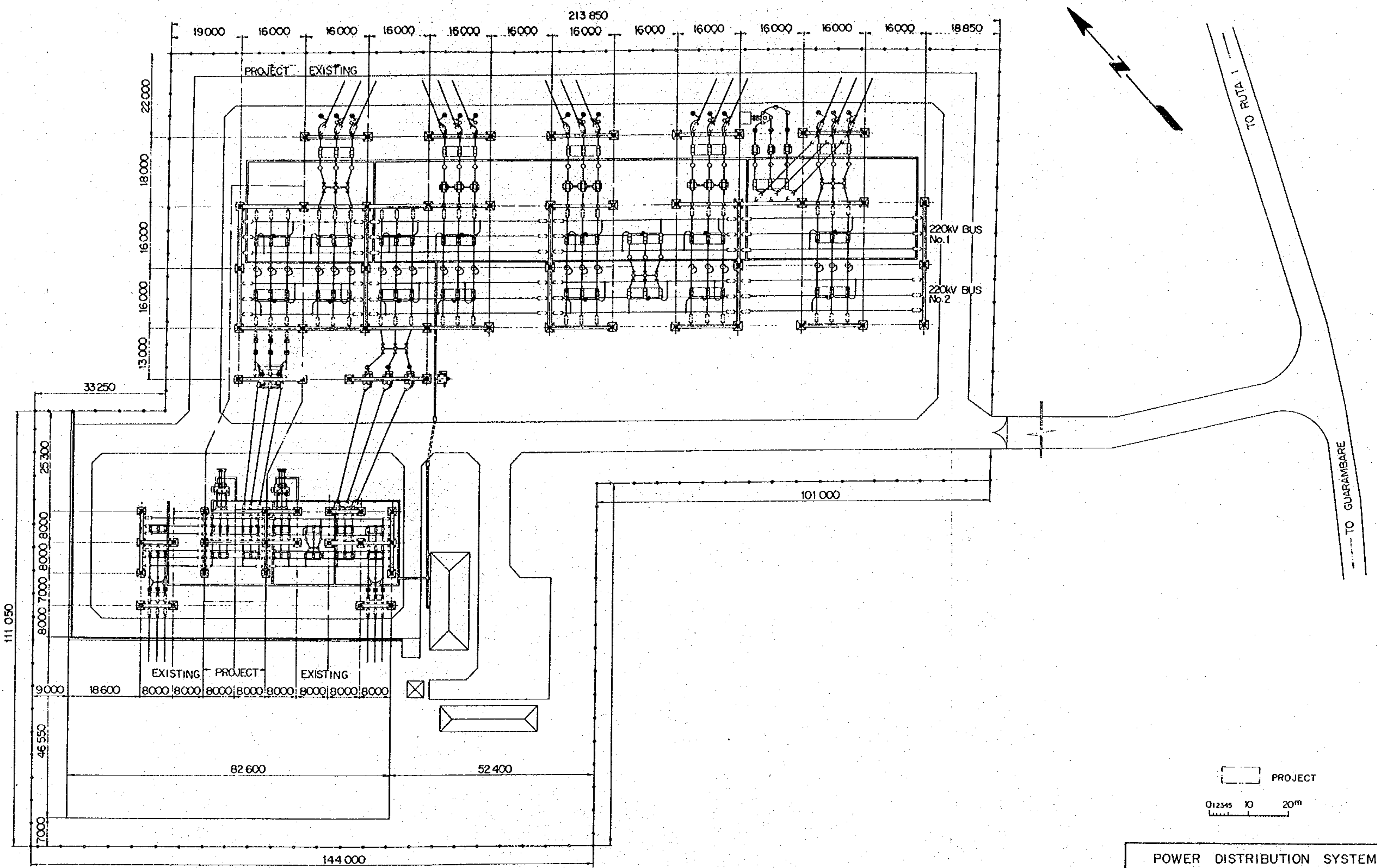
PROJECT

POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM

(EXISTING BARRIO PARQUE SUBSTATION)

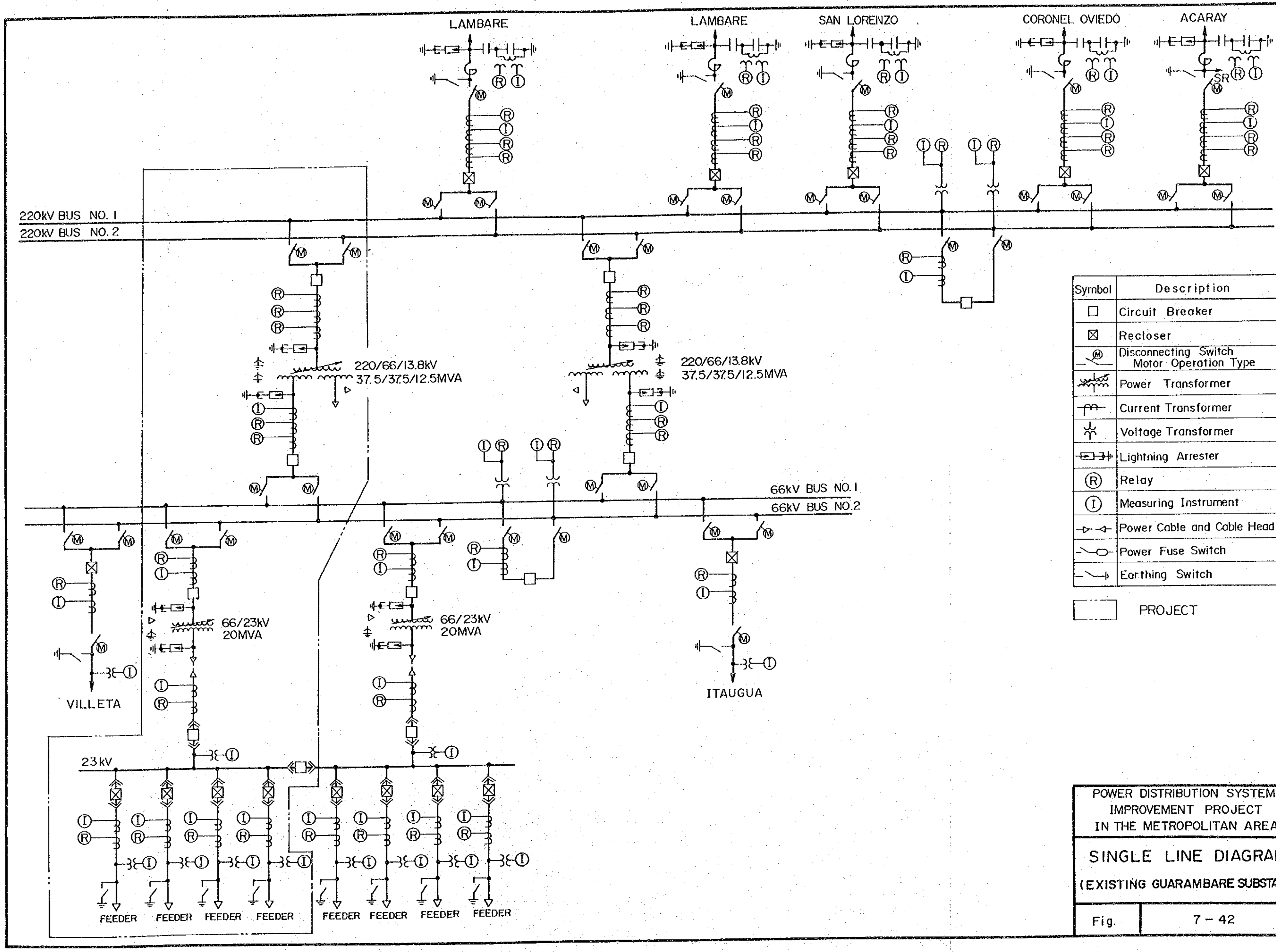
Fig. 7 - 40



POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRAGEMENT PLAN
(EXISTING. GUARAMBARE SUBSTATION)

Fig. 7 - 41



Symbol	Description
	Circuit Breaker
	Recloser
	Disconnecting Switch Motor Operation Type
	Power Transformer
	Current Transformer
	Voltage Transformer
	Lightning Arrester
R	Relay
I	Measuring Instrument
	Power Cable and Cable Head
	Power Fuse Switch
	Earthing Switch

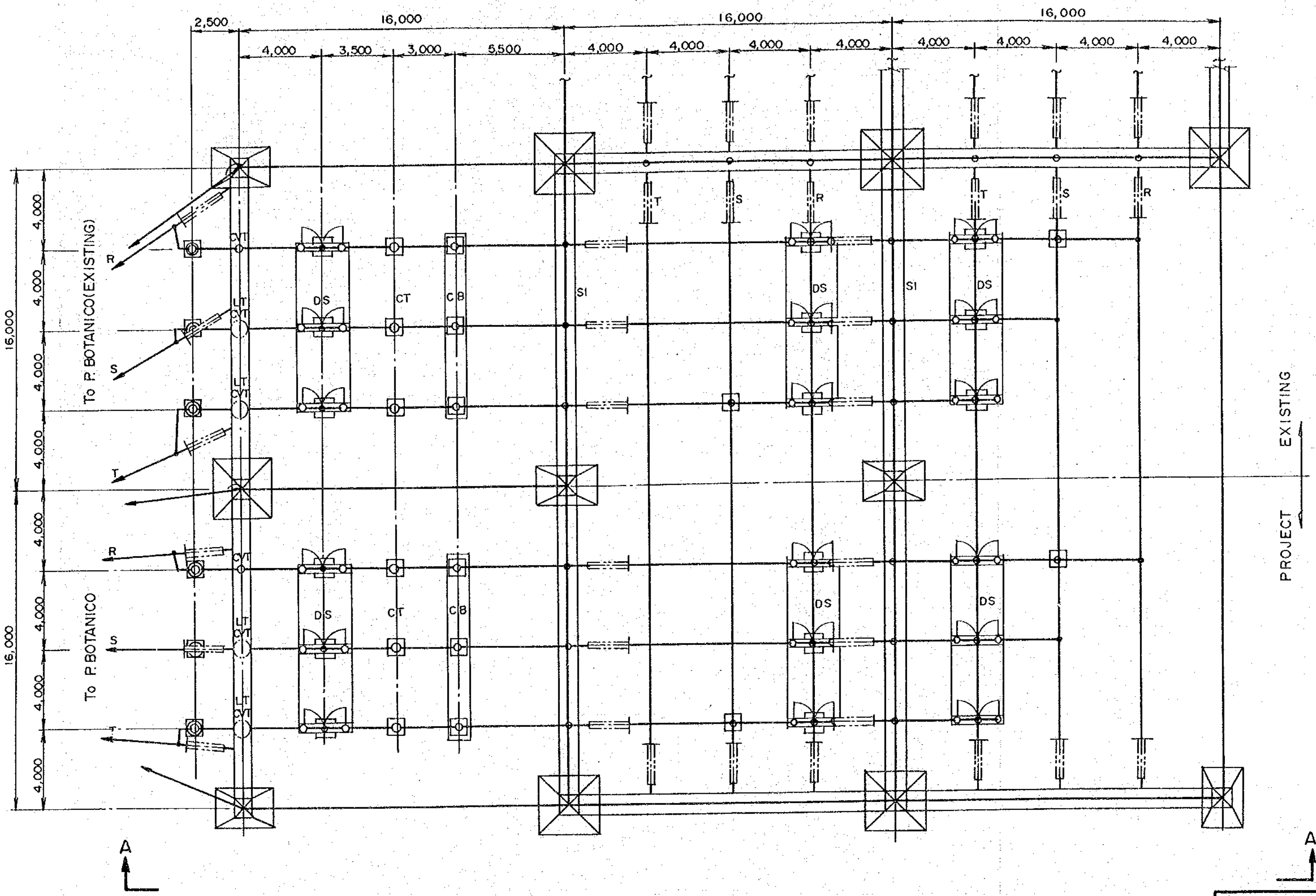
PROJECT

POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM

(EXISTING GUARAMBARE SUBSTATION)

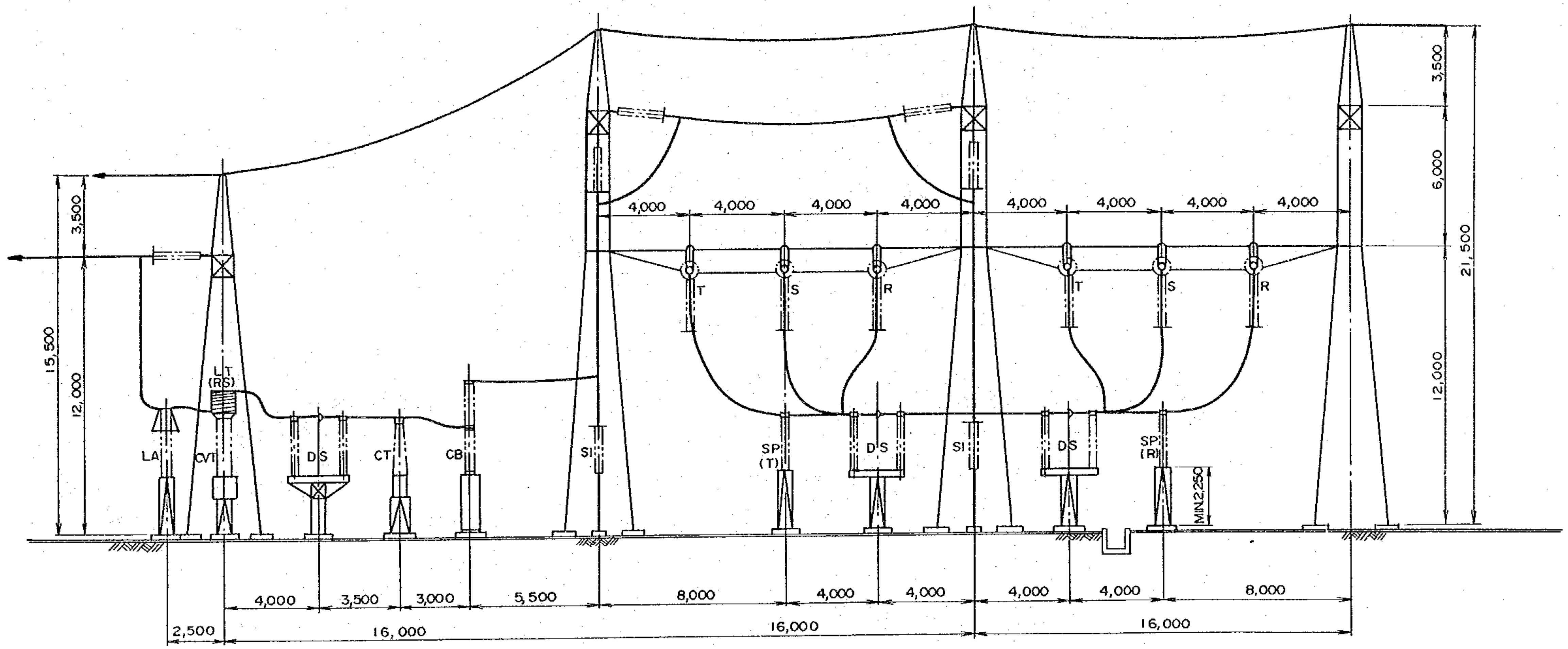
Fig. 7 - 42



POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT PLAN
(EXISTING LIMPIO SUBSTATION)

Fig. 7 - 43



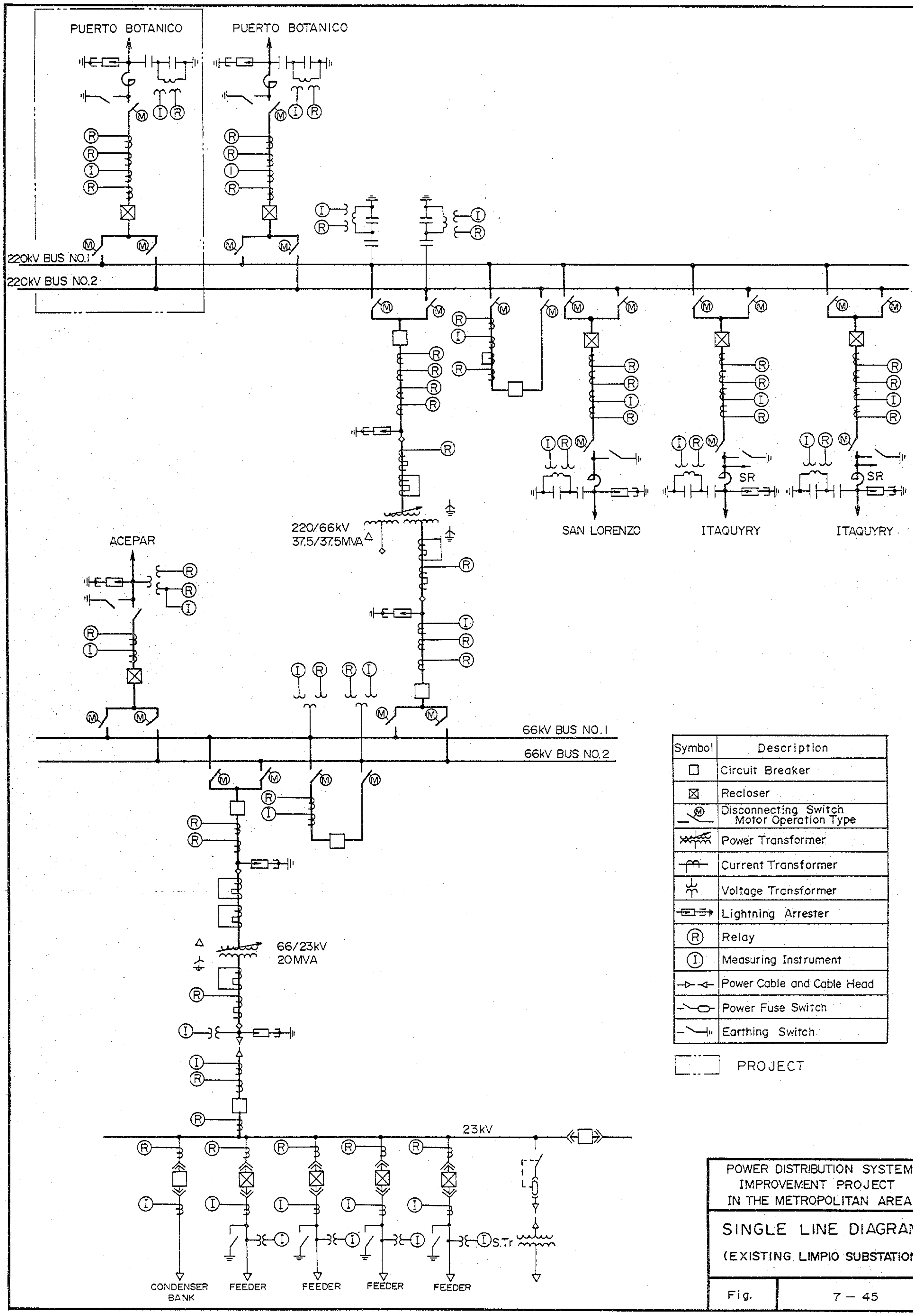
SECTION A－A

POWER DISTRIBUTION SYSTEM
IMPROVEMENT PROJECT
IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT SECTION

(EXISTING LIMPIO SUBSTATION)

Fig. 7－44



Symbol	Description
	Circuit Breaker
	Recloser
	Disconnecting Switch Motor Operation Type
	Power Transformer
	Current Transformer
	Voltage Transformer
	Lightning Arrester
R	Relay
I	Measuring Instrument
	Power Cable and Cable Head
	Power Fuse Switch
	Earthing Switch

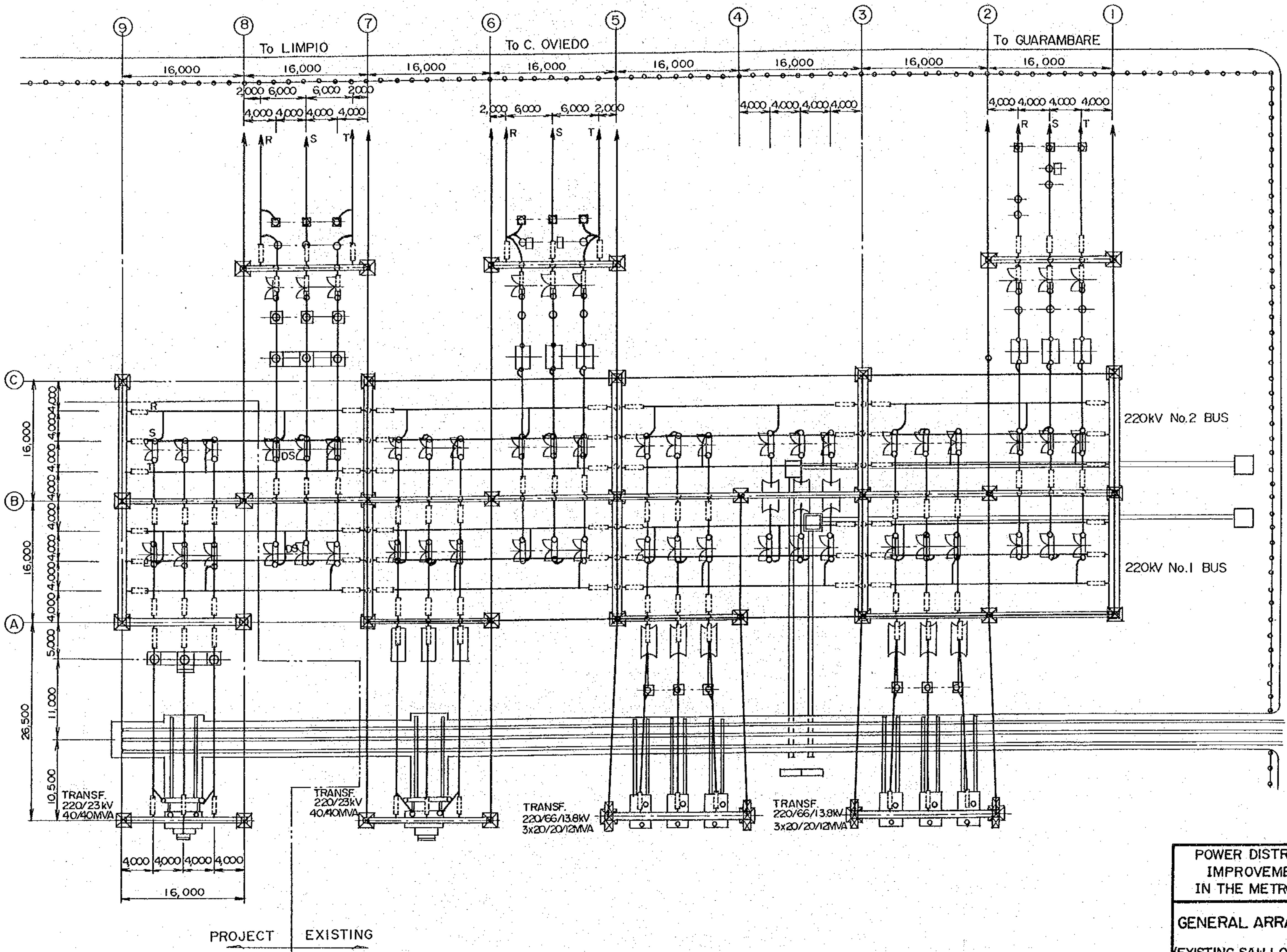
PROJECT

POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

SINGLE LINE DIAGRAM

(EXISTING LIMPIO SUBSTATION)

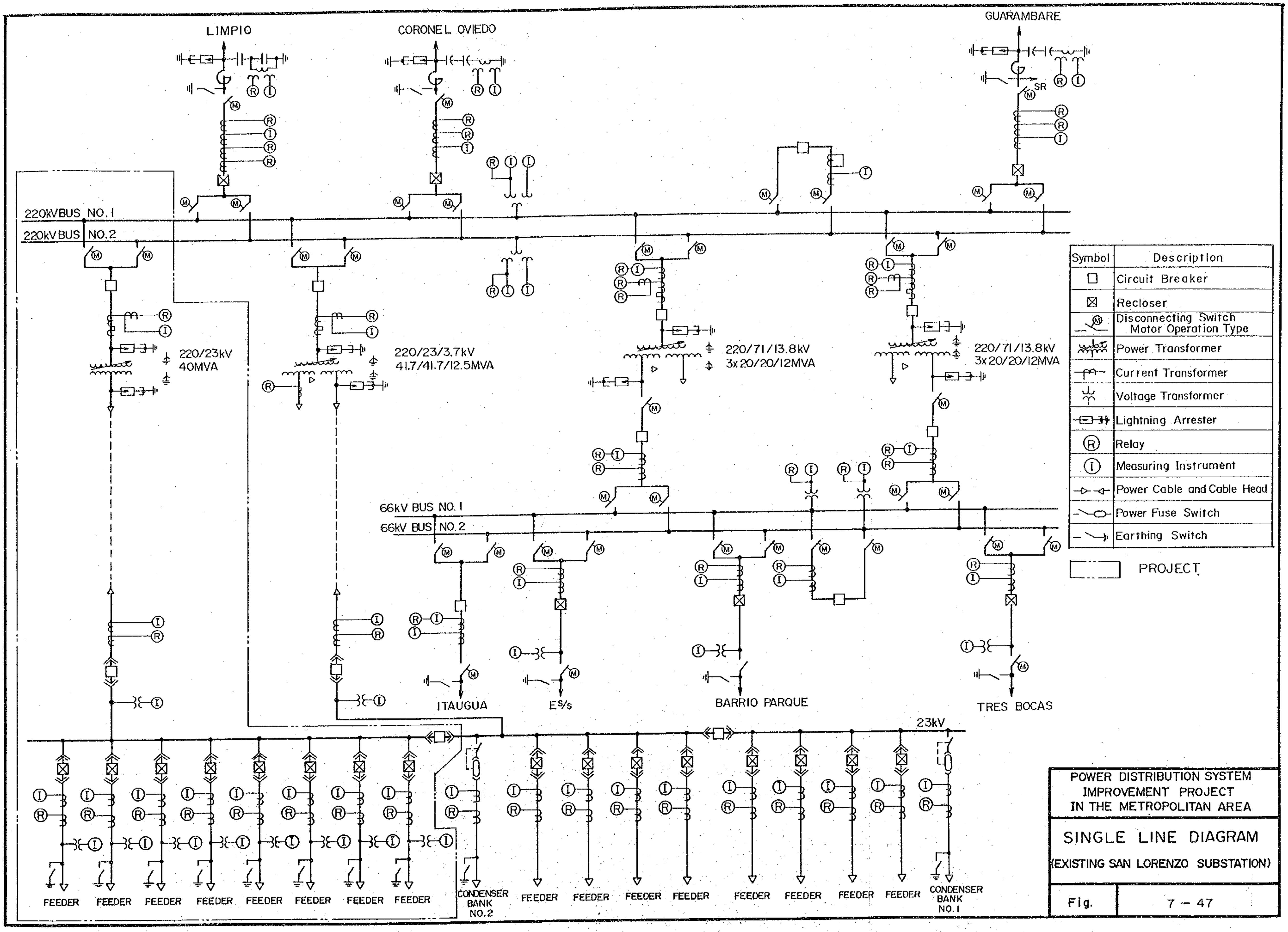
Fig. 7 – 45

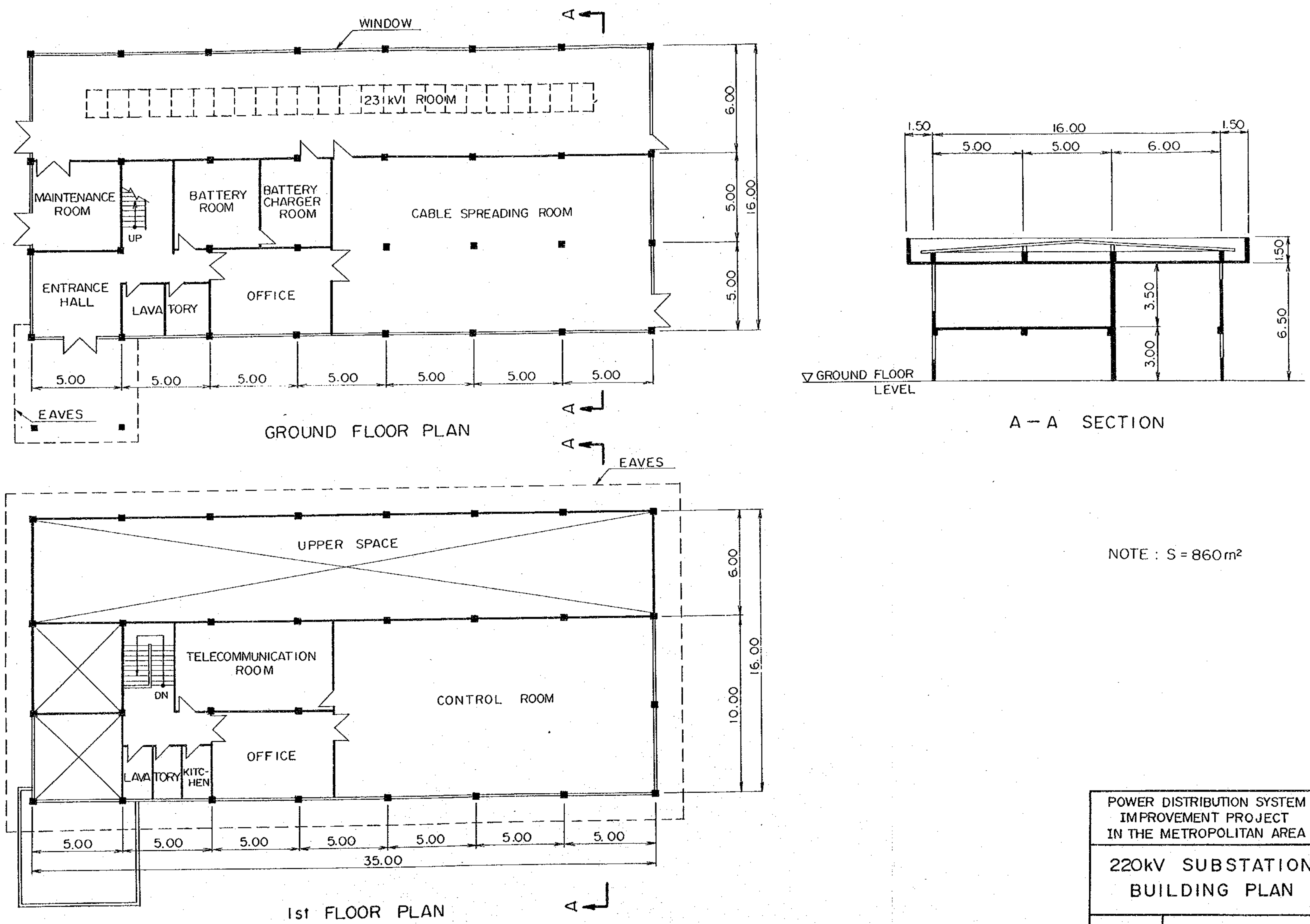


POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

GENERAL ARRANGEMENT PLAN (EXISTING SAN LORENZO SUBSTATION)

Fig. 7 - 46


LIMPIO
CORONEL OVIEDO
GUARAMBARE
SR
220kVBUS NO.1
220kVBUS NO.2
220/23kV
40MVA
220/23/3.7kV
41.7/41.7/12.5MVA
220/71/13.8kV
3x20/20/12MVA
220/71/13.8kV
3x20/20/12MVA
66kV BUS NO.1
66kV BUS NO.2
ITAUGUA
E%/s
BARRIO PARQUE
TRES BOCAS
23kV
FEEDER
FEEDER
FEEDER
FEEDER
FEEDER
FEEDER
FEEDER
FEEDER
CONDENSER BANK NO.2
FEEDER
FEEDER
FEEDER
FEEDER
FEEDER
FEEDER
FEEDER
FEEDER
CONDENSER BANK NO.1
Symbol
Description
Circuit Breaker
Recloser
Disconnecting Switch Motor Operation Type
Power Transformer
Current Transformer
Voltage Transformer
Lightning Arrester
Relay
Measuring Instrument
Power Cable and Cable Head
Power Fuse Switch
Earthing Switch
PROJECT
POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA
SINGLE LINE DIAGRAM
(EXISTING SAN LORENZO SUBSTATION)
Fig. 7 - 47

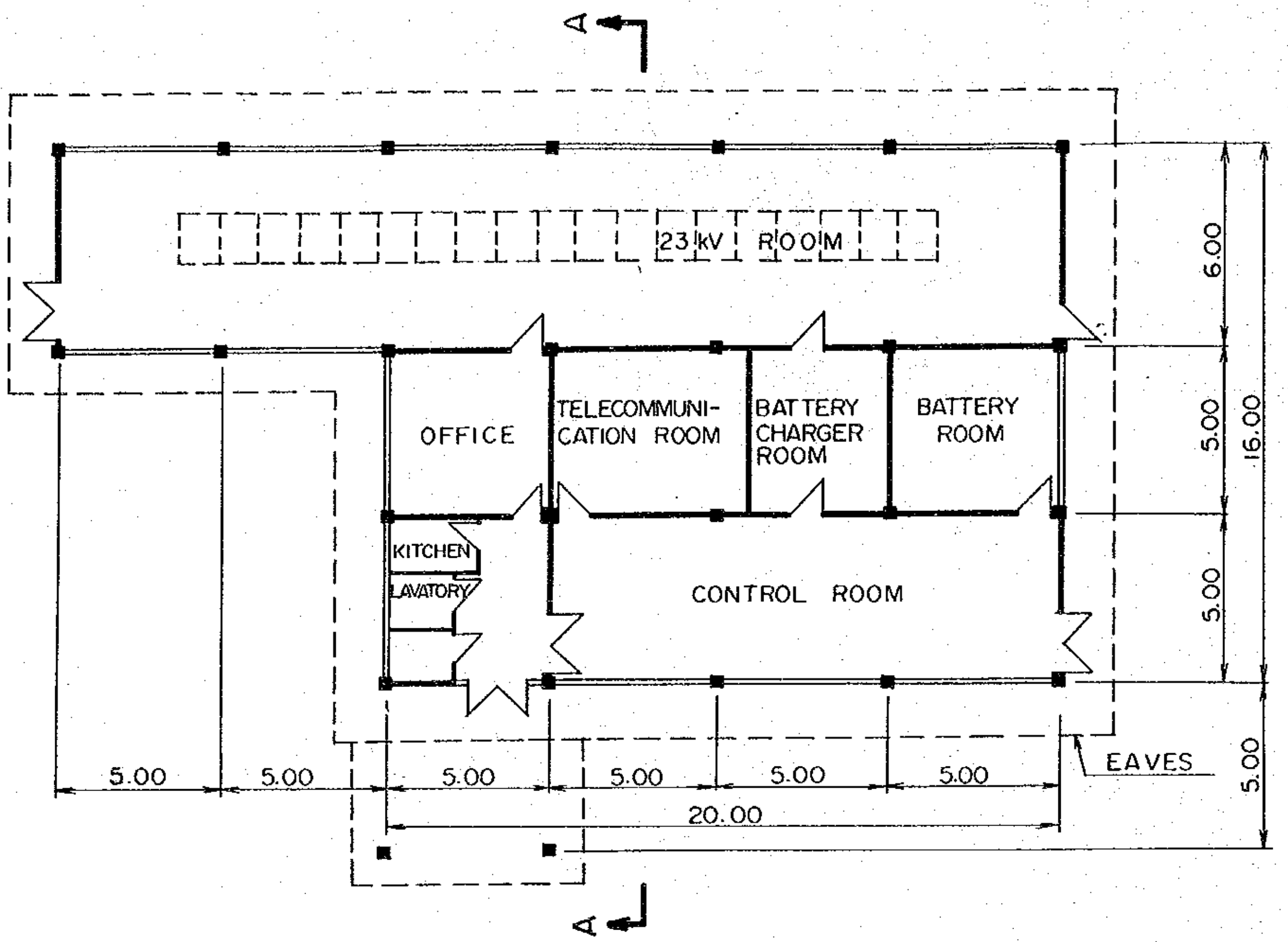


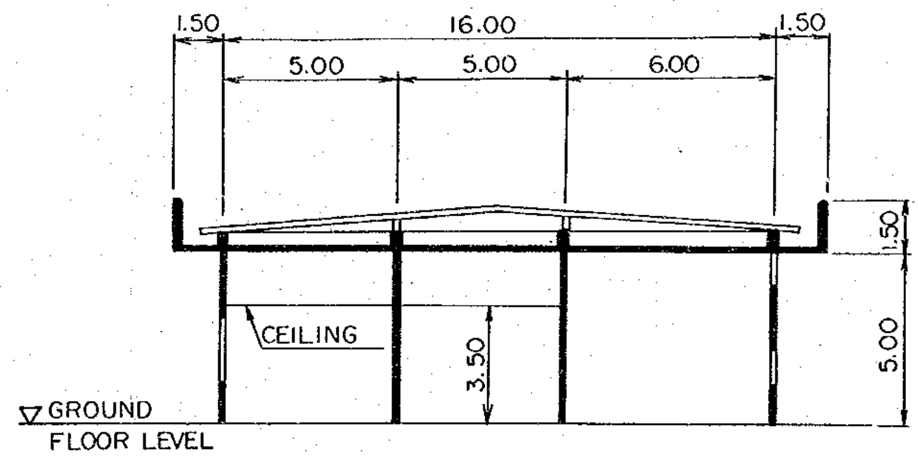
POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

220kV SUBSTATION BUILDING PLAN

Fig. 7 – 48

SHEET NO. OF





A - A SECTION

NOTE : S = 380m²

POWER DISTRIBUTION SYSTEM IMPROVEMENT PROJECT IN THE METROPOLITAN AREA

66kV SUBSTATION BUILDING PLAN

Fig. 7 - 49

SHEET No. OF

buildings shall be designed with due consideration on the actual siting and site conditions.

It is recommended for lighting system to be designed according to the illuminance standard presented in Table 7-10.

Table 7-10 Illuminance Standard

Room	Position	Illuminance (Lux)	Lighting
Distribution Control Room	Desk Surface	500	Fluorescent Lamp
	Vertical Surface	400	Incandescent Lamp Spot Lighting or Fluorescent Lamp
Control Room	Desk Surface	400	Fluorescent Lamp
Relay Room	Desk Surface	400	Fluorescent Lamp
Telecommunication Room	Desk Surface	400	Fluorescent Lamp
Battery Room	Floor Surface	150	Fluorescent Lamp
Cable Spreading Room	Floor Surface	100	Fluorescent Lamp
Office	Desk Surface	300	Fluorescent Lamp
Computer Room	Desk Surface	500	Fluorescent Lamp

7.3 Environmental Problem

7.3.1 Prevention of Pollution and Hazardous Conditions

(1) The transmission lines shall be so designed that conductor height above ground is sufficient to prevent any influence of harmful electrostatic induction to people. The conductor height shall be selected carefully because the transmission lines pass in urban center in the Project Area where there is frequent human traffic.

(2) Substations shall be guarded by fences, etc. to prevent trespassing. When such barriers are made of, for example,

steel fence, such barriers shall be completely grounded to prevent electric shock.

7.3.2 Natural Environmental Problem

(1) As transmission lines pass urban areas, their support type will be chosen in the following three, either, steel tower, steel pole or steel pipe, to prevent deterioration of scenery.

(2) Social Environmental Problem

Conductor type was so decided that no corona noise may cause electromagnetic interference on TV reception, radio reception, etc. near transmission line.

CHAPTER 8

DISTRIBUTION NETWORK PLAN

CHAPTER 8 DISTRIBUTION NETWORK PLAN

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List of Tables and Figures

CHAPTER 8 DISTRIBUTION NETWORK PLAN

8.1 Current Status of Distribution Equipment

8.1.1 Current Status

The substation capacities, number of circuits connected to substations, and the aggregate length of 23 kV distribution lines in the project area are presented in Table 8-1. The equipment status of 23 kV feeders is presented in Fig. 8-1.

The electrical system of the low voltage distribution lines is the "Y" configuration, 3-phase 4-wire system, as illustrated in the figure below, and the rated voltage is 23 kV on the middle voltage lines, 220 V for the low voltage lines for single phase loads, and 380 kV, 3-phase 3-wire system for the low voltage lines of three phase loads.

The main feeders consist of 3-phase 4-wire system, and branch feeders 3-phase 4-wire or single phase 2-wire system, and the distribution networks have tree configuration.

[Distribution System]

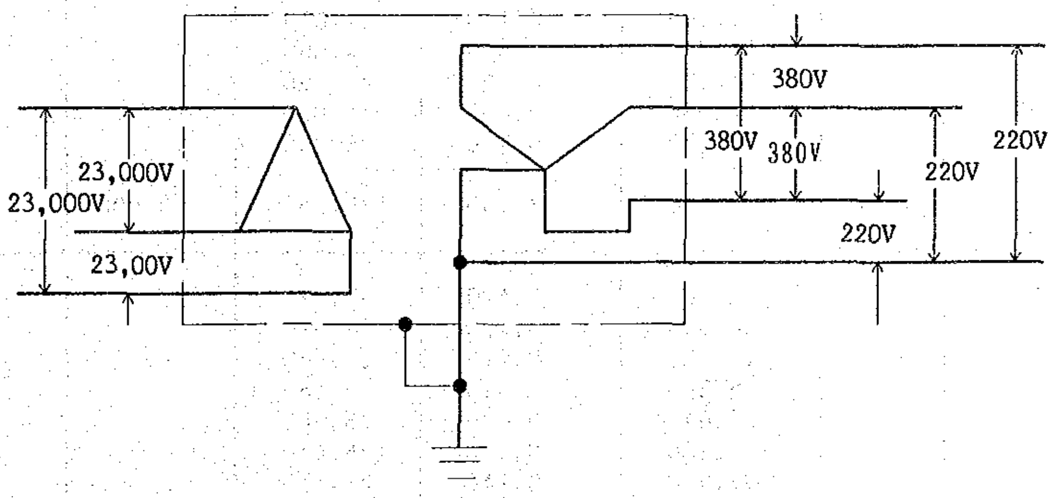


Table 8-1 Substation Equipment Capacity and Distribution Line Length

(1/2)

Substation Name and Capacity	Feeder Name	Distribution Line Length (km)			(C)/(B)	(A)/(C)
		Overhead Line	Underground Line	Total	(km)	(kVA/km)
PSA	3	4.000	0.730	4.730		
	4	5.720	4.600	10.320		
	5	24.450	0.200	24.650		
	6	8.850	0.600	9.450		
40,000 kVA	7		5.320	5.320		
(A)	8	3.800	6.560	10.360		
Subtotal	6 (B)	46.820	18.010	69.830(C)	10.800	617.00
CEN	1		4.250	4.250		
	2		2.300	2.300		
40,000 kVA	3		2.450	2.450		
	4		2.670	2.670		
Subtotal	4 (B)		11.670	11.670(C)	2.900	3427.600
SMI	1	5.410	2.100	7.510		
	2	4.530	2.300	6.830		
	3	21.490	0.600	22.090		
	4	19.520	0.800	20.320		
	5	1.800	8.150	9.950		
40,000 kVA	6		6.770	6.770		
(A)	7		0.020	0.020		
Subtotal	7 (B)	52.750	20.740	73.490(C)	10.500	544.300
BPA	1	25.690	0.300	25.990		
	2	27.270	0.250	27.520		
	3	11.640	0.170	11.810		
	4	13.790	0.870	14.660		
	5	21.830	0.560	22.390		
40,000 kVA	6	14.430	0.450	14.880		
(A)	7	21.050	0.750	21.800		
Subtotal	7 (B)	135.700	3.350	139.05(C)	19.900	287.700
SLO	1	62.300	0.420	67.720		
	2	44.190	0.120	44.310		
	3	11.420	0.220	11.640		
	4	8.840	0.320	9.160		
	5	122.640	0.420	123.060		
	6	126.280	0.130	126.410		
40,000 kVA	7	27.970	0.140	28.110		
(A)	8	9.000	0.130	9.130		
Subtotal	8 (B)	412.640	1.900	414.540(C)	51.800	96.500

Substation Name and Capacity	Feeder Name	Distribution Line Length (km)			(C)/(B)	(A)/(C)
		Overhead Line	Underground Line	Total	(km)	(kVA/km)
LAM	1	25.700	0.320	26.020		
	2	26.250	0.570	26.820		
	3	52.150	0.880	53.030		
	4	33.120	0.250	33.370		
	5	21.880	0.370	22.250		
	6	24.820	0.470	25.290		
	7	7.000	5.000	12.000		
	8	2.800	2.500	5.300		
120,000 kVA	9	22.040	0.870	22.910		
(A)	10	24.170	0.340	24.510		
Subtotal	10 (B)	239.930	11.570	251.500(C)	25.100	477.100
JBO	1	25.180	0.740	25.920		
	2	2.000	0.350	2.350		
	3	136.370	0.650	137.020		
	4	64.140	0.340	64.480		
24,000 kVA	6	12.200	0.120	12.320		
(A)	7	27.190	0.320	27.510		
Subtotal	6 (B)	267.080	2.520	269.600(C)	44.900	89.000
TBO	1	20.710	0.150	20.860		
	2	50.120	0.140	50.260		
20,000 kVA	4	20.370	0.130	20.500		
(A)	9	41.270	0.300	41.570		
Subtotal	4 (B)	132.470	0.720	133.190(C)	33.300	150.200
GUA	1	80.270		80.270		
	2	59.200		59.200		
20,000 kVA	3	77.200		77.200		
(A)	4	27.200		27.200		
Subtotal	4 (B)	243.870		243.870(C)	61.000	82.000
Total (A) 384,000 kVA	56	1531.260	70.480	1601.740	28.600	239.700

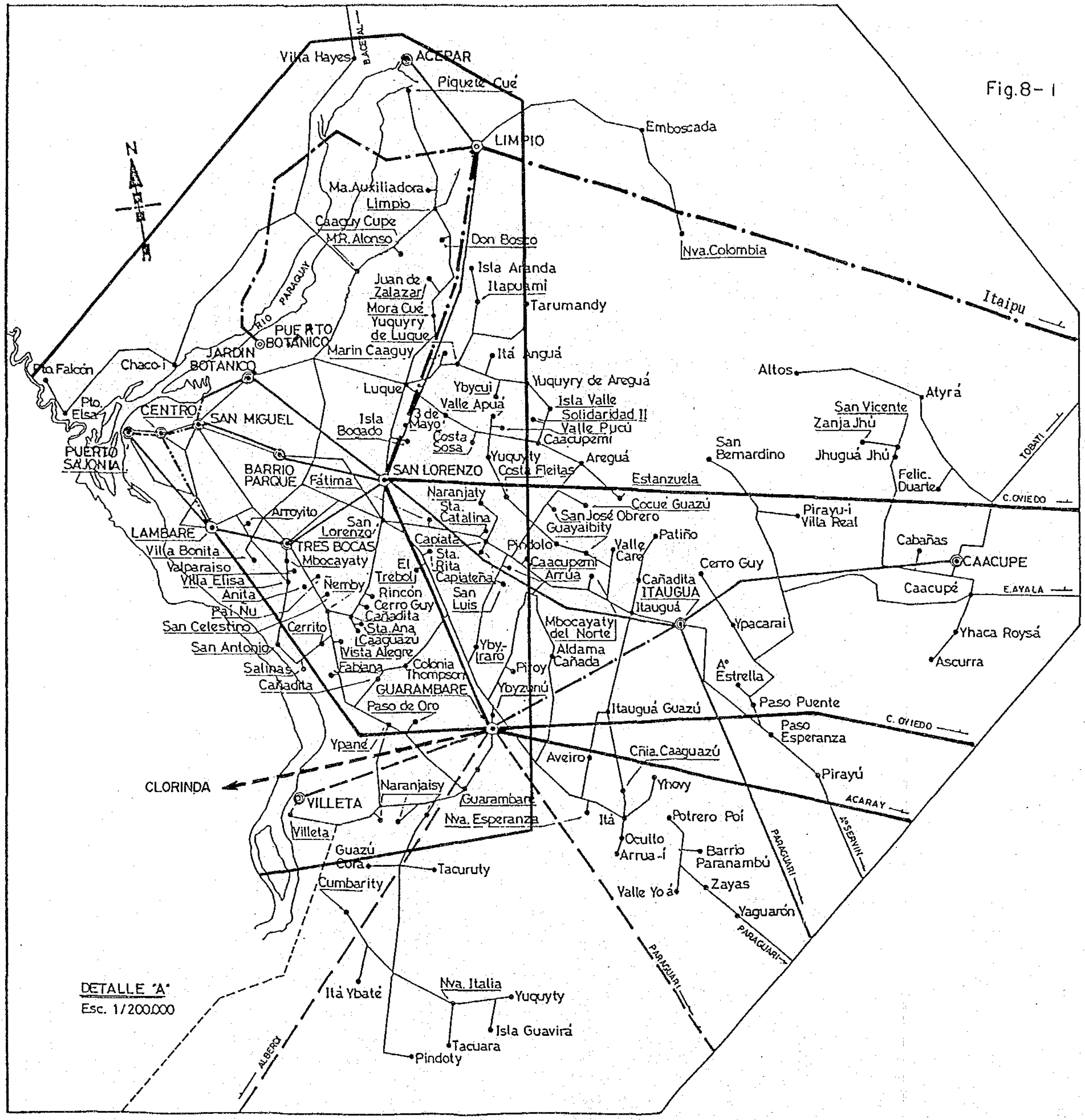
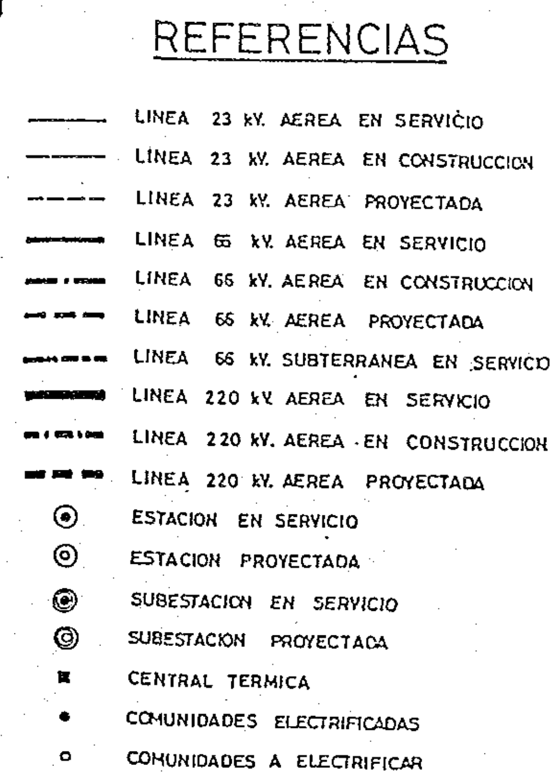


Fig.8-1 Transmission and distribution line net work in the project area.



The average length of a feeder is as long as 28.6 km. The longest feeder is the one supplying Chanco area from Jardin Botanico Substation, which is as long as 137 km. The average of feeder length is approximately 8.1 km (the average of PSA, CEN, and SMI substations).

In the Metropolitan Area, ANDE has 777 km overhead lines and 318 km underground lines in the 23 km distribution line, and 2,409 km overhead lines and 6 km underground lines in the low voltage distribution line as of the end of 1988.

The underground cables are more frequently used for substation connections and in Micro Centro district at the center of Asuncion City.

The distribution line conductors are bare conductors except for few regions. This is the reason why there are many distribution line failures due to contact to tree and kite playing.

In the 23 kV distribution lines, the support structures are either steel pipe poles or concrete poles. The conductors are aluminum alloy bare conductors with 35, 70, 95 and 150 mm^2 sizes. The nail type fuses are used as section switches, and the three phase section switches are rarely used. The distribution line voltage regulator is not used.

Ground wires are provided on most distribution lines, but some lines do not have ground wires.

The IPR aluminum cables of 50 and 240 mm^2 conductors are used for underground lines, which are directly buried, and protected by conduits at locations where mechanical loads are applied, such as intersections.

The low voltage transformers are rated at 5, 10 and 25 kVA for single phase transformers. For three phase transformers, there are 8 different types ranging in capacity from 63 kVA to 1,000 kVA. The total installed capacity was 764 MVA as of the end of 1988. Small transformers having 200 kVA or less capacity are installed on poles, and those having capacity of 300 kVA or more are often installed on ground or in basements of buildings.

The support structures in the project area used to be steel poles in urban areas, but poles rebuilt in recent years are mostly concrete poles. In some areas, wooden poles (palm trees) are used even in urban areas of the project area.

The conductor arrangement is not standardized, being vertical arrangement in some areas and horizontal arrangement in others.

Most of conductors are bare aluminum conductors of 16, 25, 35, 50 and 70 mm size.

There was not opportunity during the survey to exactly identify the magnitude of voltage drop. But it has been observed that fluorescent lamps turn dark occasionally, and there seemed to be substantial voltage drop.

8.1.2 Problems with Current Facilities

(1) 23 kV Distribution Lines

There are many trees which are planted along streets in the Project Area, and they are under good protection according to the direct instruction of the President of Paraguay. As Paraguay has a subtropical climate, these trees grow quickly, and often approach or touch power conductors in all places. To deal with this situation, ANDE has a special branch which is in charge of cutting trees along power lines, and conducts regular tree cutting operations. Although the line faults due to trees have been reduced substantially since this branch has been established, the current situation is such that this operation can not catch up to the speedy growth of trees.

Feeders are connected to other feeders through cut out fuses which is normally open. However, as feeders often do not have sufficient current capacity in certain sections, the switching of loads under line failure can not be implemented smoothly.

As underground cable lines have been installed recently, there has not been failure due to insulation deterioration. However, the routes and locations of cables are not indicated by markings provided on ground surface or on cables. It will be problem for water supply pipe and sewage installation works in future.

(2) Low Voltage Distribution Line

The transformer for distribution burn-out accident is frequent. There are many cases which can be identified as transformer overloading. In view of this situation, we think that it is not to apply systematic load current measurement practice, to identify the status of loading, and realize suitable divisions of loads. It is also recommended to supply at least the minimum required capacity and number of transformers to the new customers.

Where conductors are arranged vertically, the sag of each conductor is not uniform in many cases. As bare conductors are used, this condition will eventually lead to phase-to-phase short circuits. Spacers are provided between conductors in some places, but this seems to be provisional measures, and permanent measures are required. We found a crossing of power line and telephone line (telephone line of ANTELCO) where the distance between these lines is not enough. ANDE should consult ANTELCO to remedy this situation. (In Japan, the distance of low voltage overhead line and telephone line is established 60 cm more.)

As in the case with 23 kV feeders, conductors approaching or contacting trees and buildings are found almost anywhere. As conductors contacting trees could cause break, and ensuing electric shock to the public, this situation must be remedied through daily routine works.

(3) Metering

The all metering is imported. In starting metering, official calibration is done, and the calibration equipments are up to date products which have been imported. Therefore, the current practice as such is satisfactory.

However, the calibration is conducted only when the meters are placed to service, and they are used as such until a claim is placed by the customer, and some meters are more than 20 years old.

Generally speaking, the error of rotating type kWh meter increases with time, and it is desirable to calibrate meters at regular intervals.

Improvement of metering accuracy can contribute to reduction of distribution system loss. (In Japan, the meters of general customers are calibrated in every 7 years.)

(4) Street Lighting

Sufficient street lighting is provided in the Project Area. Modern street lighting system is equipped on the main road running from the airport to the urban center.

We observed, however, that one out of 10 street lights is lit even during daytime. This is due to the malfunction of the automatic switching system. ANDE is making effort to repair these automatic switch systems, and such improvement will contribute to the reduction of distribution system loss.

8.2 Promoting Introduction of Insulated Conductors to Distribution Lines

Faults on distribution line conductors are primarily caused by contacts of animals, birds, trees, kites and other foreign objects, lightening strokes, and unintended damages caused by activities of some persons. Of these faults, line-to-ground and short circuit faults caused by contacts are most frequent.

In the Project Area, the major cause of distribution line faults is the contact of trees to conductors. This is due to subtropical climate that makes trees grow very quickly, and because ANDE use bare conductors in most of its distribution line.

ANDE emphasizes the practice of cutting trees in an effort to prevent line faults. If this work progresses as planned, the tree contact accidents would be reduced substantially.

However, the fundamental countermeasure for prevention of line failures caused by foreign object contact is introduction of insulated conductors to distribution line.

The effect of introducing insulated conductors to distribution systems in Japan is illustrated in Fig. 8-2.

It can be seen in this figure that the frequency of line faults, which was 3 per customer per year before introduction of insulated conductors, has decreased to 0.2 per customer after insulation is completed.

This fact verifies that the insulation of distribution line conductors has contributed a great deal in improving the supply reliability of distribution networks. We recommend that ANDE adopts insulated conductors for distribution lines of ANDE, in which bare conductors are mostly used today.

8.3 Promoting Use of Underground Cables in Distribution Lines

Although the distribution lines were built as overhead lines in the past, the installation of underground lines are increasing in urban areas due to following reasons.

(i) In central commercial areas of cities where there are many buildings, there is little space to build overhead lines.

(ii) When distribution lines cross high voltage overhead transmission lines and sufficient clearance can not be secured.

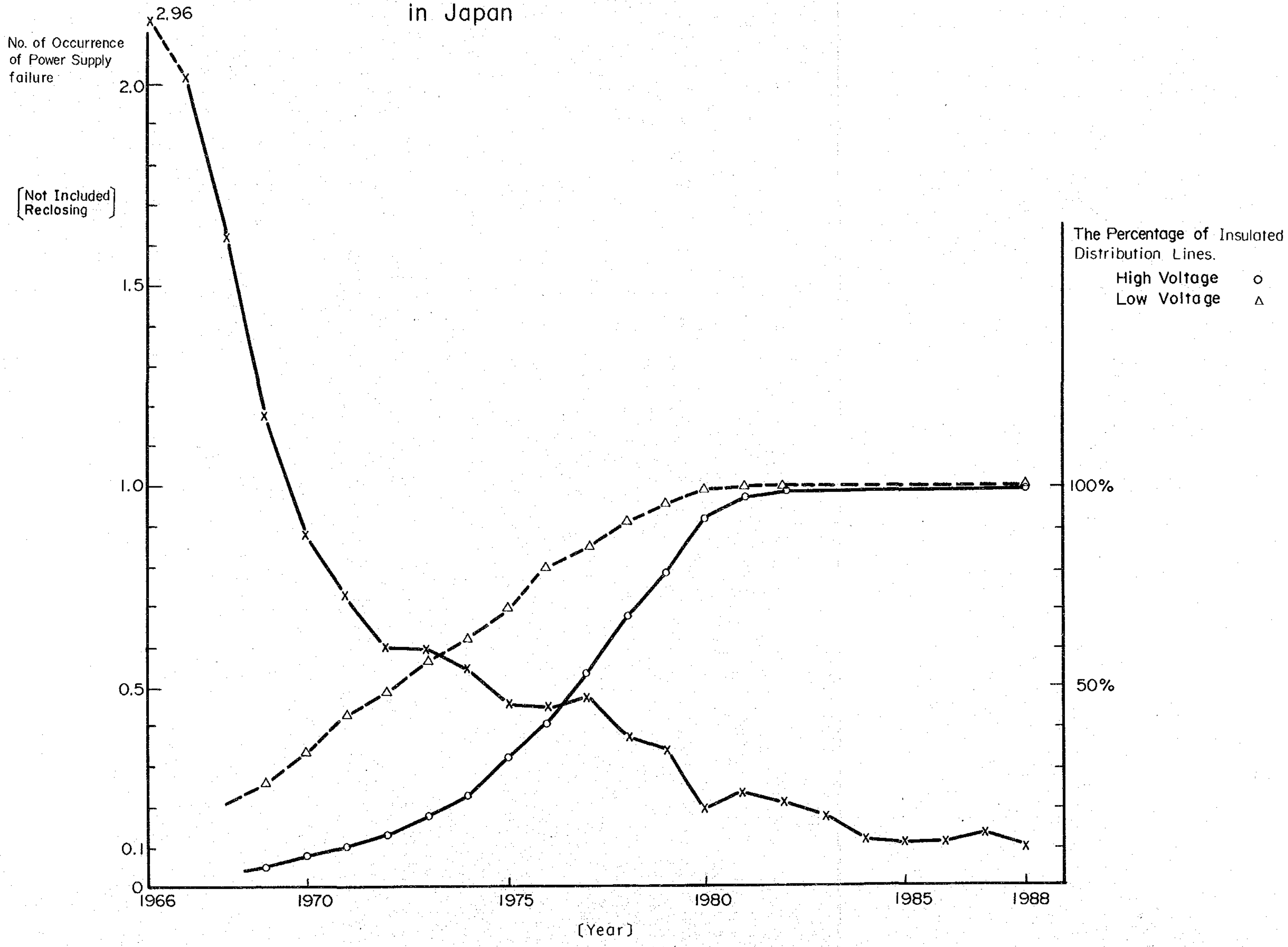
(iii) Underground cables are required in crossing a wide street.

(iv) Underground cable lines are more preferable in view of the urban scenery.

(v) As the number of feeders coming out of a substation increases, the arrangement of feeders becomes complex, presenting constraints on maintenance works.

Generally, the advantage of introducing underground cable lines can be summarized as:

Fig. 8-2 The Relation Curve Between the Percentage of an Insulated Wire of Distribution Line and the Improvement of Supply Reliability in Japan



(i) Prevention of broken conductors in storms, contact faults and lightning faults.

(ii) Better urban scenery.

On the other hand, there are such disadvantages as:

(i) The construction cost is several times as high as overhead lines with the direct cable burial system, and more than 10 times as high with the conduit burial system.

(ii) The construction work is more difficult, in cases such as crossing roads.

(iii) It is more difficult to locate the fault point in case of insulation failure, broken conductor, etc.

ANDE is currently actively pursuing introduction of underground distribution lines in urban centers. The JICA Study Team further recommends that this effort on introduction of underground cables is extended to every feasible place because it contributes to reduction of fault frequency which is high on the overhead lines.

8.4 The 23 kV and Low Voltage Distribution Line Plan

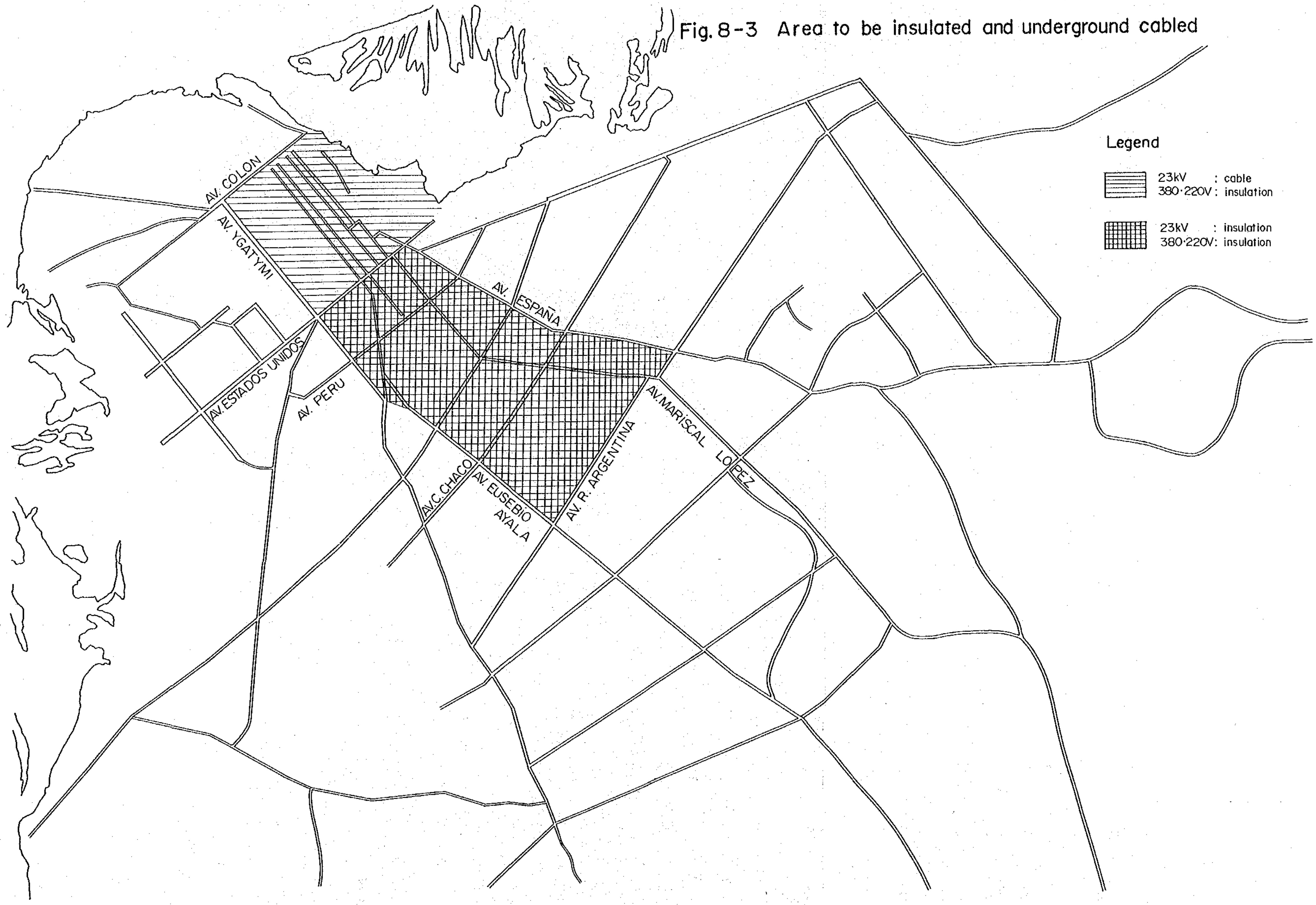
8.4.1 Insulation of Distribution Lines and Introduction of Underground Cables

It has been discussed in Sections 8.2 and 8.3 that introduction of underground cables is very effective in improving the reliability of distribution systems.

In the discussion between ANDE and the JICA Study Team, it was decided, considering the cost involved, that the introduction of insulated conductors to overhead lines and the conversion to underground cable lines will be implemented only in Micro Centro district and in areas of particular importance.

The areas to where insulated conductors and underground cables are introduced are Micro Centro district and areas where the load density is high, as defined in Fig. 8-3. The 23 kV distribution line

Fig. 8-3 Area to be insulated and underground cabled



will be converted to underground cables, and low voltage lines will be converted to insulated cables in the areas which are marked by hatched in the figure.

In the latticed areas in the figure, both 23 kV lines and low voltage lines will be converted to insulated overhead conductors. The related construction works will be implemented in three phases in order to avoid concentration of works.

Phase 1 Construction Work: Av. Argentina and Av. Choferes Chaco
Phase 2 Construction Work: Av. Choferes Chaco and Av. Peru
Phase 3 Construction Work: Av. Peru and Av. Colon

The area of each zone and the aggregate distribution line length are presented in the table below.

	Area (km^2)	23 kV Lines (km)	Low Voltage Lines (km)	Total Length (km)
Phase 1	4.7	44	36	80
Phase 2	5.1	48	39	87
Phase 3	4.0	38	30	68
Total	13.8	130	105	235

8.4.2 Increase of Load on Distribution Lines

The load on a distribution line is increased either by new customers, or by existing customers who introduce new electrical equipments. The distribution lines must be expanded when either of the following situation is reached.

(1) When the maximum allowable load of conductors, etc. is *exceeded:*

The distribution system equipments which have certain limit on the load they can carry are conductors (including cables), switches, voltage regulators, conductor connection fixtures, etc. These equipments are usually designed to match the maximum load capacity of the conductor, and they have to be replaced with those having higher rating when the expected conductor current exceeds the allowable conductor current.

(2) When the line voltage drop exceeds a certain allowable limit:

The distribution line equipments must be replaced when the line voltage drop exceeds the standard value in order to maintain the voltage at customers' end within an allowable range.

In this Project, the ratio of the distribution line allowable load to the maximum power flow in 1988 was calculated, and the incremental length of distribution lines that must be constructed during the period studied by this Project, from 1994 to 2000, has been estimated. (It has been assumed that the required distribution lines for the period from 1989 to 1993 will be constructed by ANDE.)

According to this calculation, the incremental length of distribution lines required for the maximum demand increase in the period of 294 MW is 1,225 km for the 23 kV distribution lines and 3,070 km for the low voltage lines.

8.4.3 Voltage Regulation of Long Distance Distribution Lines (Feeders)

As discussed before, the longest distribution line is the line supplying Chaco district from Jardin Botanico Substation, the length of this line is 137 km. In addition, there are two more long distance distribution lines, each exceeding 120 km, which are supplied by San Lorenzo Substation.

The voltage drop at the end such long distribution lines is substantial, and the voltage fluctuation can not be kept within an allowable range without additional measures.

As a measure of maintaining the voltage fluctuations within a certain limit, an automatic voltage regulation system, consisting of voltage regulators and single winding transformers located at appropriate locations on the line, is commonly used in Japan.

Although the areas where the voltage fluctuation become problematic are outside the Project Area, and they are outside the scope of this study, it is recommended to use the voltage regulation system, which is currently used in Japan for voltage regulation of long distance distribution lines, is applied to such long distance distribution lines.

8.5 Distribution Transformers

The total capacity of distribution transformers must be increased as the power system load increases. In investing on new distribution transformers, due considerations must be given on the actual operation of each transformer so that they are not overloaded, and at the same time excessive investment is avoided.

When the utilization factor of distribution transformers is too high, the voltage drop in the transformer increases, with increased load loss and temperature rise, thereby leading to short life of the transformer. On the other hand, if the utilization factor is too low, the total capacity of transformers is increased, with increased investment cost and decreased investment efficiency. In view of these factors, the increase in the total incremental capacity of distribution transformers has been calculated in this Project by obtaining the ratio of the total transformer capacity in 1988 to the maximum system demand, and applying this ratio to the incremental power system demand for the Project Period of 1994 to 2000. (It has been assumed that the additional distribution transformers required for the period from 1989 to 1993 will be supplied by ANDE.)

In this project, it has been assumed that the utilization factor of transformers will be improved by the increase in load density. The calculated incremental transformer capacity is 432 MVA as against the incremental power system demand of 294 MW.

8.6 Section Switches

The 23 kV distribution systems must be be so designed that no serious power supply failure is created during maintenance shutdown or failure of a part of the systems, and operation and switching of the systems are easy.

Section switches are provided at suitable locations on lines in order to reduce the area affected by maintenance shutdown. Some of these section switches are automatically operated, so that the faulty section of the system is separated automatically in the event of a fault, and the unfaulted part of the system is not shut down for a long period. These automatic systems can be either controlled remotely by means of communication line or power line carrier, or operated completely automatically with a time delay automatic control sequence.

The time delay automatic control is generally used because the operation is simple and the cost is low with this system. When the automatic section switch employing this system is introduced, the faulty feeder and the fault point can be easily identified, and the time of fault recovery is drastically improved as compared to the old system.

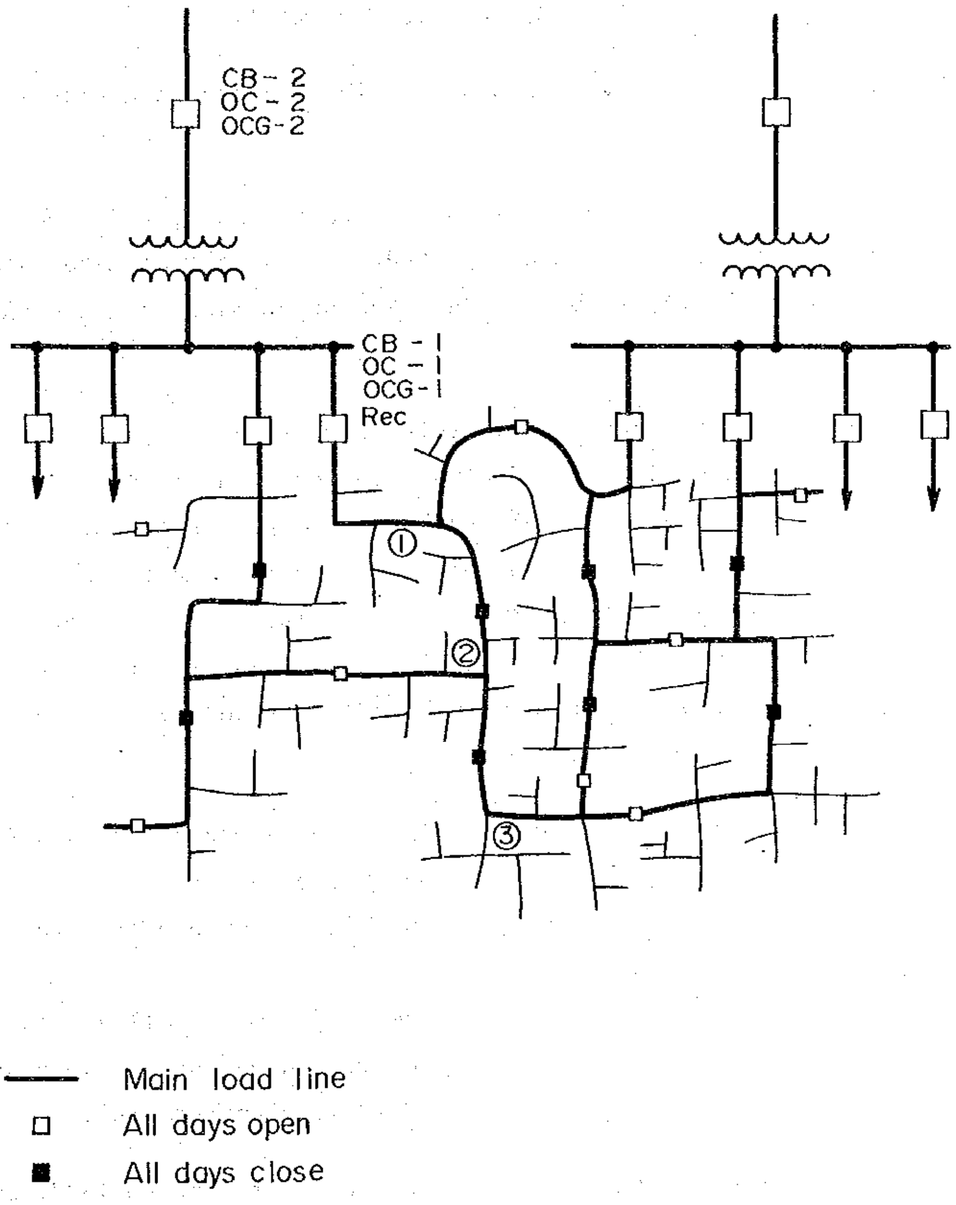
The JICA Study Team recommends ANDE to adopt the 3-loop, 3-division type system in the distribution net work. (Fig. 8-4) The fault section identification method used in this system is described in 9.4.4 (2).

In employing this system, a feeder is divided to 3 sections by section switches, and 2 automatic section switches and 1.5 manual section switches are installed on each feeder.

As of 1988, there are 56 feeders in the Project Area. It is expected that the number of feeders will be increased to 172 by year 2000 due to load increase and expansion of substations. The number of automatic section switches required for introduction of this system will be 344, the manual section switches will be 258, and the total number of section switches will be 602. The question of converting the 200 manual load switches, currently owned by ANDE, to automatic operation has been studied. However, it was judged that such conversion is difficult, due to the particular mechanism of these switches. All of the automatic section switches, capable of separating faulty lines, are supplied under this Project.

The manual section switches required for this system will be first filled by the 200 switches currently owned by ANDE, and the balance will be supplied by this Project. Concerning the feeders located outside the Project Area, it has been agreed upon with ANDE that these

Fig.8-4 3 Divisions and 3 Loops Form



feeders will be equipped with the circuit breakers having reclosing function, which are currently owned by ANDE, and faults outside the Project Area will be dealt with by these circuit breakers.

8.7 Reliability of Distribution Systems in Project Area

8.7.1 Current Reliability Level of Distribution Systems in Metropolitan Area

The faults records, supply reliability performance, and other data of the Metropolitan Area are reported in "Statistical Materials" which is monthly issued by the Business Department of ANDE since 1986.

ANDE describes the supply reliability performance in terms of D.E.K and F.E.K. D.E.K (Duracion Equivalente por potencia instalada) is defined as the "average supply failure time per unit installed capacity for a particular time period", and F.E.K (Frecuencia Equivalente por potencia instalada) is defined as the "average number of supply failure per unit installed capacity for a particular time period", and these values are calculated by the following equations.

$$\text{D.E.K.} = \sum_{i=1-n} \frac{p(i) \times t(i)}{\text{Ptotal}}$$

$$\text{F.E.K.} = \sum_{i=1-n} \frac{p(i)}{\text{Ptotal}}$$

p(i): installed capacity (kVA) affected by supply failure.

t(i): duration of supply failure.

Ptotal: power system installed capacity. (expressed by the total capacity of 23 kV transformers).

The D.E.K and F.E.K levels for the period from 1986 to 1988 are illustrated in Table 8-2, and it can be seen in this table that these values have been improving in recent years. Statistics are also available on the number of supply failures as classified by causes and the durations of failures in each month on low voltage and medium voltage systems. Fault statistics of medium voltage systems are given in Table 8-3 through Table 8-6, of low voltage systems in Table 8-7, of high voltage systems (66 kV or above) in

Table 8-2 Electric Power Supply Reliability in the Metropolitan Area

		1986 *1	1987	1988
D.E.K. Outage Hour per kVA		(8.54)	14.05	8.244
F.E.K. Outage No. per kVA		(16.62)	27.42	20.33
% (Hour of Outage)	Fault	(52.34)	59.80	69.06
	Maintenance	(23.53)	18.43	14.60
	Fault and Maintenance Outage of more than 66 kV System	(24.13)	21.78	16.34
% (No. of Outage)	Fault	(51.15)	60.79	60.84
	Maintenance	(7.24)	5.03	3.45
	Fault and Maintenance Outage of more than 66 kV System	(41.61)	34.17	35.71

*1 Seven-month total

Table 8-3 Outage of Middle Voltage Distribution Line (Including Maintenance Outage)

(1986 - 1988)

	1986	1987	1988
No. of Outage	2,102	1,361	1,106
Hours of Outage	501.074	460.328	400.684

Table 8-4 Cause of Faults of Middle Voltage Distribution Line

(1986 - 1988)

Cause	No. 1986	1987	1988
Imperfection of Manufacture		3	
Imperfect Workings	5	11	42
Sub-total	5	14	42
Wind, Rain	27	34	10
Thunder	9	13	12
Sub-total	36	47	22
Bird, Tree, Kite	72	113	90
Others	820	953	646
Unknown	67	68	90
Total	1,000	1,195	890

Table 8-5 Kinds of Faults of Middle Voltage Distribution Line

Kinds of Faults			No. 1986	1987	1988
Overhead Line	Wire	Breaking of Wire	76	59	48
		Bind is Off	27	34	10
		Interference of Middle and Low Voltage Wire	55	67	64
		Others	220	319	150
		Sub-total	378	479	272
	Pole Tr.	Winding	26	66	36
		Others	101	139	172
		Sub-total	127	205	208
		Others	421	419	774
		Sub-total	926	1,103	1,254
Cable		Others	7	31	26
		Sub-total	7	31	26
Total			933	1,134	1,280

Table 8-6 Cause of Faults of Pole Transformer

Cause		No. 1986	1987	1988
Thunder		9	13	12
Overcurrent caused by Short Circuit of Low Voltage Side		17	46	26
Transformer Unit	Imperfection of Manufacture		3	
	Imperfect Workings	5	11	42
	Sub-total	5	14	42
Others		29	64	38
Unknown		67	68	90
Total		127	205	208

Table 8-7 Cause of Faults of Low Voltage Distribution Line

(1986 - 1988)

Cause	1986		1987		1988	
	No.	Hour of Outage	No.	Hour of Outage	No.	Hour of Outage
Breaking of Wire	1,385		1,309		1,049	
Falling Down of Pole	3,135		2,566		2,218	
Short Circuit of Line	976		901		798	
Fuse Melting Away of Pole Tr. Secondary Side	3,276		2,617		2,871	
Unknown	87,453		44,193		35,561	
Car-hit	25		99		152	
Total	96,250	145,981	51,685	51,133	42,649	50,113

Table 8-8 through Table 8-9, respectively. According to ANDE's statistics, the electric energy sales which was lost by supply failure was 2,806 MWh in 1987, and 2,043 MWh in 1988 respectively, with corresponding revenue loss of 65.8 million guarani and 57.6 million guarani.

The fault statistics are collected by classifying the medium voltage systems and the low voltage systems. The fault causes are analyzed to 7 items including the scheduled shutdown, and data are gathered on each feeder of substations, and edited every month.

The low voltage systems in the Metropolitan Area are classified into 10 areas. The fault causes are analyzed for each area, and edited every month.

Since 1989, the fault cause in the low voltage system are analyzed with 6 more classifications. The new classifications are the separation of joints between aluminum and copper conductors, broken conductor on the branch to the customer, breakdown of conductor joints, breakdown of WH meters, etc. The failures due to these causes are substantially large, and the countermeasures against these failures must be established immediately.

Although the supply reliability must be represented in terms of the relation of supply failure and its effect on customers, this effect can not be represented by D.E.K and F.E.K, as these indices are based on the installed capacity.

The data of supply reliability to an average customer in France, Britain, U.S. and Japan for the period from 1980 to 1985 in Figure 8-5.

It is difficult to quantify the relative level of power supply reliability in the Metropolitan Area in comparison with the supply reliability data presented in this figure, since the criteria of evaluation is different. However, it is expected that the target values of D.E.K (8 hours/kVA) and F.E.K (10 times/kVA) which have been set forth by Eletropaulo of Brazil will be attained by ANDE in several years owning to ANDE's efforts.

Table 8-8 Fault and Maintenance Outages of 66 kV and 220 kV Systems

(1988)

		220 kV	66 kV
Hours of Outage	Faults	101 : 59	89 : 12
	Maintenance	68 : 09	126 : 46
No. of Outage	Faults	72	139
	Maintenance	17	42

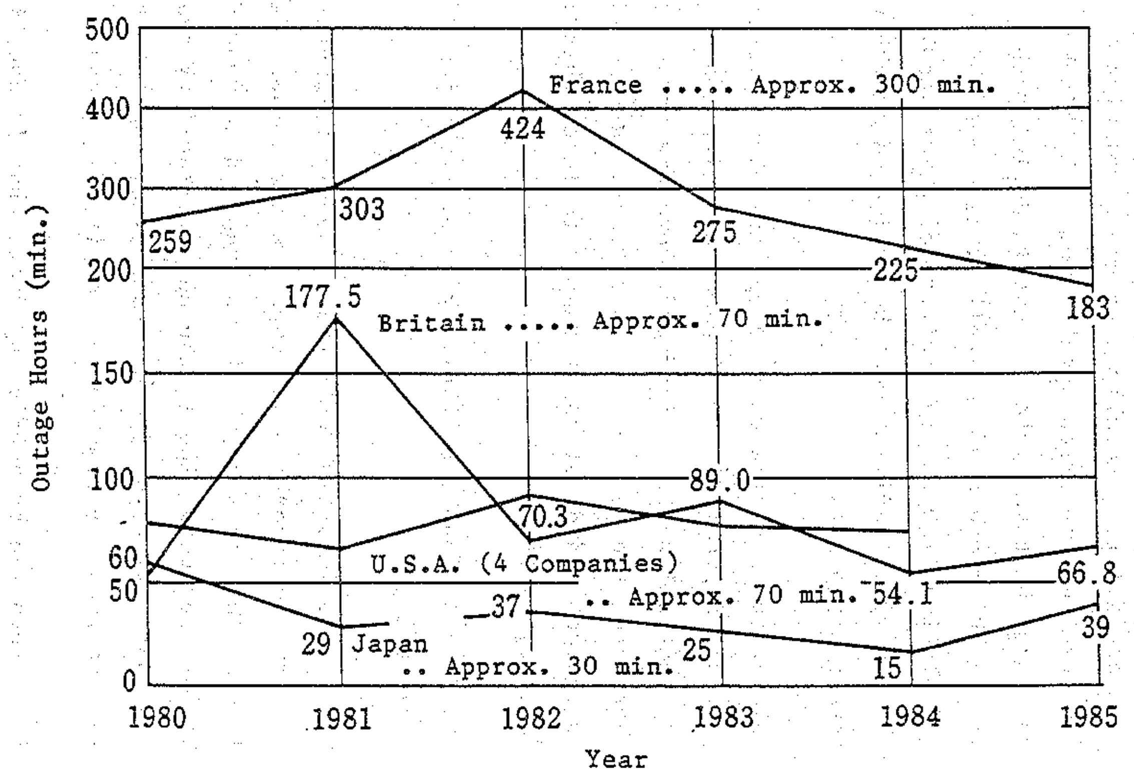
Table 8-9 Fault and Maintenance Outages of 66 kV and 220 kV System in the Metropolitan Area

(1988)

			220 kV	66 kV
Hours of Outage	Faults	Line	43	9 : 50
		Tr.	17 : 52	30 : 28
		Sub-total	18 : 35	40 : 18
	Maintenance	Line	1 : 59	0
		Tr.	0	26 : 20
		Sub-total	1 : 59	26 : 20
	Total		20 : 34	66 : 38
No. of Outage	Faults	Line	9	17
		Tr.	15	21
		Sub-total	24	38
	Maintenance	Line	1	0
		Tr.	0	8
		Sub-total	1	8
	Total		25	44

*1 : Excluding from Itaugua S/S

Fig. 8-5 Supply Reliability in Leading Industrialized Nations



The record of Supply Reliability per Customer for the Period from 1980 through 1985

8.7.2 Supply Reliability of Distribution Systems

(1) Philosophy of Supply Reliability

The supply reliability is the measure of the reliability of power supply, and it is expressed by the correlation between supply failures and their effect on customers. As the frequency of supply failure, the extent of failure, and the duration of failure generally have close relation to the degree of inconvenience incurred upon customers by blackouts, these factors must be taken into account in defining the supply reliability. The measure of reliability also must have some correlation with the reliability of power supply facilities, as the supply reliability must be reflected in the power facility investment plans.

However, no accurate methodology has been established to express the reliability of power distribution systems in such a way that all factors discussed above are adequately reflected. Therefore, the reliability is currently expressed in terms of the extent and duration of supply failures that are caused by facility faults.

(2) Standard of Supply Reliability of Distribution Network of Project Area

One of the important criteria of supply reliability is the time required to recover power supply after a power facility fault. To calculate this value, it is required to know the average failure recovery time in the current facility faults. As ANDE does not have this type of statistics, the target value for the longest recovery time for a facility fault can not be set.

It is reported by ANDE's engineers that it usually takes from 2 to 3 hours to recover from a supply failure under current conditions.

The question is how this status would be improved by the reliability improvement measures recommended by JICA Study Team. The Study Team estimates that the time required for recovery from supply failure would be reduced by approximately 30 minutes if the SCADA System of Distribution Control Center (Chapter 9) and the mobile radio system (Section 10.3.1) are adopted. The supply reliability would be further improved if the automatic operation of automatic section switch is adopted.

To summarize the recommendations proposed by JICA Study Team for reliability improvement, they consist of the following two major items.

(a) Reduction of Area Affected by a Fault

In the current configuration of distribution systems, all supplies from a feeder fails should a fault (grounding or short circuit fault) occur on a 23 kV feeder.

To prevent this, it is recommended to reduce the area affected by a fault by dividing each feeder into three sections, and providing automatic switches (3-phase switches) with fault detectors at each point of division. (Refer to Section 8.6.)

(b) Reduction of Shutdown Duration

At present, the information of occurrence of fault on a distribution facility is first transmitted by the distribution substation and sent to the Distribution Control Center via Central Load Dispatching Center (by telephone communication between operators). When the new Distribution Control Center equipped with SCADA System is completed, a fault can be immediately identified by the Center, thereby reducing the time required to deploy the repair personnel.

In addition, the faulted section on the distribution line can be identified by the computer program, thereby reducing the time required for the recovery work. (Refer to Chapter 9.)