E-1 CAPACITY OF AUXILIARY TRANSFORMER

1. Basic Requirement

The unit auxiliary transformer (herein after UAT) will be provided with one (1) set per unit.

The type of UAT to be applied is a split type three (3) winding transformer.

Unit auxiliary load capacity used for calculation have been estimated to be the same as load capacities of machinery and equipment in the similar thermal power plant with the same unit capacity and kind of fuel.

2. Calculation Conditions

(1) Efficiency x power factor --- 0.8
(High voltage motor and Low voltage motor)

(2) Load factor

Normal operation	-----------	1.0
Intermittent operation	-----------	0.5
Selected intermittent operation	------	0.1

(3) Unit starting load capacity
Total capacity of operating auxiliary power at 30% MCR when plant is starting.

(4) Tripping load capacity
Total capacity of operating auxiliary power when plant is tripping.

(5) Coefficient of 1.1 is a safety factor for unknown matter of the time of manufacturer's detail design stage e.g. changing motor capacity, adding new motor and etc.

The required capacity

= (Unit M/C total capacity) + (Required capacity for stand-by BFP minimum flow operation capacity)

. Unit M/C total capacity 14,754.0 kVA

. BFP min. flow operation 1,850.0 kVA

14,754.0 + 1,850.0 = 16,604 kVA

16,604 kVA x 1.1 = 18,264.4 kVA

It was determined that the expected capacity is 19,000 kVA.

3. Calculation of Capacity

The required capacity

= (Unit M/C total capacity) + (Required capacity for stand-by BFP minimum flow operation capacity)

. Unit M/C total capacity 14,754.0 kVA

. BFP min. flow operation 1,850.0 kVA

14,754.0 + 1,850.0 = 16,604 kVA

16,604 kVA x 1.1 = 18,264.4 kVA

If was determined that the expected capacity is 19,000 kVA.

AUXILIARY LOAD BALANCE LIST

ESTIMATED

1. Calculation of Transformer Capacity

. Unit station service transformer (Unit P/C TR)

Unit P/C load 1,004.0 kVA 2,300 kVA

X1.1 = 1,104.4 1,200 kVA

. Common station service transformer (Common P/C TR)

Common P/C load 2,011.3 kVA

2,011.3 = 2,011.3 kVA 2,300 kVA

2,011.3 x 1.1 = 2,212.4 2,300 kVA

2. Unit Auxiliary Transformer

Unit M/C load 14,754.0 kVA

Required capacity for the stand-by BFP minimum flow operation is 1,850 kVA. (50% of the rated capacity)

14,754.0 + 1,850 = 16,604.0 kVA

16,604.0 x 1.1 = 18,264.4 19,000 kVA

3. Starting Transformer

Common P/C load	2,011.3 kVA
Chlorination M/C load	600.0 kVA
Starting capacity of unit No. 1 (30% MCR)	8,611.5 kVA
Starting capacity of unit No. 2 (30% MCR)	8,611.5 kVA

2,011.3 + 600 + 2 x 8,611.5 = 19,834.3 kVA

19,834.3 x 1.1 = 21,817.7 kVA 22,000 kVA

4. Transformer Capacity

Transformer	Capacity
Unit station service transformer	2,300 kVA
Common station service transformer	2,300 kVA
Unit auxiliary transformer	19,000 kVA
Starting transformer	22,000 kVA

5. Summary Capacity of M/C and P/C

M/C, P/C	Summary Capacity
UNIT M/C	14,754.0 kVA
COMMON M/C	2,611.3 kVA
CHLORI M/C	600.0 kVA
UNIT P/C	1,004.0 kVA
COMMON P/C	2,011.3 kVA

6. Capacity of Unit Load at Each Operating Condition

Unit: kVA

	Normal	Starting (30% MCR)	Tripping
M/C Motor load	13,750	7,620	5,503
P/C Motor load	250	237.5	237.5
C/C, D/P load	754	754.0	754.0
Total	14,754.0	8,611.5	6,494.5

6.6 kV UNIT M/C (1/2)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	TRIPPING	
BOILER FEED PUMP	2	1	2,960		0.8	1.0	7,400		3,000	3,700	3,400	
FORCED DRAFT FAN	2	0	1,220		0.8	1.0	3,050		1,830		1,150	
CIRCULATING WATER PUMP	2	0	400		0.8	1.0	1,000		1,000		500	
CONDENSATE PUMP	1	1	340		0.8	1.0	425		425	425	213	
AUXILIARY OIL PUMP	0	1	190				0		240		240	
GAS RECIRCULATION FAN	2	0	750		0.8	1.0	1,875		1,125			
MOTOR SUB TOTAL							13,750	-	7,620	4,125	5,503	

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6.6 kV UNIT M/C (2/2)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	TRIPPING	
400 V UNIT P/C							1,004.0		991.5	250	991.5	1,004.0 kVA
SUB TOTAL							1,004.0		991.5	250	991.5	
GRAND TOTAL							14,754	-	8,611.5	4,375	6,494.5	

6.6 kV COMMON M/C (1/1)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	TRIPPING	
COMMON P/C							1,801.0	210.3				1,801.0 + 210.3 = 2,011.3 kVA
CHLORINATION M/C	2	1					600	-		300		969.1 kVA
							2,401.0	210.3		300		2,401.0 + 210.3 = 2,611.3 kVA

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400 V UNIT P/C (1/2)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	TRIPPING	
1-1A C/C (TURBINE & ELECTRICAL (2-1A)							245.1		245.1		245.1	
1-1B C/C (DITTO) (2-1B)							25.8		25.8		25.8	
1-2A C/C (Boiler) (2-2A)							118.0		118.0		118.0	
1-2B C/C (DITTO) (2-2B)							56.6		56.6		56.6	
1-3 C/C (Emergency) (2-3)							296.0		296.0		296.0	
MOTOR VALVE C/C			100		0.8	0.1	12.5		12.5		12.5	
SUB TOTAL							754.0		754.0		754.0	

400 V UNIT P/C (2/2)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	TRIPPING	
FURNACE OIL PUMP	1	1	90		0.8	1.0	112.5		100	112.5	100	
COOLING WATER PUMP	1	1	110		0.8	1.0	137.5		137.5	137.5	137.5	
SUB TOTAL							250		237.5	250	237.5	
GRAND TOTAL							1,004.0		991.5	250	991.5	

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SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
CHLORINATION M/C	2	1	kVA 300			1.0	600			300		
SUB TOTAL							600			300		

400 V COMMON P/C (1/3)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
SERVICE AIR COMPRESSOR	1	1	150		0.8	0.5		94		94		
SUB TOTAL							-	94	-	94	-	

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400 V COMMON P/C (2/3)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE (CAPACITY)
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
COMMON-1 C/C							43.7	15.1		38.5		58.8 kVA
COMMON-2 C/C							110.5	25.4		50.5		135.9 kVA
PLANT WATER C/C							56.9	0.5		27.5		65.4 kVA
WASTE WATER C/C							100.7	25.1		88.2		125.8 kVA
SCREEN & CHLORINATION C/C							364.2	0.2		49.0		364.4 kVA
NO. 1 LIGHTING POWER D/P	1	0	kVA 100			1.0	100					100 kVA
NO. 2 LIGHTING POWER D/P	1	0	kVA 100			1.0	100					100 kVA
SUB TOTAL							876.0	66.3	~	253.7		

400 V COMMON P/C (3/3)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
A. AIR CONDITIONER	1	0	kVA 70			1.0	70					70 kVA
B. AIR CONDITIONER	1	0	kVA 135			1.0	135					135 kVA
C. AIR CONDITIONER	1	0	kVA 120			1.0	120					120 kVA
OVER HEAD TRAVELING CRANE	1	0	kVA 100			0.5		50				50 kVA
MISCELLANEOUS D/P	1	0	kVA 300			1.0	300					300 kVA
ADMINISTRATION BUILDING	1	0	kVA 300			1.0	300					300 kVA
SUB TOTAL							925.0	50				
GRAND TOTAL							1,801.0	210.3	-	347.7		1,801.0 + 210.3 = 2,011.3 kVA

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400 V 1-1A C/C (T,E C/C) (1/3)

SERVICE	QUAN-TITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
MAKE UP WATER T. PUMP	1	0	22		0.8	0.1			3.0			
GRAND STEAM EXHAUSTER	1	0	11		0.8	1.0	13.8					
SEA WATER BOOSTER PUMP	1	0	45		0.8	1.0	56.3					
CHEMICAL INJECTION PUMP	1	0	0.4		0.8	0.5		0.3				
TAPROGGE BALL RECIRCULATION PUMP	1	0	3.0		0.8	0.5		1.9				
DIFF. PRESS FLUSHING PUMP	1	0	0.55		0.8	0.5		0.4				
LP HEATER DRAIN PUMP	1	0	85		0.8	1.0	106.3					
SUB TOTAL							176.4	2.6	3.0	-	-	

400 V 1-1A C/C (T,E C/C) (2/3)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
THYRISTOR RECTIFIER COOLING FAN	1	1	1.2		0.8	1.0	1.5			1.5		
SEAL OIL VACUUM PUMP	1	0	2.2		0.8	1.0	2.8					
MAIN TR. COOLER CONTROL PANEL	1	0	25kVA			1.0	25					
TRANSFER OIL PUMP	1	0	5.5		0.8	1.0	7.0					
COND. SEA WATER LEAK DET. PANEL	1	0	kVA 1.0			1.0	1.0					
BOLT HEATER	1	0	30		0.8	1.0					37.5	FOR INSTALLATION
TRAPROGGE BALL CLEANING PANEL	1	0	kVA 1.0			1.0	1.0					
SUB TOTAL							38.3	-	-	1.5	37.5	

400 V 1-1A C/C (T,E C/C) (3/3)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
CWP VALVE PIT SUMP PUMP	1	0	1.5		0.8	1.0		0.2				
CWP OUTLET MOTOR VALVE	1	1	0.4		0.8	0.1		0.1		0.1		
CIRCULATING WATER PUMP OF STATOR COOLING	1	0	22.0		0.8	1.0	27.5					
SUB TOTAL							27.5	0.3	-	-	-	
GRAND TOTAL							242.2	2.9	3.0	1.6	37.5	CAPACITY 242.2 + 2.9 = 245.1 kVA

400 V 1-1B C/C (T,E C/C) (1/3)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
MAKE UP WATER T. PUMP	0	1	22		0.8	0.1				3.0		
GLAND STEAM EXHAUSTER	0	1	11		0.8	1.0				13.8		
OIL PURIFIRE FILTER PUMP	1	0	2.2		0.8	1.0	2.8					
OIL PURIFIRE VENT FAN	1	0	0.2		0.8	1.0	0.3					
SEA WATER BOOSTER PUMP	0	1	45		0.8	1.0				56.3		
CONDENSER BACK WASH PANEL	1	0	kVA 1.0			1.0						
TAPROGGE BALL RECIRCULATION PUMP	1	0	3.0		0.5	1.0		1.9				
SUB TOTAL							4.1	1.9	-	73.1	-	

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460 V 3-1B C/C (T,E C/C) (2/3)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
PRIMING VACUUM PUMP	1	0	7.5		0.8	0.5		4.7				
THYRISTER RECTIFIRE COOLING FAN	1	1	1.2		0.8	1.0	1.5			1.5		
MAIN TRANS. COOLER CONTROL PANEL	0	1	25kVA			1.0				25		
CATHODIC PROTECTION SYSTEM	1	0	kVA 9.0			1.0	9.0					
CHEMICAL INJECTION PUMP	0	1	0.4		0.8	0.5				0.3		
CHEMICAL INJECTION TANK AGITATOR	1	0	0.2		0.8	0.5		0.2				
CHEMICAL INJECTION SYSTEM MIXER	1	0	0.4		0.8	0.5		0.3				
SUB TOTAL							10.5	5.2	-	26.8	-	

460 V 3-1B C/C (T,E C/C) (3/3)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
CWP OUTLET VALVE	1	0	0.4		0.8	0.1		0.1				
CWP GANTRY CRANE	1	0	40kVA			0.1		4.0				
CIRCULATING WATER PUMP OF STATOR COOLING	0	1	22.0		0.8	1.0				27.5		
SUB TOTAL							-	4.1	-	27.5	-	
GRAND TOTAL							14.6	11.2	-	127.4	-	CAPACITY 14.6 + 11.2 = 25.8

2087

400 V 1-2A C/C (B C/C) (1/2)

SERVICE	QUAN-TITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
AIR PREHEATER ROTOR DRIVE	1	0	7.5		0.8	1.0	9.4					
AIR PREHEATER LUB. OIL PUMP	1	0	0.75		0.8	1.0	1.0					
FURNACE GAS TEMPERATURE PROVE	1	0	0.4		0.8	1.0			0.5			
SEAL AIR BOOSTER FAN	1	0	15		0.8	1.0	18.8					
INSTRUMENT AIR COMPRESSOR	1	0	45		0.8	0.5		28.2				
BFP AUXILIARY OIL PUMP	1	1	3.7		0.8	1.0	4.7			4.7		
EVAPORATOR FEED WATER PUMP	1	0	15		0.8	1.0	18.8					
SUB TOTAL							52.7	28.2	0.5	4.7	-	

400 V 1-2A C/C (B C/C)   (2/2)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
DUMPER	1 set	0	2.1		0.8	0.1		0.3				
SOOT BLOWER	1	0	6kVA			0.5		3.0				
INSTRUMENT AIR DRYER	1	0	3kW		0.8	1.0	3.8					
CVCF	1	0	30kVA			1.0	30					
												86.5 + 31.5 = 118 kVA
SUB TOTAL												
GRAND TOTAL												

289

400 V 1-2B C/C (B C/C) (1/2)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
AIR PREHEATER ROTOR DRIVE	1	0	7.5		0.8	1.0	9.4					
AIR PREHEATER LUB. OIL PUMP	1	0	0.75		0.8	1.0	1.0					
EVAPORATOR DRAIN PUMP	1	0	1.5		0.8	0.1		0.2				
FLAME DETECTOR AND FLAME VIEWING T.V. COOLING AIR FAN	1	0	22		0.8	1.0	27.5					
BFP AUX. OIL PUMP	1	0	3.7		0.8	1.0	4.7					
INSTRUMENT AIR COMPRESSOR	0	1	45		0.8	0.5				28.2		
EVAPORATOR FEED WATER PUMP	0	1	15		0.8	1.0				18.8		
SUB TOTAL							42.6	0.2	-	47.0	-	

400 V 1-2B C/C (B C/C) (2/2)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
DUMPER	1 set	0	2.1		0.8	0.1		0.3				
BURNER ACTUATOR	1	0	15kVA			0.5		7.5				
CHEMICAL FEED EQUIPMENT	1	0	6kA			1.0	6.0					
SUB TOTAL							6.0	7.8	-	-	-	
GRAND TOTAL							48.6	8.0	-	47	-	CAPACITY 48.6 + 8.0 = 56.6 kVA

291

400 V 1-3 C/C (1/4) EMERGENCY

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
TURNING GEAR OIL PUMP	1		30.0		0.8		0		37.5			
OIL TANK VAPOUR EXTRACTOR	1		2.2		0.8	1.0	3.0					2.75 3.0
SEAL OIL PUMP	1		11.0		0.8	1.0	14.0					13.75 14.0
SEAL OIL VACUUM PUMP	1		2.2		0.2	1.0	3.0					
SEAL OIL RECIRCULATION PUMP	1		3.7		0.8	1.0	5.0					4.63
BATTERY ROOM EXASTER FAN	2		0.4		0.8	1.0	1.0					
FLAME DETECTOR & FLAME VIEWING T.V. COOLING FAN	1		22.0		0.8	1.0	27.5					
SUB TOTAL							53.5	-	37.5	-	-	

400 V 1-3 C/C (2/4)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
PAGING EQUIPMENT	1		kVA 3.0			1.0	3.0					
INSTRUMENT POWER D/P	1		kVA 30			1.0	30					
Unit Battery Charger			kVA 95			1.0	95					
SWYD Battery Charger			kVA 20			1.0	20					
PABX Battery Charger			kVA 20			1.0	20					
NORMAL EMERGENCY LIGHTING D/P			kVA 30			1.0	30					
OBSTRUCTION LIGHTING OF STACK			kVA 20			1.0	20					
SUB TOTAL							218.0	-	-	-	-	

293

400 V 1-3 C/C (3/4) EMERGENCY

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
H.D. TURBINE BYPASS VALVE SERBOMOTOR AMP.	1		11.5			0.1		1.5				1.15 1.5
TURNING GEAR	1		7.5		0.8				9.5			9.38 9.5
ELEVATOR FOR MAIN BUILDING	1		12.0		0.8	0.1		1.5				
ELEVATOR FOR ADMI. BUILDING	1		12.0		0.8	0.1		1.5				
MOTOR VALVE FOR FIRE PROTECTION	1		0.5		0.8	0.1			0.5			0.188 0.5
CHEMICAL INJECTION PUMP	1		0.75		0.8	0.1			1.0			
SUB TOTAL							-	4.5	9.5	1.5	-	

400 V 1-3 C/C (4/4) EMERGENCY

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
AIR COMPRESSOR FOR D/G	1		3.7		0.8	0.5		5.0				
RADIATOR FAN FOR D/G	1		11.0		0.8	0.5		14.0				
LUBRICANT OIL PRIMING PUMP FOR D/G	1		0.75		0.8	0.5		1.0				
SUB TOTAL							-	20.0	-	-	-	
GRAND TOTAL							271.5	24.5	47.0	1.5	-	CAPACITY kVA 271.5 + 24.5 = 296.0

>95

400 V COMMON-1 C/C (1/2)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
FERROUS SULFATE INJECTION PUMP	1	1	0.75		0.8	0.5		0.5		0.5		
FERROS SULFATE INJECTION SYSTEM AGITATOR	1	0	1.5		0.8	0.5		1.0				
FURNACE OIL TRANSFER PUMP	1	1	30		0.8	1.0	37.5			37.5		
TURBINE OIL SUMP PUMP	1	0	3.7		0.8	0.1		0.5				
TURBINE ROOM SUMP PUMP	1	0	2.2		0.8	0.1		0.3				
CONDENSER PIT SUMP PUMP	1	1	3.7		0.8	0.1		0.5		0.5		
SUB TOTAL							37.5	2.8	-	38.5	-	

400 V COMMON-1 C/C (1/2)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
UNIT NEUTRALIZING PIT PUMP	1	0	18.5		0.8	0.5		12.0				
UNIT NEUTRALIZING PIT BLOWER	1	0	3.7		0.8	1.0	4.7					
MAIN BUILDING SHUTTER-A	1	0	kVA 2.2			0.1		0.3				
SERVICE AIR COMPRESSOR CONTROL	1	0	kVA 1.5			1.0	1.5					
SUB TOTAL							6.2	12.3	-	-	-	
GRAND TOTAL							43.7	15.1	-	38.5		CAPACITY 43.7 + 15.1 = 58.8

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400 V COMMON-2 C/C (1/2)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
FERROUS SULFATE INJECTION PUMP	1	1	0.75		0.8	0.5		0.5		0.5		
FERROUS SULFATE INJECTION SYSTEM AGITATOR	1	0	1.5		0.8	0.5		1.0				
FURNACE OIL TRANSFER PUMP	1	1	30		0.8	1.0	37.5			37.5		
TURBINE ROOM SUMP PUMP	1	0	2.2		0.8	0.1		0.3				
CONDENSER PIT SUMP PUMP	1	1	3.7		0.8	0.1		0.5		0.5		
TURBINE OIL SUMP PUMP	1	0	3.7		0.8	0.1		0.5				
SUB TOTAL							37.5	2.8	-	38.5		

400 V COMMON-2 C/C (2/2)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
UNIT NEUTRALIZING PIT PUMP	0	1	18.5		0.8	0.5				12.0		
NO. 2 STARTING TRANSF. COOLING FAN	1	0	15kVA			1.0	15.0					
MAIN BUILDING SHUTTER-B	1	0	kVA 0.6			0.1		0.1				
ROOM WATER HEATER	1	0	45kVA			0.5		22.5				
MAIN BUILDING ROOF FAN	1	0	58kVA			1.0	58.0					
SUB TOTAL							73.0	22.6		12.0		
GRAND TOTAL							110.5	25.4	-	50.5	-	CAPACITY 110.5 + 25.4 = 135.9

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400 V PLANT WATER C/C (1/2)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
WATER TREATMENT CONTROL PANEL	1	0	kVA 3.0			1.0	3.0					
MOTOR VALVE	1 set	0	1.5		0.8	0.1		0.2				
CONTROL PANEL FOR WATER TREAT. DRAIN PUMP	1	0	kVA 0.2			1.0	2.0					
YARD INSTRUMENT AIR COMP. CONTROL PANEL	1	0	kVA 0.5			1.0	0.5					
YARD INSTRUMENT AIR DRYER	1	0	kW 1.0		0.8	1.0	1.3					
OIL SAMPLER	1	0	kVA 1.0			0.5		0.5				
WATER TREATMENT SYSTEM DRAIN PIT PUMP	1	0	1.5		0.8	0.1		0.2				
SUB TOTAL							5.0	0.9				

400 V PLANT WATER C/C (2/2)

SERVICE	QUAN-TITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
WATER TREATMENT SUPPLY PUMP	1	1	7.5		0.8	1.0	9.4					
WATER TREATMENT NaOH UNLOADING PUMP	1	0	0.75		0.8	0.5		0.5				
YARD INSTRUMENT AIR COMPRESSOR	1	1	22.0		0.8	1.0	27.5			27.5		
LIGHTING AND MISC. POWER D/P			kVA 15			1.0	15.0					
SUB TOTAL							51.9	0.5	-	27.5	-	
GRAND TOTAL							56.9	0.5	-	27.5	-	CAPACITY kVA 56.9 + 0.5 = 65.4

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460 V WASTE WATER C/C (1/4)

SERVICE	QUANTITY NORMAL	QUANTITY STAND-BY	RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA) NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	NOTE
WASTE WATER STORAGE POND PUMP	1	1	3.7		0.8	1.0	4.7			4.7		
WASTE WATER STORAGE POND & PH CONTROL OXIDATION PIT BLOWER	1	1	45.0		0.8	1.0	57.0			57.0		
MIXING PIT AGITATOR	1	0	0.4		0.8	1.0	0.5					
AIR SCRUBBING BLOWER	1	0	7.5		0.8	0.5		4.7				
COAGULATION SEDIMENTATION TANK SCRAPER	1	0	1.5		0.8	1.0	1.9					
SEDIMENTATION TANK SLUDGE PUMP	1	0	2.2		0.8	1.0	2.8					
FILTER FEED PUMP	1	1	7.5		0.8	1.0	9.4			9.4		
SUB TOTAL							76.3	4.7	-	71.1		

400 V WASTE WATER C/C (2/4)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
DIL HCL TANK AGITATOR	1	0	0.2		0.8	0.1		0.1				
DIL NaOH DOSING PUMP	1	1	2.2		0.8	1.0	2.8			2.8		
DIL NaOH TANK AGITATOR	1	0	2.2		0.8	0.1		0.3				
COAGULANT DOSING PUMP	1	1	0.2		0.8	1.0	0.3			0.3		
COAGULANT AID TANK AGITATOR	1	0	1.5		0.8	0.1		0.2				
COAGULANT AID DOSING PUMP	1	1	0.4		0.8	1.0	0.5			0.5		
CHEMICAL STORAGE YARD PIT PUMP	1	0	1.5		0.8	0.1		0.2				
SUB TOTAL							3.6	0.8	-	3.6		

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400 V WASTE WATER C/C (2/4)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
NEUTRALIZING PIT PUMP	1	1	5.5		0.8	1.0	6.9			6.9		
NEUTRALIZING PIT AGITATOR	1	0	0.75		0.8	1.0	1.0					
FILTER BACK WASH PUMP	1	0	30		0.8	0.5		18.8				
SLUDGE ENRICHMENT TANK SCRAPPER	1	0	0.4		0.8	1.0	0.5					
SLUDGE ENRICHMENT TANK SLUDGE PUMP	1	0	2.2		0.8	1.0	2.8					
SLUDGE STORAGE POND DISCHARGE PUMP	1	1	3.7		0.8	1.0	4.7			4.7		
DIL HCL DOSING PUMP	1	1	1.5		0.8	1.0	1.9			1.9		
SUB TOTAL							17.8	18.8	-	13.5	-	

460 V WASTE WATER C/C (4/4)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
CONC. HCL TRANSFER PUMP	1	0	2.2		0.8	0.1		0.3				
CONC. NaOH TRANSFER PUMP	1	0	2.2		0.8	0.1		0.3				
MOTOR VALVE	2	0	0.8		0.8	0.1		0.2				
WASTE WATER CONTROL PANEL	1	0	kVA 3.0			1.0	3.0					
					(SUB TOTAL)		102.7	25.1	0	88.2		102.7 + 25.1 = 127.8 kVA
SUB TOTAL							3.0	0.8	-	-	-	
GRAND TOTAL							100.7	25.1	-	88.2	-	CAPACITY kVA 100.7 + 25.1 = 125.8

460 V SCREEN & CHLORI. C/C (1/3)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
SEA WATER BOOSTER PUMP	2	1	18.7		0.8	1.0	46.7			23.4		
SEA WATER STRAINER	2	1	0.25		0.8	1.0	0.7			0.4		
TANK DEGAS BLOWER	2	1	1.12		0.8	1.0	2.8			1.4		
CHROLI. INJECTION PUMP	2	1	18.7		0.8	1.0	46.7			23.4		
SCREEN & CHROLI. LIGHTING MISC. POWER D/P	1	0	50kVA			1.0	50					
SUB TOTAL							146.9	-	-	48.6	-	

460 V SCREEN & CHLORI. C/C (2/3)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
PIT SUMP PUMP	1	0	1.5		0.8	0.1		0.2				
CHLORI. SYSTEM CONTROL PANEL	1	0	5kVA			1.0	5.0					
CELL SAFETY ALARM PANEL	2	1	kVA 0.1			1.0	0.2			0.1		
RECTIFIRE CONTROL	2	1	kVA 0.3			1.0	0.6			0.3		
SCREEN CONTROL PANEL	1	0	2kVA			1.0	2.0					
							7.8	0.2	-	0.4	-	

460 V SCREEN & CHLORI. C/C (3/3)

SERVICE	QUANTITY		RATED POWER (kW)	ACTUAL POWER (kW)	EFFICIENCY X POWER FACTOR	LOAD FACTOR	CAPACITY OF LOAD (kVA)					NOTE
	NORMAL	STAND-BY					NORMAL	INTERMITT-ENT	STARTING, TRIPPING	STAND-BY	SPARE	
WASH PUMP	2	0	75		0.8	1.0	187.5					
BAR SCREEN	4	0	2.2		0.8	1.0	11.0					
TRAVELLING SCREEN	4	0	2.2		0.8	1.0	11.0					
SUB TOTAL							209.5	-	-	-		
GRAND TOTAL							364.2	0.2	-	49.0		364.2 + 0.2 = 364.4 kVA

E-2 CAPACITY OF STARTING TRSNSFORMER

1. Basic Requirement

   The starting transformer will be provided with one (1) set for Units No. 1 and No. 2.

   The type of starting transformer to be applied is a split type three (3) winding transformer.

2. Condition Assumed for Calculation of Capacity

   (1) The capacity of the auxiliary machines is as described in the item designated as E-1, "Capacity of Auxiliary Transformer".

   (2) The capacity of the auxiliary machines for Unit IV is the same as that for Unit No. 2.

   (3) The capacity of the starting transformer is calculated on the assumption that Units No. 1 and No. 2 will be started up at the same time.

   (4) The capacity of the Unit starting is total capacity of operating auxiliary power at 30% MCR.

   (5) Coefficient of 1.1 a safety factor for unknown matter at the time of manufacturer's detail design stage e.g. changing motor capacity, add. new motor, changing operation scheme and etc.

3. Calculation of the Capacity

   The required capacity of the starting transformer has been calculated taking into account the following load:

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Required capacity (kVA)

= Common P/C load (kVA) + Chlorination load (kVA)

+ 2 x Unit start-up load (kVA)

where:

Common P/C load	:	2,011.3 kVA
Chlorination load	:	600.0 kVA
Start-up load of Unit No. 1	:	8,611.5 kVA
Start-up load of Unit No. 2	:	8,611.5 kVA

Therefore, the capacity of the starting transformer is as follows:

2,011.3 (kVA) + 600 (kVA) + 2 x 8,611.5 (kVA) = 19,834.3 (kVA)

19,834.8 (kVA) x 1.1 = 21,817.73 (kVA)

= 22,000 (kVA)

E-3 IMPEDANCE OF AUXILIARY TRANSFORMER

The value of impedance x_{AT} of the auxiliary transformer for the West Wharf Thermal Power Plant Units No. 1 and No. 2 has been decided to be 8% as a result of calculation made in the following manner.

1. Conditions Assumed for Deciding the Impedance

The capacity of the auxiliary transformer is 19,000 kVA.
The following values have been adopted for the impedance, X_M, X_G and Xe of the main transformer, generator and power system, respectively.

X_M : 11% (247 MVA base)
X_G : 20% (248.3 MVA base)
Xe : 0.65% (100 MVA base)

However, other values of impedance of cables, bus-bars, etc. are not taken into account.

The specifications of the incoming circuit breakers for 6.6 kV M/C are as follows:

Rated bus voltage:	6.6 kV
Interrupting capacity:	390 MVA at 7.2 kV
Interrupting current:	31,500 A

The allowable limit of voltage drop at the time of start-up of BFP motor is 15%, and the starting current is 500% of the rated value.

The locked rotor impedance of motor is 20% on the basis of the total capacity of motors taking into account motor contribution.

Moreover, the damping coefficient of short circuit current is assumed to be 0.4. Meanwhile, the time elapsed after short circuit fault is made 0.1 sec. in accordance with the opening time of 0.1 sec. of 6.6 kV M/C circuit breaker.

Load of motor

Since 6.6 kV common load is small in contrast with the load for Unit No. 1, it is considered that the common load is negligible. The load of low tension motors has been decided to be the capacity of the power center transformer.

Each capacity of high tension motors is described in Table 1.

Table 1 Breakdown of the load of high tension motors

Motors for:	Capacity (kVA)	Quantity	Total capacity (kVA)
FDF	1,525	2	3,050
GRF	937.5	2	1,873
BFP	3,700	2	7,400
CWP	500	2	1,000
CP	425	2 (1) standby	425
Total	7,087.5		13,750

Total load of motors: 13,750 + 2,300 = 16,050 kVA

2. Calculation of Impedance

The impedance of the following equipment and circuit is calculated on the basis of 100 MVA.

(1) The system impedance of the high tension side of the main transformer is calculated based upon the short circuit capacity of the 220 kV bus bar as follows:

$$3 \times 220\ \text{kV} \times 40\ \text{kA} = 15{,}224\ \text{MVA}$$

$$Xe = \frac{100}{15{,}224} \times 100 = 0.65$$

(2) Generator

$$XG = 20 \times \frac{100}{248.3} = 8.05\%$$

(3) Main transformer

$$XMT = 11 \times \frac{100}{247} = 4.45\%$$

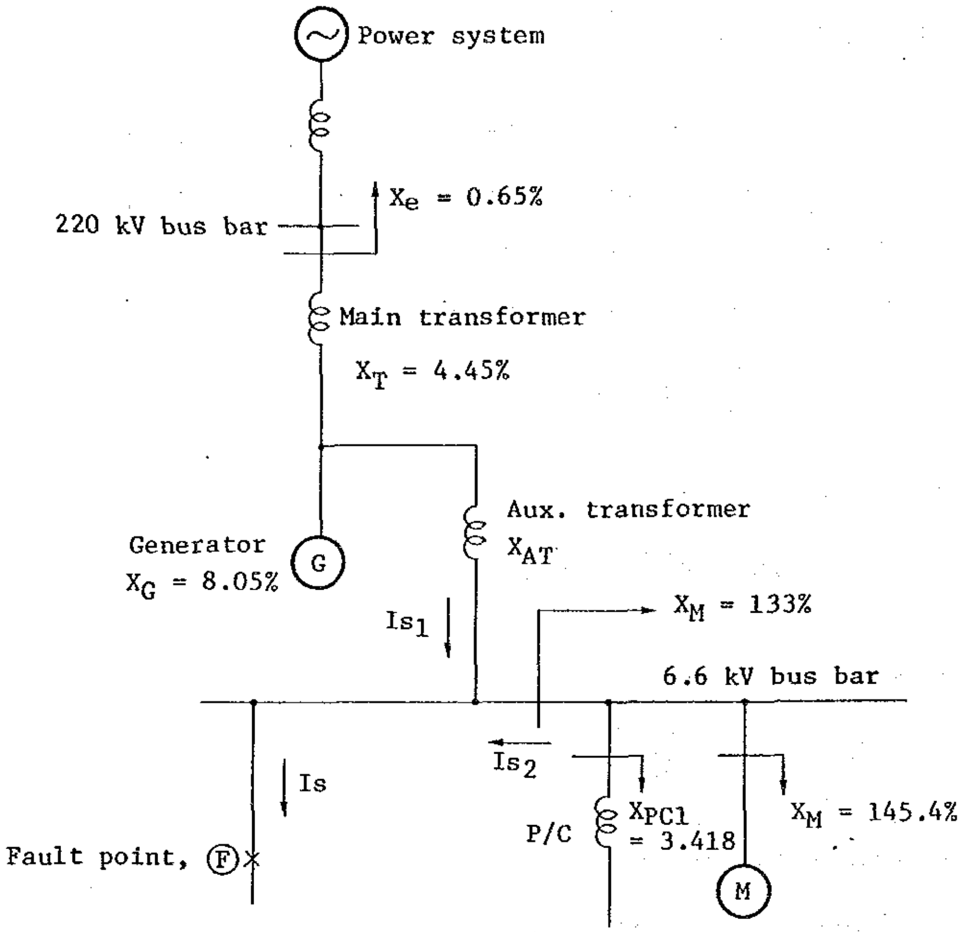
(4) High voltage motor contribution

$$XHM = 20 \times \frac{100}{13{,}750} = 145.4\%$$

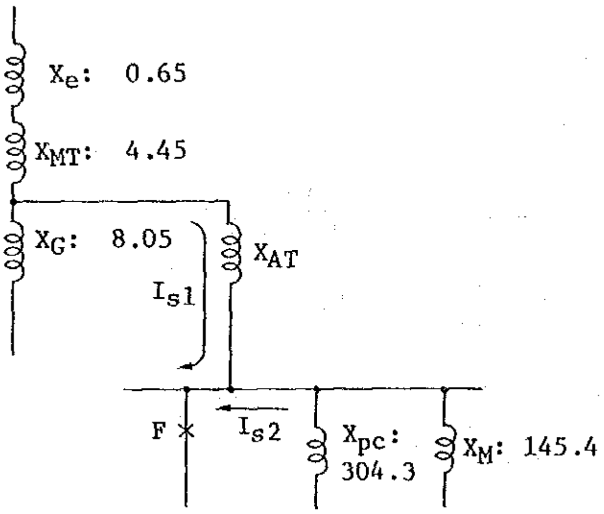
(5) Station service transformer

$$XPC = 7 \times \frac{100}{2.3} = 304.3\%$$

3. Impedance Map (on the basis of 100 MVA)



4. Calculation of Short Circuit Current



(1) Short circuit current, I_{s1} flowing the power system is:

$$X_{s1} = \frac{1}{\frac{1}{Xe + X_{MT}} + XG} + X_{AT}$$

$$= \frac{1}{\frac{1}{0.76 + 4.45} + \frac{1}{8.05}} + X_{AT}$$

$$= \frac{1}{\frac{1}{5.1} + \frac{1}{8.05}} + X_{AT} = \frac{1}{0.196 + 0.124} + X_{AT}$$

$$= \frac{1}{0.32} + X_{AT} = 3.125 + X_{AT}$$

$$I_{s1} = 100 \times \frac{100}{3.125 + X_{AT}} \times \frac{10}{3 \times 6.6}$$

$$\approx \frac{875.2 \times 10^3}{3.125 + X_{AT}} \text{(A)}$$

(2) Short circuit current, I_{s2} due to motor contribution is:

$$X_{s2} = \frac{1}{\frac{1}{xpc} + \frac{1}{XM}}$$

$$= \frac{1}{\frac{1}{304.3} + \frac{1}{145.4}} = \frac{1}{0.003 + 0.006}$$

$$= \frac{1}{0.009}$$

$$= 111.11$$

$$I_{s2} = 100 \times \frac{100}{111.11} \times \frac{10}{3 \times 6.6} \times 0.4$$

$$= \frac{875.8 \times 10}{111.11} \times 0.4$$

$$= 7,882.3 \times 0.4$$

$$= 3,152.9 \text{ (A)}$$

(3) Short circuit current, Is at fault point F 0.1 sec. after a fault arises:

$$Is = I_{s1} + I_{s2}$$

$$= \frac{875.8 \times 10^3}{3,125 + X_{AT}} + 3,152.9 \text{ (A)}$$

(4) Examination of X_{AT}

Since, interrupting current of the incoming circuit breaker is 390 MVA, at 7.2 kV.

Therefore, interrupting current is;

$$\frac{390 \text{ MVA} \times 10^3}{3 \times 7.2 \text{ kV}} = 31.5 \text{ kA}$$

Therefore, percent impedance of auxiliary transformer shall be required to meet the following condition.

$$31,500 > \frac{875.8 \times 10^3}{3.125 \times X_{AT}} + 3,152.9$$

$$31,500 - 3,152.9 > \frac{875.8 \times 10^3}{3,125 + X_{AT}}$$

$$28,347.1 > \frac{875.8 \times 10^3}{3.125 + X_{AT}}$$

$$(28,347.1 \times 3,125) + (28,347.1 \times X_{AT}) > 875.8 \times 10^3$$

$$88,584.69 + 28,347.1 \times X_{AT} > 875.8 \times 10^3$$

$$28,347.1 \times X_{AT} > 875.8 \times 10^3 - 88,584.69$$

$$28,347.1 \times X_{AT} > 787,215.31$$

$$X_{AT} > \frac{787,215.31}{28,347.1}$$

$$X_{AT} > 27.77$$

When X_{AT} is calculated on the basis of the capacity of 19 MVA of auxiliary transformer.

$$X_{AT} > X_{AT} \times \frac{19}{100}$$

$$X_{AT} > 27.77 \times \frac{19}{100}$$

$$X_{AT} > 5.27$$

Therefore, X_{AT} of the auxiliary transformer is required to be 5.3% or over judging from the restriction of short circuit.

5. Calculation of Voltage Regulation

The voltage regulation is calculated so that voltage drop at start-up of the BFP motor having the largest capacity among various motors will be within 15% of the limited value when the power plant is in full load operation.

This calculation has been made based upon the following concept: Namely, it is assumed that the capacity obtained by deducting the capacity of start-up motor for BFP from that of the rated capacity has been loaded on the auxiliary transformer.

In such a case, the sum of voltage drop due to the above load and that due to start-up of BFP is required to be the above limit value.

Calculation formula:

$$q > \{ \frac{P}{0.8} \times 5.0 \times (\sqrt{1 - 0.2^2} + 0.08 \times 0.2) +$$

$$(w - \frac{P}{0.8}) \times (\sqrt{1 - 0.8^2} + 0.08 \times 0.8)\} \times \frac{XAT}{W}$$

where

P: Capacity of BFP motor (MW) : 3.7

q: Allowable value of voltage drop : 15%

W: Capacity of auxiliary transformer (MVA) : 19

X_{AT}: Impedance (%) of auxiliary transformer

(Power factor) x (Efficiency) of motor: 0.8

Multiple of starting current of BFP motor to rated current: 5.0

Power factor at start-up of BFP motor: 0.2

$\frac{R}{X}$ of auxiliary transformer: 0.08

$$q > \{2.96 \times 5.0 \times (\sqrt{1 - 0.2^2} + 0.08 \times 0.2)$$

$$+ (19 - 3.7) \times (\sqrt{1 - 0.8^2} + 0.08 \times 0.8)\} \times \frac{XAT}{W}$$

$$> \{14.8 \times (0.979 + 0.016) + 15.3 \times (0.6 + 0.064)\} \times \frac{XAT}{W}$$

$$> \{(14.8 \times 0.995 + (14.8 \times 0.664)\} \frac{XAT}{W}$$

$$> \{14.726 + 9.827\} \frac{XAT}{W}$$

$$> \{24.553\} \frac{XAT}{W}$$

where:

q ---- 15%

W --- 19 MVA

$$15 > 24.553 \times \frac{XAT}{19}$$

$$15 \times 19 > 24.553 \times X_{AT}$$

$$285 > 24.553 \times X_{AT}$$

$$\frac{285}{24.553} > X_{AT}$$

$$11.6 < X_{AT}$$

Therefore, the required percent impedance of auxiliary transformer from view point voltage drop at the time of largest motor starting is not more than 11.6%.

6. Conclusion

The impedance, X_{AT} of the auxiliary transformer is required to meet the following condition on the bases of 19 MVA:

$$11.6\% > X_{AT} > 5.27\%$$

In consideration of the above requirements, therefore, the value of impedance, X_{AT} of the auxiliary transformer for West Wharf Thermal Power Plant Units No. 1 and No. 2 will be adopted 8%.

E-4 IMPEDANCE OF STARTING TRANSFORMER

The value of impedance X of the starting transformer for the West Wharf Thermal Power Plant has been decided to be 10% as a result of calculation made in the following manner.

1. Conditions Assumed for Deciding the Impedance

(1) The capacity of the starting transformer is 22,000 kVA.

(2) The specifications of the circuit breaker for MCSG are as follows:

Rated bus voltage:	6.6 kV
Interrupting capacity:	390 MVA at 7.2 kV
Interrupting current:	31,500 A

(3) The allowable limit of voltage drop at the time of start-up of the largest motor among various motors is assumed to be 15%, and the starting current is assumed to be 500% of the rated current.

(4) The locked rotor impedance of the motor is assumed to be 20% on the basis of the total capacity of motors taking into account motor contribution.

Moreover, the damping coefficient of short circuit current is assumed to be 0.4, and the time elapsed after short circuit fault is made 0.1 sec. in accordance with the opening time of 0.1 sec. of 6.6 kV M/C circuit breaker.

(5) Load of motor

Since 6.6 kV common load is small in contrast with the load for

Units No. 1 and No. 2, it is considered that the common load is negligible. The load of low tension motors for Units No. 1 and No. 2 has been decided to be the capacity of the power center transformers. Moreover, the load of auxiliary load at simultaneous start-up of the motors for Units No. 1 and No. 2 is as follows:

Load of high tension motors:

7,620 kVA x 2 = 15,240 kVA

Load of low tension motors:

2,011.3 kVA x 2 x 0.6 = 2,413.6 kVA

(1,004.0 kVA x 2 + 2,011) x 0.6 = 3,214.6

Total load of motors:

15,240 + 3,214.6 = 18,454.6 kVA

2. Calculation of Impedance

The impedance of the following equipment is calculated on the basis of 100 MVA.

(1) Power system

The impedance Xe of the power system is calculated based upon the short circuit capacity as follows:

3 x 132 kV x 31.5 kA = 7,193.34 MVA

$$Xe = 100 \times \frac{100}{2,193.34} = 1.39\%$$

(2) Motor contribution

$$X_M = 20 \times \frac{100}{18.45} = 108.4\%$$

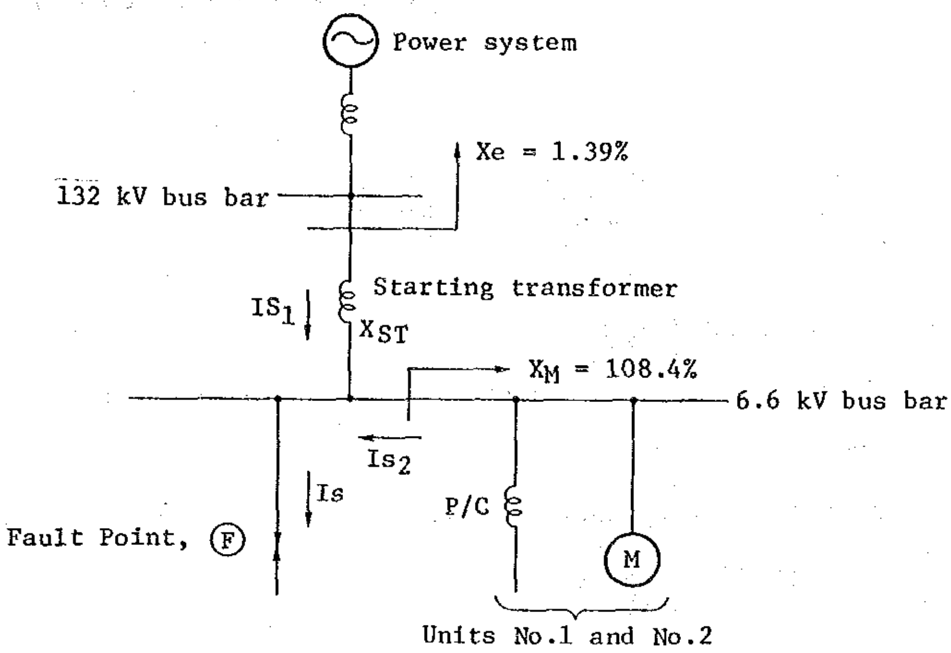


Fig. 1 Impedance map (on the basis of 100 MVA)

3. Calculation of Short Circuit Current

The short circuit current when three phase short circuit fault arises at Point F of 6.6 kV feeder is calculated as follows:

(1) Short circuit current, I_{S1} flowing from the power system is:

$$I_{S1} = 100 \times \frac{100}{1.0 + X_{ST}} \times \frac{1,000}{3 \times 6.6}$$

$$= \frac{875.8 \times 10^3}{1.39 + X_{ST}} \text{ A}$$

(2) Short circuit current, I_{S2} due to motor contribution:

$$I_{S2} = 100 \times \frac{100}{108.4} \times \frac{1,000}{\sqrt{3} \times 6.6} \times 0.4 = \frac{875.8 \times 10}{108.4} \times 0.4$$

$$= 3,231.7 \text{ A}$$

(3) Short circuit current, I_S at Point F 0.1 sec. after a fault arises:

$$I_S = I_{S1} + I_{S2}$$

$$= \frac{875.8 \times 10}{1.39 + X_{ST}} + 3,231.7 \text{ A}$$

(4) Examination of X_{AT}

Since, interrupting current of the incoming circuit breaker is 390 MVA, at 7.2 kV.

Therefore, interrupting current is;

$$\frac{390 \text{ MVA} \times 10^3}{3 \times 7.2 \text{ kV}} 31.5 \text{ kA}$$

Therefore, percent impedance of starting transformer shall be required to meet the following condition.

$$31,500 > \frac{875.8 \times 10^3}{1.39 + X_{ST}} + 3,231.7$$

$$31,500 - 3,231.7 > \frac{875.8 \times 10^3}{1.39 + X_{ST}}$$

$$28,268.3 > \frac{875.8 \times 10^3}{1.39 + X_{ST}}$$

$$(28,268.3 \times 1.39) + 28,268.3\ X_{ST} > 875.8 \times 10^3$$

$$39,292.9 + 28,268.3\ X_{ST} > 875.8 \times 10^3$$

$$28,268.3\ X_{ST} > 875.8 \times 10^3 - 39,292.9$$

$$28,268.3\ X_{ST} > 836,507.1$$

$$X_{ST} > \frac{836,507.1}{28,268.3}$$

$$X_{ST} > 29.59$$

When X_{ST} is calculated on the basis of the capacity of 22 MVA of the starting transformer,

$$X_{ST} > X_{ST} \times \frac{22}{100} = 10.0$$

$$X_{ST} > 29.59 \times \frac{22}{100}$$

$$X_{ST} > 6.5\%$$

Therefore, X_{ST} of the starting transformer is required to be 10% or over judging from the restriction of short circuit current.

4. Calculation of Voltage Regulation

The voltage regulation is calculated so that voltage drop at start-up the BFP motor having the largest capacity among various motors will be within 15% of the limited value when Units No. 1 and No. 2 are started up at the same time.

The impedance, X_{ST} of starting transformer is expressed according to the following formula (Regarding the symbols and conditions of this impedance, refer to Detailed Design Sheet No. E-4 Impedance of Auxiliary Transformer).

$$15 > 24,553 \times \frac{XST}{22}$$

$$15 \times 22 > 24,553 \times X_{ST}$$

$$330 > 24,553 \times X_{ST}$$

$$\frac{330}{24,553} > X_{ST}$$

$$13.43 > X_{ST}$$

Therefore, X_{ST} of the starting transformer is required to be 13.43% judging from the restriction in voltage regulation.

5. Conclusion

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5. Conclusion

The impedance, X_{ST} of the starting transformer is required to meet the following conditions on the bases of 22 MVA:

$$13.43\% > X_{ST} > 6.5\%$$

In consideration of the above requirements, therefore, the impedance, X_{ST} of the starting transformer for West Wharf Thermal Power Plant Units No. 1 and No. 2 will be adopted 10.0%.

E-5 CAPACITY OF BATTERY AND BATTERY CHARGER

1. Unit Station Battery

1.1 Basic Requirement

Emergency electric power source facilities shall be installed in order to maintain the power source for safety shutdown of the turbine-generator, should occur trip trouble, etc.

The facilities shall also be used for emergency lighting, the communication system and control.

A stationary-type storage battery shall be used to supply the DC electric power.

The type of battery will be the adopted lead acid storage battery, and a battery charger shall be installed for charging and equalization during normal operation.

1.2 Capacity of Facilities

(1) Battery

Capacity	3,100 AH/10HR
Minimum temperature	25°C
Minimum voltage	1.8 V/Cell
Normal voltage	2.15 V/Cell
Cell quantity	55 Cells
Rated voltage	110 V

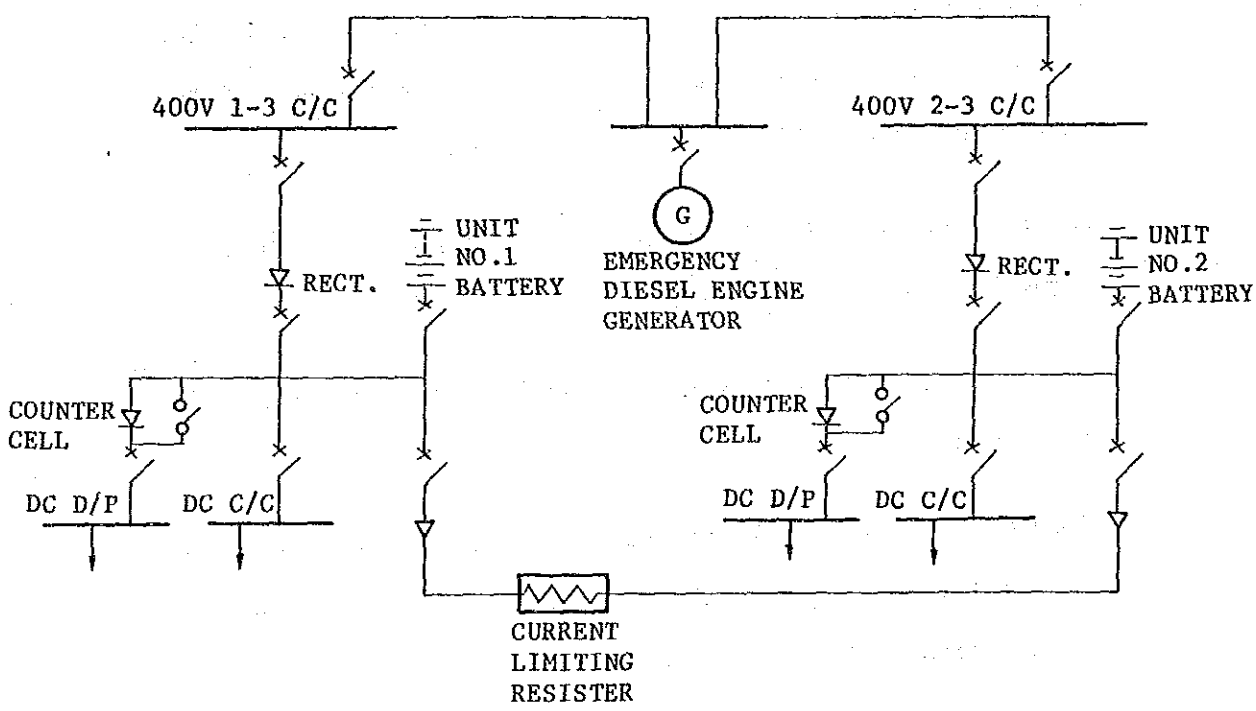
(2) Battery charger

Capacity	500 A

(3) Counter cell

Capacity 410 A

1.3 System Configulation of Unit DC Power Source



The power source of battery charger will be supply from 400 V emergency control center which to connect the emergency diesel engine generator output circuit.

The tie line between units No. 1 and No. 2 will be provided so as to back up at the time of maintenance of reactifier.

The current limiting resister will be provided on the tie line taking into consideration to reduce the short circuit.

The counter cell will be provided on the DC D/P circuit so as to compensate over voltage during equalizing change and just after changing to equalize against equipment.

1.3 Prequisite Conditions

The capacity of unit station battery has been determined with estimate in case of AC power failure for one (1) hour.

The AC power failure is not consider more than one (1) hour, because, the emergency diesel engine generator will be operated and system will be recovered.

(1) Application load

a. Auxiliary load of fuel shutdown for extenguish of boiler

. Fuel shutoff valve

. From detector and T.V. coding fan

b. Auxiliary load of safety shutdown for turbine

. Emergency bearing oil pump

. Vacuum breaker

c. Emergency seal oil pump

d. Emergency lighting

e. Automatic control during unit shutdown

(2) Concerning load capacities used for this capacity calculation, indefinite capacity values have been estimated to be the same as load capacities of equipment and machines in the same capacity steam power plant.

(3) The battery charger will be used for Unit only. However, the

back up for other unit has been considered.

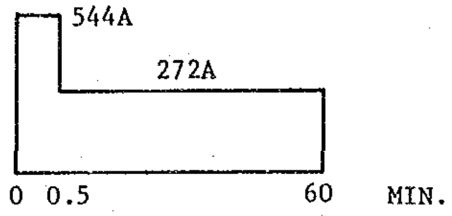
1.4 Load and Current Estimation

(1) DC 110 V control center and distribution panel load

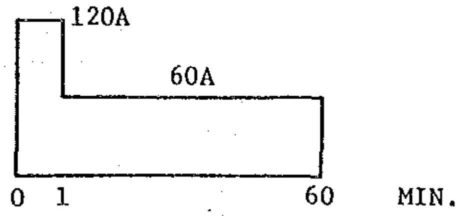
No.	Name	Capacity (kW)	Current I_1 (A)	Current I_2 (A)	Current I_3 (A)	Remarks
1	Emergency oil pump	25	544	272	272	Estimation
2	Emergency seal oil pump	5.5	120	60	60	"
3	Vacuum breaker	0.2	5	-	-	"
4	Flame scanner, TV cooling fan	22.0	482	241	241	"
5	UPS (CVCF)	30.0	200	200	200	"
6	Paging	1.0	9	9	9	"
7	Emergency lighting	8.0	80	80	80	"
8	Circuit breaker operation	-	67	-	120	"
9	Control and indicating lamp	-	40	40	40	"
	Total		1551.5	902	1022	

(2) Time schedule of each equipment

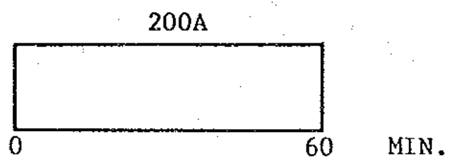
The operating time for emergency equipment shall be one (1) hour.



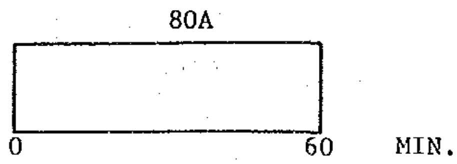
Emergency oil pump



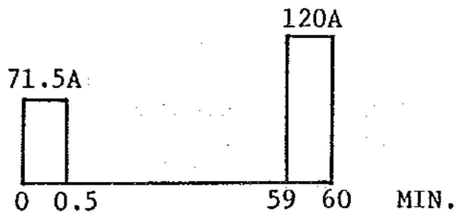
Emergency seal oil pump



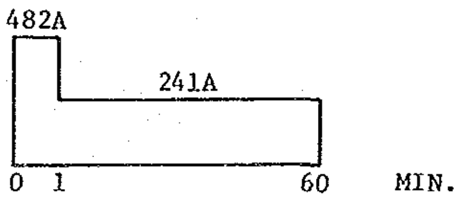
UPS (CVCF)



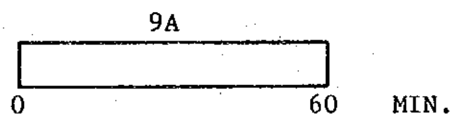
Emergency lighting



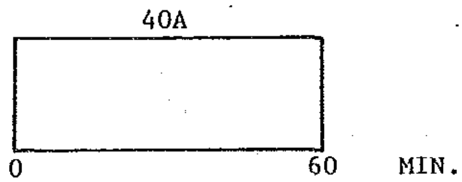
Circuit breaker operation



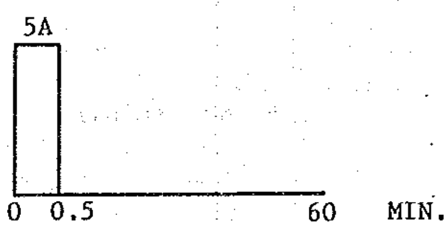
TV cooling fan



Paging

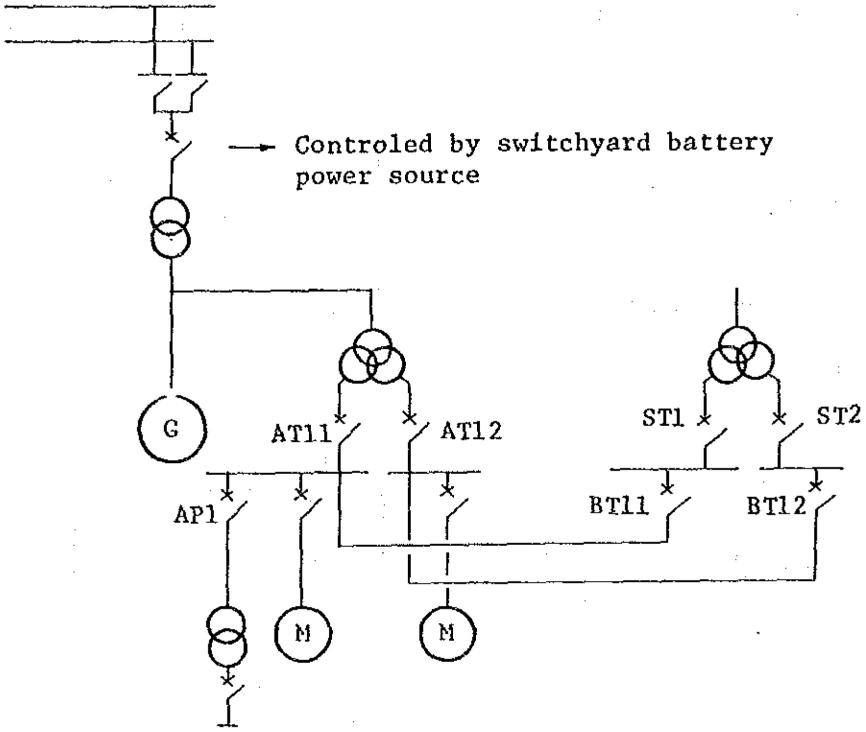


Indication lamp



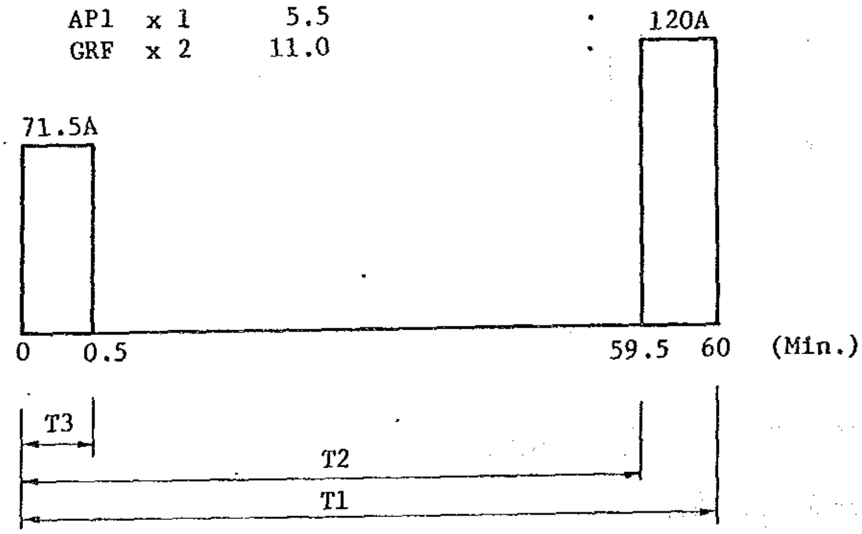
Vacuum breaker

Circuit Breaker Operation

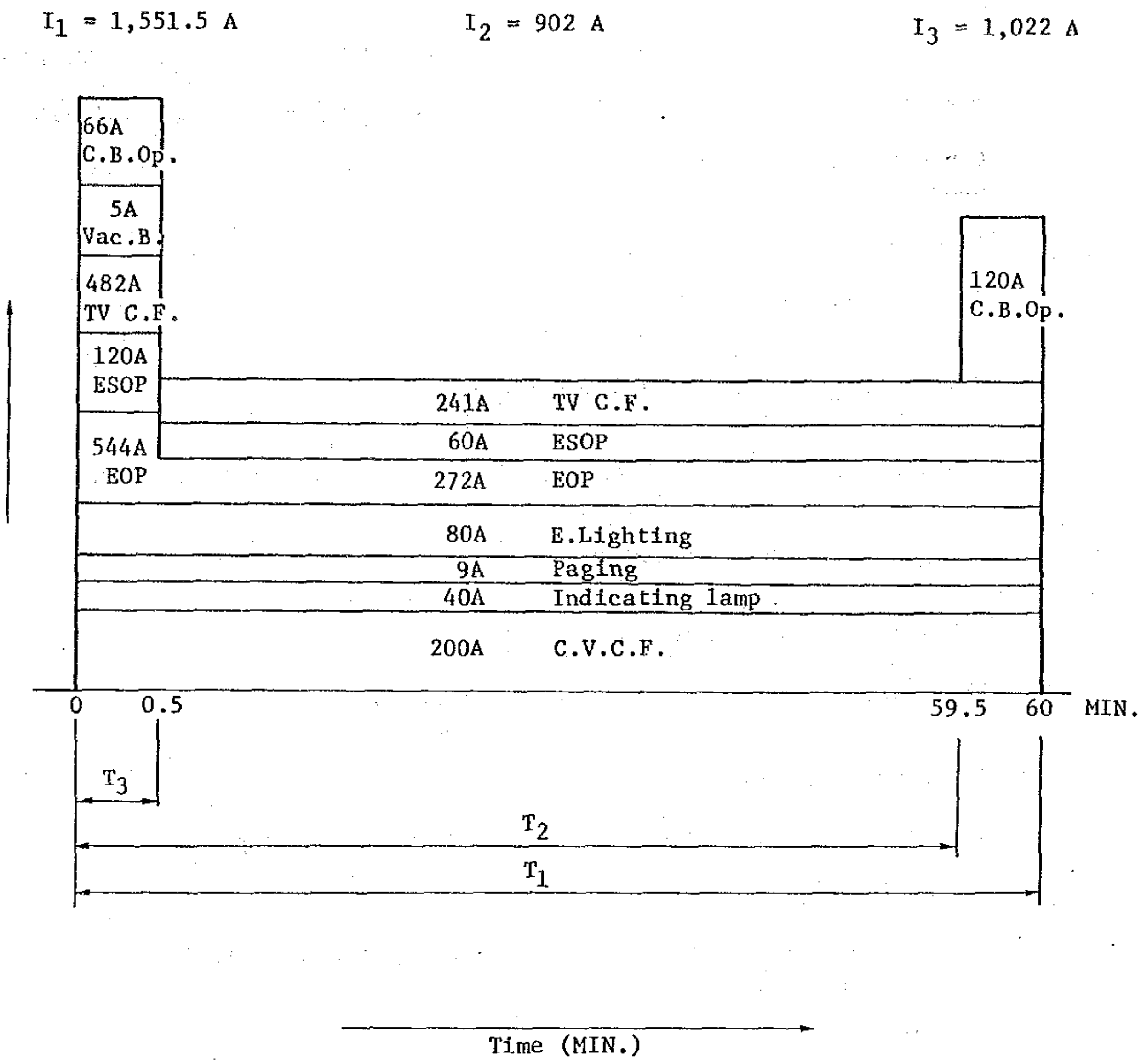


Circuit breaker	Trip current (A)
AT11 x 1	5.5
AT12 x 1	5.5
FDF x 2	11.0
BFP x 2	11.0
CWP x 2	11.0
CP x 2	11.0
AP1 x 1	5.5
GRF x 2	11.0

Circuit breaker	Closing current (A)
BT11 x 1	5.5
BT12 x 1	5.5
API x 1	5.5
.	
.	
.	
.	
.	



(3) Time schedule of DC 110 V load



1.5 Calculation

(1) Capacity of station battery

Current	I_1 = 1,551.5 A	I_2 = 902 A	I_3 = 1,022 A
Discharge time	T_1 60 MIN.	T_2 = 59.5 MIN.	T_3 = 0.5 MIN.
Capacity exchange factor	K_1 = 2.5	K_2 = 2.45	K_3 = 1.5
Life factor	L = 0.8		

Battery capacity C AH

$$C = \frac{1}{L} \{K_1 I_1 + K_2(I_2 - I_1) + K_3(I_3 - I_2)\}$$

$$= \frac{1}{0.8} \{2.5 \times 1551.5 + 2.45 \times (902 - 1551.5) + 1.5 \times (1022 - 902)\}$$

$$= \frac{1}{0.8} \{3{,}878.8 - 1{,}591.3 + 180\}$$

$$= 3{,}084.38 \text{ AH} \quad 3{,}100 \text{ AH (10 HR)}$$

Therefore, tentative capacity is 3,100 AH to 10 HR.

(2) Capacity of battery charger

a. The calculation formula of the battery charger capacity is as follows.

$$\frac{\text{Battery capacity}}{\text{10 H}} \times \frac{1}{2} + \text{Normal operation current}$$

where,

Battery capacity	3,100 AH/10 HR
Normal operation current	249 A

Breakdown,

(i)	C.V.C.F.	200 A
(ii)	Control and indication lamp	40 A
(iii)	Paging	9 A

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Then,

$$\frac{3,100/AH}{10\ H} \times \frac{1}{2} + 249\ A = 404\ A \qquad 410\ A$$

Therefore, the installed capacity is 410 A.

b. Normal operation current

249 A/unit

249 A x 2 = 498 A/2 unit

c. Determination of capacity

Installed capacity ------------- 404

Normal operation current -------- 498

Normal operation current is langer than installed capacity, therefore, tentative capacity of battery charger is 500 A.

(3) Capacity of counter cell

a. Rated capacity

Based on normal operation current 249 250 A

b. Short time rating

The counter cell shall be able to withstand the maximum discharge current taking into account AC power failure during counter cell in service.

2. Switchyard Station Battery

2.1 Basic Requirement

Battery and charger system will be provided for switchyard equipment.

The battery has the capacity that covers control power for switchyard equipment for 60 minutes in case of charger failure.

The charger has the capacity that covers control and indication of switchyard equipment and charging current to the battery.

The type of battery will be adopted lead acid stationary storage battery.

2.2 Capacity of Facilities

(1) Battery

Capacity	400 AH/10HR
Minimum temperature	25°C
Minimum voltage	1.8 V/Cell
Normal voltage	2.15 V/Cell
Cell quantity	55 Cells
Rated voltage	110 V

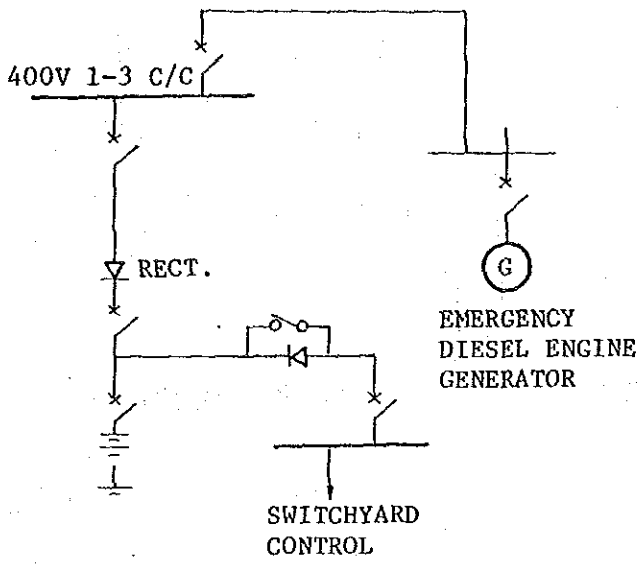
(2) Battery Charger

Capacity	100 A

(3) Counter cell

Capacity	60 A

2.3 System Configulation



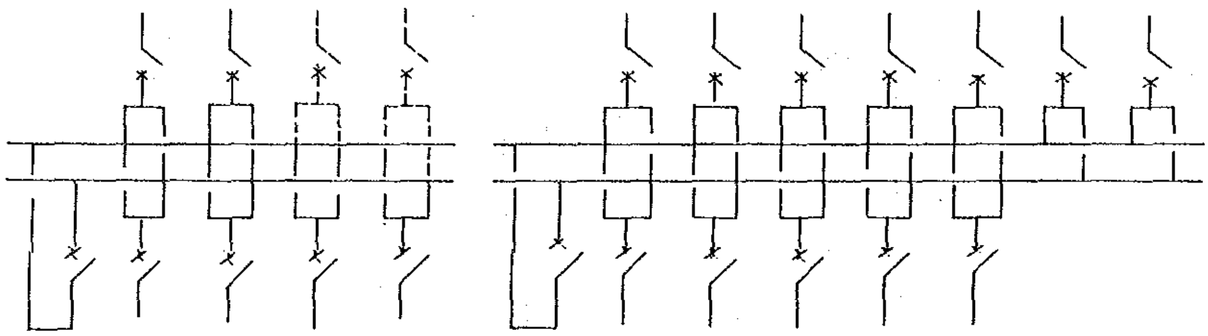
2.4 Prerequisite Conditions

(1) The capacity of unit station battery has been determined with estimate in case of AC power failure for one (1) hour.

(2) The AC power failure is not consider more than one (1) hour, because, the emergency diesel engine generator will be operated and system will be recovered.

(3) The most server condition to the battery system is defined as the time of 60 minutes after occurrence of A.C. failure on a bus of the battery charger.

(4) Switchyard bus component



220 kV switchyard   132 kV switchyard

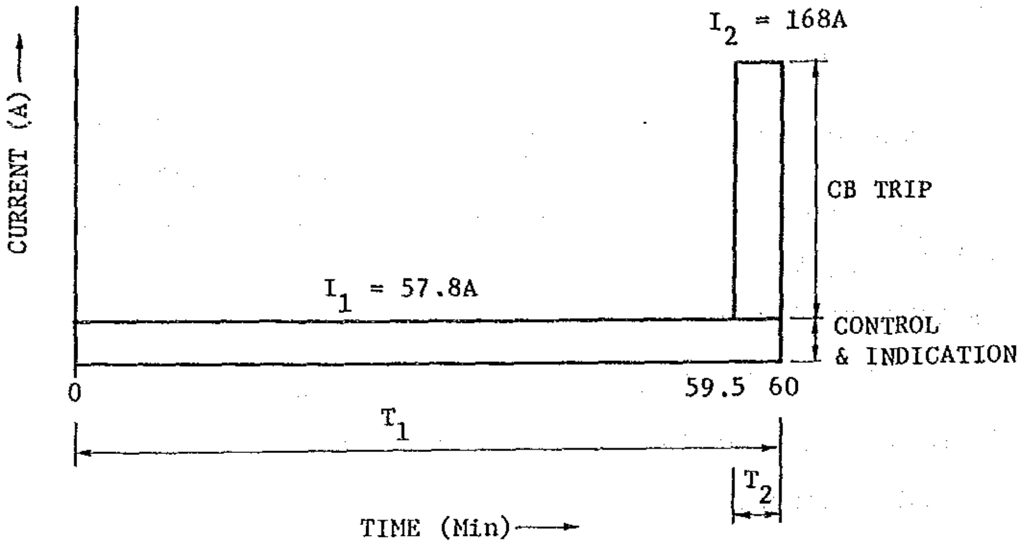
		220 kV	132 kV
a.	Bay number	9	13
b.	Circuit breaker operation current		
	. Closing (A)	10 A/set	6A/set
	. Tripping (A)	10 A/set	6A/set
c.	Total tripping current	90 A	78 A

2.5 Lead and Current Estimation

(1) Load and current of switchyard

KIND OF FEEDER	RATED CAPACITY	NOMINAL CONTINUOUS CAPACITY	CAPACITY AT AC FAILURE	
<u>220 kV Switchyard</u>				
CB INDICATION LAMP (9 sets)	180 W	1.62 A	1.62 A	0.18 A
DS " " (22 sets)	440 W	3.96 A	3.96 A	
CB TRIPPING CURRENT (9)	90 A	-	-	10A/set
DS CONTROL OPEN/CLOSING (22 sets)				Short/time only
CONTROL PANEL	9A	9.0 A	9.0 A	
PR. RELAY PANEL	9A	9.0 A	9.0 A	
<u>132 kV Switchyard</u>				
CB INDICATION LAMP (13 sets)	260 A	2.34 A	2.34 A	
DS " " (33 sets)	660 W	5.94 A	5.94 A	
CB TRIPPING CURRENT	78 A	-	-	6 A/set
DS CONTROL OPEN/CLOSING				Short time only
CONTROL PANEL	13 A	13 A	13 A	1 A/bay
PR. RELAY PANEL	13 A	13 A	13 A	1 A/bay
		57.86 A	57.86 A	

(2) Time schedule



2.6 Calculation

Minimum temperature of battery	:	25°C
Minimum voltage of battery	:	1.75V/cell*
Minimum voltage of battery	:	2.15V/cell
Life factor (L)	:	0.8
Switchyard equipment load	:	Refer to table 1.4 (1)

(1) Capacity of station battery

$$C = \frac{1}{L} \{K_1T_1 + K_2(I_2 - I_1)\}$$

Here, L = 0.8

I_1 = 57.8 A, T_1 = 60 min., K_1 = 2.6

I_2 = 168 A, T_2 = 0.5 min., K_2 = 1.3

* K_1, K_2 is the rating factor that is given by attachment-1.

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$$C = \frac{1}{0.8} \{2.6 \times 57.8 + 1.3 (168 - 57.8)\}$$

$$= \frac{1}{0.8} (150.28 + 143.26) = \frac{293.54}{0.8}$$

$$= 366.9 \text{ Ah} \quad 400 \text{ Ah}$$

Battery capacity of 400 Ah will be applied.

(2) Capacity of battery charger

Current rating is as follows,

Battery charging current + Normal operation current

Battery charging current	$\frac{400 \text{ AH}}{10 \text{ H}} = 40$
Normal operation current	57.8 A

Then,

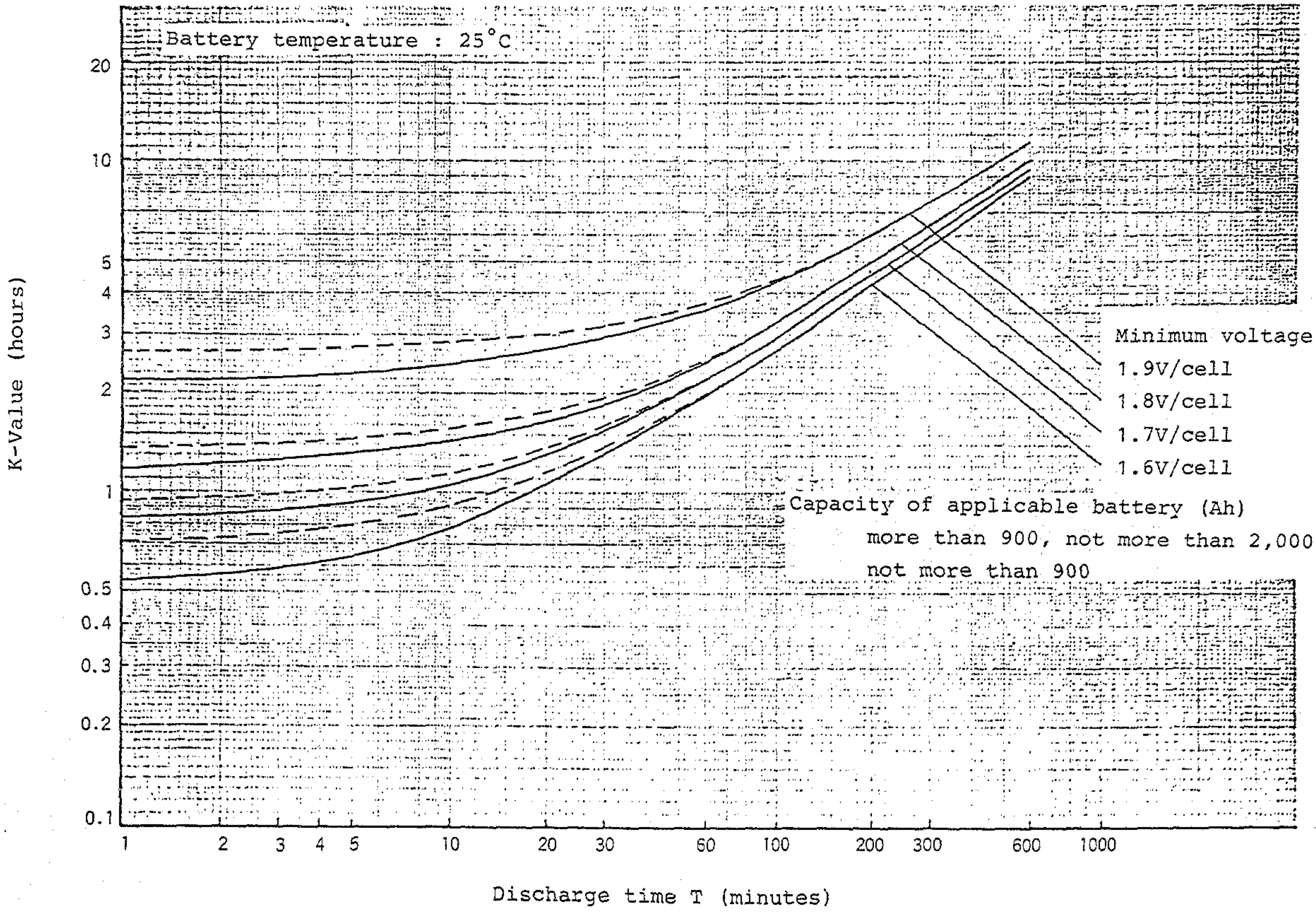
40 A + 57.8 A = 92.8 A

Therefore, the installed capacity is 100 A.

(3) Capacity of counter cell

Based on normal operation current   57.8   60 A

Characterristic of lead-acid batteries (10HR capacity)



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E-6 CAPACITY AND DESIGN CRITERIA OF EMERGENCY DIESEL ENGINE GENERATOR

The diesel engine generator will be provided for emergency power for Units No. 1 and No. 2 in order to enable safe shutdown through supply of minimum required power in case of blackout, namely, all power source failure from units and transmission lines.

1. Capacity of Emergency Diesel Engine Generator

(1) Selection of various emergency auxiliary machines

(1) Definition of emergency auxiliary machines

The emergency auxiliary machines and devices refer to those installed to prevent the following troubles:

a. Damage of main power plant equipment;

b. Failure in plant control;

c. Hazardous effect upon the safety of personnel unless these auxiliary machines and devices operate properly.

(2) Classification of emergency auxiliary machines and devices

a. For safe shutdown and prompt start-up of mechanical equipment

Bearing oil pumps

Turning gear

Seal oil pump

Flame scaner & TV cooling fan

Oil tank gas extractor

b. For control (instrument) power source equipment

Battery charger

Instrument power source

UPS (CVCF) (The ups load has not been consider for calculation of capacity.
Because, the ups normal power source from DC circuit.)

c. For safety of public and personnel

Elevator power source

Emergency lamps and obstruction light

Paging equipment

d. Others

Auxiliary machines for diesel engine generator

2. Prerequisite Conditions

Auxiliary load to be borne by diesel engine generator

Concerning load capacities used for this capacity calculation, indefinite capacity values have been estimated to be the same as load capacities of equipment and machines in the same capacity steam power plant.

Kind	Breakdown of load	Capacity			
		Unit No.1	Unit No.2	Common	Remarks
Put into automatic operation	Seal oil pump	11 x 1	11 x 1		Estimated
	Seal oil recirculation pump	3.7 x 1	3.7 x 1		
	Turning gear oil pump	30 x 1	30 x 1		
	Seal oil vacuum pump	2.2 x 2	2.2 x 2		
	Vapor extractor	2.2 x 2	2.2 x 2		
	Flame detector cooling fan	22 x 1	22 x 1		
	Batt. room exh. fan	-	-	0.4 x 2	
	D/G aux. equipment	20 x 1	-		Air compressor Radiator Fan L.O prinning
	Total motor load	95.5	75.5	0.4	
	Unit battery charger	95	95		
	Switchyard battery charger			20.0	
	Paging equip.	-	-	3.0	
	Normal emergency lighting	20	20		
	Obstruction lighting	20	-		
	Instrument power source	30	30		
	HP turbine bypass valve serbo. amp	10	10		
	Transformer load	175	155	27.5	
Put into manual operation	Turning gear	7.5	7.5		
	Total motor load	7.5	7.5		
	Elevator for main building	15	15		
	Intermittent load	15	15	0.5	

3. Calculation

(1) Calculation of diesel engine generator capacity

a. Automatic operation load

Motor load = 95.5 + 75.5 + 0.4 = 171.4 kW

where power factor is assumed to be 0.8,

Motor load = 171.4/0.8 = 214.25 kVA

Transformer load = 175 + 155 + 27.5 = 357.5 kVA

b. Manual operation load

Motor load = 7.5 + 7.5 + 0.75 = 15.75 kW

where power factor is assumed to be 0.8,

Motor load = 15.75/0.8 = 19.69 kVA

Intermittent load = 15 + 15 + 0.63 = 30.63 kVA

Motor load = 0.5/0.8 0.63

c. Therefore, the total auxiliary load is calculated as follows:

214.25 + 257.5 + 19.69 + (30.63 x 1/2) = 606.76 kVA

606.76 x 1.1 = 667.44 667.5 kVA

Where the coefficient of 1.1 is an allowance for unknown factor (Change of motor capacity, additional capacity of new motors, etc.)

Capacity of diesel engine generator

= 667.5 x 0.8 = 534 kW

= 540 kW

where the power factor is assumed to be 0.8,

The capacity = 540/0.8 = 675 kVA

(2) Voltage drop (at the time of starting)

The value of voltage drop arising due to the load applied instantaneously at the time of starting the diesel engine generator has been calculated in accordance with the load of Unit No. 1 because such voltage drop will hardly be affected irrespective of whether there is any initial load or not. Moreover, load will be applied to Unit No. 2 a little after load has been applied to Unit No. 1.

a. Calculation of voltage drop

Instantaneous current, Is

$$Is = \frac{E}{Xd' + Xe}$$

where Xd': Generator transient reactance (assumed to be 22%)

Xe : Load reactance

$$= \frac{\text{Generator [kVA]}}{\text{Load [kVA]}} \times 100\%$$

E : Generator voltage at no load

Voltage drop, V

$$V = Is \times Xd' \times \frac{1}{E} \times 100\% = \frac{Xd'}{Xd' + Xe}$$

b. Calculation of Xe

$$\text{Load [kVA]} = \sqrt{(KW)^2 + (KVR)^{22}}$$

Active power : 540 kW

Reactive power

$= \text{Motor load} \times \tan(\cos^{-1} 0.4) + \text{transformer load} \times \tan(\cos^{-1} 0.95)$

$= 95.9 \times \tan(\cos^{-1} 0.4) + 202.5 \times \tan(\cos^{-1} 0.95)$

$= 95.9 \times 2.3 + 202.5 \times 0.33$

$= 220.57 + 66.83$ = 287.4 kVR

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$$\text{Load [kVA]} = \sqrt{540^2 + 287.4^2}$$
$$= \sqrt{291{,}600 + 82{,}598.76}$$
$$= \sqrt{374{,}198.76}$$
$$= 611.72 \ \text{kVA}$$

$$Xe = \frac{675}{611.72} \times 100 \qquad = 110.34\%$$

Calculation of voltage drop

$$V = \frac{22}{22 + 110.34} \times 100 \qquad = 16.62$$

Although voltage drop of 16.62% will take place instantaneously at the time of closing, there will not be any problem actually since such voltage drop will be restored quickly by means of AVR.

4. Control System

The control system for the diesel engine generator shall be designed to provide automatic and manual start and stop. The automatic start control system shall be provided to start the engine by receiving the signal from both control centers in case of power failure in 1-3 460 V control center of 2-3 400 V control center. However, engine stop shall be provided manually.

The main circuit breaker for the generator shall be automatically closed after confirming the rated speed of the engine and rated voltage of the generator.

(1) Starting method

There are the following three diesel engine generator starting

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systems:

a. Automatic starting

When the changeover switch on the diesel engine generator control panel is put to automatic position, the undervoltage relay is actuated at the time of power failure from the normal power source or voltage drop, and after a certain confirmation time limit (about 5 seconds), the starting solenoid valve is opened and the diesel engine is started up by means of compressed air.

b. Manual starting from control panel

When the changeover switch is put to manual position from control panel, and the control switch is put to starting, the diesel engine is started up in the same way as in the above item (1).

c. Local starting

When the changeover switch is put to local starting position, the diesel engine is started up directly from the engine side.

(2) Operation after starting

When the engine has been started up and accelerated to the self-combustion condition, and the low speed contact is actuated at 30% speed, the starting signal is cut off, and the initial excitation of the generator is carried out by means of unit DC power source from the station battery. When the engine has been put to combustion condition and accelerated to 90% of the rated speed, the alarm and protection circuits of the engine are energized and the engine is protected.

When the engine is accelerated to a rated speed through operation of the governor, the voltage is detected by constant voltage relay (84EG), and the initial excitation is suspended. Then, the diesel engine is put to normal operating conditions.

(3) Starting failure

In the event where the engine has not been put to self-combustion condition for a certain time limit after starting command has been given, then alarm is displayed and the starting circuit is shut off at the same time.

(4) Shutdown

When the control switch has been changed over to stop or when the engine protective relay is actuated, the circuit breaker is opened, and the engine stop solenoid valve is excited after a certain time limit. Then, fuel supply is cut off and the engine is shut down.

Meanwhile, when the engine protective relay is actuated, the engine starting circuit is also locked.

(5) Protection

a. Protection against trouble

Simultaneously with indication of alarm, the circuit breaker is tripped, the engine is shut down and the starting circuit is locked in the following cases:

Overspeed

Starting failure

Lubricating oil pressure low (final)

Cooling water temperature high

Overvoltage

Overcurrent

b. Protection against minor trouble

In the event of minor trouble, only alarm is issued in the following cases:

Lubricating oil pressure low (first stage)

Cooling water temperature high

Air pressure low

Fuel oil tank level low

Generator ground fault

Air compressor trouble

Radiater fan trouble

Other troubles

5. Configuration and Sequence of Load Circuit

(1) Auxiliary load circuit of diesel engine generator

The auxiliary load of the emergency diesel engine generator is connected to the emergency power receiving circuit in the emergency control center 1-3C/C or 2-3C/C with changeover switch for the respective units as shown in Fig. 1. Should it become impossible to receive power from normal power source, the emergency system is so designed as to enable to receive the output of the diesel engine generator from the above circuit through automatic changeover.

(2) Changeover sequence of load

a. Start-up and preparation for power supply

In the event where power failure or abnormal voltage drop should arise in the emergency control center 1-3C/C or 2-3C/C, the undervoltage relay (27) of bus in the control center detects such failure or voltage drop, and starting signal is given to the diesel engine.

When the diesel engine has been started up, and the voltage has been raised to a specified level, the circuit breaker (52EG) on the output side of diesel engine generator is automatically closed and preparation for power supply is completed.

b. Changeover of power supply (receiving)

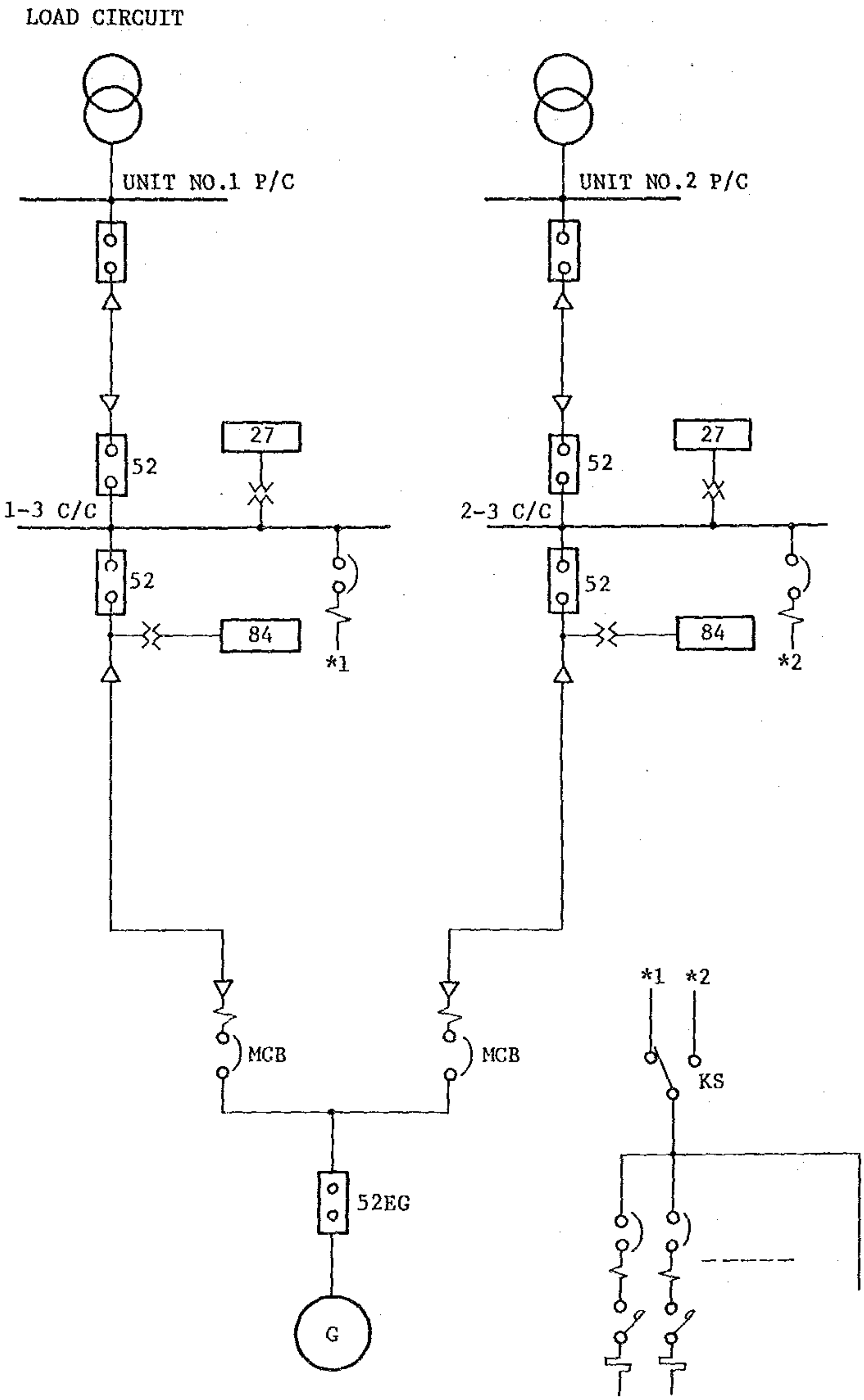
After undervoltage of bus and the output voltage from the diesel engine generator have been confirmed from the emergency control power source, then the normal power receiving circuit breaker is tripped, whereas the emergency power receiving circuit breaker is closed automatically, and the power source is changed over from the power center to the diesel engine generator.

c. Restoration

When the normal power source has been restored, the normal power receiving circuit breaker in the emergency control center is closed by means of changeover switch.

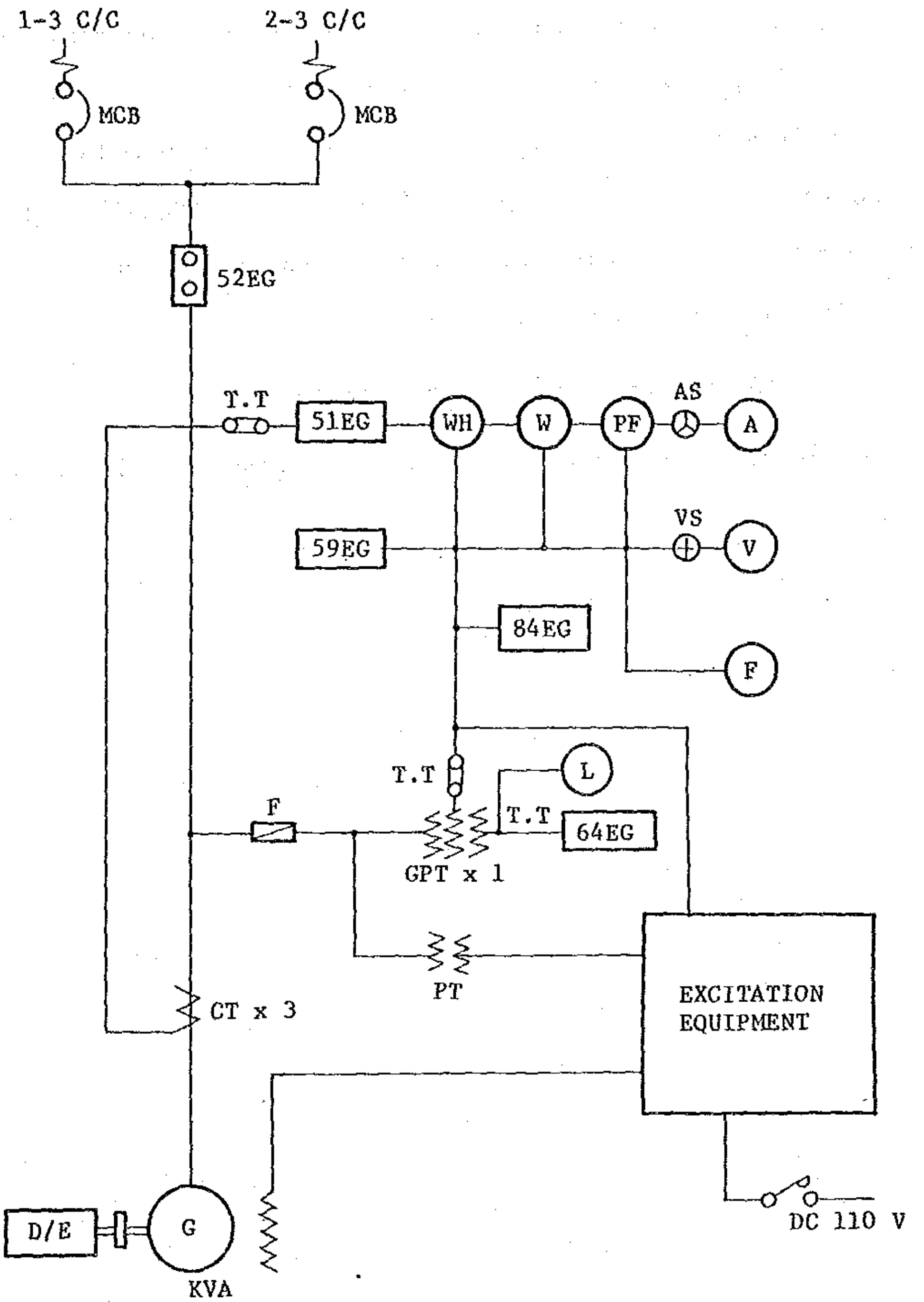
The emergency power receiving circuit breaker is opened automatically and the normal power receiving circuit breaker is closed.

As described above, when the power source in the emergency control has been changed over, the diesel engine generator is shut down through manual operation.



AUX. LOAD FOR EMERGENCY DIESEL ENGINE

ONE LINE DIAGRAM



400 V 3ϕ PF 0.8

FROM STATION BATTERY

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4. Required Capacity of Diesel Engine

The diesel engine is required to have a capacity sufficient for driving a generator with a maximum capacity of 540 kW. Therefore, when the efficiency of the generator and the overload factor of the engine are assumed to be 93% and 110%, respectively, the required capacity of the diesel engine is calculated as follows:

Capacity of diesel engine, PS

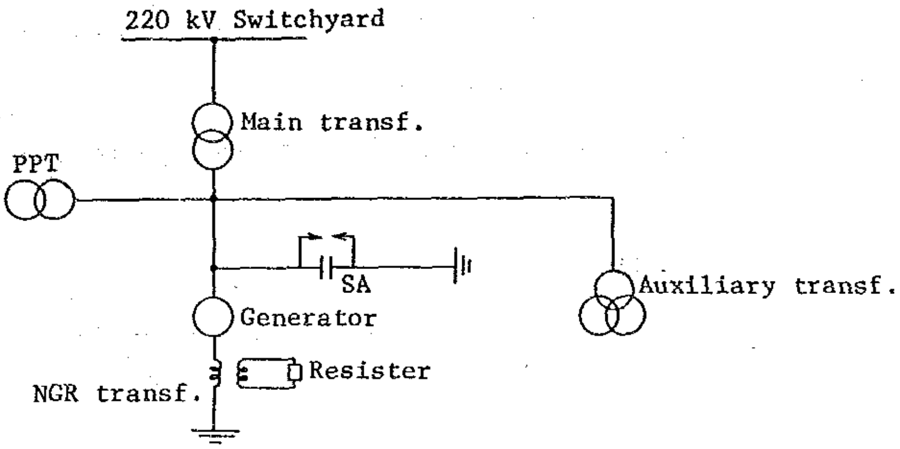
$$= 540 \times \frac{1}{0.736} \times \frac{1}{0.93} \times \frac{1}{1.1} = 717.2 \text{ [PS]}$$

Therefore, the required capacity of diesel engine is 717.2 PS or over.

E-7 CAPACITY OF GENERATOR NGR TRANSFORMER

The capacity of the generator NGR transformer and resister has been calculated based on the changing current on fault point though capacitance on the generator main circuit, as describe hereunder.

1. Circuit



2. Capacitance

Concerning capacitance used for this calculation, indefinite capacitance values have been estimated to be the same as load capacities of equipment and machines in the same capacity steam power plant.

Supposing capacitance value will be as follows:

C_G	:	Generator capacitance	0.442 (μF/phase)
C_M	:	Main transf. capacitance (Low side-Earth)	0.0024 (μF/phase)
C_A	:	Auxiliary transf. capacitance (High side-Earth)	0.0018 (μF/phase)
C_S	:	Sarge absorber capacitance	0.125 (μF/phase)
C_I	:	Isolated phase bus capacitance	64.9 (pF/phase/m) 0.0026 (μF/phase)

C_E : Power potential transf. capacitance 0.002 (μF/phase)

IPB length : 40 (m/phase)

3. Calculation

(1) Total capacitance and current

Total capacitance $C = C_G + C_M + C_A + C_S + C_I + C_E$

$C = 0.442 + 0.0024 + 0.0018 + 0.125 + 0.0026 + 0.002$

$= 0.5758$ (F/phase)

Capacitive fault current (Ic) at the line to ground fault in the generator circuit.

$Ic = j3 \quad c\ Eg$

$= j3 \times 2 \quad \times 50 \times 0.5758 \times 10^{-6} \times \frac{18,000}{\sqrt{3}}$

$= 5.64$ (A)

(2) Neutral grounding transformer rating

Rated voltage

Primary $V_1 = 18,000$ (V)

Secondary $V_2 = 190$ (V)

Secondary voltage under one phase groud fault

$$V_{2c} = \frac{Vg}{\sqrt{3}} \times \frac{V2}{V1}$$

$$= \frac{18,000}{\sqrt{3}} \times \frac{190}{18,000} = 109.7 = 110 \text{ (V)}$$

Capacity of neutral grounding transformer

$Pc = V_1 \times Ic$

$= 18,000 \times 5.64 = 101.5$ (KVA)

Therefore, 110 (KVA) (5 minutes)

(3) Neutral grounding resister

Secondary current of neutral grounding resister

$$I_2 = \frac{Pc}{V_2}$$

$$= \frac{100 \times 10}{190} = 578.9 = 579 \text{ (A)}$$

Resistance of neutral grounding resister

$$R = \frac{V_{2c}}{Ic_2} = \frac{V_{2c}}{Ic \times \frac{V1}{V2}}$$

$$= \frac{110}{5.64 \times \frac{18,000}{190}} = \frac{110}{534.3} = 0.206 = 0.21 \ (\Omega)$$

4. Conclusion

In case of generator voltage 18 (KV) is as follows.

(1) Grounding transformer

Rated voltage	
Primary	18,000 (V)
Secondary	190 (V)
Time rating	5 (minutes)

(2) Grounding resister

Resistance	0.21 (ohm)
Rated current	579 (A)
Rated voltage	110 (V)
Time rating	5 (minutes)

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E-8 MINIMUM CAPACITY OF GENERATOR SURGE ABSORBER

1. Configuration of Circuit

The configuration of the circuit for the generator surge absorber is as indicated in Fig. 1.

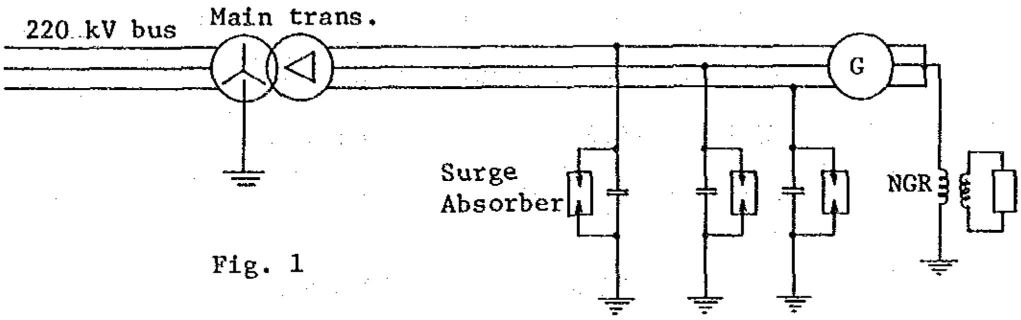


Fig. 1

2. Design Conditions

(1) Advancing surge

The surge voltage advancing from the high voltage side of the main transformer shall be equivalent to BIL of the high voltage side of the main transformer.

220 KV side (E_2) : 950 KV : 1.2 x 50 μs

(2) Constant of generator

Rated capacity:	248.3 MVA
Frequency:	50 Hz
Rated voltage:	18 KV
Surge impedance (Z_1):	42 Ω/phase

(3) Main transformer constant

Rated capacity:	247 MVA

Rated voltage

Low voltage side: 18 KV

High voltage side: 220 KV

%IZ: 11%

Capacitance

High-Low, Earth (CHE): 1,700 pF/phase

Low-High, Earth (CHE): 3,400 pF/phase

High-Low (CHE): 2,500 pF/phase

Transformer ratio, N

$$= \frac{18}{220} = 0.0818 \qquad \frac{20}{220} = 0.0909$$

Transformer inductance, L_1

$$= \frac{1}{2F \times 50} \times \frac{(18)^2}{247} \times \frac{11}{100} = 0.473 \text{ (mH)}$$

(4) Impulse withstand voltage of generator

$$(2E + 3) \times 1.25 \times \sqrt{2} = (2 \times 18 + 3) \times 1.25 \times \sqrt{2}$$

$$= 68.9 \text{ (KV)}$$

where E: Generator voltage (KV)

1.25: Margin of generator

(5) Capacitance

C_1 = 0.1 (μF/phase)

(6) Surge absorber

Rated voltage: 22.5 KV

Discharge spark voltage: 33.8 KV or more

Impulse spart voltage: 65.5 KV

(7) Other capacitance of this circuit

Any ground static current capacity of the IPB and auxiliary transformer will not be taken into account in this calculation.

3. Calculation of Surge Transition Voltage

Among the voltage transferred into the low voltage side, there are a component transferred into static current when surge equivalent to BIL is applied into the high voltage side of main transformer. These components are calculated hereunder.

(1) Calculation of voltage transferred into electromagnet Fig. 1 is converted as shown in Fig. 2.

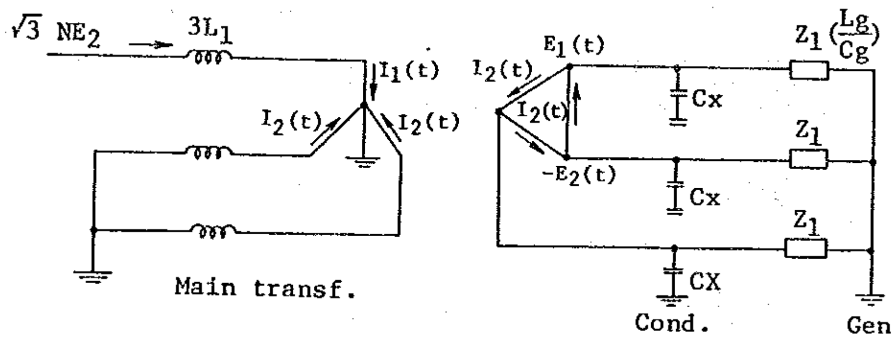


Fig. 2

The voltage electromagnetic, $E_1(t)$ transferred into the low voltage side from this circuit is expressed according to the following equation:

$$e_2(t) = E_2K\ (\xi^{-\alpha t} - \xi^{-\beta t})$$

where $e_2(t)$: Surge voltage applied into the high voltage side. The full wave form of surging shall be 1 x 10 μs

E_2 : Value of BIL of high voltage side

K : Constant of 1.039

α : Reciprocal number of time constant and is 0.0184×10^6 1/sec.

β : Reciprocal number of time constant and is 2.95×10^6 1/sec.

In case $Z_1 > \frac{i}{2} \cdot \frac{L1}{Cx}$.; the solution of the above equation is:

$$Z_1 = 39 > \frac{1}{2}\sqrt{\frac{0.413 \times 10}{0.1 \times 10^{-6}}} = 34.4$$

$$E_1 = NE_2 \frac{K}{3L_1 Cx}\left[\frac{1}{(A-\alpha)^2 + B^2}\{e^{- t}\right.$$

$$\sqrt{\frac{(A-\alpha)^2 + B^2}{B}}\, e^{-At} \sin(Bt + \varphi)\} - \frac{1}{(A-B)^2 + B^2}\{e^{-\beta t} -$$

$$\left.\sqrt{\frac{(A-\alpha)^2 + B^2}{B}}\, e^{-At} \sin(Bt + \varphi)\}\right]$$

$$= NE_2 \cdot K_1$$

where

$$A = \frac{1}{2CxZ_1}$$

$$B = \frac{1}{LCx} - \frac{1}{4CxZ_1}$$

$$= \tan^{-1}\frac{B}{A-\alpha}$$

$$= \frac{B}{A-\beta}$$

$$K_1 = \frac{K}{3L_1 Cx}\sqrt{\frac{1}{(A-\alpha)^2 + B^2}}\{e^{-\alpha t} -$$

$$\sqrt{\frac{(A-\alpha)^2 - B^2}{B}}\, e^{-At} \sin(Bt + \varphi)\} -$$

$$\frac{1}{(A-\beta)^2 + B^2} \{e^{-\beta t} - \frac{(A-\beta)^2 + B^2}{B} e^{-At} \sin(Bt + \theta)\}$$

Therefore,

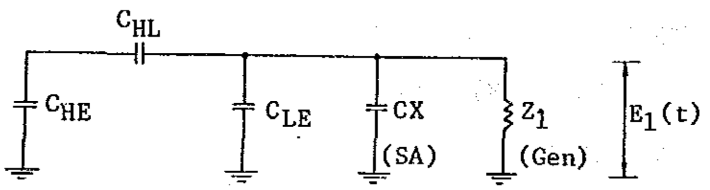
$E_1max = N \cdot E_2 \cdot Kmax = 31.8$ (KV)

The time, T in this case is:

T = 26.1 (s)

(2) Calculation of static transition voltage

Since the static transition component is transferred due to connection of condenser, the component becomes as indicated in the following diagram because of the static current capacity of the main transformer and generator circuit, as well as the surge impedance of the generator.



where

CHL: Static current capacity/phase between high voltage and low voltage sides of main transformer

CHE: Static current capacity/phase between high voltage side of main transformer and ground

CLE: Static current capacity/phase between low voltage side of main transformer and ground

Cx : Protective condenser capacity/phase

Z_1 : Surge impedance of generator

In case $e_2(t) = E_2 . k(\varepsilon^{-\alpha t} - \varepsilon^{-\beta t})$, the static transition voltage is calculated as follows:

$$E_1(t) = E_2 . k . a \left\{ \frac{1}{a-b} (a\varepsilon^{-\alpha t} - b\varepsilon^{-\beta t}) - \frac{1}{\beta - b} (\beta\varepsilon^{-\beta t} - b\varepsilon^{-bt}) \right\}$$

$$= E_2 . a . K$$

where

$$a = \frac{C_{HL}}{C_{HL} + C_{LX} + C_x}$$

$$b = \frac{1}{Z_1(C_{HL} + C_{LE} + C_x)}$$

$$K = k \left\{ \frac{1}{a-b} (a\varepsilon^{-\alpha t} - b\varepsilon^{-bt}) - \frac{1}{\beta - b} (\beta\varepsilon^{-\beta t} - b\varepsilon^{-bt}) \right\}$$

Therefore,

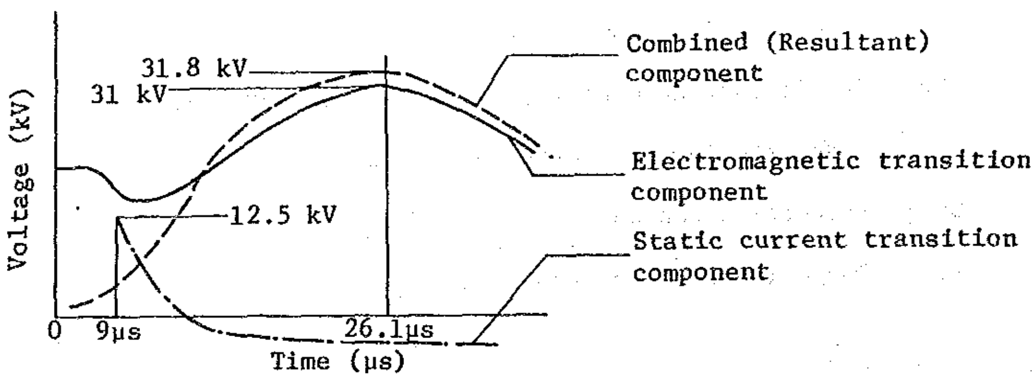
$$E_1 max = E_2 . a . k$$

$$= 12.5 \text{ (KV)}$$

$$T = 0.9 \text{ (}\mu s\text{)}$$

4. Result of Calculation

Based upon the results of calculation, the electromagnetic transition component and the static current transition component are superimposed in the following diagram:



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There will be no problem since the maximum value of Compined (Result) component is 31 KV, and less than 68.9 KV of the impulse wave dielectric strength of generator as indicated in the above diagram.

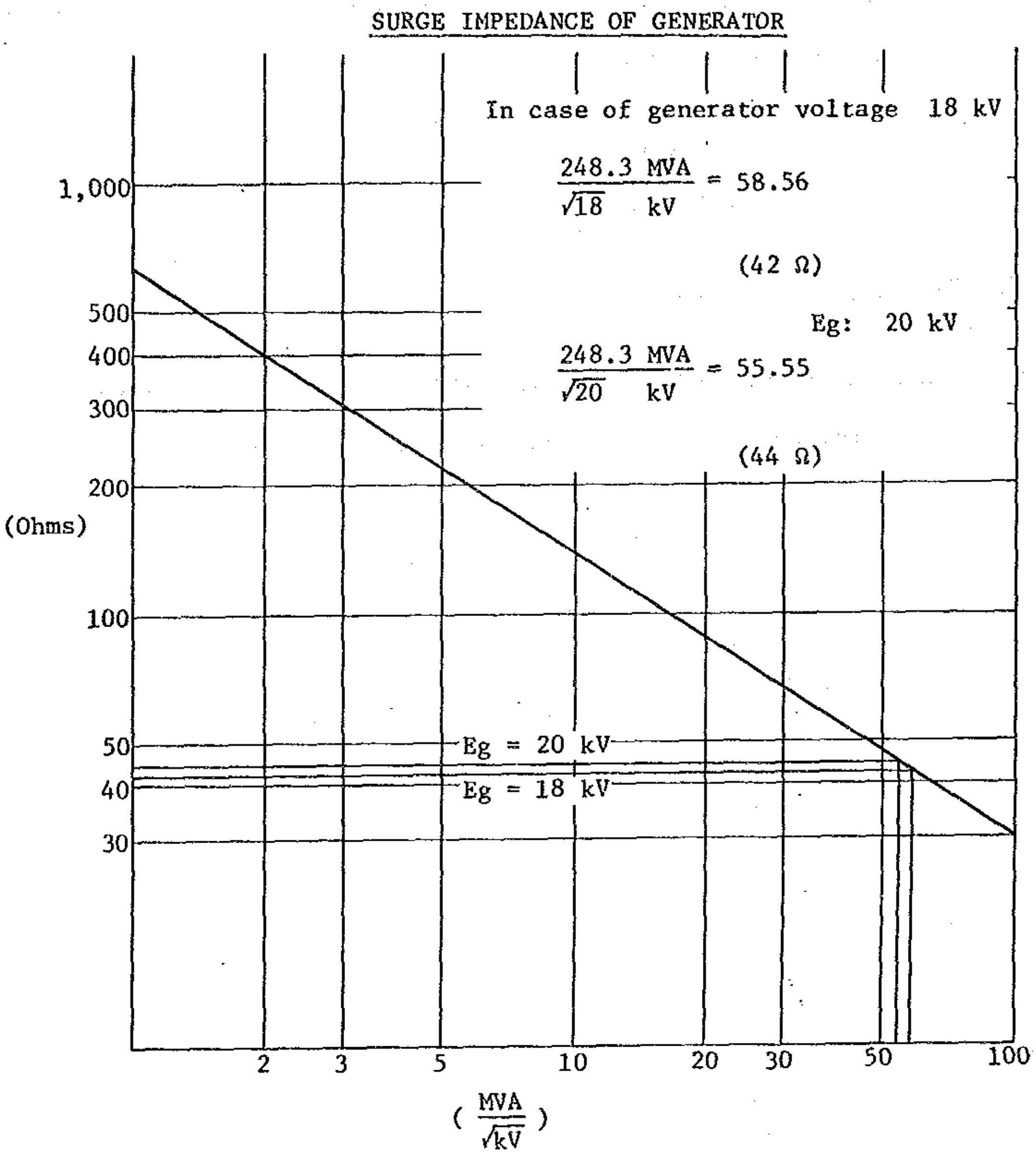
$E_1max = 31$ (KV)

$T = 26.1$ (μs)

5. Capacity of Condenser

The capacity of condenser is calculated to be 0.1 μF per phase. Therefore, the minimum capacity of condenser is 0.1 μF.

SURGE IMPEDANCE OF GENERATOR



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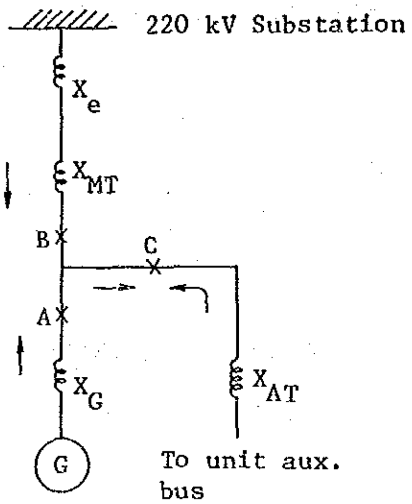
E-9 SHORT CIRCUIT CAPACITY OF IPB

1. Impedance Map

Impedance map is shown in Fig. 1.



where:

X_e : System external impedance

X_{MT}: Main transf. impedance

X_{AT}: Auxiliary transf. impedance

X_G : Generator subtrasient impedance

The impedance are supposing as follows:

$x_e = 0$

$X_{MT} = 0.11(PU)$ at 247 MVA

$X_{AT} = 0.08(PU)$ at 19 MVA

$X_G = 0.2$ (PU) at 248.3 MVA

Conversion of above impedance to 100 MVA base and per unit indication.

$X_e = 0$

$X_{MT} = 0.044(PU)$ $\qquad 0.11 \times \frac{100}{247}$ PU

$X_{AT} = 0.4$ (PU) $\qquad 0.08 \times \frac{100}{20}$ PU

$X_G = 0.08$ (PU) $\qquad 0.2 \times \frac{100}{248.3}$ PU

2. Calculation of Short Circuit Current

Calculate for short circuit current at each point (A, B, C) shown in Fig. 1 is as follows.

(1) First, short circuit capacity of point "A" is as follows.

From generator

$$P_G = \frac{100}{X_G} = \frac{100}{0.08} = 1,250 \text{ (MVA)}$$

From main transformer

$$P_{MT} = \frac{100}{X_{MT} + X_e} = \frac{100}{0.044} = 2,272.7 \text{ (MVA)} \quad 2,273 \text{ (MVA)}$$

From auxiliary transformer

$$P_{AT} = \frac{100}{X_{AT}} = \frac{100}{0.4} = 250 \text{ (MVA)}$$

Therefore,

Point "A" = P_G or $P_{MT} + P_{AT}$

Point "A" = 2,523 (MVA)   1,250 < 2,273 + 250

(2) The same as above short circuit capacity of point "B" is as follows.

Point "B" = P_{MT} or $P_G + P_{AT}$

Point "B" = 2,273 (MVA)   2,273 < 1,250 + 200 = 1,450

(3) And also, short circuit capacity of point "C" is as follows.

Point "C" = $P_{MT} + P_{AT}$ or P_{AT}

Point "C" = 3,523 (MVA)   2,273 + 1,250 = 3,523 > 200

(4) Conversion of short circuit capacity to short circuit current.

Usually, generator rated voltage is considered in the rage of

18 kV to 20 kV.

As we are supposing the most usually condition, generator voltage is 18 kV.

Therefore, current of each point are as follows:

$$\text{Point "A"} = \frac{2{,}523 \times 10^3}{\sqrt{3} \times 18} = 81.0 \text{ (KA)}$$

$$\text{Point "A"} = \frac{2{,}273 \times 10^3}{\sqrt{3} \times 18} = 73.0 \text{ (KA)}$$

$$\text{Point "C"} = \frac{3{,}523 \times 10^3}{\sqrt{3} \times 18} = 113.1 \text{ (KA)}$$

Momentary short circuit current are as follows.

Asymmetrical factor should be 1.73 (Note 1).

$$\text{Asymmetrical factor} = \frac{\text{Asymmetrical Valve}}{\text{Symmetrical Valve}}$$

Point "A" = 1.73 x 81.0 = 140.1 (KA)

Point "B" = 1.73 x 73.0 = 126.3 (KA)

Point "C" = 1.73 x 113.1 = 195.6 (KA)

Therefore,

	Symmetrical short circuit capacity (KA)	Momentary short circuit capacity asymmetrical (rms) (KA)
Point "A"	81.0	140.1
Point "B"	73.0	126.3
Point "C"	113.1	195.6

In case of generator voltage is 15 KV:

	Symmetrical short circuit capacity (KA)	Momentary short circuit capacity asymmetrical (rms) (KA)
Point "A"	97.22	168.2
Point "B"	87.6	151.5
Point "C"	135.8	234.9

In case of generator voltage is 20 KV:

	Symmetrical short circuit capacity (KA)	Momentary short circuit capacity asymmetrical (rms) (KA)
Point "A"	72.9	126.1
Point "B"	65.7	113.7
Point "C"	101.8	176.1

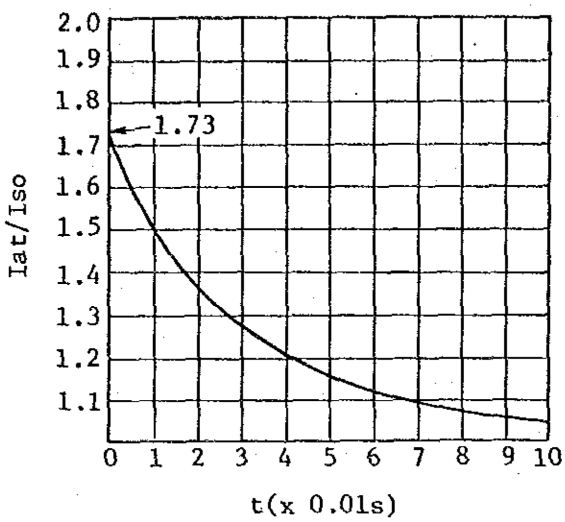
(5) Rating of main bus between the generator and the main transformer at 18 kV.

Normal current rating	11,000 (A)
Short time current rating (2 seconds)	81.0 (KA)
Momentary current rating	140.1 (KA)

(6) Rating of auxiliary bus between the tap of main bus and the auxiliary transformer.

Normal current rating	800 (A)
Short time current rating (2 seconds)	113.1 (KA)
Momentary current rating	195.6 (KA)

Note 1. When not attenuation of symmetrical current is not taken into account, 3 = 1.73 according to the following diagram:



where

Iat: Asymmetrical short circuit current (A)

Iso: Symmetrical short circuit current (A)

t: Time after occurrence of short circuit (sec.)

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E-10 BUS VOLTAGE OF ELECTRIC CIRCUIT

1. General

The electric circuit in the West Wharf Thermal Power Plant will be planned as unit system taking into consideration of high reliability and economical operation for the power system and respective auxiliaries of the plant.

The values of bus voltage were adopted based on the KESC'S practice for the existing power plant so as to perform easy operation and maintenance.

The key single line diagram is as attached.

2. Substation

The substation will comprise 220 kV and 132 kV switchyard having two (2) sets of the transformer.

The 220 kV switchyard will compose the double bus system. To improve the reliability of electric power supply. The electric power generated from the generator will be received into the switchyard, and supplied to the power system through a transmission line. Meanwhile, the 220 kV bus bar will be connected to the 132 kV bus bar though the transformers.

The outgoing 220 kV transmission lines will be connected to the BARDIA grid station with two (2) circuits and the 220 kV substation will prepare future two (2) circuits bays.

However, future bays will be prepared with their space only.

The 132 kV switchyard will consist of the double bus system, the electrical power will be received into the switchyard from 220 kV switchyard through tie transformers, the bus will be connected to the starting transformer and two (2) sets of 132 kV/11 kV grid station transformers. The outgoing 132 kV transmission lines will be connected with the following seven (7) circuits.

- To S.I.T.E : One (1) cct
- To MAULIPUR : One (1) cct
- To OLD TOWN : One (1) cct
- To GARDEN EAST : One (1) cct
- To QUEEN ROAD : Two (2) ccts
- To DIFENCE EAST : One (1) cct

3. Generator Main Circuit

The voltage of electric power generated from the generator will be stepped up by the main transformer and sent to the 220 kV switchyard. On the other hand, the station auxiliary power will be branched from the generator main circuit, stepped down into 6.6 kV by the auxiliary transformer and supplied to the respective load. However, since auxiliary power should be supplied from the starting transformer at the time of unit starting up and shutdown.

4. Common Power Circuit

The starting transformer will receive power from the 132 kV switchyard, step down the voltage into 6.6 kV and supply station auxiliary power for Unit starting up.

This starting transformer shall also have a capacity sufficient to supply station auxiliary power for starting up Units No. 1 and No. 2, and shall be furnished with the common 6.6 kV bus bar for station. When the generator has been started up and reached 10 - 20% of the rated load, the station auxiliary power will be changed over from the starting transformer to the auxiliary transformer.

Sequentially, the station auxiliary power for common load in Units No. 1 and No. 2 (water treatment, lighting etc.) will be supplied from the starting transformer continuously. The starting transformer will also be in stand by as to supply the power when the auxiliary transformer is in interruption of service for some reason.

5. Station Auxiliary Power Circuit

As the station auxiliary power source equipment, the 6.6 kV metal clad switchgear (MCSG) will be installed to supply power to the high voltage auxiliary machines.

In addition, the station service transformer will step down the 6.6 kV power source supplied from 6.6 kV MCSG into 400 V and supply it to the low voltage switchgear. This low voltage switchgear is divided into the 400 V power center and the control center depending upon the capacity of the auxiliary machines. For low voltage circuits, the distribution boards for lighting, site work, control and others will be installed according to the respective (AC 380 V,

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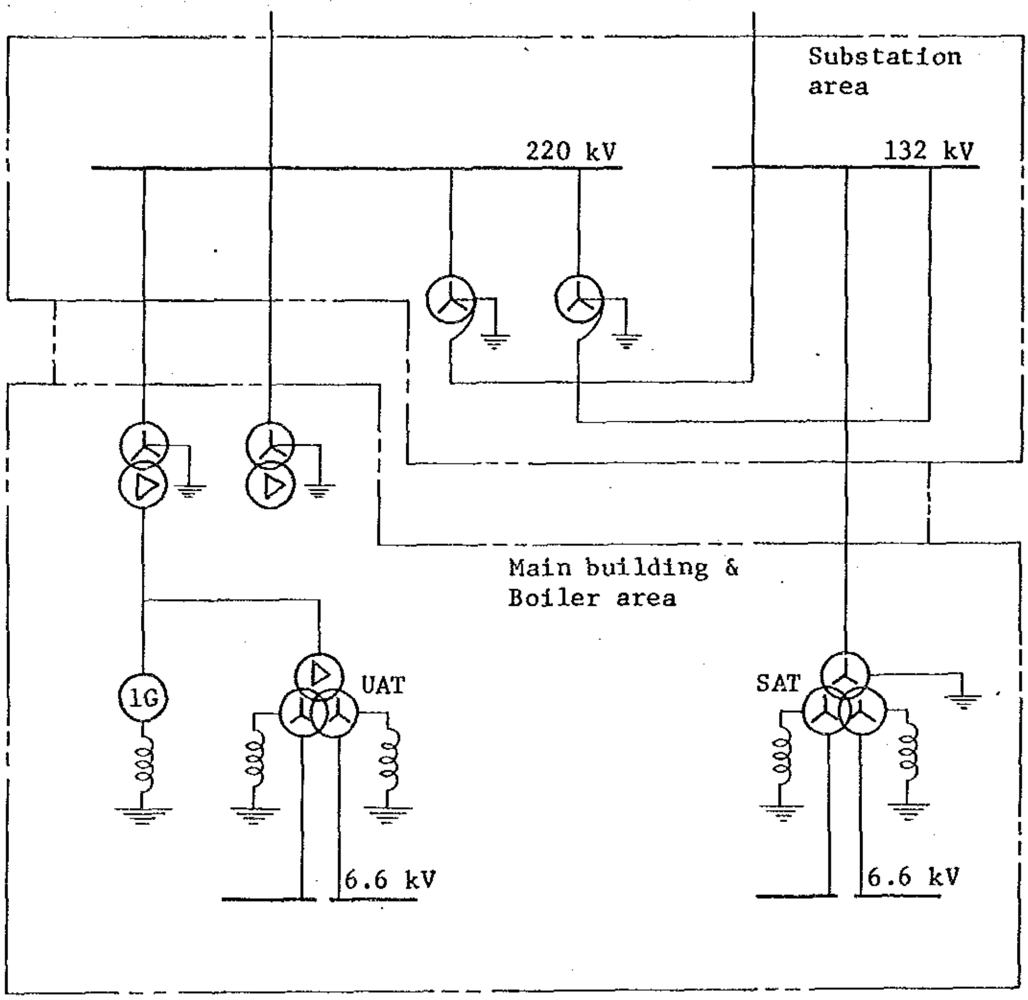
System	Phase and Wire	Rated Voltage (V) Bus	Motor	Fixtures	Lightning Impulse Withstand Voltage BIL £kV) Full Wave	Power Frequency Withstand Voltage (kV)	Grounding System
220 kV 220 kW Switchyard	AC 3ϕ-3W	220	-	-	950	395	Direct grounding
132 kV Switchyard	AC 3ϕ-3W	132	-	-	650	145	Direct grounding
18 kV - 21 kV Generator Main Circuit	AC-3ϕ-3W		-	-	-	50	Single phase transformer grounding
6.6 kV Metal Clad Switchgear	AC 3ϕ-3W	6.6		-	60	22	High resistance grounding (10A)
400 V Power Center	AC 3ϕ-3W	0.4	0.38	-	-	2.2	GPT grounded
400 V Control Center	AC 3ϕ-3W	0.4	0.38	-	-	2.2	GPT grounded
220 V Control Center	AC 3ϕ-3W	0.22	0.22	-	-	1.5	Ungrounded
220 V Lighting Distribution Panel	AC 3ϕ-3W	0.22	-	0.22	-	1.5	Ungrounded
Miscellaneous Distribution Panel	AC 3ϕ-4W	0.38	-	0.38(3ϕ)	-	2.2/1.5	Direct grounding
Instrument Distribution Panel	AC 1ϕ-2W	0.11	-	0.11	-	1.5	Ungrounded
Emergency Diesel Engine Generator	AC 3ϕ-3W	0.43	0.38	-	-	2.2	Ungrounded
UPS (CVCF)	AC 3ϕ-3W	0.11	-	-	-	1.5	Ungrounded
DC Control Center and Distribution Panel	DC 1ϕ-2W	0.11	0.11	0.11	-	-	

E-11 REQUIRED GROUNDING RESISTANCE VALUE

This engineering sheet covers the grounding system configuration and target value of grounding resistance in the West Wharf thermal power station.

1. Grounding System Configuration

(1) One line diagram



The grounding system of the West Wharf power station will be comprised inside the main building including boiler area and substation area.

The both grounding system shall be interconnected so as to ensure the grounding circuits.

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1.2 Particular Grounding System

(1) Generator main circuit

The neutral point of the generator is grounded through a pole transformer primary winding. Therefore, one (1) phase grounding current is flowing in a small value.

In case of two (2) phase ground fault occures, a large current will flow in the enclosure of the IPB (Isolated Phase Bus Duct).

The grounding current is devided into two (2) circuits, one is a loop current through generator stator winding and another is a grounding current through IPB grounding point, grounding mesh and generator neutral point. However, this grounding current is reduced to limit by pole transformer winding.

(2) 220 kV switchyard bus

The 220 kV circuit is directly grounded through high tension neutral point of the generator main transformer.

Therefore, the fault current from substation is dissipated into the ground mesh, and it does not affect the main grounding mesh.

(3) 6.6 kV high voltage circuit

The 6.6 kV high voltage circuit is grounded with high impedance of pole transformer on the low tension side of the auxiliary and staring transformer.

Therefore, one (1) phase ground current is flowing as small as not more than 10A.

In case of two (2) phase ground occurs, a large short current will flow in the circuit. However, the grounding current is a circulated flow in the ground bus bar, and it does not affect the main grounding mesh.

(4) 400 V low voltage circuit

The 400 V low voltage circuit is grounded through GPT (Ground Potential Transformer) on the low tension side of the station transformer.

Therefore, the ground-fault current flows in a very small quantity, about 100 mA.

2. Grounding Design

The grounding system should be designed to prevent hazards to human bodies and apparatus.

(1) Potential rise value should be less than 1,000 V taking into account step voltage, touch voltage and withstand voltage of electrical apparatus.

(2) The maximum potential value is as follows

$$V_E = I_A \cdot R_G$$

where: V_E: Maximum potential difference (V)

I_A: Maximum grounding current (A)

R_G: Grounding mesh resistance (ohms)

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(3) The target value of grounding resistance should be determined based on the voltage rising of sound phase when one phase is grounding.

That is,

In case of $I_A - I_N > I_N$ ---- $R \leqq \frac{10}{I_A - I_N}$ (ohm)

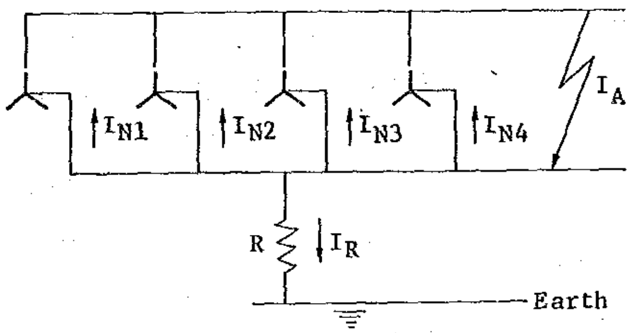
In case of $I_A - I_N < I_N$ ---- $R \leqq \frac{10}{I_N}$ (ohm)

where: I_A: Maximum grounding current when one phase ground

I_N: Total neutral current

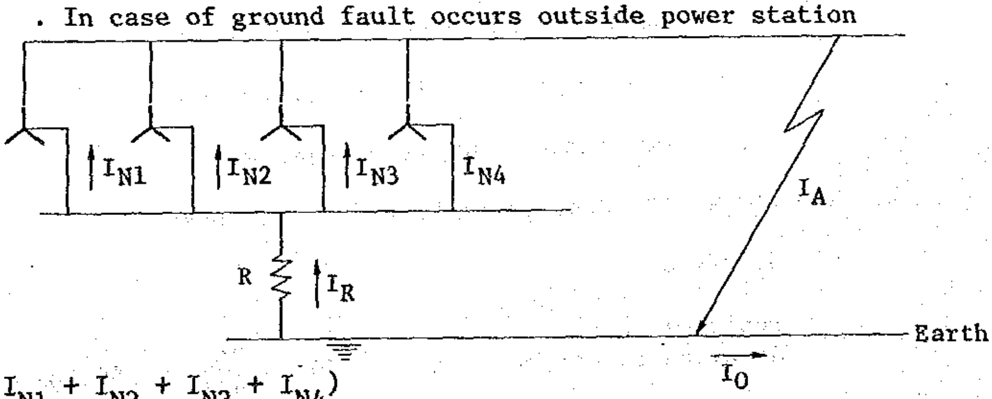
(4) Distribution of ground fault current

. In case of ground fault occurs inside power station



$$I_R = I_A - (I_{N1} + I_{N2} + I_{N3} + I_{N4})$$

. In case of ground fault occurs outside power station



$$I_R = I_{N1} + I_{N2} + I_{N3} + I_{N4})$$

$$I_o = I_A - (I_{N1} + I_{N2} + I_{N3} + I_{N4}$$

3. Calculation

3.1 Calculation of Ground Fault Current

Prerequisite Conditions

(1) Maximum grounding fault current

The supporsing grounding fault current of 220 kV used for calculation has been adopted as 40 kA.

(2) Impedance and neutral current

The following respective impedance used for calculation have been estimated to be the same as capacities of generator and transformer.

a. Impedance at rated capacity

	(MVA)	X_1 (%)	X_2 (%)	X_0 (%)
Generator	248.3	160.0	20.0	10.0
Gen. main transformer	247.0	11.0	11.0	8.0
Tie transformer	250.0	11.0	11.0	8.0

Note;

X_1: Positive phase sequence reactance

X_2: Negative phase sequence reactance

X_0: Zero phase sequence reaclance

b. The above impedance is converted to 247 base.

a) Generator % Z

Positive phase sequence reactance $X_{1G} = 160 \times \frac{247}{248.3} = 159.16\%$

Negative phase

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sequence reactance $X_{2G} = 20 \times \frac{247}{248.3} = 19.89\%$

b) Generator main transformer % Z

$X_{1M} = 11$ ---- 11.0%

$X_{2M} = 11$ ---- 11.0%

$X_{0M} = 8$ ---- 8.0%

c) 220 kV/132 kV tie transformer % Z

$$X_{1T} = 11 \times \frac{247}{250} = 10.86\%$$

$$X_{2T} = 11 \times \frac{247}{250} = 10.86\%$$

$$X_{0T} = 8 \times \frac{247}{250} = 7.90\%$$

c. The above percent impedance is converted to ohms value from the following equation.

$$\text{ohms} = \frac{\%Z \times 10E}{\text{kVA}}$$

where:

E: Rated voltage ---- 220 kV

kVA: Base kVA ---- 247,000 kVA

a) Generator

$$X_{1G} = \frac{159.16 \times 10 \times 220}{247 \times 10^3} = 311.87 \text{ ohm}$$

$$X_{2G} = \frac{19.89 \times 10 \times 220}{247 \times 10^3} = 38.97 \text{ ohm}$$

$$X_{0G} = \frac{9.94 \times 10 \times 220}{247 \times 10^3} = 19.47 \text{ ohm}$$

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b) Generator main transformer

$$X_{1M} = \frac{11.0 \times 10 \times 220}{247 \times 10^3} = 21.55 \text{ ohm}$$

$$X_{2M} = \frac{11.0 \times 10 \times 220}{247 \times 10^3} = 21.55 \text{ ohm}$$

$$X_{0M} = \frac{8.0 \times 10 \times 220}{247 \times 10^3} = 25.67 \text{ ohm}$$

c) 220 kV/132 kV tie transformer

$$X_{1T} = \frac{10.86 \times 10 \times 220}{247 \times 10^3} = 21.28 \text{ ohm}$$

$$X_{2T} = \frac{10.86 \times 10 \times 220}{247 \times 10^3} = 21.28 \text{ ohm}$$

$$X_{0T} = \frac{7.9 \times 10 \times 220}{247 \times 10^3} = 15.48 \text{ ohm}$$

d. One line ground fault current to obtain the following equation.

$$I_N = \frac{3 \times Eo}{Z_0 + Z_1 + Z_2} \quad (A)$$

where:

E_0: Phase voltage --- 220 kV/$\sqrt{3}$

Z_0: Zero phase sequence impedance --- $Z_0$1M (ohm)

Z_1: Positive phase sequence impedance --- $Z_{1G} + Z_{1M}$ (ohm)

Z_2: Negative phase sequence impedance --- $Z_{2G} + Z_{2M}$ (ohm)

a) Generator main transformer neutral current

$$I_{IGT} = \frac{3 \times 220 \times 10 \quad \times 1/\ 3}{21.55 + (311.87 + 21.55) \times (38.97 + 21.55)}$$

$$= \frac{381,502.89}{415.49}$$

$$= 918.19 \text{ (A)}$$

b) 220 kV/132 kV tie transformer neutral current

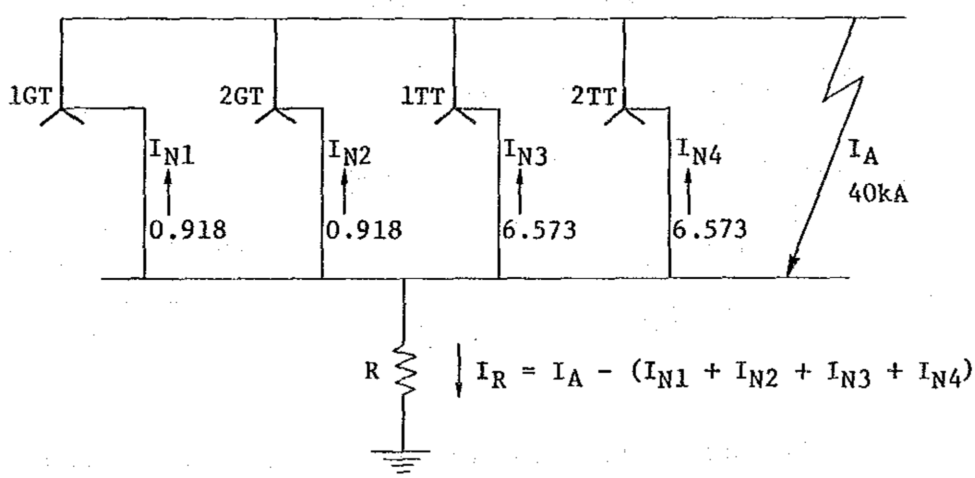
$$I_{NT} = \frac{3 \times 220 \times 10 \times 1/\sqrt{3}}{21.28 + 21.28 + 15.48}$$

$$= \frac{381,502.89}{58.04}$$

$$= 6,573.1 \text{ (A)}$$

c) Ground fault current flow

(Unit: kA)



$$I_R = 40 - (0.918 + 0.918 + 6.573 + 6.573)$$

$$= 40 - 14.982$$

$$= 25.018 \text{ kA}$$

3. Required Grounding Resistance

The required grounding resistance is obtained by the following equations.

$$R \leqq \frac{1,000}{I_A - I_{NO}}$$

$$R \leqq \frac{1,000}{25.018 \times 10^3}$$

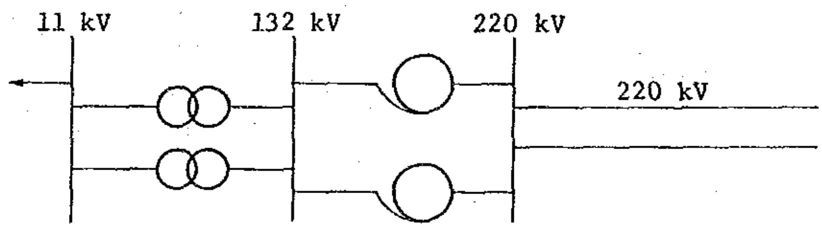
$$R \leqq 0.039 \text{ (ohm)}$$

(4) Required grounding resistance at the time of power receiving

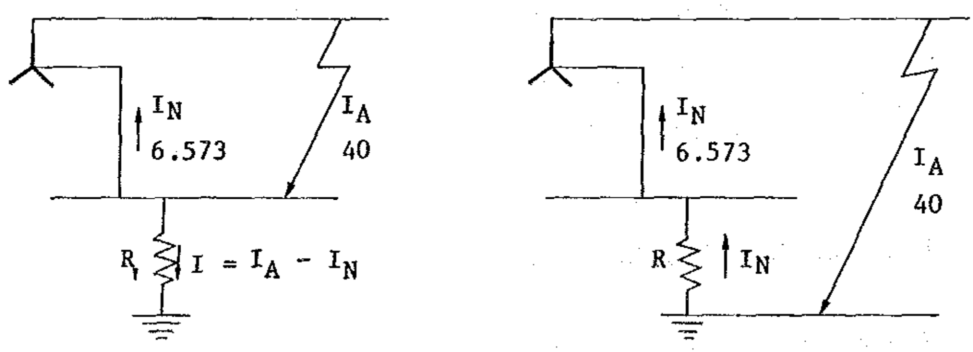
The West Wharf thermal power plant should to receive 220 kV electric power so as to supply power to the 11 kV grid station though 220 kV, 132 kV switchyard via tie transformer.

Therefore, the required grounding resistance value should be determined based on the following circuit.

a) Power receiving circuit



b) One set of tie transformer operation has been considered



c) Required grounding resistance

$$R \leqq \frac{1,000}{(40 - 6.573) \times 10^3} \qquad R \leqq \frac{1,000}{6.573 \times 10^3}$$

$$\leqq \frac{1,000}{33.427 \times 10^3} \qquad R \leqq 0.152$$

$$\leqq 0.0299 \text{ (ohm)}$$

The required grounding resistance should be less than 0.029 ohm.

4. Calculation of Grounding Area

(1) Grounding wire construction method

In order to get the resistance value less than 0.029 , the grounding method of thermal power plant and switchyard should be combined the mesh method with steel pile method.

(2) Mesh grounding resistance value

Main building space
unit No. 1 = 3,444.3 m^2

unit No. 2 = 2,984.3 m^2

Switchyard space = 1,421.2 m^2

Mesh distance is about 20 m.

(3) Ground fault current (I_s)

The same as interrupting current

I_s = 40 kA

(4) Foult duration time (t)

t = 2 sec.

(5) Earth peculiar resistance (ρ)

= 100 ohm/m

(6) Potential rising of grounding (E)

E = Not more than 1,000 V

(7) Calculation of mesh grounding resistance

The following formula is applied to the calculation of ground resistance.

$$R = \frac{\rho}{4r} + \frac{\rho}{L}$$

where R : Grounding mesh resistance (ohm)

ρ : Average ground resistivity (ohm-m)

γ : Radius of grounding mesh area (m)

$$= \sqrt{\frac{A}{\pi}}$$

A : Ground mesh area (m^2)

L : Total length of buried conductor (m)

$$\gamma = \sqrt{\frac{3,444.3 + 2,984.3}{3.14}} = \sqrt{\frac{7,428.6}{3.14}} = 2,365.8 = 48.6 \text{ m}$$

L = 981.4 m

Accordingly;

$$R = \frac{100}{4 \times 48.6} + \frac{100}{981.4}$$

$$= \frac{100}{194.4} + \frac{100}{981.4} = 0.514 + 0.102$$

$$= 0.616 \text{ ohm}$$

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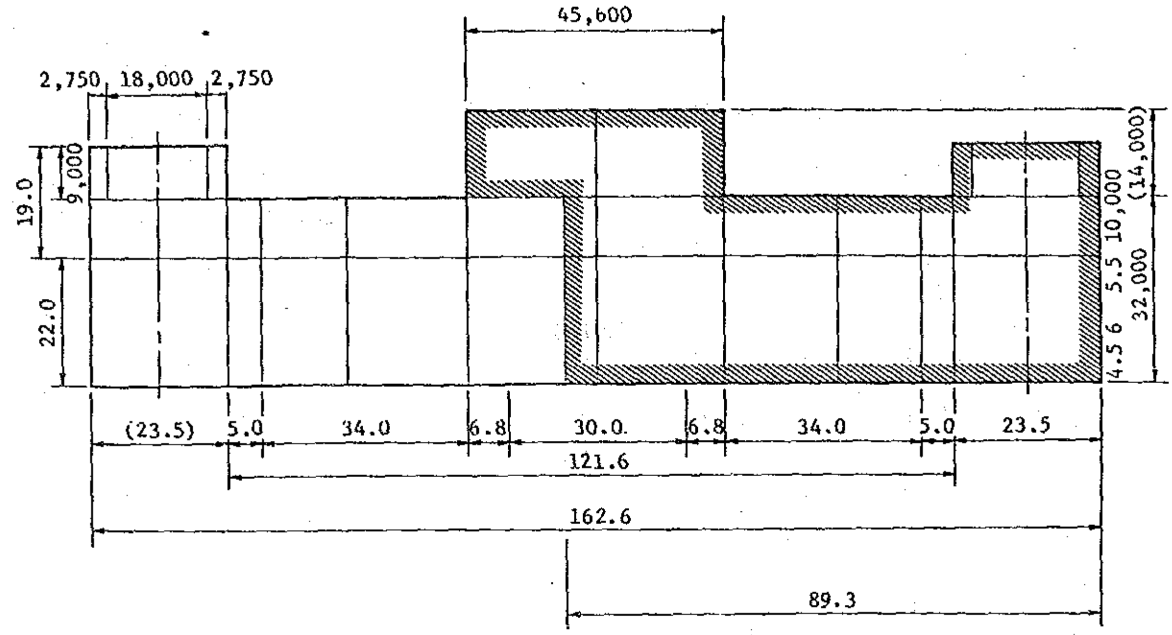


Space

Unit No. 1 main building

and boiler area (m^2) : (89.3 m x 32.0 m) + (14.0 m x 26.8 m)

= 2,857.6 m^2 + 375.2 m^2 + 211.5

= 3,444.3 m^2

Unit No. 2 : (79.3 m x 32.0 m) + (14.0 m x 16.8 m)

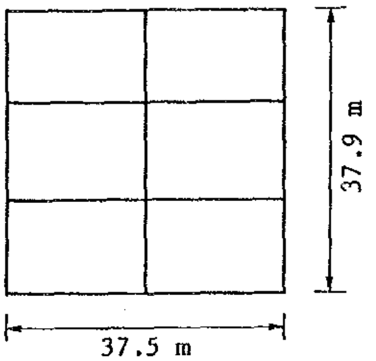
= 2,537.6 m^2 + 235.2 m^2 + 211.5

= 2,984.3 m^2

Length:

H	168.6 m x 2 = 337.2	551.4 m	Total 981.4 m
	121.6 x 1 = 121.6		
	23.5 x 2 = 47.0		
	45.6 x 1 = 45.6		
D	22.0 x 11 = 242.0	430.0 m	
	19.0 x 4 = 76.0		
	10.0 x 7 = 70.0		
	14.0 x 3 = 42.0		

Switchyard



Space:

37.5 m x 37.9 m = 1,421.1 m^2

Length: 37.5 x 4 = 149.6 m

37.9 x 3 = 113.7 m

Total 263.3 m

(8) Steel pile resistance and number of steel pile

(1) Steel pile resistance value

$$\gamma = \frac{\rho}{2\pi\ell}\left(2.3\ \log_{10}\frac{4\ell}{\frac{\phi}{2}} - 1\right)\ \text{ohm}$$

where:

ℓ : Pile length 24 m

ϕ : Pile diameter 0.61 m

ρ : Earth peculiar resistance 100 ohm-m

$$= \frac{100}{2\ \ x\ 24}\left(2.3\ \log_{10}\frac{4\ x\ 24}{\frac{0.61}{2}} - 1\right) = 3.15$$

Total of steel pile resistance value should be less than 0.028 ohm.

because
$$\frac{R_1\ .\ R_2}{R_1 + R_2} = 0.029$$

$$R_2 = \frac{R_1 . R}{R_1 - R} = \frac{0.616\ x\ 0.029}{0.616 - 0.029} = \frac{0.017}{0.587} = 0.028$$

where:

R_1 : Mesh grounding resistance 0.616 ohm

R_2 : Steel pile grounding resistance 0.028 ohm

Accordingly, number of steel piles are

$$n = \frac{g.r}{R} = \frac{1.35\ x\ 3.15}{0.022} = 151.8$$

where:

n : Number of steel pile

g : Gathering factor 1.35

r : Steel pile resistance 3.15

R : Required grounding resistance 0.029

Therefore, necessary number of steel pile are .

$$= \frac{100}{2 \times 24} (2.3 \log_{10} \frac{4 \times 24}{\frac{0.61}{2}} - 1)$$

$$= 0.663 \times (2.3 \log_{10} 314.75 - 1)$$

$$= 0.663 \times (2.3 \times 2.498 - 1)$$

$$= 0.663 \times 4.745$$

$$= 3.146 \text{ ohm}$$

Total of steel pile resistance value should be less than 0.028 ohm.

(9) Calculation of mesh grounding resistance at the time of 220 kV power receiving.

. $R_M = \frac{\rho}{4r} + \frac{\rho}{L}$

		Unit No. 1	Switchyard
A (m^2)	:	3,444.3	1,421.1
L (m)	:	551.4	263.3

. $r = \sqrt{\frac{A}{\pi}}$

$$= \sqrt{\frac{3,444.3 + 1,421.2}{3.14}} = \sqrt{\frac{4,865.5}{3.14}} = \sqrt{1,549.5}$$

$$= 39.4$$

$$R_M = \frac{100}{4 \times 39.4} + \frac{100}{814.7}$$

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$= 0.635 + 0.123$

$= 0.758\ (\ )$

$$R_P = \frac{R\ .\ RM}{RM - R}$$

$$= \frac{0.758 \times 0.029}{0.758 - 0.029} = \frac{0.022}{0.729} = 0.03$$

Accordingly, number of steel pile are

$$n = \frac{q.r}{R_P}$$

$$= \frac{1.35 \times 3.15}{0.03} = \frac{42,525}{0.03} = 141.75$$

5. Size of Grounding Wine

The grounding wire specification has been determine based on the following formura.

$$A = \frac{C_1\ I_s}{\sqrt{\frac{\log_{10}\left(\frac{Im - Ta}{234 + Ta} + 1\right)}{33x2}}}$$

where;

C_1 :	Connection content of unit (CM mm^2)		$C_1 = 507 \times 10^{-6}$
I :	Maximum ground fault current	(A)	40,000
S :	Dulation of ground fault current	(sec.)	2
T_M :	Maximum allowable temperature rising of conductor	(°C)	1,083
Ta :	Ambient temperature	(°C)	40
A :	Section area		
d :	Diameter		

$$A \geq \frac{507 \times 10^{-6} \times 40{,}000}{\sqrt{\dfrac{\log_{10}\left(\dfrac{1{,}083 - 40}{234 + 40} + 1\right)}{33 \times 2}}} = \frac{5.07 \times 4}{\sqrt{\dfrac{\log_{10} 4.807}{66}}}$$

$$\geq \frac{20.28}{\sqrt{\dfrac{0.682}{66}}} = \frac{20.28}{\sqrt{0.0103}} = \frac{20.28}{0.1} =$$

≥ 202.8 ⟶ Bare conductor copper wire

250 mm^2

E-12 DESIGN CRITRIA OF SUBSTATION

1. General

The substation will comprise 220 kV and 132 kV switchyard having 2 sets of tie transformers. Both circuits will be double bus systems.

2. Type of Switchyard

The 220 kV and 132 kV switchyard will be applied with SF_6 gas insulated switchgear (GIS), which will be installed indoor so as to prevent salt contamination.

This type of switchgear requires less space than conventional type, and realizes higher reliability, easy operation and maintenance, improved safety, simple construction and a shorter construction period.

Moreover, the SF_6 gas insulated bus (GIB) will be applied between the tie transformer and both, 220 kV and 132 kV switchyard buses.

3. Circuit Arrangement System for Switchyard

The circuit arrangement system for the switchyard is selected after studying the following items:

(1) The arrangement shall be made so as to minimize spread of trouble to other circuits as far as possible and permit prompt restoration of the system, should any trouble arise in any circuits.

(2) The arrangement shall be made systematic so as to ensure easy

operation and maintenance and avoid any possibility of operational error.

(3) The arrangement shall be made to ensure the safety of work and minimize the section of power failure as far as possible in the case of repair, extension and other works.

Items	Single bus system	Double bus system	One-and-half CB system
Economic comparison	The required number of equipment and installation space are smallest among the three systems. Thus, this system is most economical.	The required number of equipment and installation space are larger than those of the single bus system.	The required number of equipment and installation space are larger than those of the double bus system.
Operation and maintenance	Since any trouble in the equipment results in entire power failure, this system is not so reliable.	Inspection of the equipment and operation of the system are extremely easy. Moreover, this system enables single bus operation even at the time of trouble in the equipment.	Inspection of the equipment and operation of the system are easier than in case of the double bus system. Moreover, it is possible to restrict and avoid spread of trouble to other systems even any trouble should arise in both buses.
Records of application	This system has been adopted for a number of local substations.	This system has been adopted for a number of substations which are important in view of power systems.	This system has been adopted partially for 500 kV substations.

The type of bus component of 220 kV and 132 kV switchyard will be adopted the double bus system based on the a above reason.

4. Bay Numbers and Outgoing Feeders

The bay numbers and outgoing feeders of the 220 kV and 132 kV switchyard will consist of the following.

The connection circuit refer to drawing No. WETS-1001 "KEY SINGLE LINE DIAGRAM" as attached.

220 kV switchyard			132 kV switchyard		
1.	NO.1 GMT	x 1	1.	NO.1 ICT	x 1
2.	NO. 2 GMT	x 1	2.	NO.2 ICT	x 1
3.	T/L BALDIA NO.1	x 1	3.	STR	x 1
4.	T/L BALDIA NO.2	x 1	4.	NO.1 GST	x 1
5.	NO.1 IGT	x 1	5.	NO.2 GST	x 1
6.	NO.2 ict	x 1	6.	T/L S.I.T.E	x 1
7.	BUS TIE	x 1	7.	T/L MAULPUR	x 1
8.	T/L FUTURE	x 1	8.	T/L OLD TOWN	x 1
	(Space only)		9.	T/L GARDEN EAST	x 1
9.	T/L FUTURE	x 1	10.	T/L QUEES ROAD NO.1	x 1
	(Space only)		11.	T/L QUESS ROAD NO.2	x 1
			12.	T/L DIFENCE VIII	x 1
			13.	BUS TIE	x 1
	Total	9 bays		Total	13 bays

5. Allowable Current Capacity

The allowable current capacity of bus, equipment, etc. is roughly classified into the following three:

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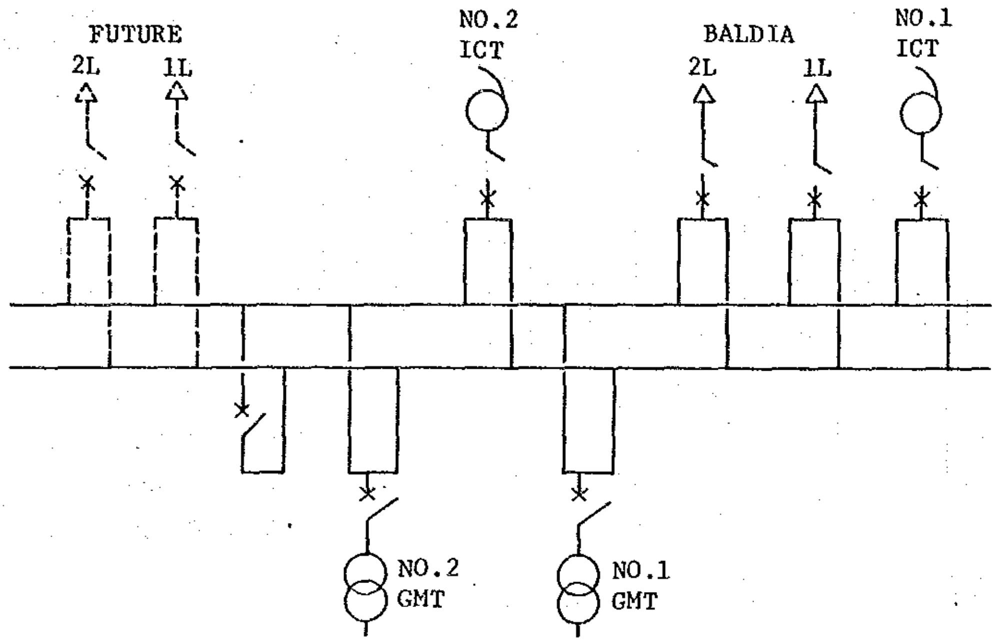
(1) Allowable continuous current capacity

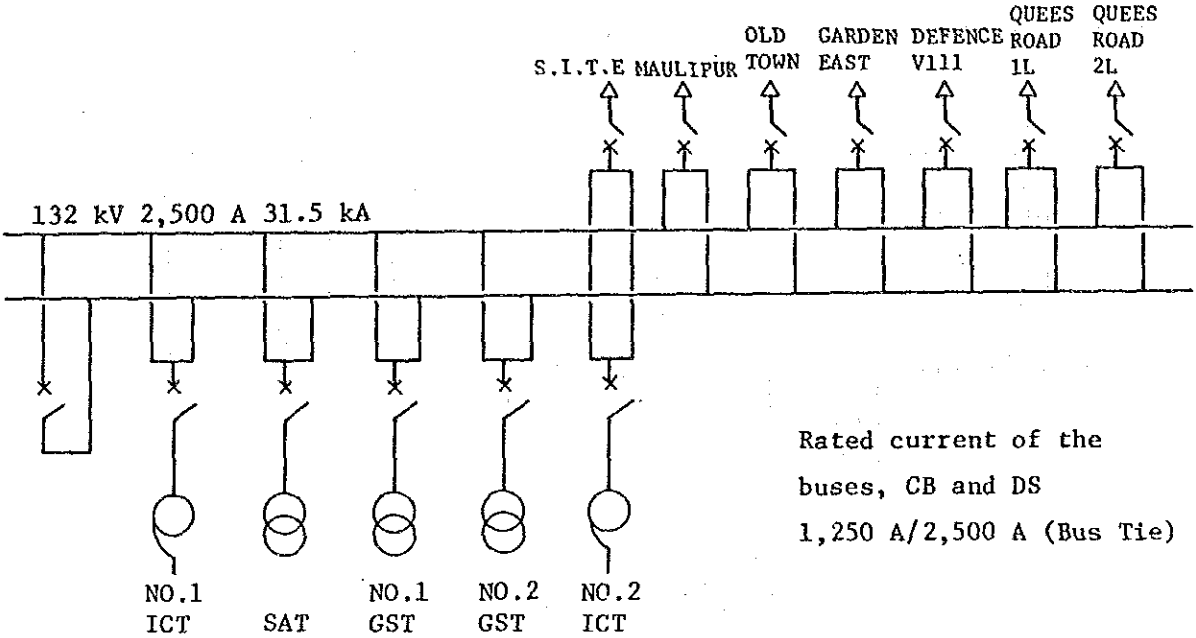
The allowable continuous current capacity is the value of current that can be transmitted continuously under normal operating conditions, and is equivalent to rated current.

a. 220 kV switchyard



Equipment	Capacity (MVA)	Rated current (A)	Remarks
1. No. 1 GMT	248.3	$\frac{248.3\ MVA}{\sqrt{3} \times 220\ kV \times 0.95} \times 10^3 = 686.73$ (A)	Where; 220 kV x 0.95: Minimum tap of the transf.
2. No. 2 GMT	248.3	- Ditto - = 686.73 (A)	
3. No. 1 ICT	250	$\frac{250\ MVA}{\sqrt{3} \times 220\ kV \times 0.95} \times 10^3 = 691.43$ (A)	
4. No. 2 ICT	250	- Ditto - = 691.43 (A)	
5. BALDIA 1L	400 MW	$\frac{400\ MW \times 0.95}{\sqrt{3} \times 220\ kV \times 0.95 \times 0.85} \times 10^3$ = 1,236 (A)	p.f: 0.85
6. BALDIA 2L	400 MW	- Ditto - = 1,236 (A)	
7. Bus Tie	500 KVA	$\frac{500\ MW}{\sqrt{3} \times 220 \times 0.95} \times 10^3 = 1,382.96$ (A)	No.1, 2 GMT under operation, through bus tie

b. 132 kV switchyard



Rated current of the buses, CB and DS
1,250 A/2,500 A (Bus Tie)

Equipment	Capacity	Rated current	Remarks
No. 1 ICT	250	$\frac{250\ \text{MVA}}{\sqrt{3} \times 132\ \text{kV} \times 0.95} \times 10^3$ = 1,152.4 (A)	Where; 132 kV x 0.95: Minimum tap of the transf.
No. 2 ICT	250	- Ditto - = 1,152.4 (A)	
SAT	30	$\frac{30\ \text{MVA}}{\sqrt{3} \times 132\ \text{kV} \times 0.95} \times 10^3$ = 138.3 (A)	
No. 1 GST	30	$\frac{30\ \text{MVA}}{\sqrt{3} \times 132\ \text{kV} \times 0.95} \times 10^3$ = 138.3 (A)	
No. 2 GST	30	- Ditto - = 138.3 (A)	
T/L SITE	160	$\frac{160\ \text{MVA}}{\sqrt{3} \times 132\ \text{kV} \times 0.95} \times 10^3$ = 737.5 (A)	
MAUUPUR	160	- Ditto - = 737.5 (A)	
OLD TOWN	160	- Ditto - = 737.5 (A)	
GARDEN EAST	160	- Ditto - = 737.5 (A)	
DEFENCE VIII	160	- Ditto - = 737.5 (A)	
1L QUEENS ROAD	160	- Ditto - = 737.5 (A)	
2L QUEENS ROAD	160	- Ditto - = 737.5 (A)	
Bus Tie	500	$\frac{500\ \text{MVA}}{\sqrt{3} \times 132\ \text{kV} \times 0.95} \times 10^3$ = 2,304.8 (A)	

(2) Allowable overload current capacity

In principle, the equipment shall not be allowed of the few percent overload operation. Even though the load current exceeds the rated current, in case of instantaneous over load, the equipment will be able to withstand without any damage immediately, according to the equipment conditions e.g. temperature characteristic, ambient temperature, etc.

(3) Allowable short time current

The allowable short time current will be determined not less than maximum fault current (symm.) with duration of 2 sec.

6. Insulation

The insulation design for the 220 kV and 132 kV equipment and busbar is on the following design conditions.

(1) Design conditions

(a) The density of salt deposits permissible in view of salt contamination shall be 0.03 mg/cm (based on the same concept as that of the insulators for transmission line).

(b) The 220 kV and 132 kV equipment will be grounded according to direct grounding system.

(2) Target value of withstand voltage

The target value of withstand voltage is intended to prevent spread of flashover to other phases due to increase of voltage to ground arising in sound phase at the time of one line ground fault.

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Therefore, the target value shall be the value, within which any sound phase can withstand the voltage to ground at the time of one line ground fault.

The target value of withstand voltage (V) is calculated according to the following formula.

$$V = q \times E \text{ (kW)}$$

where q: Increase ratio of voltage to ground in sound phase at the time of one phase ground fault; 1.3 in case of direct grounded system.

E: Voltage to ground prior to occurrence of fault Maximum circuit voltage x $1/\sqrt{3}$

(a) 220 kV

$$V = 1.3 \times 245 \times 1/\sqrt{3} = 183.89 \text{ (kV)} = 183.9 \text{ (kV)}$$

(b) 132 kV

$$V = 1.3 \times 145 \times 1/\sqrt{3} = 108.95 \text{ (kV)} = 109.0 \text{ (kV)}$$

(3) Insulation coordination

The insulation coordination of switchyard equipments and associated transmission line will be determined as follows.

Nominal voltage	220 kV	132 kV
Highest voltage	245 kV	145 kV
Insulation coordination and impulse withstand voltage	(BIL FULL WAVE)	(Power Frequency)
Transmission line	1,050 kV	650 kV
Switchyard	950 kV	650 kV
Transformer	950 kV	550 kV
Lightning arrester	1,050 kV	650 kV

Note:

In accordance with IEC 71 & 99, the following insulation level are applied.

Nominal voltage	220 kV	132 kV
Highest voltage	245 kV	145 kV
Neutral grounding system	Direct	Direct
Transformer		
Rated voltage	220 kV	132 kV
Lightning impulse	950 kV	550 kV
Power frequency	395 kV	
Arrester		
Rated voltage	198 kV	
Nominal discharge current	10 kA	10 kA
Lightning impulse	950 kV	650

7. Specification of Switchyard

		220 kV	132 kV
(1) Common features			
Type	:	Indoor, 220 kV SF6 Gas Insulated Metalclad Switchgear	
Standards	:	IEC	
Rated voltage	:	220 kV	132 kV
Maximum system voltage	:	245 kV	145 kV
Rated frequency	:	50 Hz	50 Hz
Rated short-circuit current	:	40 kA	31.5 kA
Insulation medium	:	SF6 Gas	SF6 Gas
Materials of enclosures	:	Aluminum	Aluminum

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		220 kV	132 kV
Impulse withstand voltage			
at nominal gas pressure	:	950 kV	650 kV
at minimum gas pressure	:	950 kV	650 kV
Power frequency withstand voltage			
at nominal gas pressure	:	395 kV	345 kV
at minimum gas pressure	:	395 kV	145 kV

(2) Bus bar

Rated normal current at 48°C ambient	:	3,150 A	2,500 A
Bus bar materials	:	Aluminium	Aluminium
Bus bar enclosed tubing arrangement	:	Single-phase	Three-phase

(3) Circuit breaker

Standards	:	IEC	IEC
Rated voltage	:	245 kV	145 kV
Rated current	:	1,250 A /3,150 A (Bus Tie)	1,250 A 12,500 A (Bus Tie)
Rated short circuit breaking current	:	40 kA	31.5 kA
Impulse withstand voltage (peak)	:	950 kV	650 kV
Power frequency withstand voltage	:	395 kV	145 kV
Driving mechanism			
. type	:		
. rated supply voltage	:	D.C. 110 V	
Auto-reclose (T/L only)	:	Single-phase and three-phase	
Rated operating duty	:	0-0.3sec.-CO-3min.-CO	

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		220 kV	132 kV
(4)	Isolator		
	Standards	: IEC	IEC
	Rated normal current at	: 1,250 A /3,150 A (Bus Tie)	1,250 A /2,500 A (Bus Tie)
	Rated short-time withstand current	: 40 kA	31.5 kA
	Impulse withstand voltage (full wave)	: 950 kV	650 kV
	Power frequency withstand voltage	: 395 kV	145 kV
	Operating mechanism	: Motor drive	
	. Motor voltage	: D.C. 110 V	D.C. 110 V
(5)	High speed earthing switch		
	Standards	: IEC	IEC
	Rated making current	: 40 kA	31.5 kA
	Impulse withstand voltage (full wave)	: 950 kV	650 kV
	Power frequency withstand voltage	: 395 kV	145 kV
	Operating mechanism	: Motor drive and hand-operated	
	. Motor voltage	: D.C. 110 V	D.C. 110 V
(6)	Working earthing switch		
	Standards	: IEC	IEC
	Rated making current	: 40 kA	31.5 kA
	Impulse withstand voltage (full wave)	: 950 kV	650 kV
	Power frequency withstand voltage	: 395 kV	145 kV
	Operating mechanism	: Hand operated	

		220 kV	132 kV
(7)	Lighting arrester		
	Standards :	IEC	IEC
	Rated voltage :	198 kV	109 kV
	Nominal discharge current :	10 kA	10 kA
	Lightning impulse :	1,050 kV	650 kV
(8)	Current transformer		
	Standards :	IEC	IEC
	Rated primary current :	700, 1,250, 3,000 A	600, 800, 2,500 A
	Rated secondary current :	1 A	1 A
	Accuracy class		
	. Measuring :	CL 0.2	CL 0.2
	. Protection 1 :	5P 30	5P 20
	. Protection 2 :	5P 30	5P 20
	. Differential protection :		
	Burden		
	. Measuring :	20 VA	20 VA
	. Protection 1 :	40 VA	20 VA
	. Protection 2 :	40 VA	40 VA
	Impulse withstand voltage (full wave) :	900 kV	650 kV
	Power frequency withstand voltage :	395 kV	145 kV
(9)	Voltage transformer		
	Standards :	IEC	IEC
	Rated primary voltage :	$220/\sqrt{3}$ kV	$132/\sqrt{3}$ kV
	Rated secondary voltage :	$100/\sqrt{3}$ V	$100/\sqrt{3}$ V

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		220 kV	132 kV
Rated tertiary voltage	:	$100/\sqrt{3}$ V	$100/\sqrt{3}$ V
Accuracy class	:	1.0	1.0
Burden			
. Secondary	:	200 VA	VA
. Tertiary	:	50 VA	
Impulse withstand voltage (full wave)	:	900 kV	650 kV
Power frequency withstand voltage	:	395 kV	145 kV

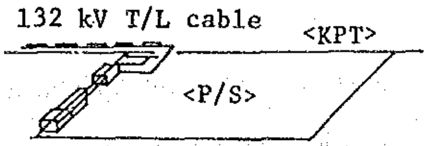
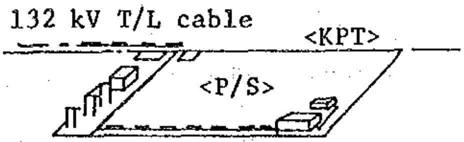
8. Location of Substation

Location of the new 220 kV and 132 kV switchyards will be planned, at present, to be installed in the southern side of the power station, it is opposite side of existing 66 kV switchyard area. Location and arrangement of the new switchyards has been carefully studied and planned by considering outgoing transmission lines and location of respective transformers. Emphasis will be placed on physical and economical advantages, keeping in mind reliable and continuous power supply to the West Wharf area.

The comparison studied of the location of switchyard is as describe hereunder.

Comparison Sheet for Location of Switchyard

Location Items	Existing 66 kV indoor switchyard area	PSO's oil tank area
Space to be obtained	66 kV outdoor switchyard should be dismantled.	Oil tanks should be dismantled.
Reliability of electrical power to feed 11 kV Gris station	Slightly lower due to modification works of 66 kV indoor switchyard circuits due to dismantling.	Can maintain present condition.
"BX" station	Unit No. 9 should be shutdown for movement of outdoor switchyard by to new bay.	"BX" station can be continuously operated.
66 kV transmission line	S.I.T.E and Queens Road Transmission Line should be shutdown due to movement of outdoor switchyard bays to new bays.	S.I.T.E and Queen Road Transmission Line can be continuously operated.
Existing 66 kV switchyard	Modification work should be carried out to obtain space for new switchyard. 1. New 66 kV switchyard should be installed. 2. Indoor switchyard bays should be moved to new switchyard on indoor switchyard bays in a step-by-step process.	Can maintain present condition.
Incoming access of transmission line. Length	Base	Length of 220 kV and 132 kV transmission lines are about 300 m 1 cct longer than the base.

Location Items	Existing 66 kV indoor switchyard area	PSO's oil tank area
132 kV cable route	 	 The 132 kV underground cables will be led through pipe reinforced by concrete.
220 kV cable route	If from road side, there will be no problem.	If from road side, there will be no problem.
Obstruction of cable route for new power station among switchyard, main and starting transformers and other control cables	1. Crossing with "BX" station discharge way. 2. Narrow space between existing administration building and "BX" station building. 3. As the cable way will be installed on the upper side of the Unit No. 2 discharge way, it is preferable to carry out construction after dischange way work is completed.	No problem expected, as the cable way will be constructed in Unit No. 1 construction area.

9. Arrangement of Substation

The arrangement of substation has been studied taking into consideration easy operation, maintenance and also extension works.

However, the space of substation is small, limited to the effective space with approximately 1,600 m^2 (40 m x 40 m) and bundary wall between power station and KPT entrance is standing at south side.

The necessory space of 220 kV, 132 kV switchyard and transformers are as follows.

220 kV Switchyard	37.5 m x 11.2 m	Nine (9) bays
132 kV Switchyard	27.0 m x 9.7 m	Thirteen (13) bays
220 kV/132 kV Transformer	2.0 m x 8.0 m	Two (2) sets
132 kV/11 kV Transformer	4.5 m x 4.5 m	Two (2) sets

The cable routes among above facilities to be designed underground cable tunnel.

The arrangement of substation has been designed taking into account the following matters.

To coordinate with power plant layout main and starting transformer

To coordinate with outgoing transmission lines (underground cable)

The arrangement of substation as attached.

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10. Location of Substation Control Room

The substation control room will be designed to be built on the second floor of the 132 kV switchyard building. The necessory panels to be installed in the substation control room are the 220 kV, 132 kV switchyard control panel and bus, transmission line protective relay panel and communication panel, etc.

The battery and battery charger for substation will be installed in the battery room located next door on the same floor.

However, No. 1, 2 generator transformer bays for synchronizing and starting transformer bay shall be controlled and supervised on the BTG board in the central control room of the power plant.

Therefore, those bays are supervised and monitered in the substation control room.

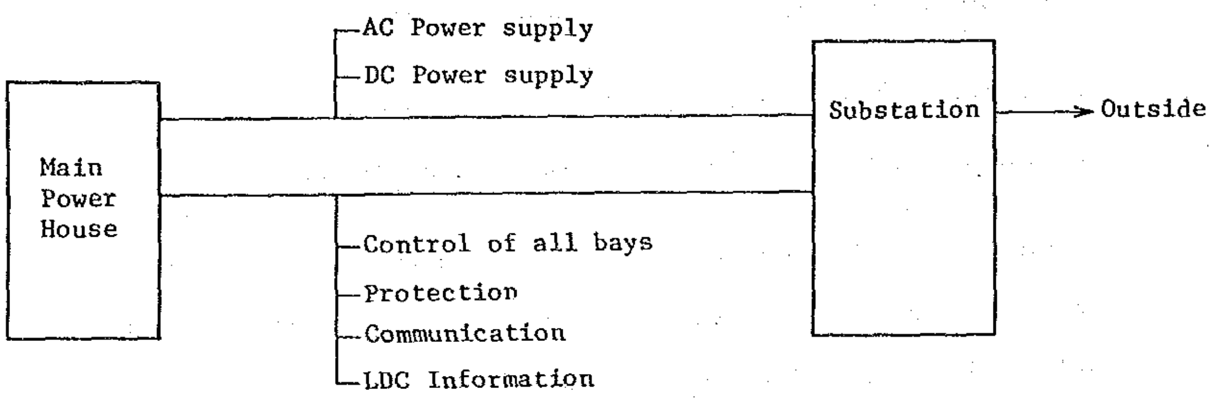
It is preferable that:
As the control room will be constructed on the substation area, the construction schedule will be able to keep the power receiving date and much economise the cables cost.

The comparison study of the location of switchyard control room is as describe hereunder.

a. Cable route among respective equipment for switchyard

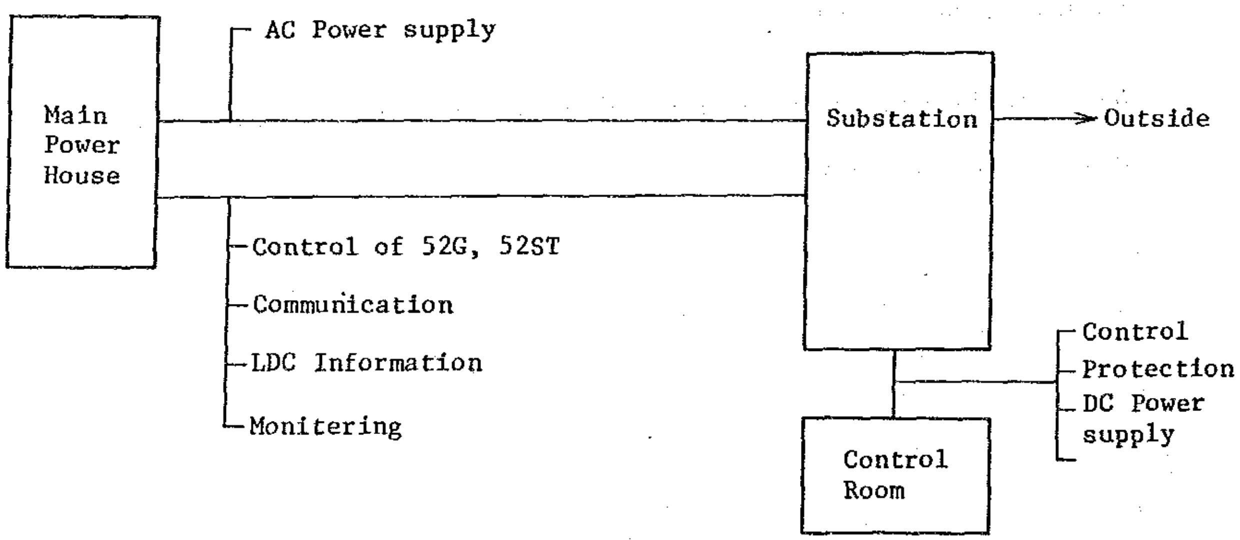
Case-1

The control and relay panel of the 220 kV and 132 kV switchyards and associated equipments will be installed in the central control room,

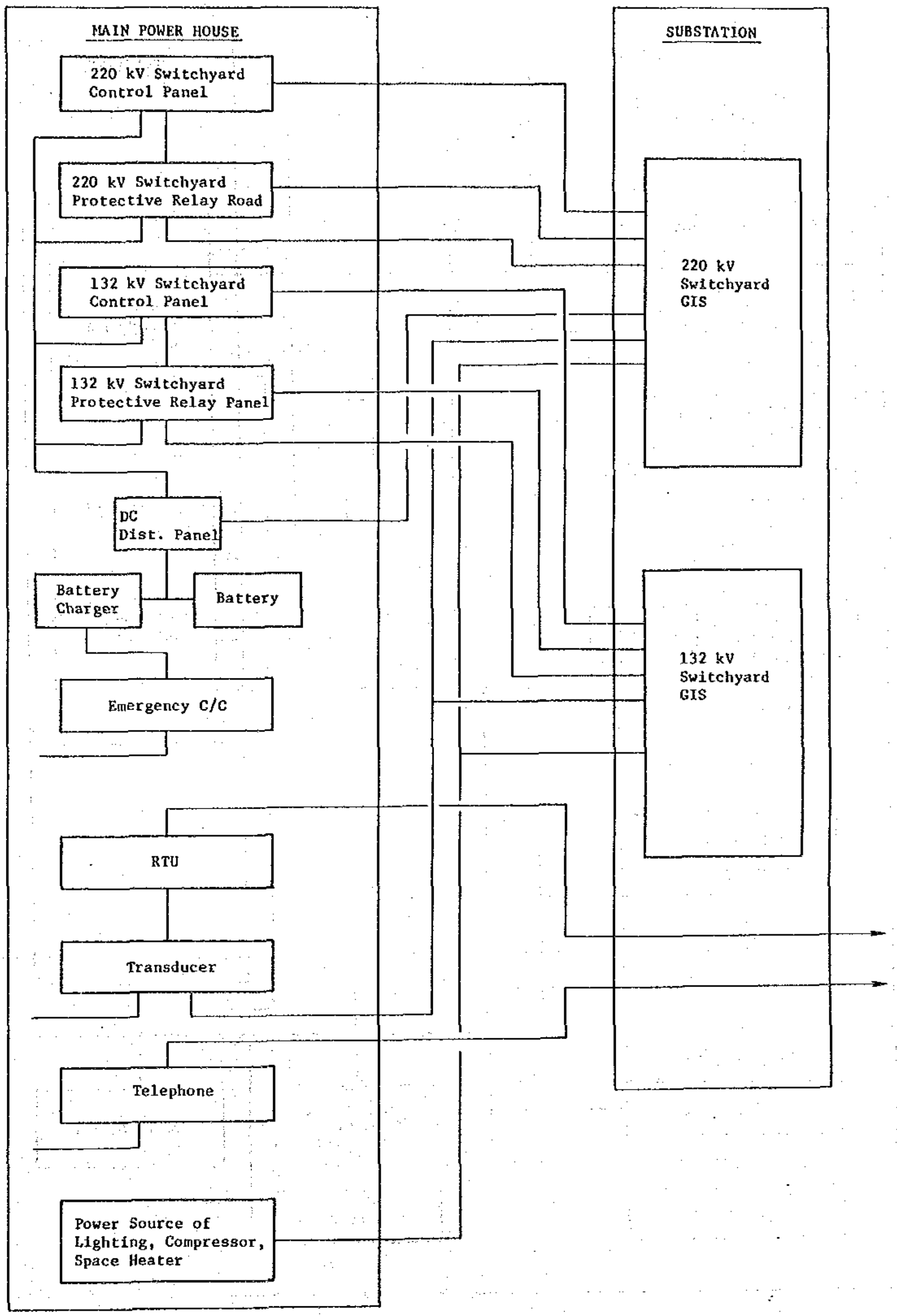


Case-2

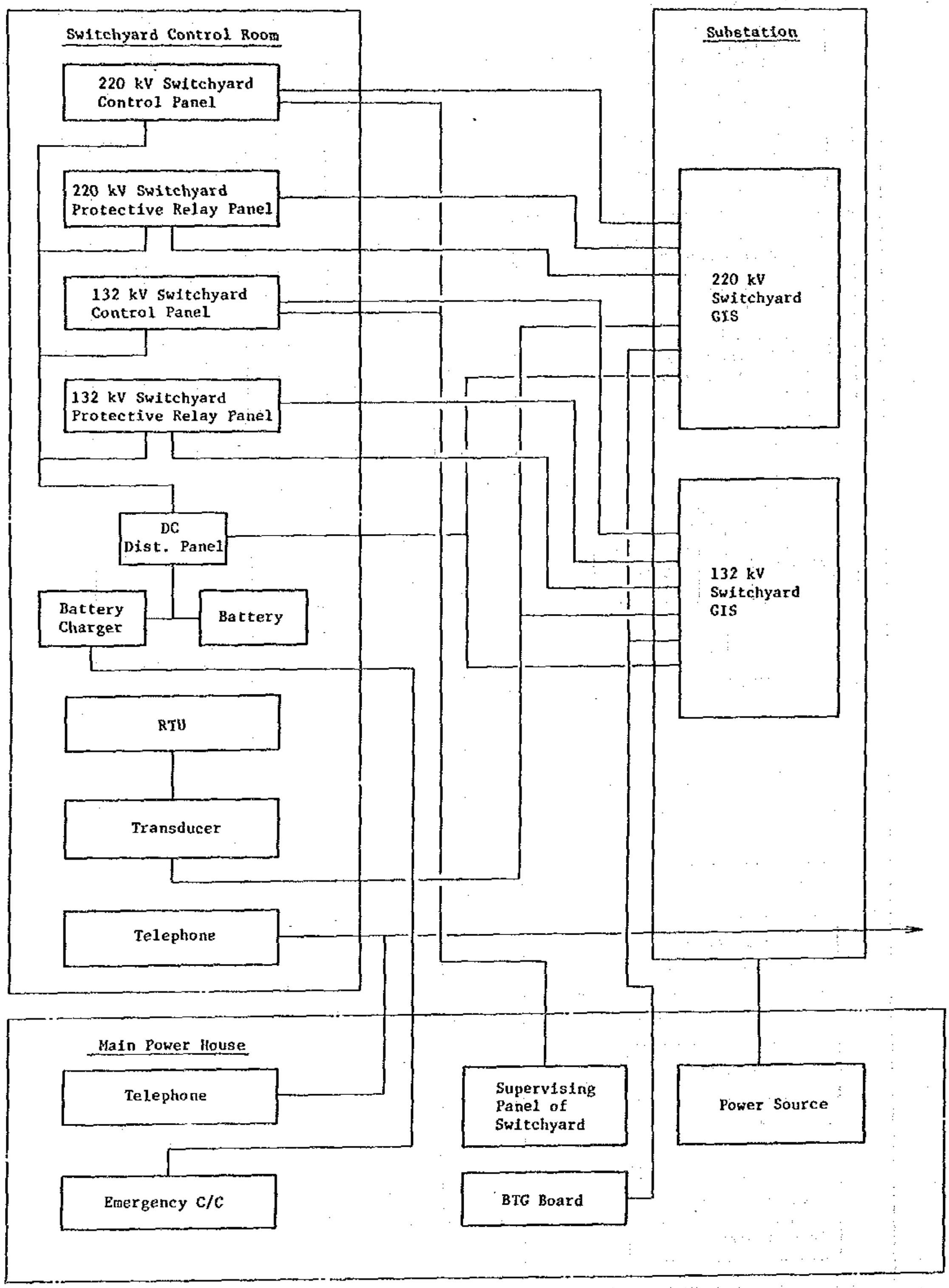
The control and relay panels of the 220 kV and 132 kV switchyard, and associated equipments will be installed in the substation control room, located in the substation area.



b. Cable Route of Control Scheme (Case-1)



c. Cable route of Control Scheme (Case-2)



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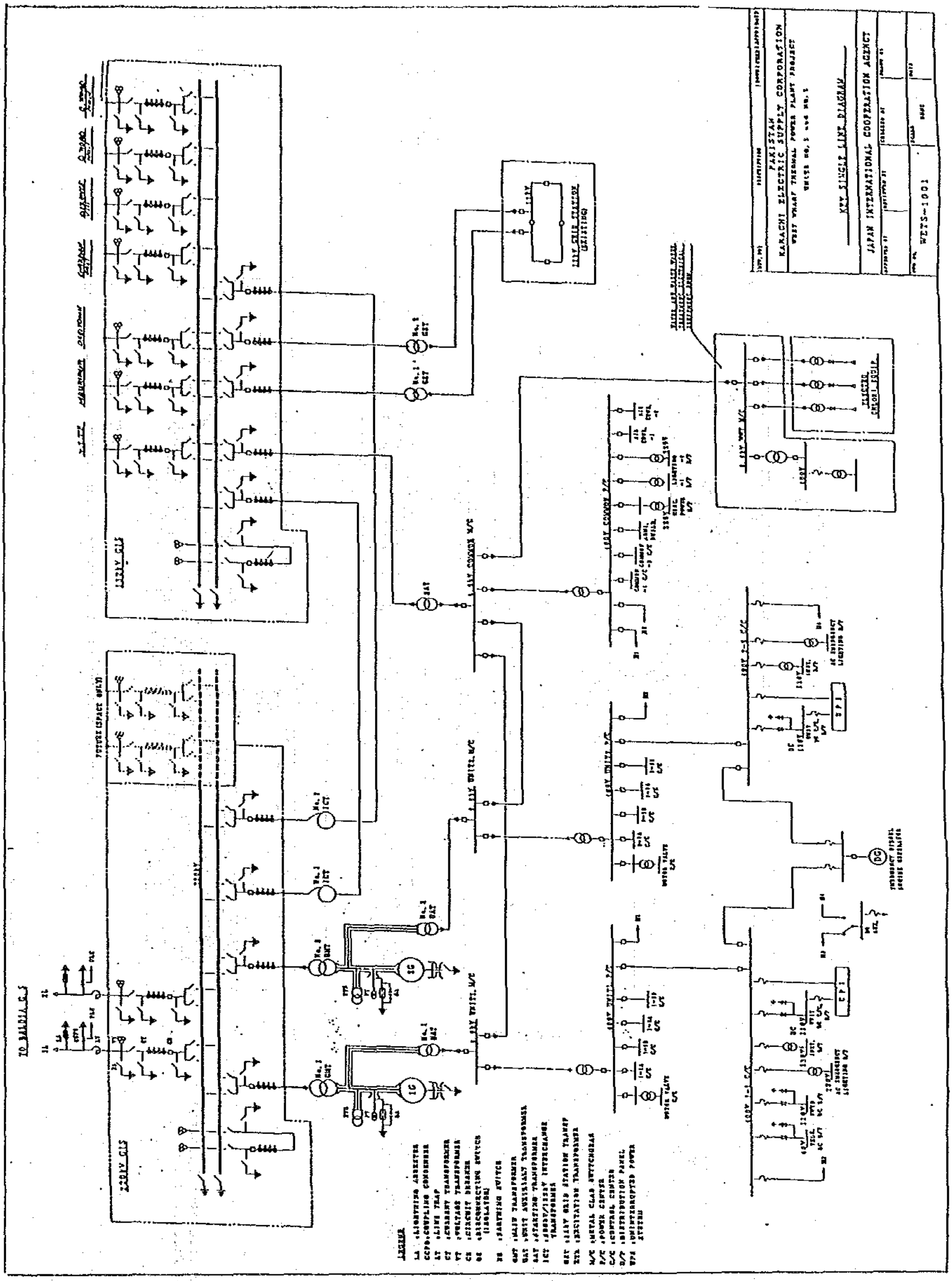
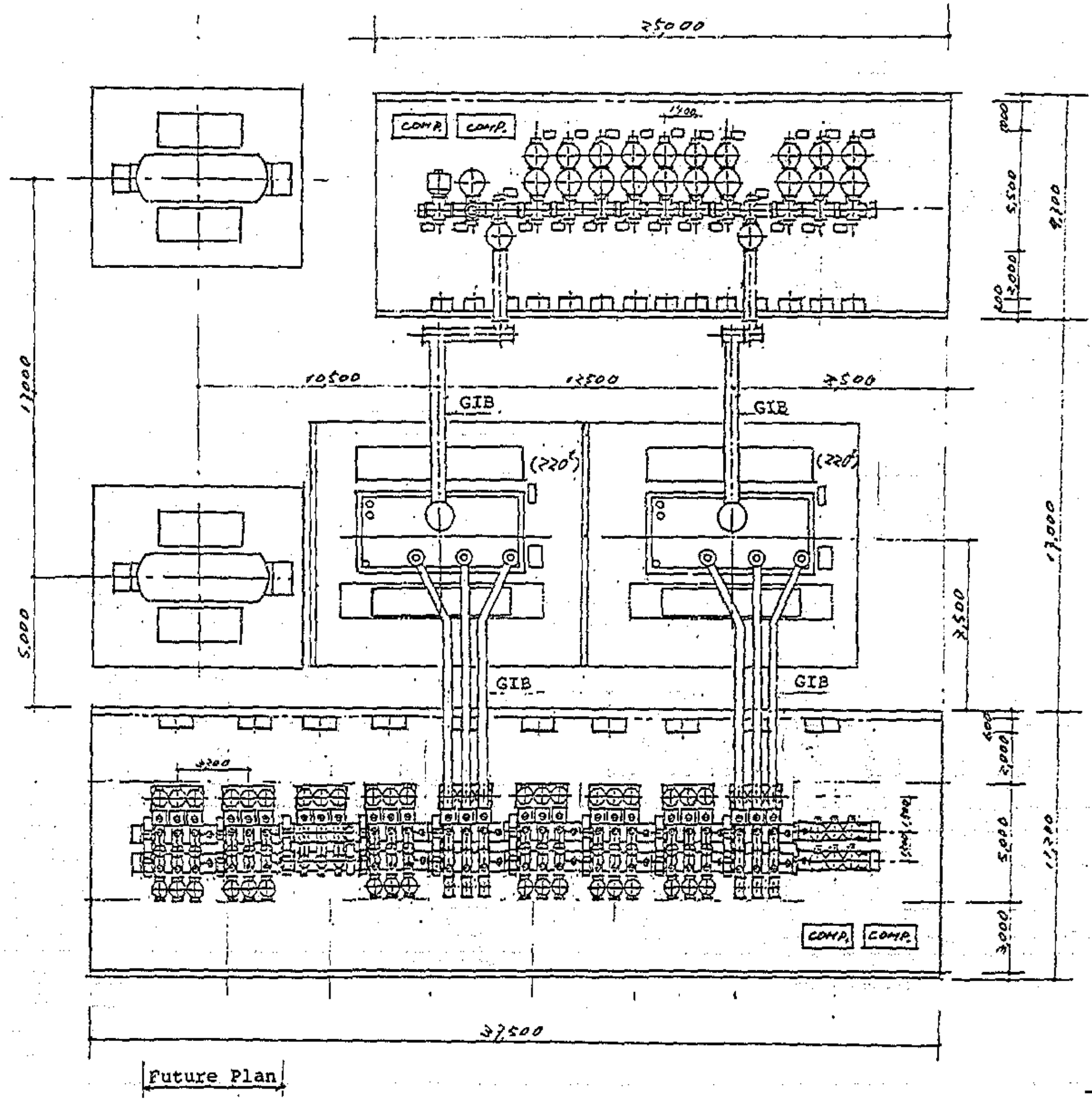

TO BALDIA G.S
220KV GIS
132KV GIS
FUTURE (SPACE ONLY)
No.1 GMT
No.2 GMT
No.1 ICT
No.2 ICT
No.1 UAT
No.2 UAT
SAT
No.1 GST
No.2 GST
11KV UNIT1 M/C
11KV UNIT2 M/C
11KV COMMON M/C
400V UNIT1 P/C
400V UNIT2 P/C
400V COMMON P/C
400V 1-1 C/C
400V 2-1 C/C
132KV GRID STATION (EXISTING)
MOTOR VALVE C/C
CPI
UPS
DG
EMERGENCY DIESEL ENGINE GENERATOR
ELECTRO CHLORI. EQUIP.
LEGEND
LA :LIGHTNING ARRESTER
CCPD:COUPLING CONDENSER
LT :LINE TRAP
CT :CURRENT TRANSFORMER
VT :VOLTAGE TRANSFORMER
CB :CIRCUIT BREAKER
DS :DISCONNECTING SWITCH (ISOLATOR)
ES :EARTHING SWITCH
GMT :MAIN TRANSFORMER
UAT :UNIT AUXILIARY TRANSFORMER
SAT :STARTING TRANSFORMER
ICT :220KV/132KV INTERCHANGE TRANSFORMER
GST :132KV GRID STATION TRANSF
ETR :EXCITATION TRANSFORMER
M/C :METAL CLAD SWITCHGEAR
P/C :POWER CENTER
C/C :CONTROL CENTER
D/P :DISTRIBUTION PANEL
UPS :UNINTERRUPTED POWER SYSTEM
PAKISTAN
KARACHI ELECTRIC SUPPLY CORPORATION
WEST WHARF THERMAL POWER PLANT PROJECT
KEY SINGLE LINE DIAGRAM
JAPAN INTERNATIONAL COOPERATION AGENCY
WETS-1001



LEGEND
GIS : Gas Insulated Switchgear
GIB : Gas Insulated Bus

ARRANGEMENT OF SUBSTATION

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SECTION VIEW OF 220 kV AND 132 kV SWITCHYARD