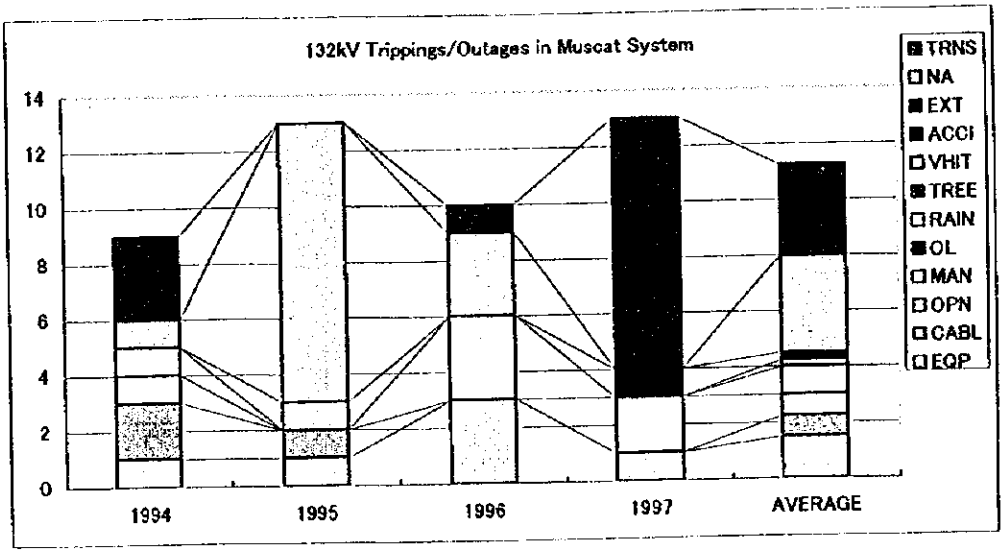
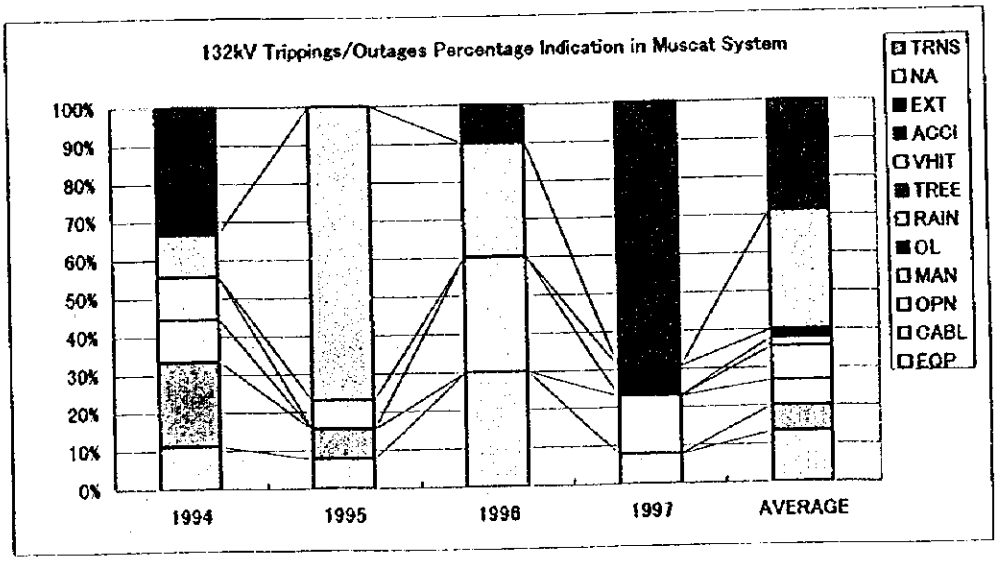
4-1-a Summary of 132kV Trippings/Outages(1994~1997 Muscat System)

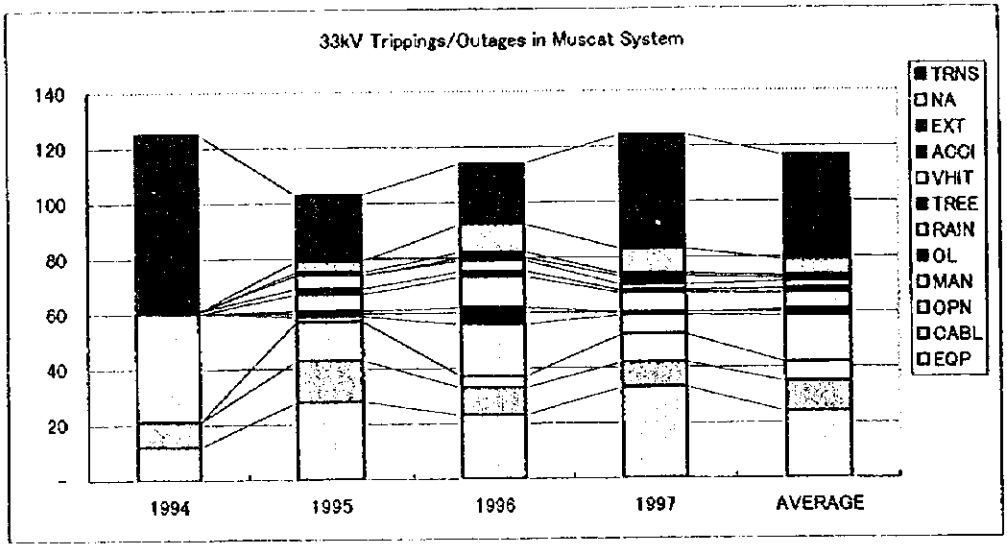
	Code	1994	1995	1996	1997	AVERAGE	TOTAL
Equipment	EQP	1	1	3	1	2	6
Cable problem	CABL	2	1			1	3
Operation related	OPN	1			2	1	3
Manually oppened	MAN	1		3		1	4
Load/Functuation/UF	OL					0	0
Weather related reasons	RAIN		1			0	1
Tree branches touching line	TREE					0	0
Vehicle hit	VHIT					0	0
(Human)Accident	ACCI				1	0	1
External reasons	EXT					0	0
Others/Not explained	NA	1	10	3		4	14
Transient/Temporary faults	TRNS	3		1	9	3	13
TOTAL		9	13	10	13	11	45

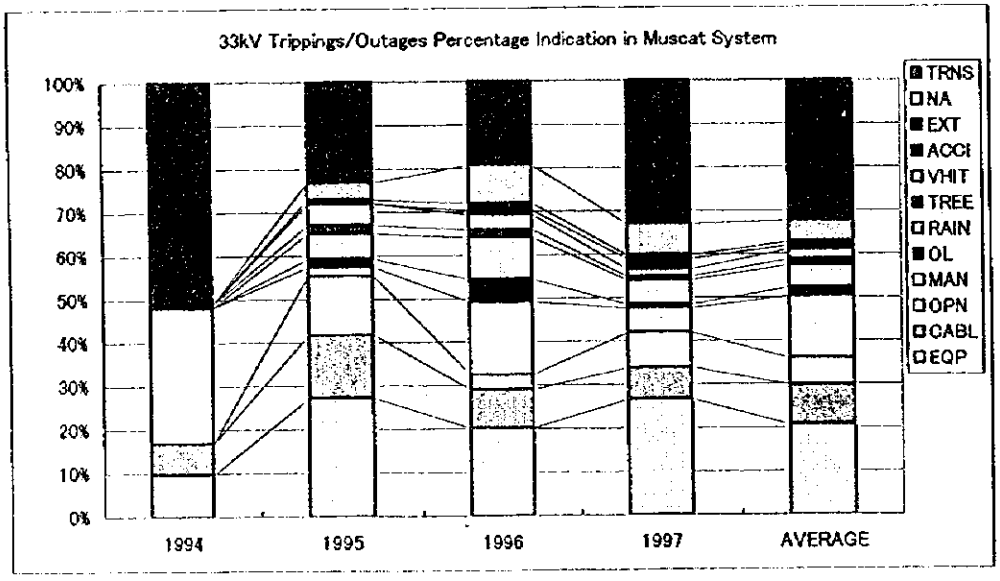




4-1-b Summary of 33kV Trippings/Outages(1994~1997 Muscat System)

	Code	1994	1995	1996	1997	AVERAGE	TOTAL
Equipment	EQP	12	28	23	33	24	96
Cable problem	CABL	9	15	10	9	11	43
Operation related	OPN		14	4	10	7	28
Manually oppened	MAN	39	2	19	7	17	67
Load/Functuation/UF	OL		2	6	1	2	9
Weather related reasons	RAIN		6	11	7	6	24
Tree branches touching line	TREE	1	2	2	1	2	6
Vehicle hit	VHIT		5	4	2	3	11
(Human)Accident	ACCI			1	3	1	4
External reasons	EXT		1	2	1	1	4
Others/Not explained	NA		4	10	9	6	23
Transient/Temporary faults	TRNS	64	24	22	41	39	151
TOTAL		125	103	114	124	117	466





4-1-c Load Flow Calculation Result(132k Muscat System)

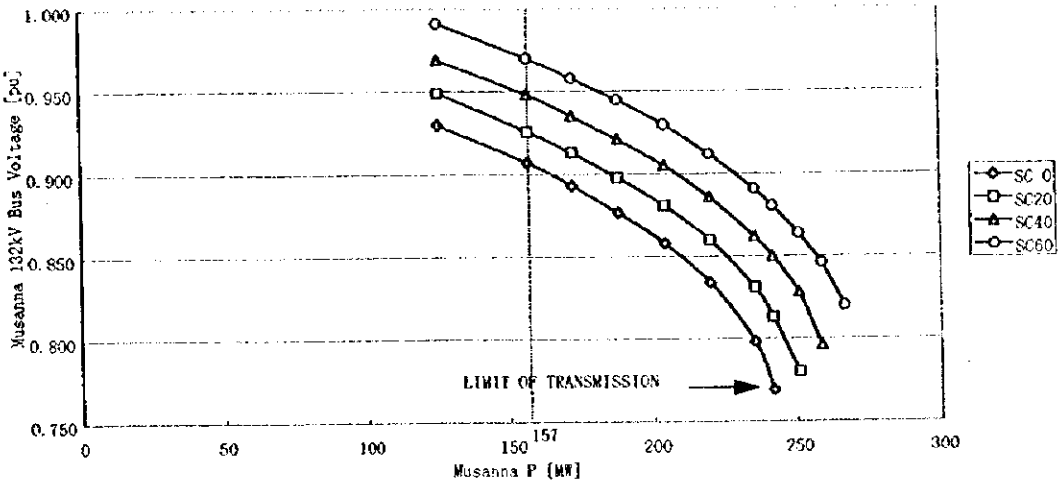
	Peak (Tr Tap ratio=1.0)							Off Peak (Tr Tap ratio=1.0)						
	Present					Improvement		Present					Improvement	
	generation		load		132kV bus voltage (p.u.)	Peak load Pf improvement (Pf=0.87→0.95)		generation		load ((Peak load)x0.7)		132kV bus voltage (p.u.)	Peak load Pf improvement (Pf=0.87→0.95)	
	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)		SC increase (MVA)	132kV voltage (p.u.)	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)		SC (MVA)	132kV voltage (p.u.)
RUSAIL PS (132kV)	(29)527	(84)458						364	273					
GHUBRAH PS (132kV)	463	(77)424						324	257					
GHUBRAH PS (33kV)	78	54						55	35					
MANAH PS	96	63						67	39					
RUSAIL PS			131	80	0.992		1.010			92	56	1.015		1.033
GHUBRAH PS			99	47	1.000		1.018			69	33	1.019		1.037
MADINAT QABOOS SS			132	80	0.985	40	1.008			92	56	1.010	40	1.032
WADI ADAI SS			139	100	0.965	50	0.996			97	70	0.998	50	1.026
AI FALAJ SS			115	70	0.963	30	0.993			81	49	0.996	30	1.026
WADI KABIL SS			106	65	0.955	30	0.989			74	46	0.991	30	1.023
SEEB SS			102	60	0.967	30	0.993			71	42	0.999	30	1.024
BAIT BARKA SS			86	30	0.952	10	0.984			60	21	0.992	10	1.021
MUSANNA SS			157	60	0.897	40	0.951			110	42	0.960	40	1.010
IZKI SS			14	8	0.988	5	1.011			10	6	1.012	5	1.034
NIZWA SS			42	25	0.989	10	1.012			29	17	1.016	10	1.035
BAHIA SS			30	18	0.980	10	1.007			21	13	1.005	10	1.032
TOTAL	(29)1164	(161)999	1153	643(Pf=0.87)		255		810	604	806	451		255	
	Load shedding quantity = 29 (over load) + 95(largest unit) = 124 (MW)													
SYSTEM LOSS (MW)					10.7		7.9					4.5		3.2

NOTE: 1.1.05 ≧ target of voltage ≧ 0.95 (p.u.)

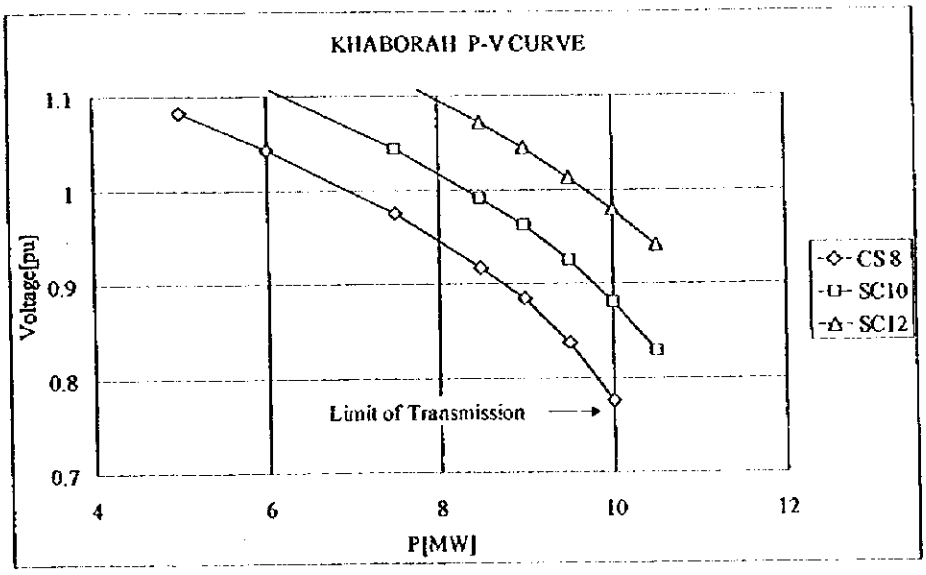
4-1-d Load Flow Calculation Result(Musanna SS 33kV System)

Load Point	Name	Load P MW	Load Q MVAR	Capacitor MVAR		33kV Bus Voltage p.u.
	Musanna 33kV Bus-1					1.03
	Musanna 33kV Bus-2					1.03
1	Khadra-2	5	3	3		0.96
2	Khaborah-1	7	5	6		0.93
3	Khaborah-2	10	7	4		0.77
4	Awabi	4	3	3		1.00
5	Rustaq-1	8	4	5		0.96
6	Thermad	11	6	5		1.00
7	Wudam Naval Base	-	-	-		
8	Bidaya-1	6	3	5		0.99
9	Bidaya-2	6	3	5		0.99
10	Khadra-1	6	3	3		0.93
11	Sana Bani Gafar	2	1			0.93
12	Musanna-1	7	4	5		1.02
13	Rustaq Hospital	6	4	5		0.92
14	Rustaq-2	10	6			0.88
15	Al Hazam-1	6	4	3		0.94
16	Al Hazam-2	6	4	3		0.94
17	Wadi Bani Gafar	4	3	3		0.92
18	Suweiq-2	9	6	5		0.87
19	Al Nasr Marble Fctory	5	3			0.68
20	Wai Jawahir	5	3			0.67
21	Suweiq-1	12	8	5		0.95
22	Billa-2	8	6	5		0.96
23	Billa-1	8	6	5		0.96
24	Musanna-2a	4	3			1.00
25	Musanna-2b	8	6	5		1.00

4-1-e Musanna SS P-V Curve



4-1-f Khaborah SS P-V Curve(Musanna SS 33kV System)

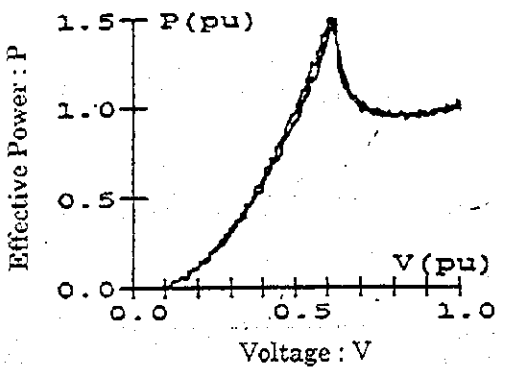
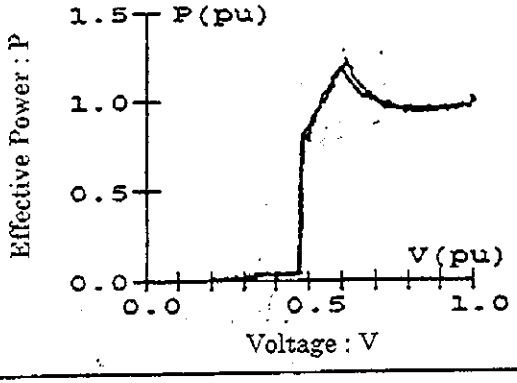
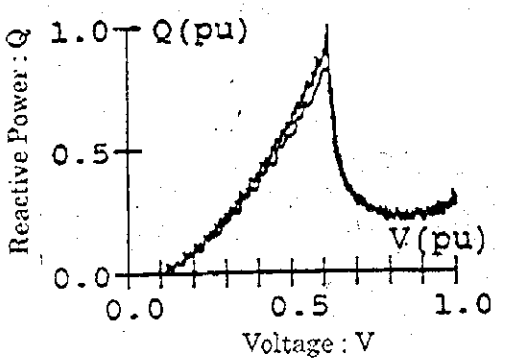
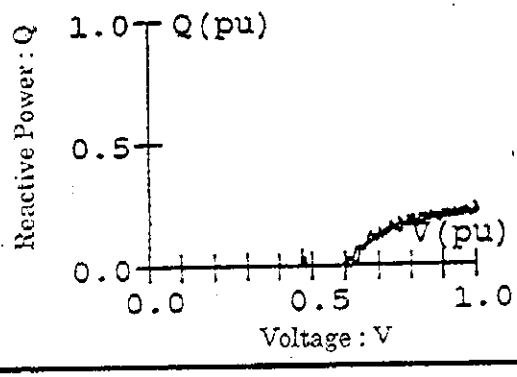


4-1-g Load Flow Calculation Result(132kV Wadi Jizzi System)

	Present method(Base)					Improvement method			
						case 1		case 2	case 3
	generation		load (total pf=0..83)		132Kv bus voltage (p.u.)	load Pf improvement (Pf=0.83→0.95)		transmission line increase(AL WASIT~DANK) 132kV bus voltage (p.u.)	IBRI SS load (35MW) ↓ MANAH PS system 132kV bus (p.u.)
	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)		SC increase (MVA)	132kV bus voltage (p.u.)		
WADI JIZZI PS (132kV)	238	263							
WADI JIZZI PS (33kV)	36	25							
WADI JIZZI PS (66kV)			18	12	0.985	6	1.022	0.993	1.004
SOHAR SS			120	84	0.960	40	1.010	0.968	0.979
UM ALINA SS			18	12	0.960	6	1.006	0.968	0.979
AL WASIT SS			10	6	0.936	3	0.996	0.955	0.981
BUREIMI SS			35	23	0.899	10	0.972	0.918	0.946
DANK SS			8	5	0.719	3	0.889	0.878	0.933
IBRI SS			35	20	0.633	10	0.847	0.819	-
AL HAIL SS			13	7	0.695	5	0.879	0.860	0.917
TOTAL	274	288	257	169		83			
	Load shedding quantity = 29 (largest unit) — 1 (reserve) = 28 (MW)								
SYSTEM LOSS (MW)					16.5		7.2	7.8	3.2

NOTE: 1. Tr Tap ratio = 1.05 ~ 0.85
2. 1.05 ≧ target of voltage 0.95 (p.u.)

4-1-h P-V,Q-V Curve (when the voltage dropped slowly)

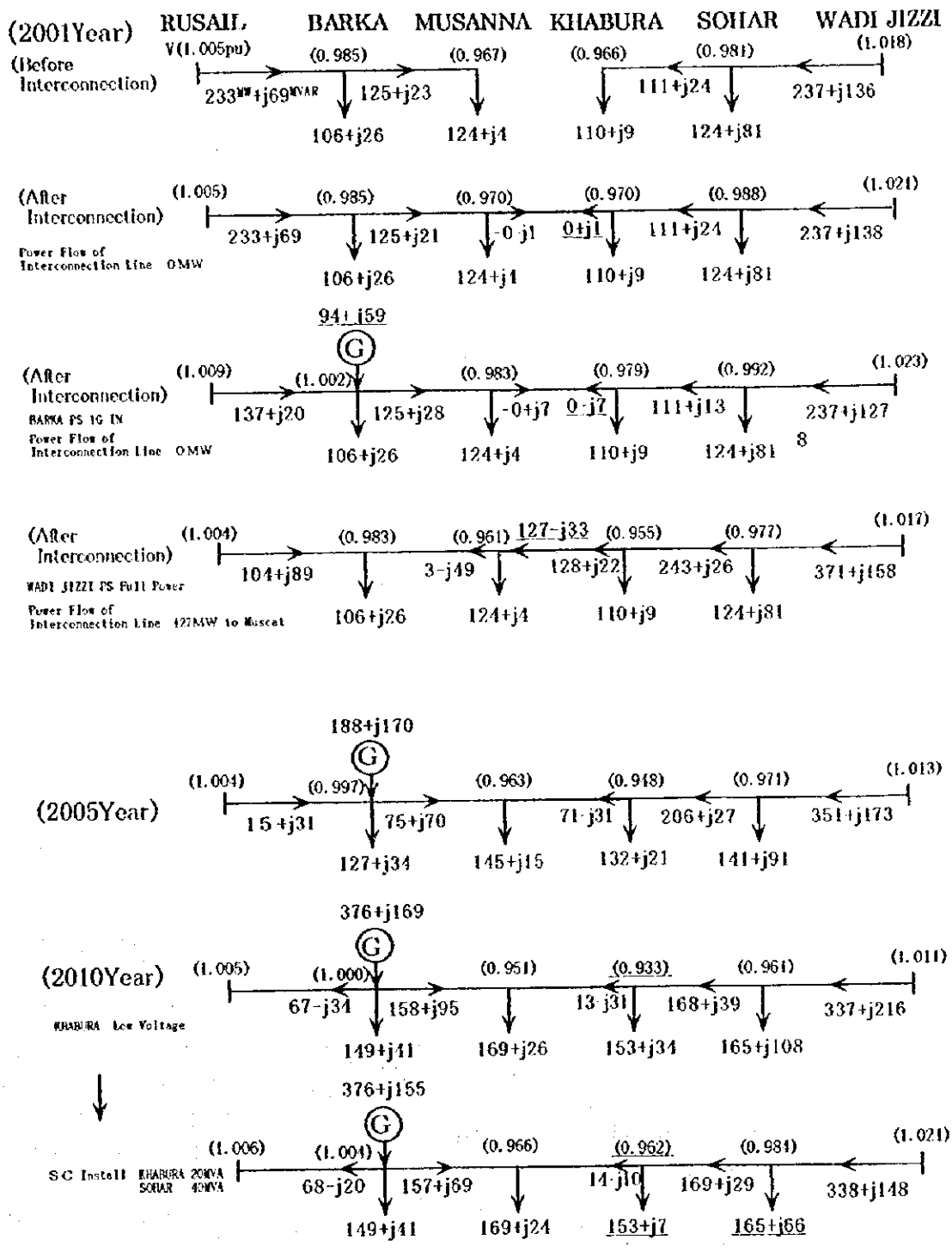
	Conventional Type Air-conditioner	Inverter Type Air-conditioner
P-V Curve		
Q-V Curve		

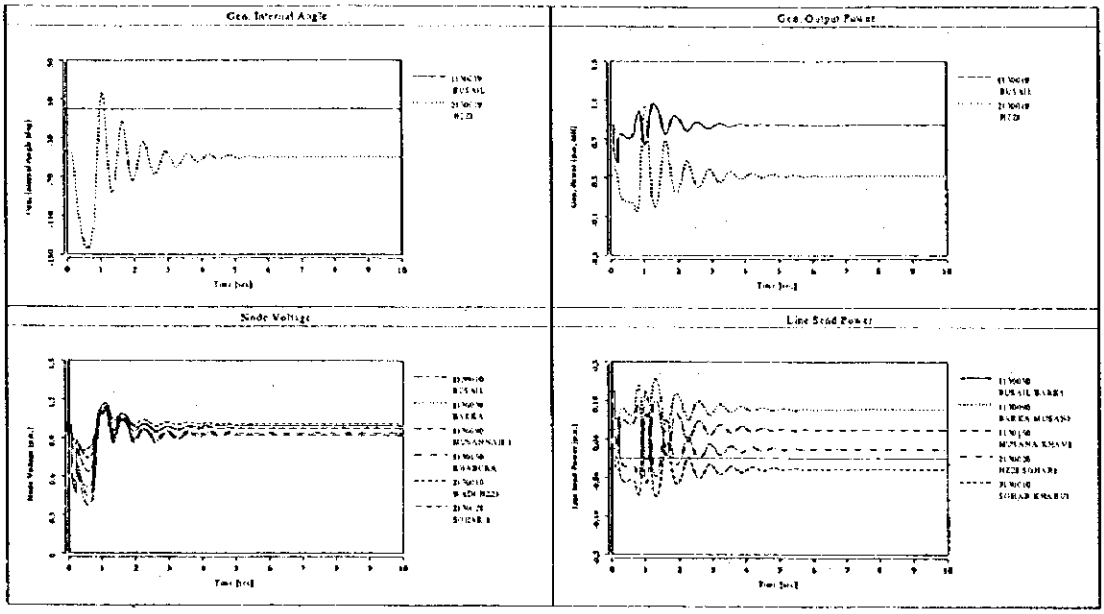
4-1-i Load and Supply Balance at 2001 Year

	2001				
	Generation		Load		SC(MVA)
	P(MW)	Q(MVAR)	P(MW)	Q(MVAR)	increase
RUSAIL PS	748	477	162	99	
GHUBRAH PS	568	484	122	58	
MANAH PS	181	109			
MADINAT QABOOS SS			163	99	
WADI ADAI SS			172	124	40
AL FALAJ SS			142	87	20
WADI KABIR SS			131	80	20
SEEB SS			126	74	
BAIT BARKA SS			106	37	10
MUSANNA SS			124	47	40
IZUKI SS			17	10	
NIZWA SS			52	31	20
BAHLA SS			37	22	10
SHARQIYA			89	51	30
IBRI SS			41	26	20
KHABURA SS			110	53	40
SOHAR SS			124	81	
WADI JIZZI PS	365	217	19	7	
UMALINA SS			21	14	
AL WASIT SS			12	8	
BUREIMI SS			44	28	20
DANK SS			12	8	5
(IBRI SS)	to Manah system				
AL HAIL SS			17	11	10
TOTAL	1862	1287	1843	1055	285

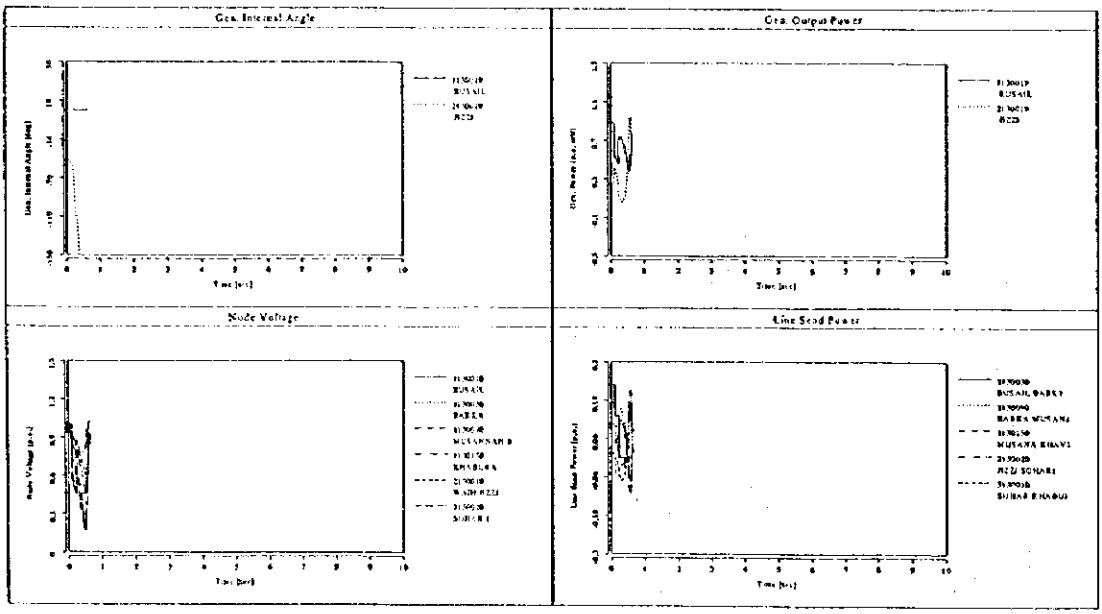
4-1-j Voltage Power Flow of Interconnection Line

(MUSCAT System) (WADI JIZZI System)



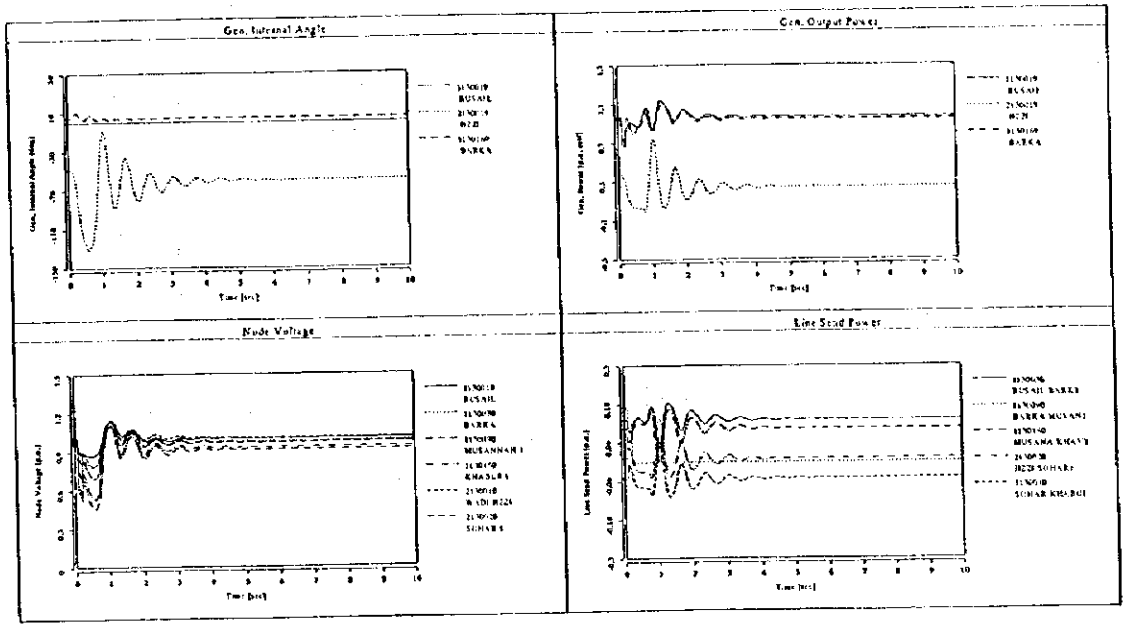


(a) Transmission Power = 173MW, T_1=6cycle, T_2=0.5sec

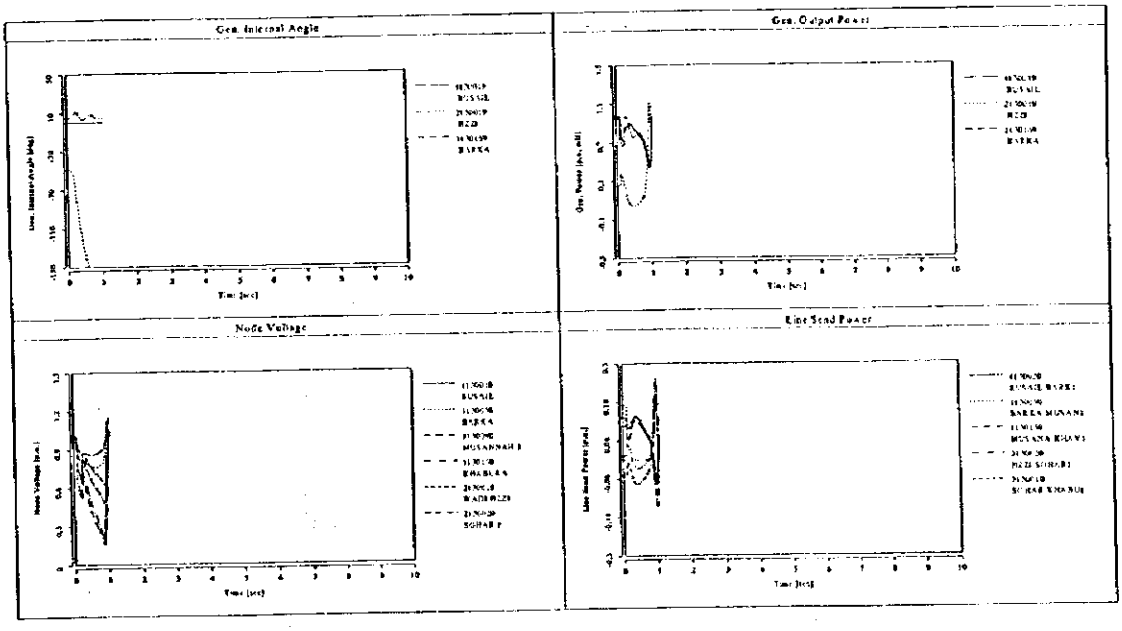


(b) Transmission Power = 212MW, T_1=6cycle, T_2=0.5sec

4-1-k Simulation Waveforms (Exclude Barka PS)



(a) Transmission Power = 212MW, T_1=6cycle, T_2=0.5sec

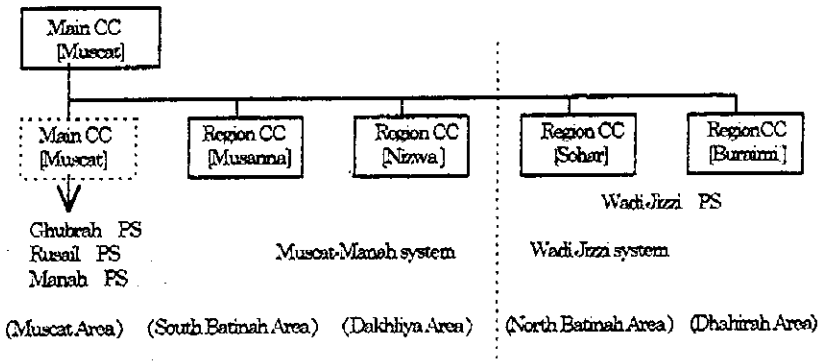


(b) Transmission Power = 212MW, T_1=7cycle, T_2=0.5sec

4-1-1 Simulation Waveforms (Include Barka PS)

4-1-m Introduction of a Central Load Dispatching Center)

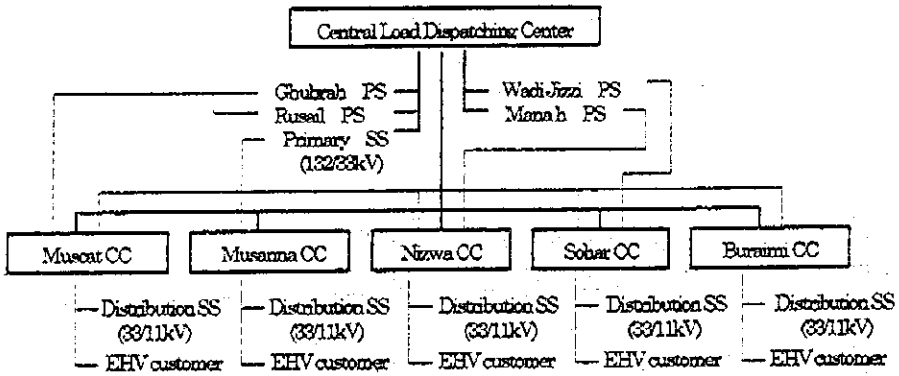
Present



1. Main CC Duties
   - Load dispatching and system operation of Muscat-Manah system
   - Sum up records of all Oman

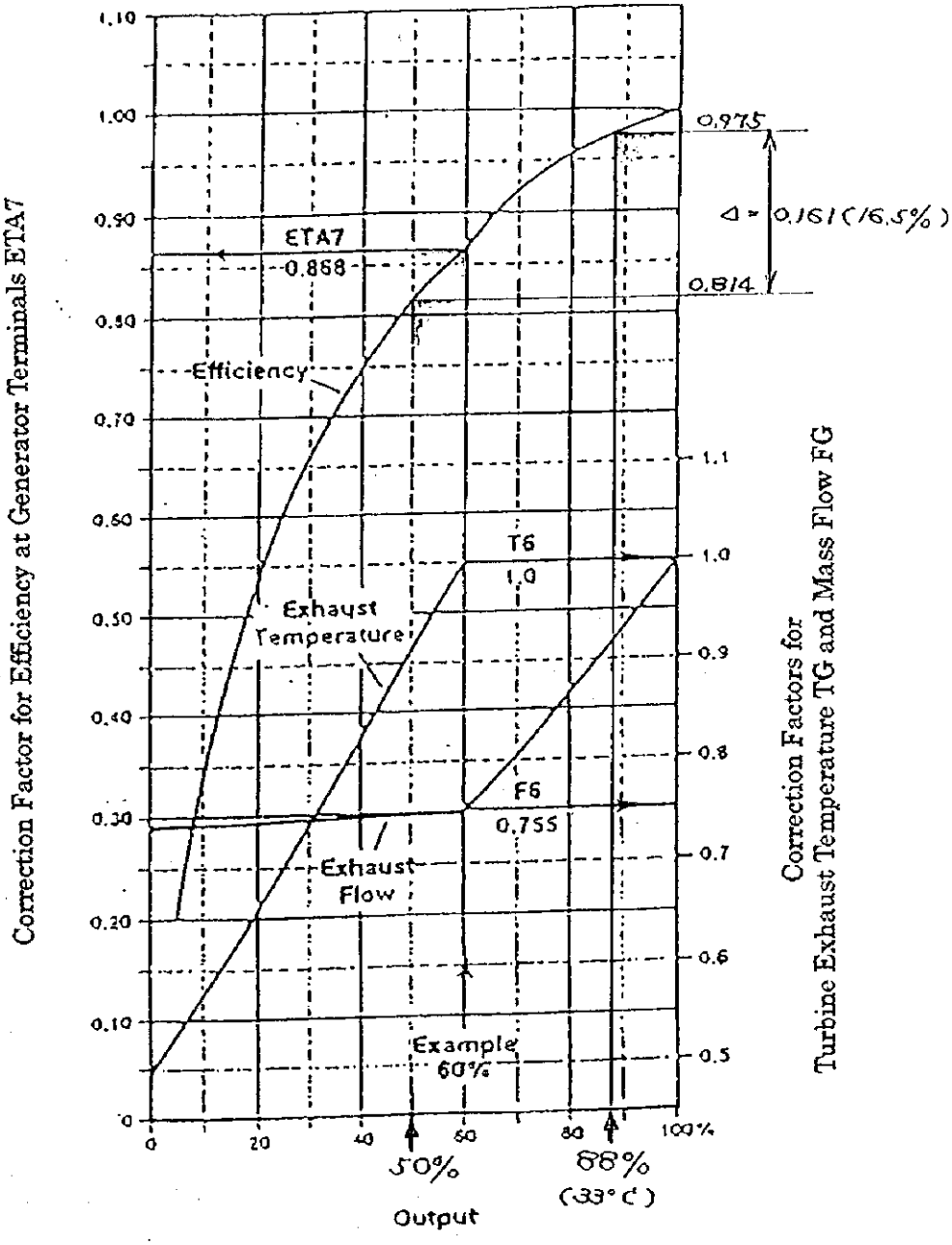
2. Region CC Duties
   - System operation under control ··· System monitoring control, Switching operation, Record keeping, Information and communication

The case introduced a Central Load Dispatching Center

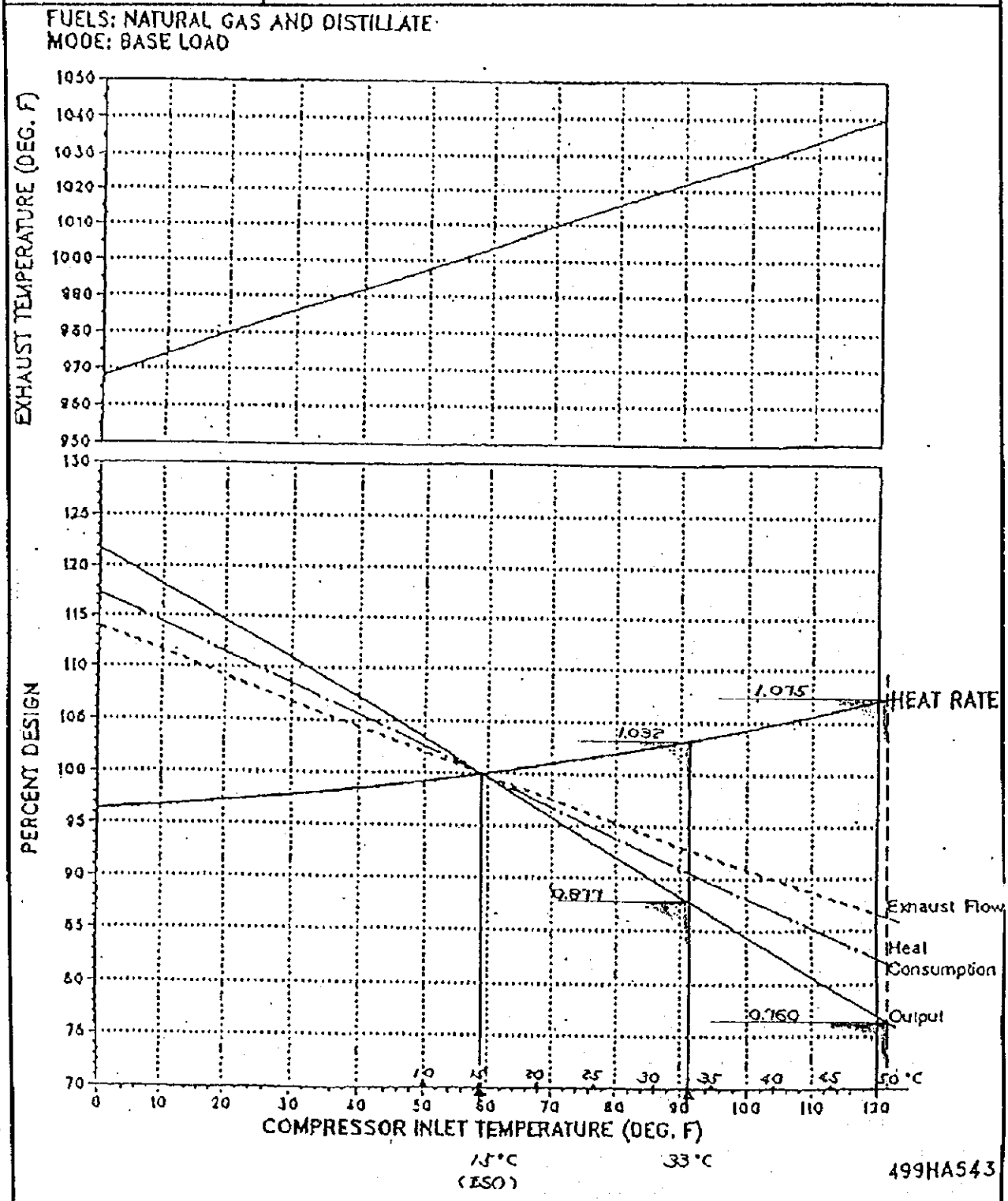


1. Central Load Dispatching Center Duties
   - Demand and supply control
   - System monitoring control ··· 132kV system(power flow, voltage, frequency)
   - Switching operation ··· 132kV system(only instruction, not operation)
   - Record keeping ··· 132kVsystem(power flow, voltage, generation, load, weather, etc)
   - Information and communication ··· System operation status ,information of faults, etc.

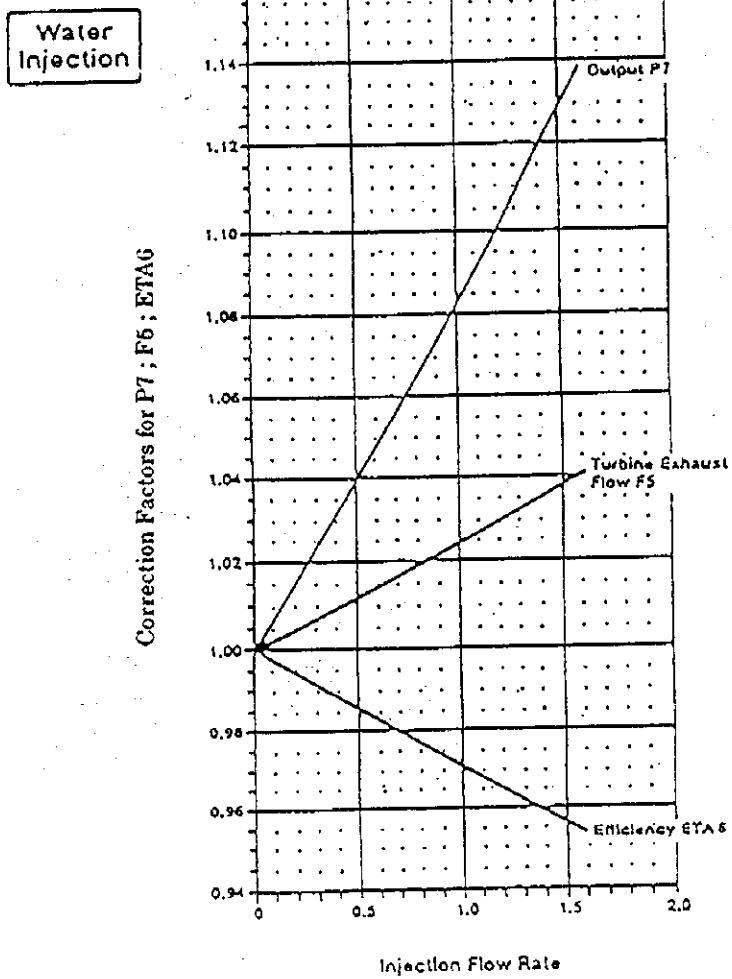
2. Control Center Duties
   - System monitoring control ··· 33kV system(power flow, voltage)
   - Switching operation ··· 33kV system and 132kV system(only operation)
   - Record keeping ··· 33kVsystem(power flow, voltage, load , weather, etc)
   - Information and communication ··· System operation status, information of faults, etc.
   - Extra high voltage customers ···. Communication on operation, response to fault, etc.

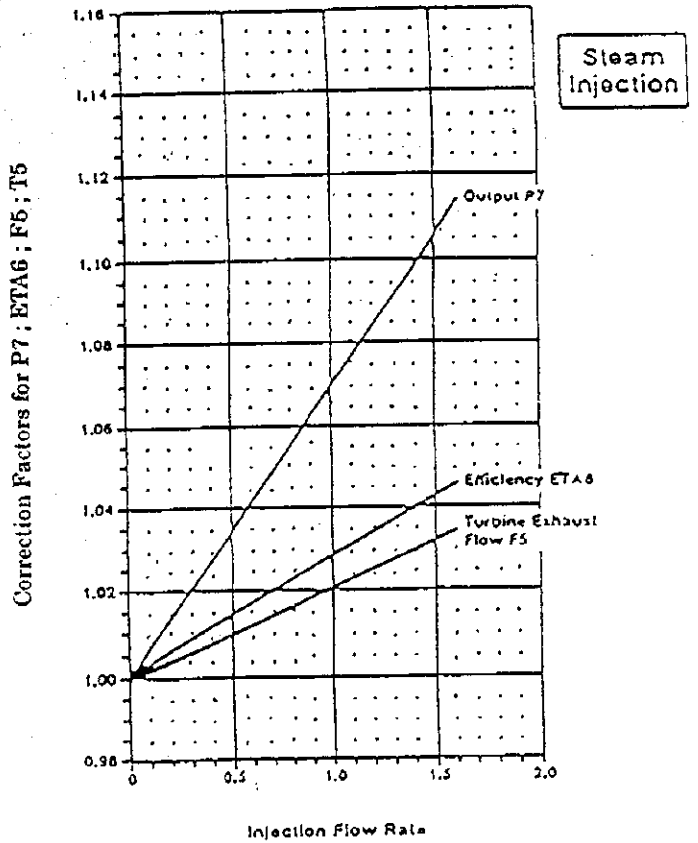


4-2-a Efficiency, Exhaust Temperature and Flow Correction for Part Load Operation (For 100% use 1.0)

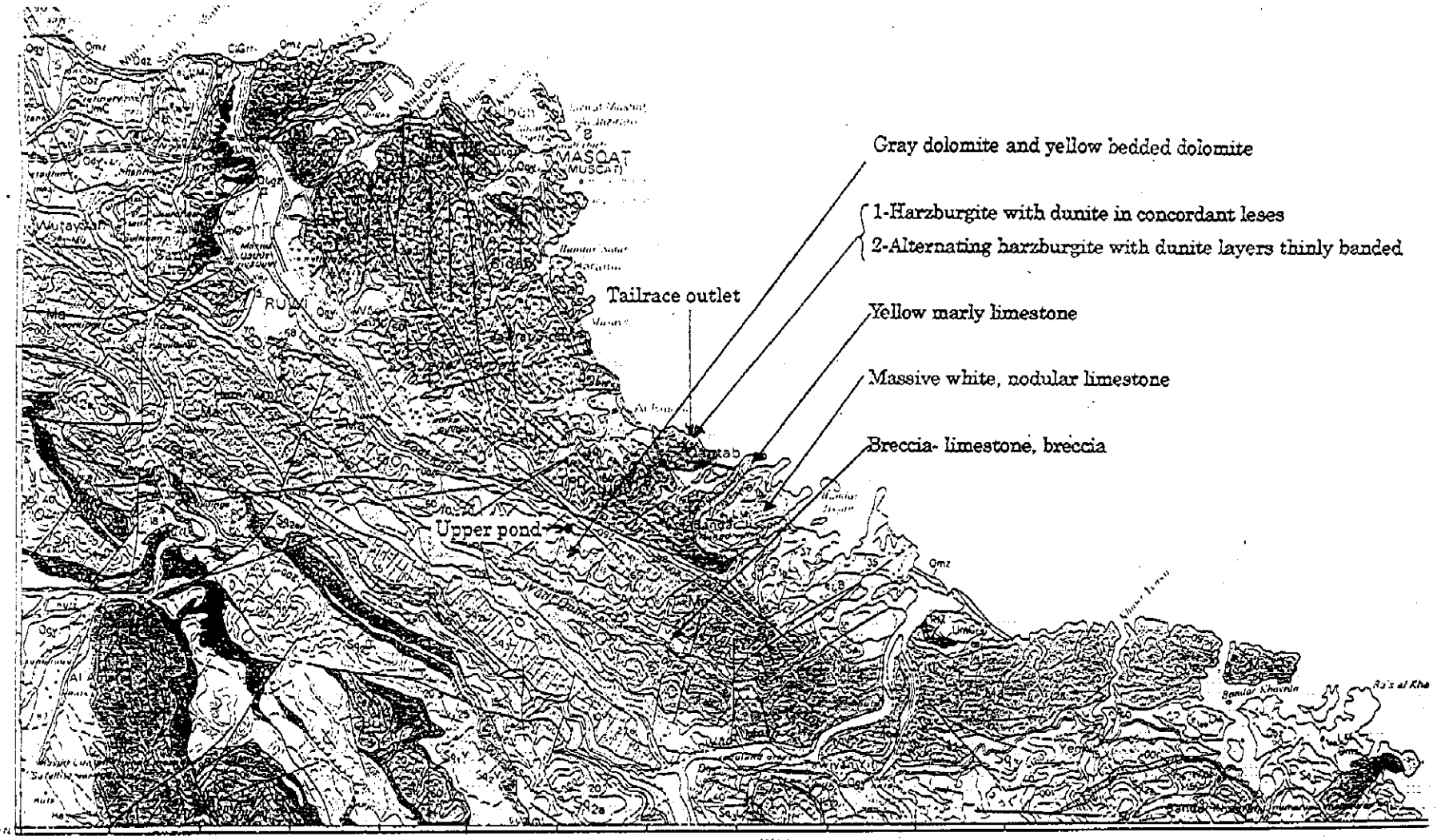


4-2-b GENERAL ELECTRIC MODEL PG6541(B) GAS TURBINE
ESTIMATED PERFORMANCE
OUTPUT, HEAT RATE, CONSUMPTION
EXHAUST FLOW AND EXHAUST TEMPERATURE AT 100% SPEED

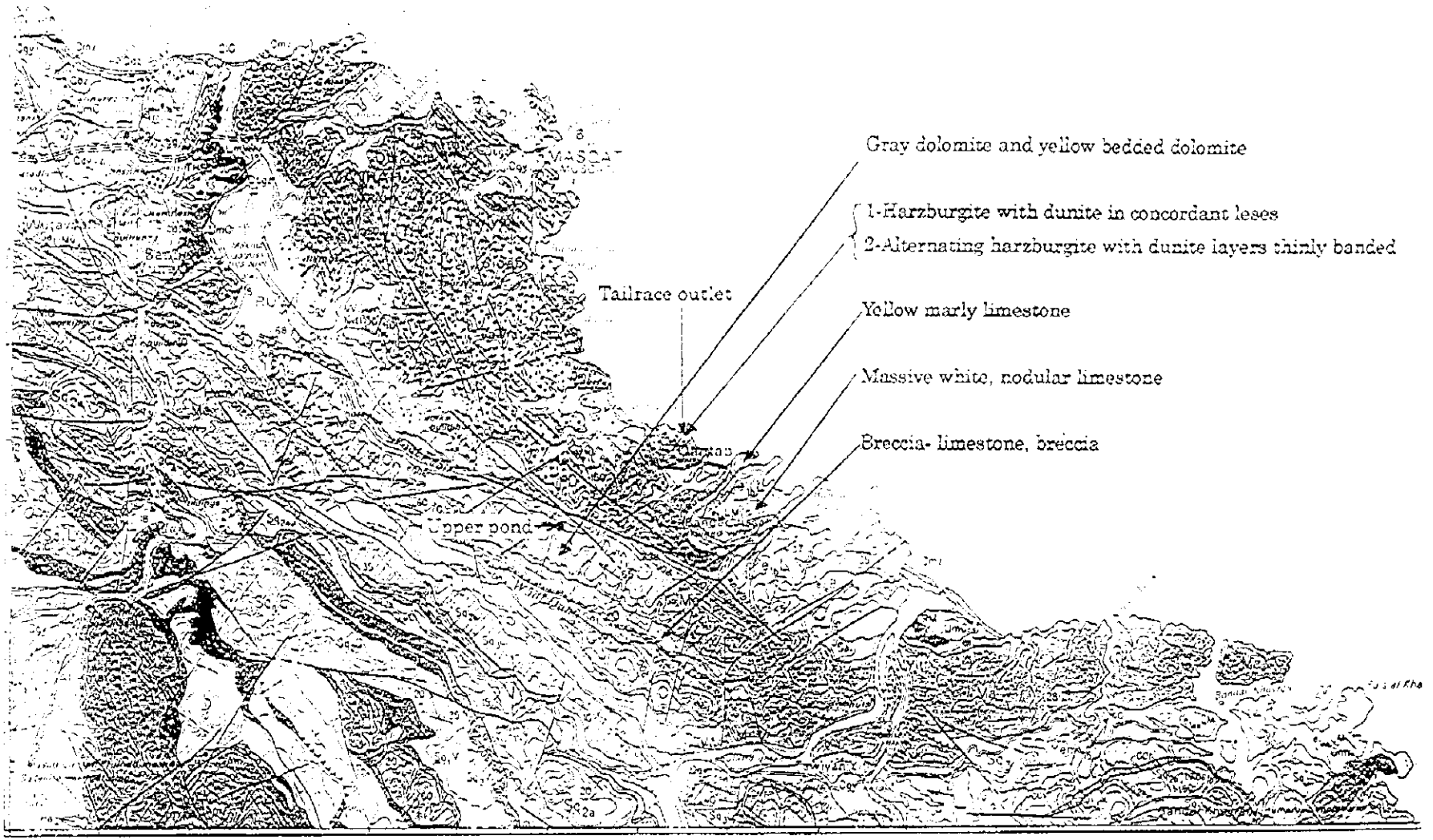




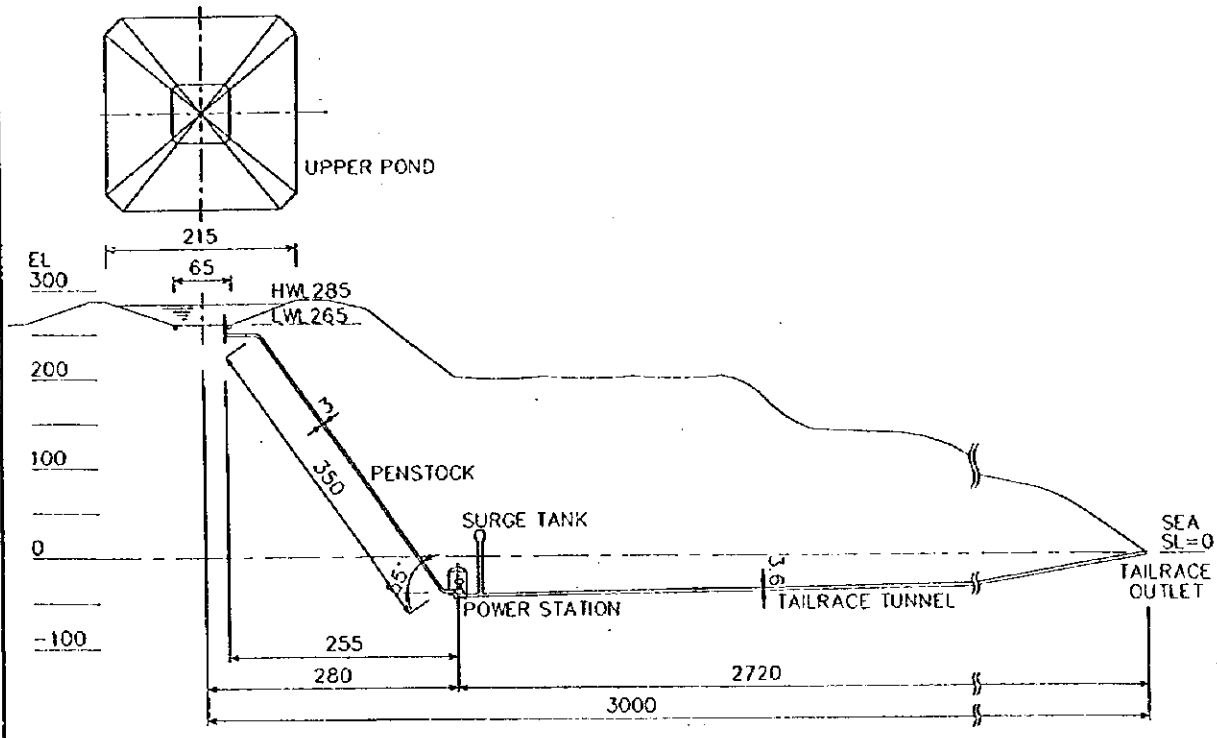
4-2-c Turbine Output, Efficiency. Exhaust Flow and Temperature Correction for Water of Steam Injection with Natural Gas Fuel.



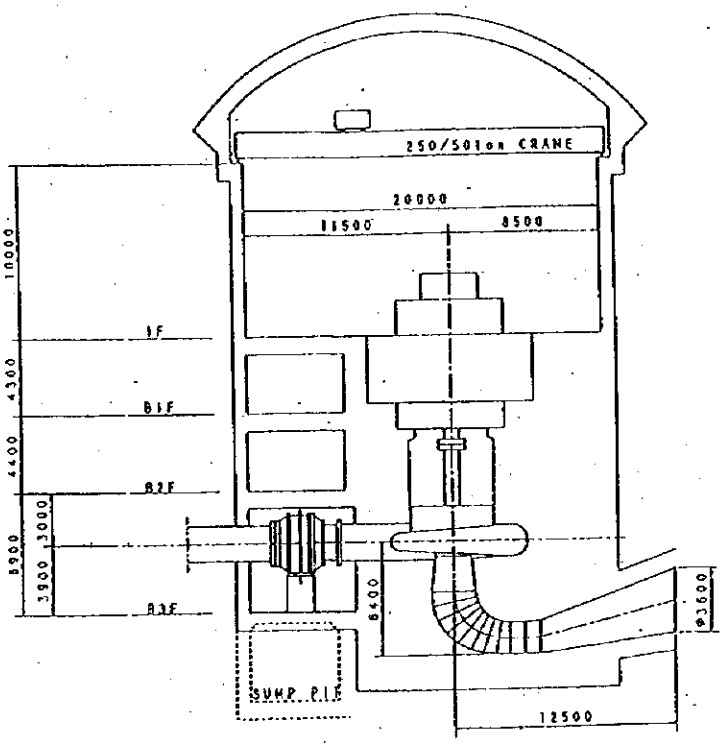
4-3-a GEOLOGICAL MAP OF MUSCAT AREA



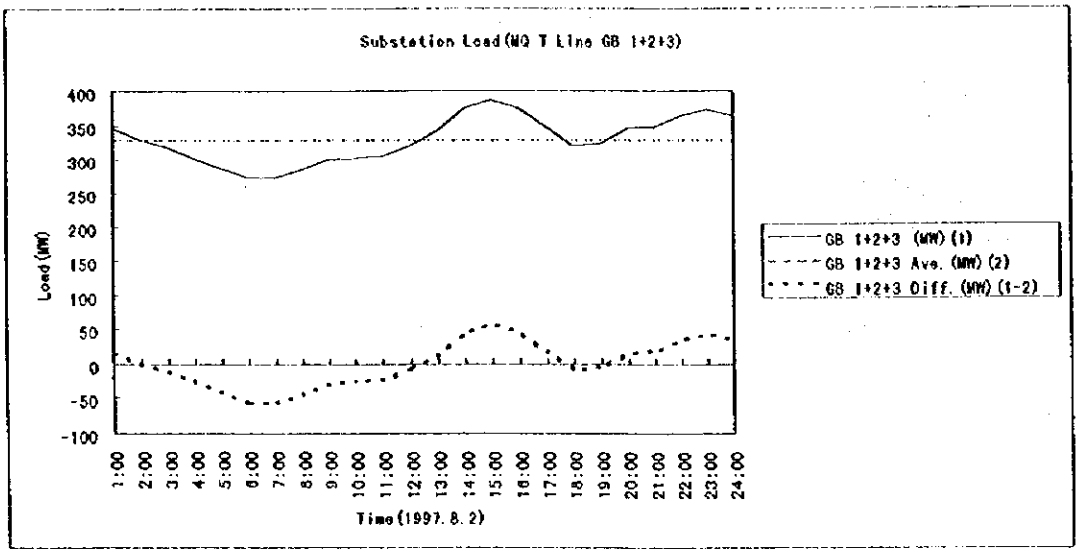
4-3-a GEOLOGICAL MAP OF MUSCAT AREA

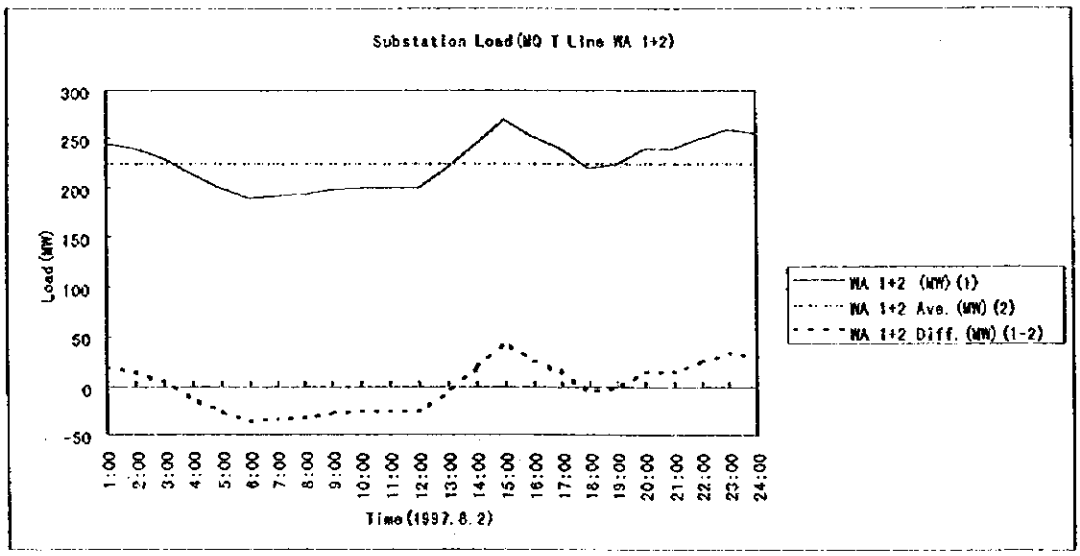


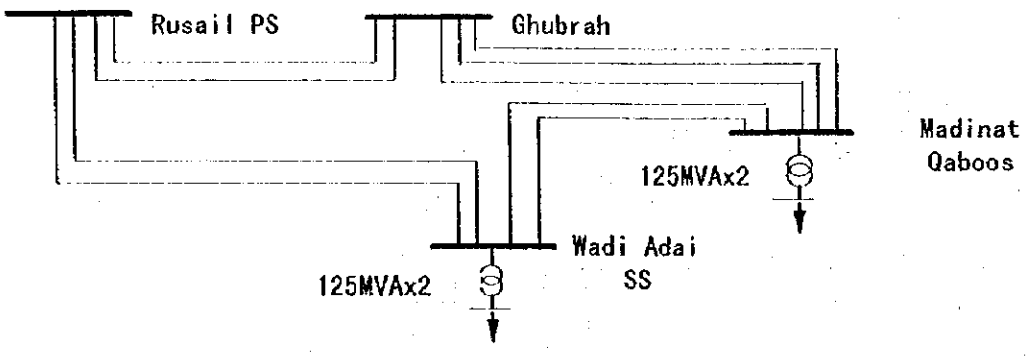
4-3-b HYDRAULIC PROFILE



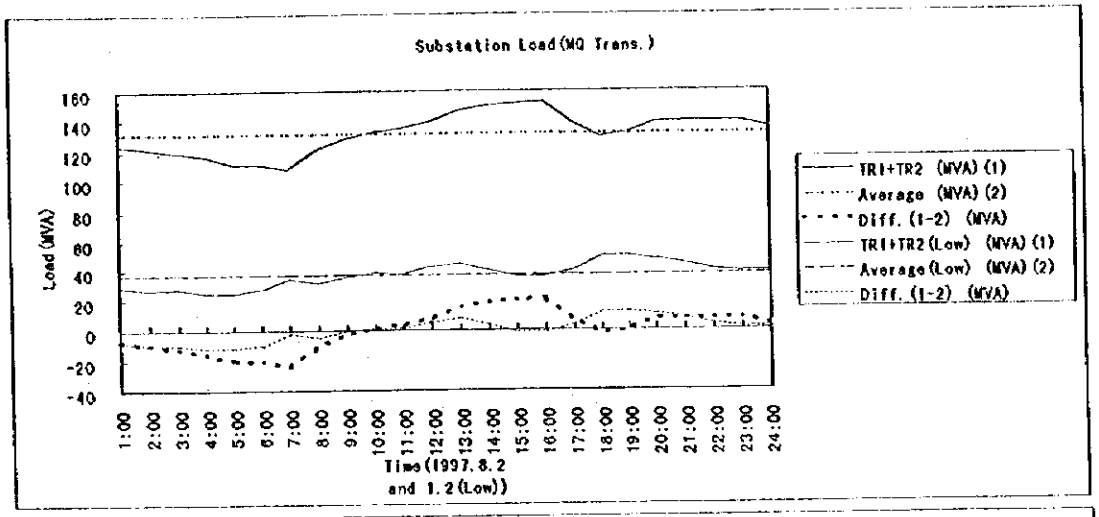
4-3-c CROSS SECTION OF POWER HOUSE

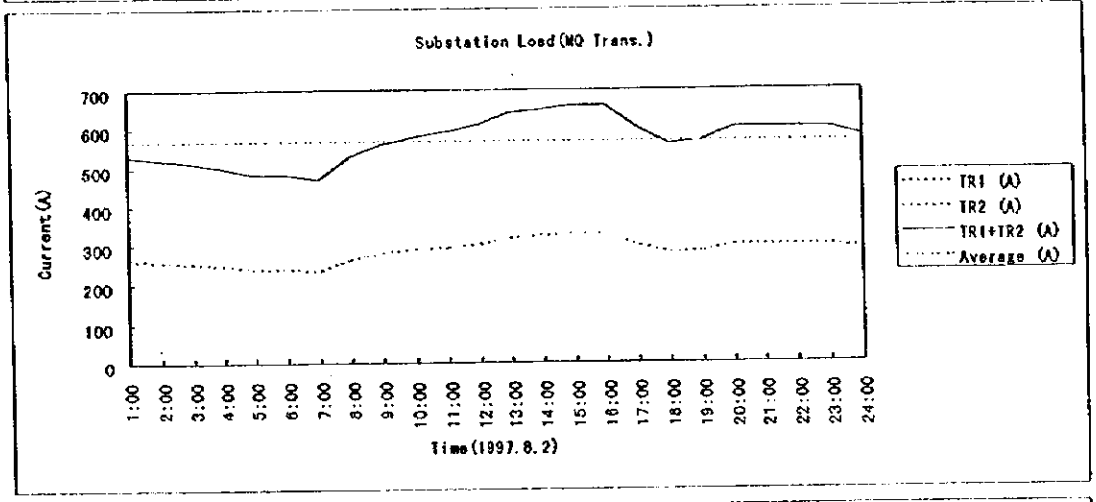


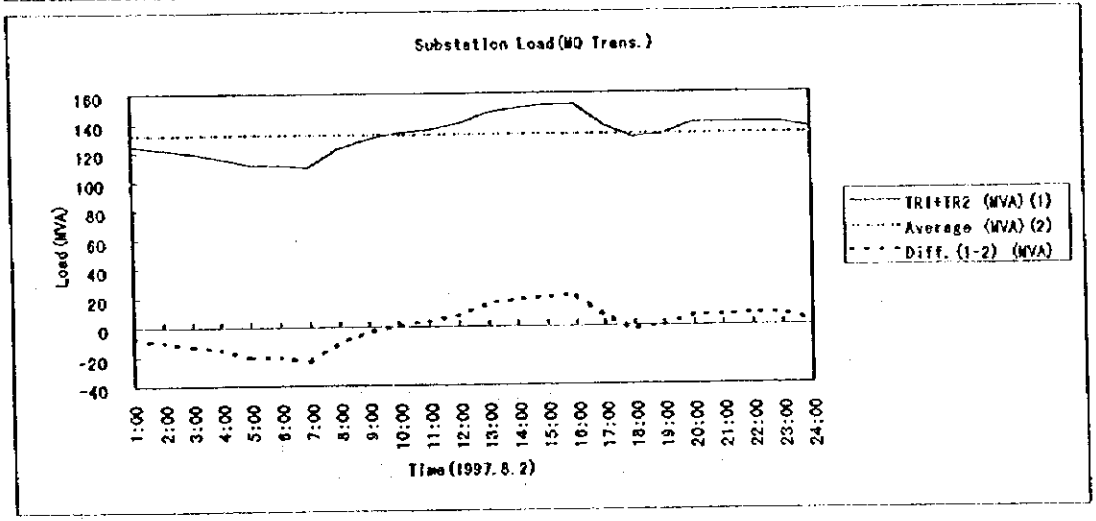




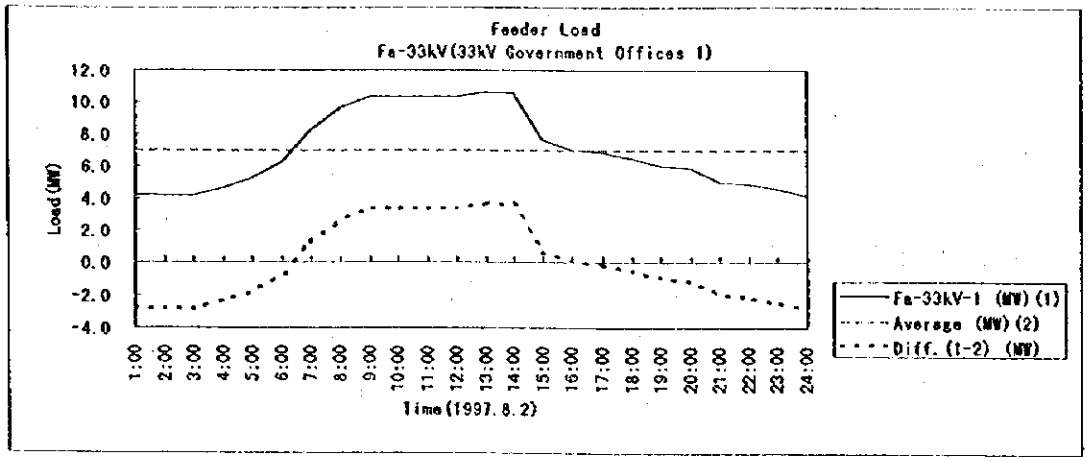
5-1-a Load Curve of Transmission Lines

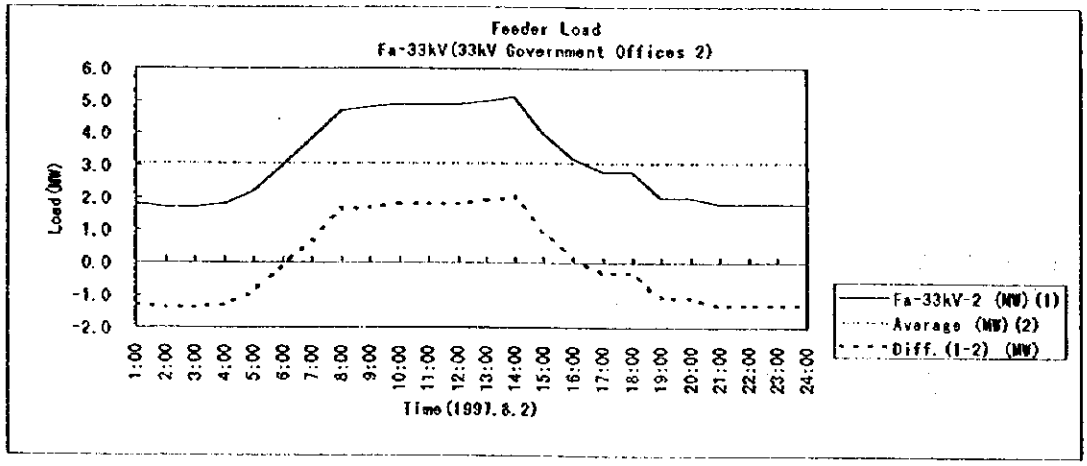


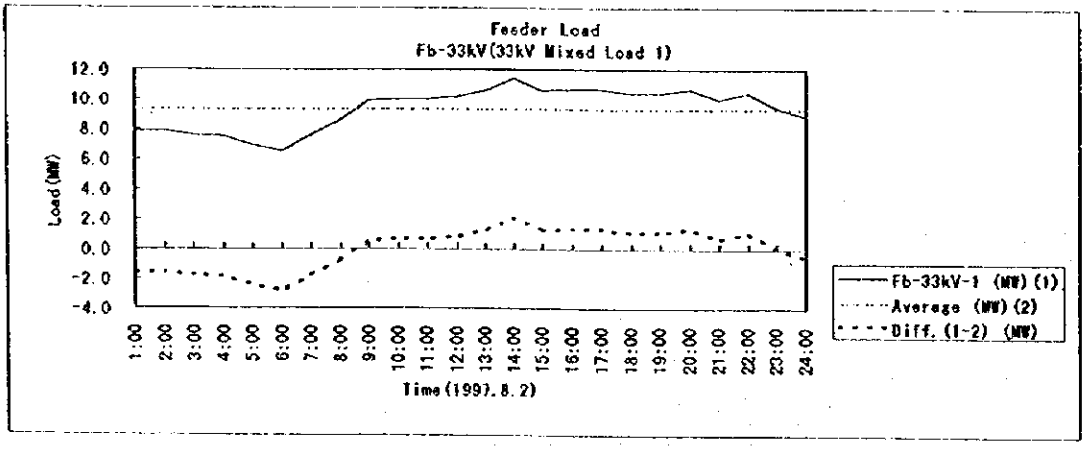




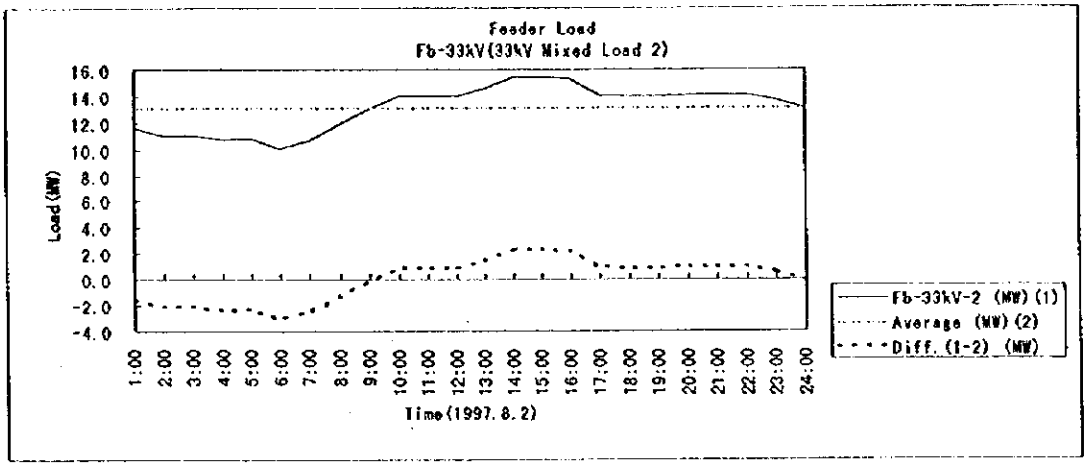
5-1-b Load Curve of Transformer

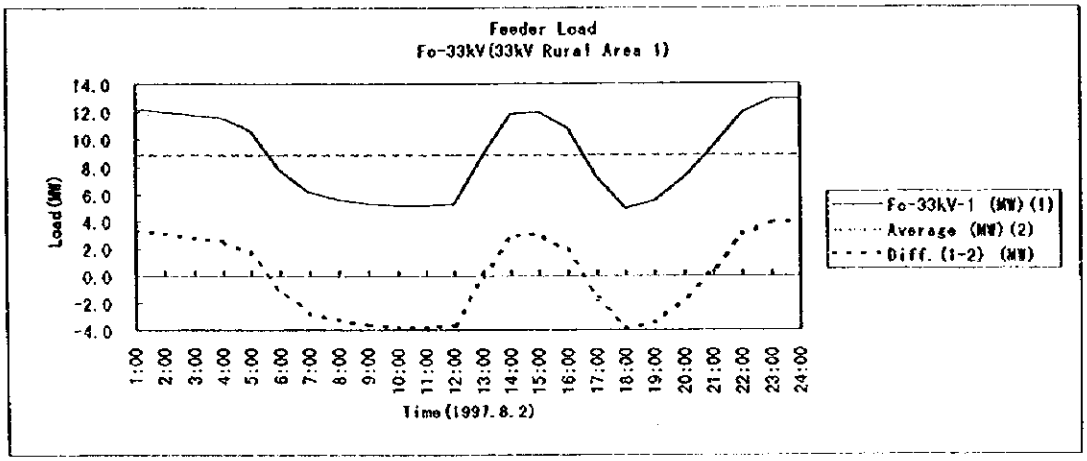


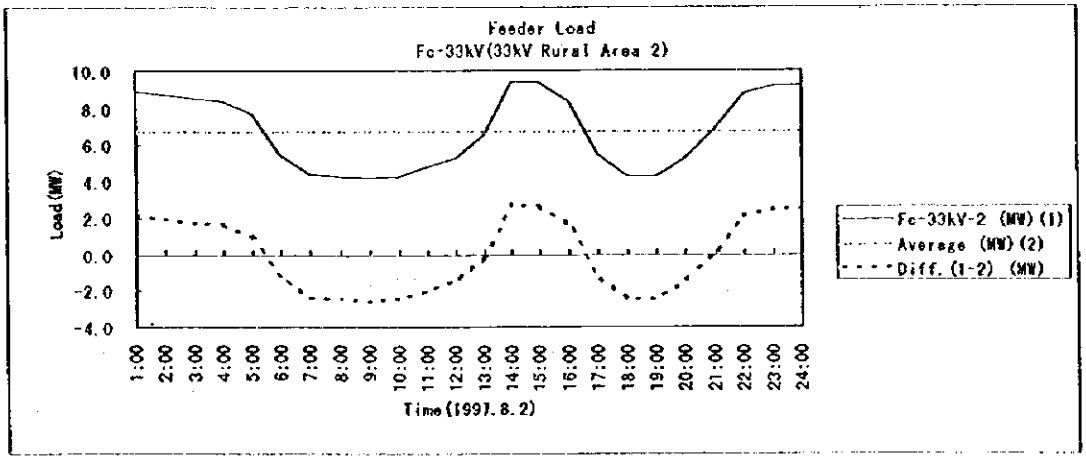




5-1-c Load Curve of 33kV Feeder







5-1-d Load Curve of 33kV Feeder

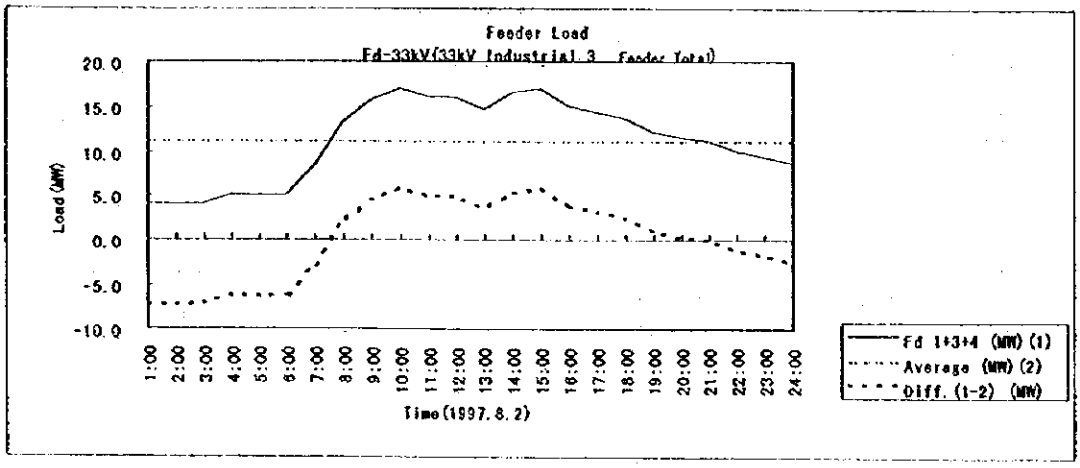
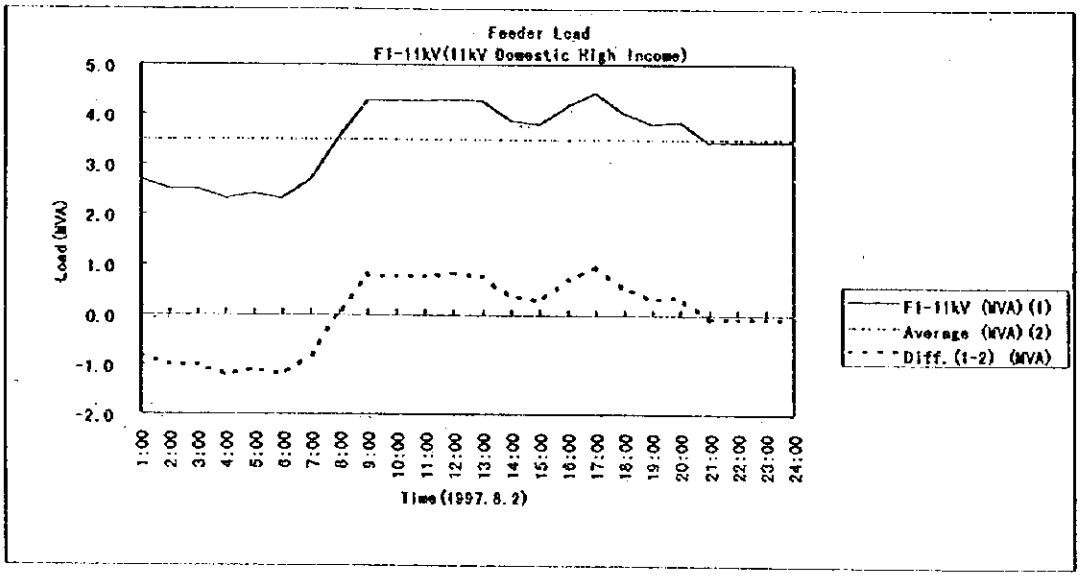
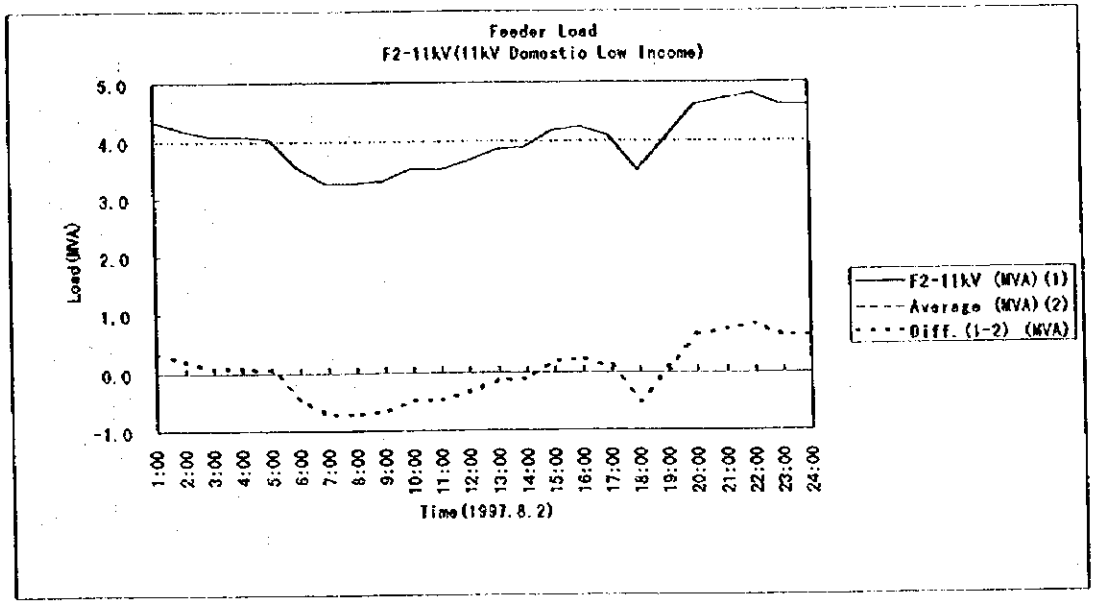
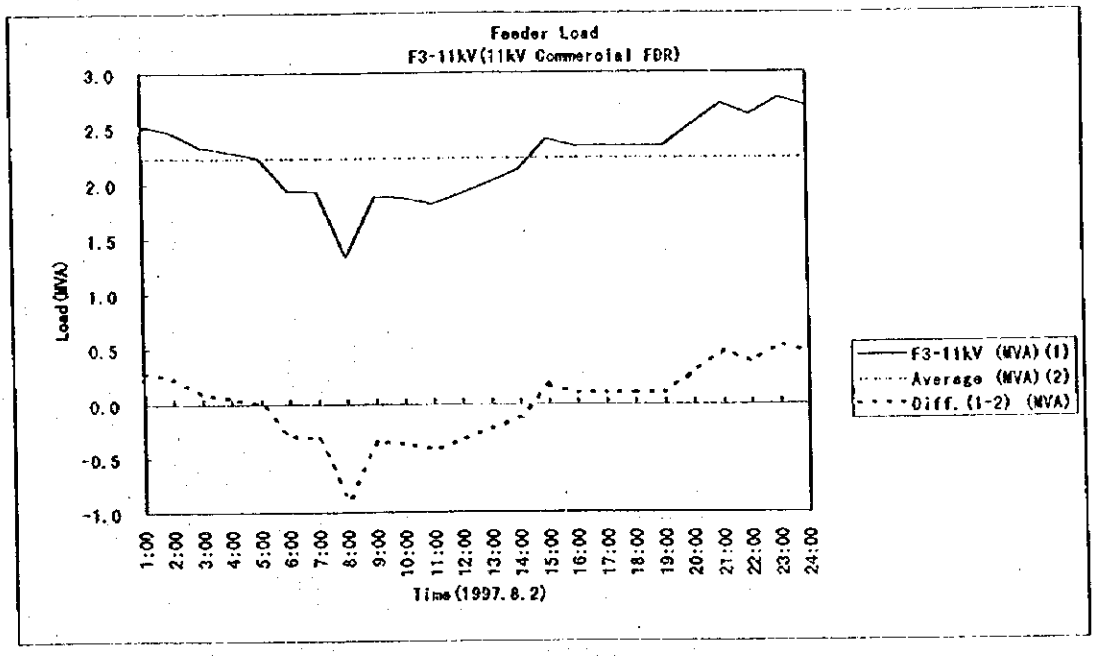


Fig.5-1-6-3 Load Curve of 33kV Feeder



5-1-e Load Curve of 11kV Feeder





5-1-f Load Curve of 11kV Feeder

5-2-a "General Weather Conditions at Muscat in Oman"

1) Monthly Average Temperature & Humidity (in Muscat) 1996

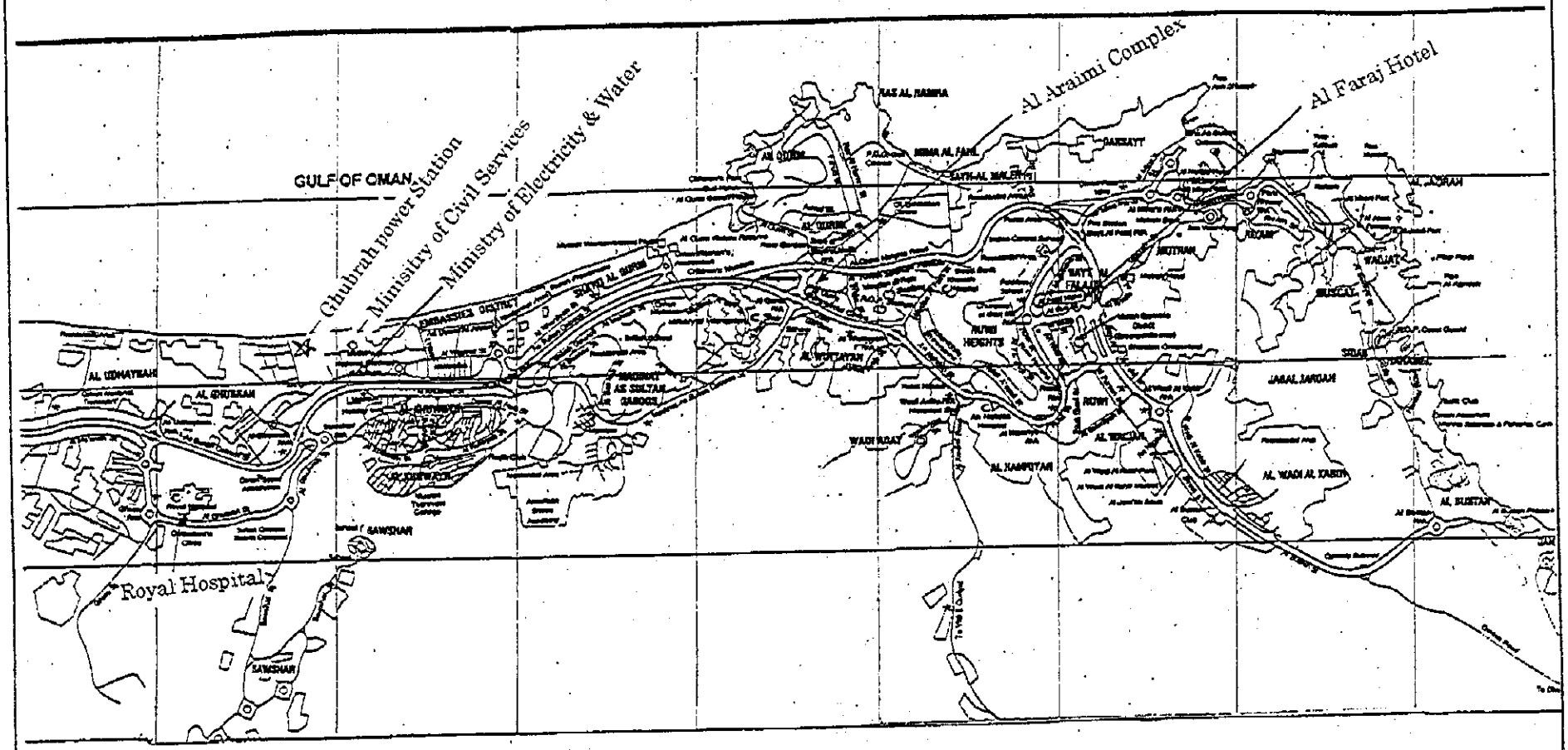
Month		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Temperature		20.4	21.7	24.4	28.8	34.1	34.4	34.6	31.2	29.7	27.5	23.6	20.6	27.6
	(Tokyo)	5.2	5.6	8.5	14.1	18.6	21.7	25.2	27.1	21.2	17.6	12.6	7.9	15.4
Humidity		64	69	69	50	41	54	54	74	70	52	57	61	59.6
(%)	(Tokyo)	50	52	56	63	66	73	76	73	73	67	61	54	63.7

2) Monthly Maximum/Minimum Temperature &Humidity (in Muscat) 1996

Month		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Temperature	[MAX]	28.5	29.1	36.5	41.5	45.2	47.8	44.1	42.1	39.8	37.5	31.5	28.4	37.7
	[MIN]	12.8	14.1	15.4	19.2	22.4	27.1	27.3	25.3	22.2	16.6	12.8	10.9	18.8
Humidity	[MAX]	96	99	97	94	89	91	100	95	94	89	89	90	93.6
(%)	[MIN]	28	34	24	11	8	8	11	24	25	4	24	22	18.6

3) Hourly Fluctuation of Temperature & Humidity in a day

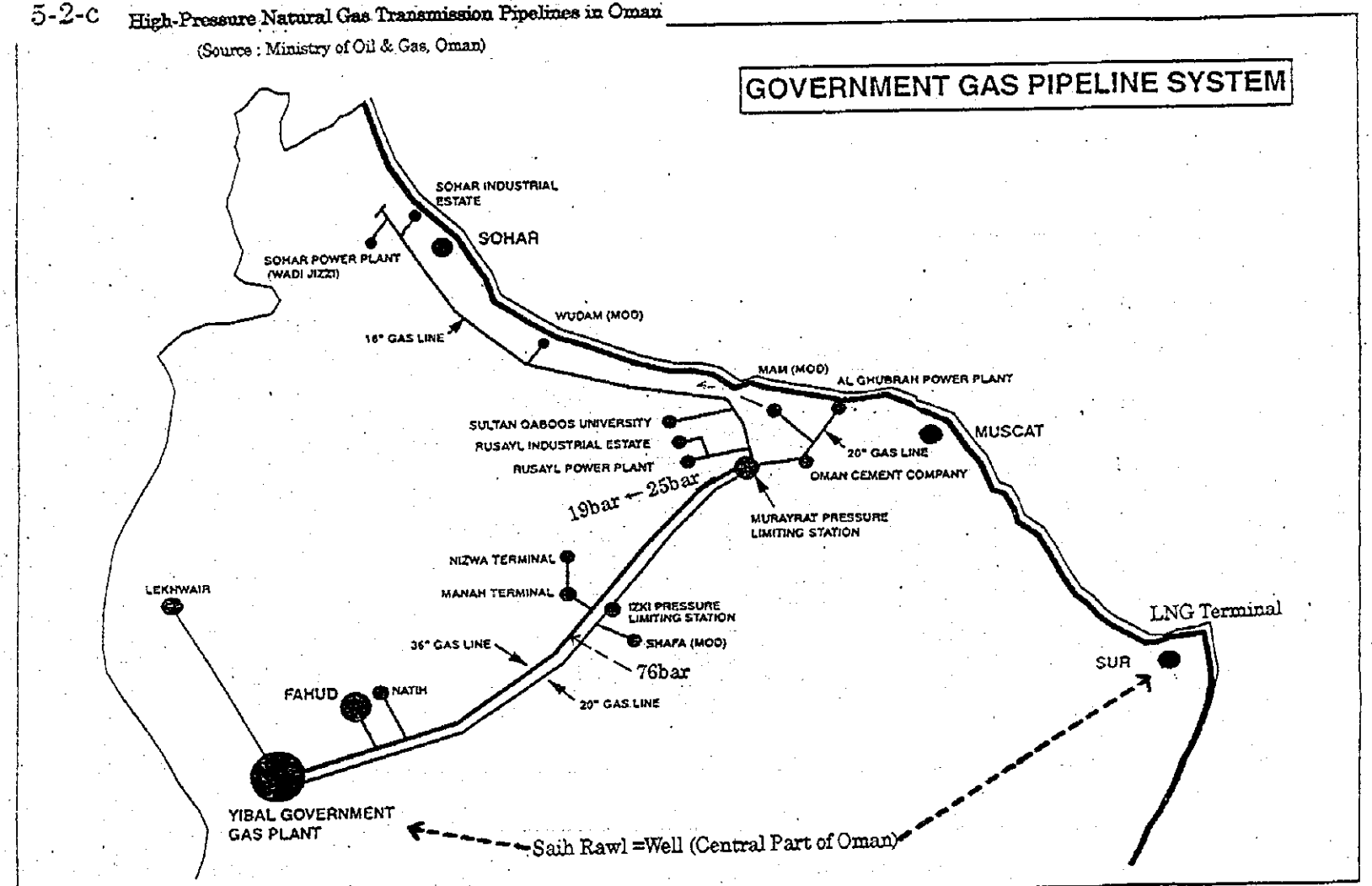
Date= Maximum 05.06.1996													
Time (o'clock)	1	2	3	4	5	6	7	8	9	10	11	12	
Temperature	37.8	37.6	38	36.9	36.6	35.9	36.4	37.5	39.3	41.2	43.8	46.9	
Humidity (%)	*18*	*21*	*31*	*35*	*35*	*37*	*38*	*35*	*31*	*25*	*17*	*7*	
Time (o'clock)	13	14	15	16	17	18	19	20	21	22	23	24	Average
Temperature	46.4	46.2	45.1	44.7	43.2	42.8	41	39.5	38.6	38.5	34.8	34.5	40.1
Humidity (%)	*10*	*9*	*10*	*11*	*12*	*10*	*12*	*14*	*15*	*14*	*20*	*35*	20.9
Date= Minimum 09.12.1996													
Time (o'clock)	1	2	3	4	5	6	7	8	9	10	11	12	
Temperature	16.1	13.9	11.7	12.7	13.1	13.1	13.2	16.6	20.5	22.6	22.7	23.3	
Humidity (%)	*42*	*48*	*54*	*54*	*52*	*53*	*52*	*41*	*34*	*32*	*40*	*41*	
Time (o'clock)	13	14	15	16	17	18	19	20	21	22	23	24	Average
Temperature	23.4	23.1	23.2	23	22.1	20.2	19.9	18.8	18.3	17.5	17.2	16.4	18.4
Humidity (%)	*41*	*42*	*41*	*46*	*49*	*53*	*56*	*58*	*61*	*65*	*66*	*68*	49.5



5-2-b Location of the Buildings/Facilities in Capital Area Muscat, Oman

5-2-c High-Pressure Natural Gas Transmission Pipelines in Oman

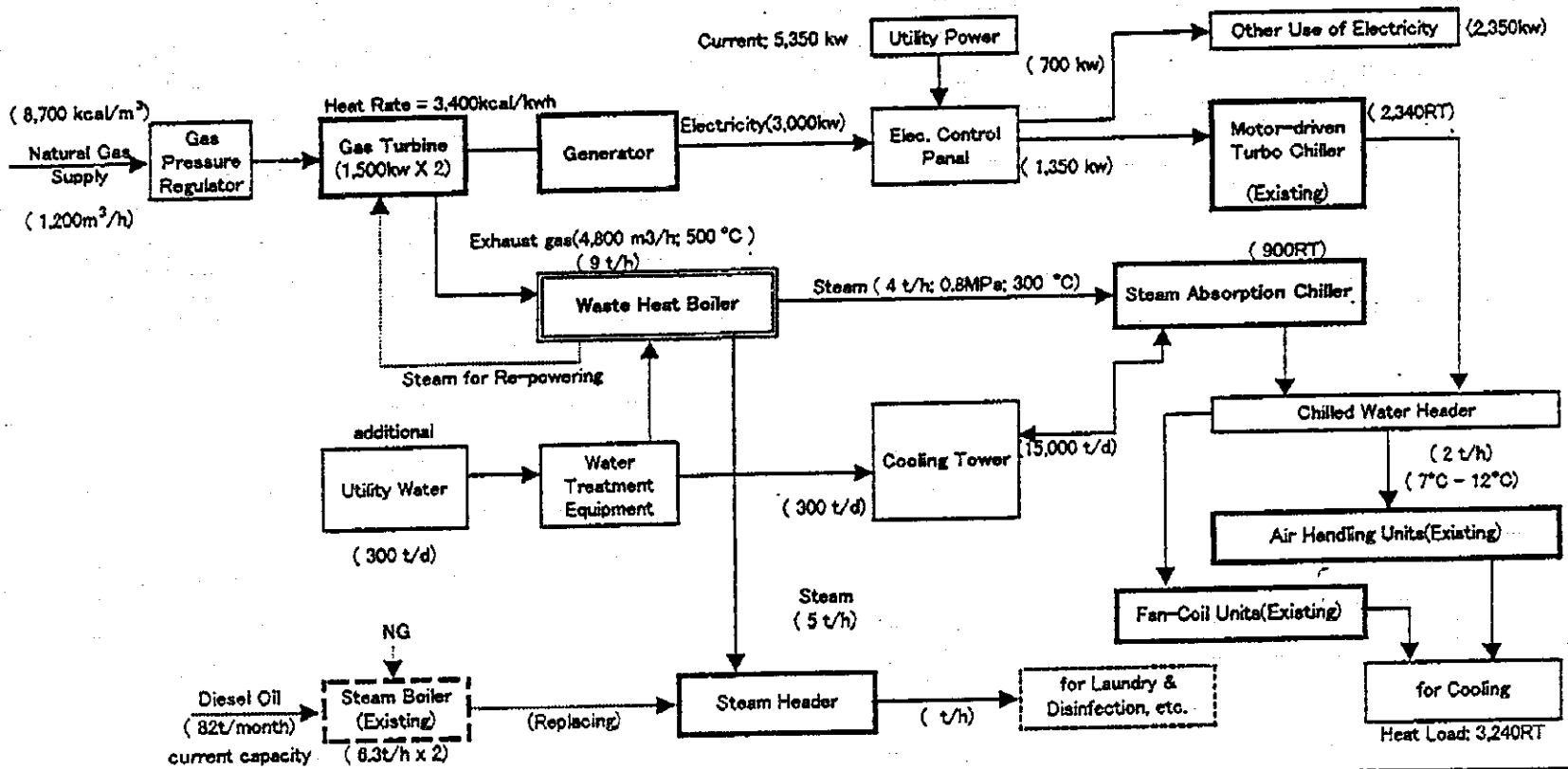
(Source : Ministry of Oil & Gas, Oman)



5-2-d

Schematic Diagram of Proposed Cooling System using NG for Royal Hospital

(Case Study 1: Co-Ganeration System with Gas Turbines embodying Absorption Chillers)



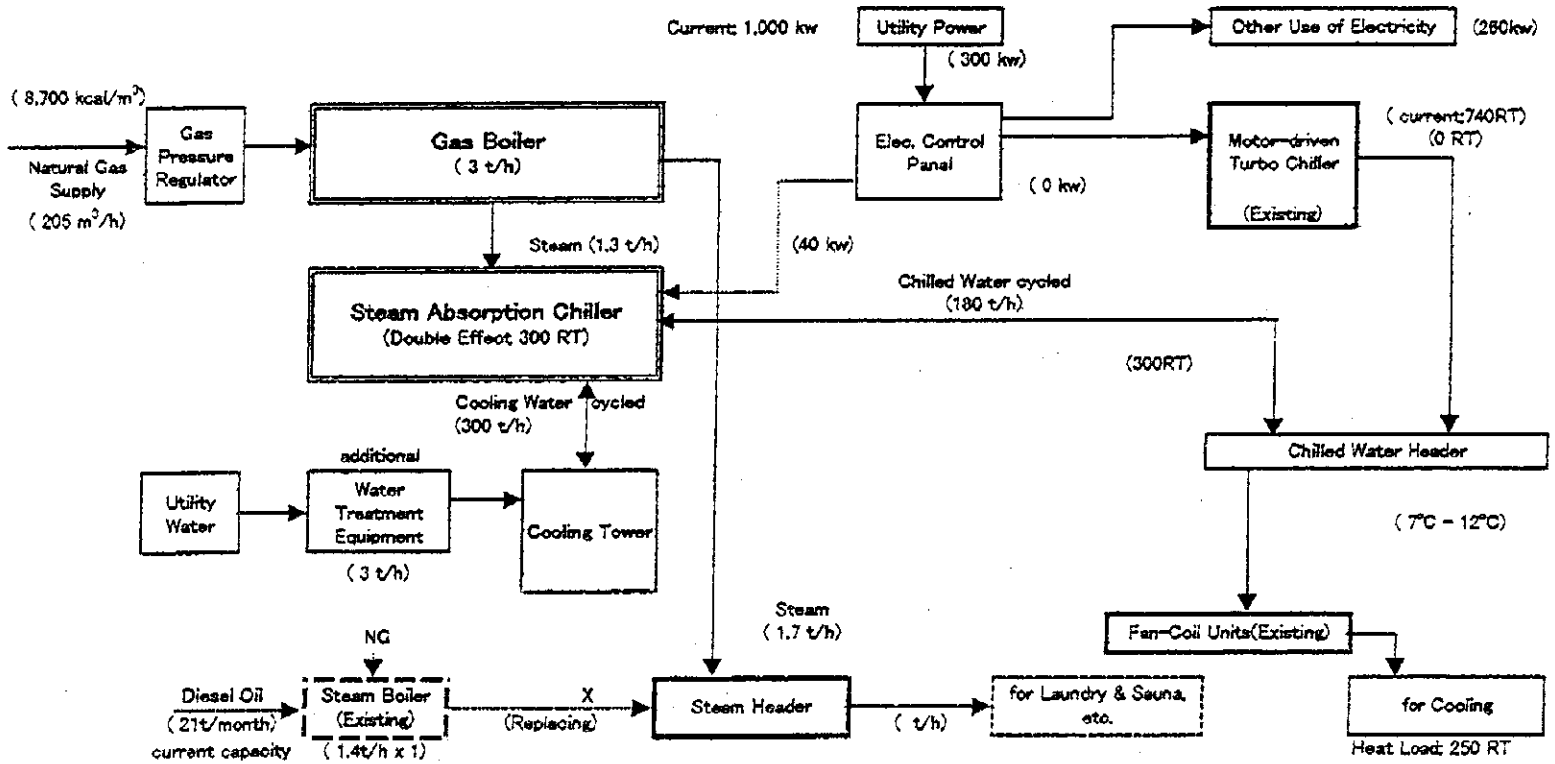
Note:
(1) Overall Heat Load of Cooling System for the Building = 3,240 RT; and about 900Rt of it can be complemented by the absorption chiller.
(2) Necessary Capacity of the Motor-driven Turbo Chiller,if for all with it, = approximately 4,000 kw, supposing its COP = 3.0 , and 0.7kw/RT.
(3) Necessary Capacity of Waste Heat Boiler is about 3t/h for 1,000kw turbine
(4) Necessary additional Water for Cooling tower of the Absorption Chiller will be about 10,000t/month.
(5) Existing Steam Boiler can be replaced by the waste heat boiler.
(6) Existing Emergency power supply generator can be replaced by this co-generation/utility power.

Recommended Co-Generation System for Royal Hospital

5-2-e

Schematic Diagram of Proposed Gas Cooling System using NG for Al Falaj Hotel

(Case Study AF(1): Gas-fired Steam Absorption Chiller System for Whole Cooling)



Note:

(1) Overall Heat Loed of Cooling System for the Building = 300 RT; and all the cooling load (300Rt) can be performed by the gas steam absorption chiller. Some units of electric turbo chillers shall be used in an emergency.
(2) Necessary Capacity of the Motor-driven Turbo Chiller,if for all with it, is supposed to be approximately 375 kw, supposing its COP = 3.0 , but currently equiped with 660 kw showing over-spec.
(3) Necessary Capacity of Gas Boilers is about 3 t/h for generating Steam
(4) Necessary additional Water for Cooling tower of the Absorption Chiller will be about 1,990t/month.
(5) Existing Steam Boiler can be replaced by the Gas boiler (both for Absorption Chillers & for Laundry/Sauna).

5-3-a Peak Cut Operation Mode -Royal Hospital

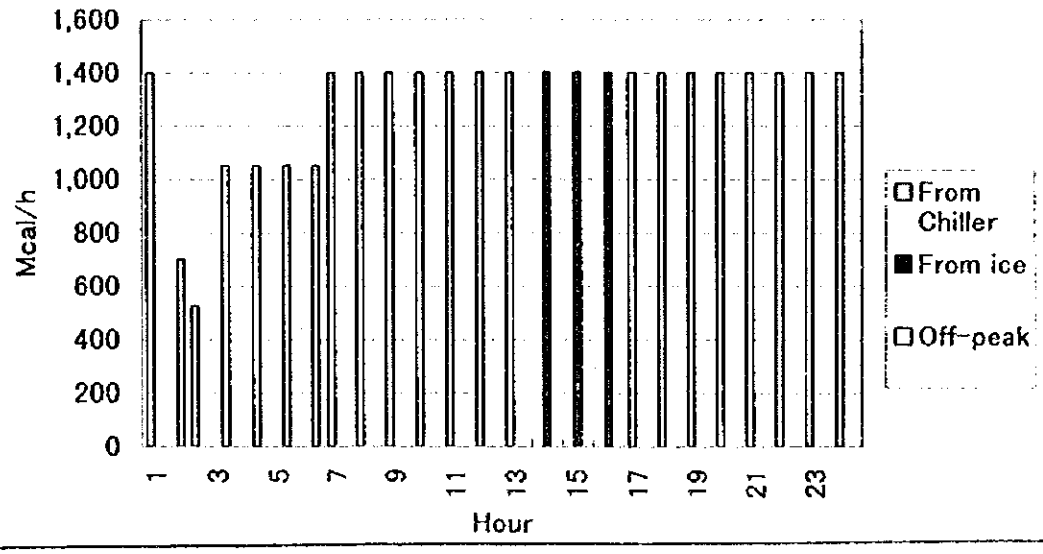
(Case 1)

2x 270RTx 3,024 Kcal/h = 1,633 Mcal/h
A/C presumed load factor=0.85

Unit: Mcal/h

	A/C operation mode			Ice stored mode
Hour	From Chiller	From ice	Total	Off-peak
1	1,400	0	1,400	0
2	700	0	700	525
3	0	0	0	1,050
4	0	0	0	1,050
5	0	0	0	1,050
6	0	0	0	1,050
7	1,400	0	1,400	0
8	1,400	0	1,400	0
9	1,400	0	1,400	0
10	1,400	0	1,400	0
11	1,400	0	1,400	0
12	1,400	0	1,400	0
13	1,400	0	1,400	0
14	0	1,400	1,400	0
15	0	1,400	1,400	0
16	0	1,400	1,400	0
17	1,400	0	1,400	0
18	1,400	0	1,400	0
19	1,400	0	1,400	0
20	1,400	0	1,400	0
21	1,400	0	1,400	0
22	1,400	0	1,400	0
23	1,400	0	1,400	0
24	1,400	0	1,400	0
Total	23,100	4,200	27,300	4,725

Operation Mode-Royal Hospital



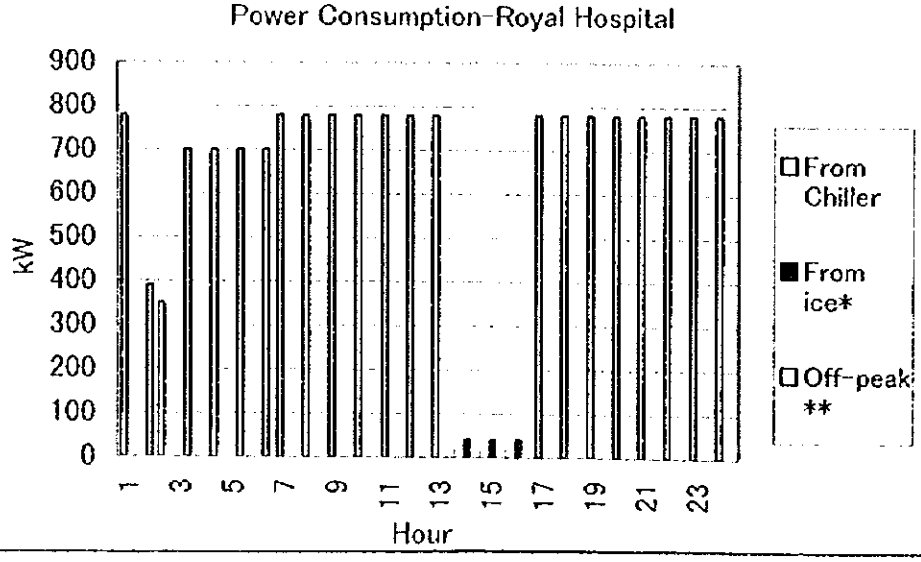
5-3-b Power Consumption by Peak Cut Operation-Royal Hospital (Case 1)

2x270RTx 3,024 Kcal/RT = 1,633 Mcal/h
A/C load factor = 0.85

Unit: kW

	A/C operation mode			Ice stored mode	Power Consumption
Hour	From Chiller	From ice*	Sub-Total	Off-peak **	Total
1	780	0	780	0	780
2	390	0	390	350	740
3	0	0	0	700	700
4	0	0	0	700	700
5	0	0	0	700	700
6	0	0	0	700	700
7	780	0	780	0	780
8	780	0	780	0	780
9	780	0	780	0	780
10	780	0	780	0	780
11	780	0	780	0	780
12	780	0	780	0	780
13	780	0	780	0	780
14	0	40	40	0	40
15	0	40	40	0	40
16	0	40	40	0	40
17	780	0	780	0	780
18	780	0	780	0	780
19	780	0	780	0	780
20	780	0	780	0	780
21	780	0	780	0	780
22	780	0	780	0	780
23	780	0	780	0	780
24	780	0	780	0	780
Total	12,870	120	12,990	3,150	16,140

*included brine circulating pump of 40kW ** included brine pump of 53kW



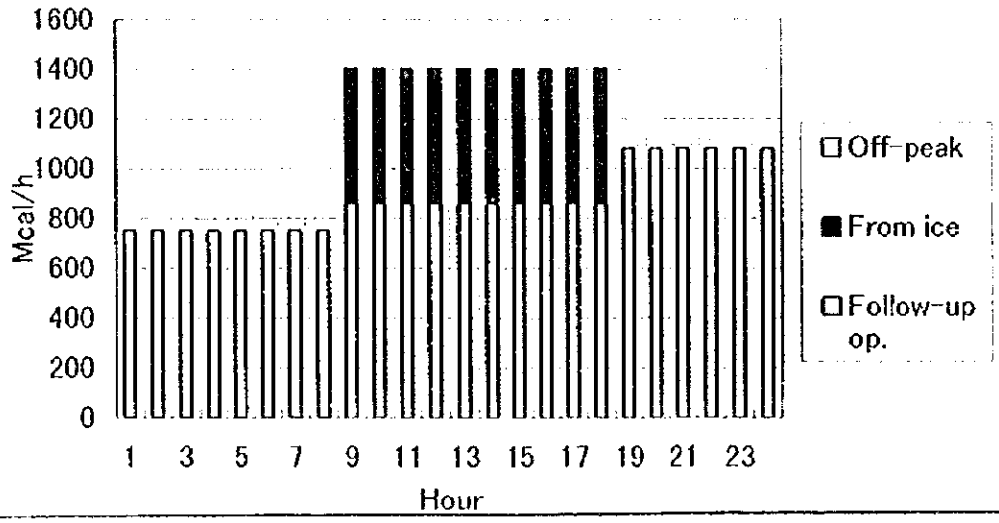
5-3-c Load Leveling Operation Mode(8Hour Ice Making)-Royal Hospital (Case 2)

2x 270RTx 3,024 Kcal/h = 1,633 Mcal/h
A/C presumed load factor=0.85 Capacity of chiller: 70%(5x120HP)

Unit: Mcal/h

	A/C operation mode			Ice stored mode
Hour	Follow-up op.	From ice	Total	Off-peak
1	0	0	0	750
2	0	0	0	750
3	0	0	0	750
4	0	0	0	750
5	0	0	0	750
6	0	0	0	750
7	0	0	0	750
8	0	0	0	750
9	860	540	1,400	0
10	860	540	1,400	0
11	860	540	1,400	0
12	860	540	1,400	0
13	860	540	1,400	0
14	860	540	1,400	0
15	860	540	1,400	0
16	860	540	1,400	0
17	860	540	1,400	0
18	860	540	1,400	0
19	1,080	0	1,080	0
20	1,080	0	1,080	0
21	1,080	0	1,080	0
22	1,080	0	1,080	0
23	1,080	0	1,080	0
24	1,080	0	1,080	0
Total	15,080	5,400	20,480	6,000

Operation Mode-Royal Hospital



5-3-d Power Consumption by Load Leveling Operation -Royal Hospital

(Case 2) Chiller capacity of 70%(5x120TP)

2x270RTx 3,024 Kcal/RT = 1,633 Mcal/h
A/C load factor = 0.85

Unit: kW

	A/C operation mode			Ice stored mode	Power Consumption
Hour	From Chiller	From ice*	Sub-Total	Off-peak **	Total
1	0	0	0	500	500
2	0	0	0	500	500
3	0	0	0	500	500
4	0	0	0	500	500
5	0	0	0	500	500
6	0	0	0	500	500
7	0	0	0	500	500
8	0	0	0	500	500
9	480	30	510	0	510
10	480	30	510	0	510
11	480	30	510	0	510
12	480	30	510	0	510
13	480	30	510	0	510
14	480	30	510	0	510
15	480	30	510	0	510
16	480	30	510	0	510
17	480	30	510	0	510
18	480	30	510	0	510
19	600	0	600	0	600
20	600	0	600	0	600
21	600	0	600	0	600
22	600	0	600	0	600
23	600	0	600	0	600
24	600	0	600	0	600
Total	8,400	300	8,700	4,000	12,700

*included brine circulating pump of 30 ** included brine pump of 38kW

Power Comsumption-Royal Hospital