2-2 Electric Power Situation in Pakistan

2-2-1 History

In 1948, electric power plants in Pakistan produced 110,400 kW in all, of which 76,400 kW, about 70%, came from electric utilities and 34,000 kW, about 30%, from independent power plants of industry.

The ratio of electric utilities in east and west at that time was, West Pakistan 91% and East Pakistan only 9%.

Directly after independence, the Pakistani Government started to plan to build new electric power plants because of electric power shortages in northern Pakistan. In the Punjab province, the construction of the Rasul Hydro Power Plant (22 MW) was speeded up and completed in 1955. A Thermal Power Plant (8 MW) was also constructed in Lyallpur. In the N.W.F. province, the Jabban Hydro Power Plant (10 MW) was expanded and the Daragai Hydro Power Plant (20 MW) was constructed. In Ahmedpur, Rahimyarkhan, Khanpur, Chistian Mandi and Bahawalnager in Bahawalpur Province, small diesel power plants were expanded from 200 kW to 650 kW.

In 1956, the Pakistan Government strongly felt the necessity to form and equip an electric system of each region on a national basis. In February, 1958, under the Federal Ordinance, the Electricity Department of each region and province was unified and in April, 1958, the West Pakistan Water and Power Development Authority (the predecessor of WAPDA) was founded as a special corporation to effectively use water resources for irrigation, flood control and sailing, and to develop electricity sources and operate electricity supplying enterprises.

In 1960, the Warsak Hydro Power Plant (40 MW x 2) and the Multan Thermal Power Plant (65 MW x 2) were completed, and in the same period a 740 km long, 132 kV, 2 circuit power line was connected between Warsak and Lyallpur and electricity was sent to large substations in Peshawar, Wah, Rawalpindi, Gujranwala, K.S. Kaku, Kot Lakhat, Lyallpur, Laudwala and Daudkhel. This new 132 kV power line was also connected at the Multan hydro-power plant to the 220 kV power line between Multan and Lyallpur. By 1967, the Mangla Hydro Power Plant (200 MW, final output 1,000 MW) and the Multan Thermal Power Plant (65 MW) were expanded. The Faisalabad thermal power plant (66 MW x 2) was constructed and a 220 kV, 2 circuit power line was connected between Mangla and Kot Lakhpat, and K.S. Kaku and Lyallpur.

With the development of industry, agriculture and commerce, and progress of social economic conditions, Pakistan's electric power system developed and expanded to Upper Sind, Lower Sind and Quetta regions in the north and with the 132 kV power line network it came to be connected to the Karachi Electric Supply Corporation (KESC) power line network. During that time, large scaled power plants like the Tarbela hydro power plant (total output 1,750 MW), Mangla hydro power plant (total output 800 MW), Warsak hydro power plant (total output 240 MW), Guddu thermal power plant (430 MW), the Faisalabad gas steam turbine power plant (total output 332 MW), the Multan thermal power plant (steam, turbine) total output 265.7 MW, the Korti gas turbine power plant (total output 130 MW) and the Korangi thermal power plant (steam, gas turbine) total output 462 MW, were built.

2-2-2 Structure of Electric Utilities

The two large electric utilities in Pakistan are WAPDA (Pakistan Water and Power Development Authority) and KESC (Karachi Electric Supply Corporation).

WAPDA conducts electricity services (construction of power plants, transmission lines, substations, distribution lines, electricity generation, electric supply, electricity transformation and building, and operation and maintenance of electric power supply facilities) and also services concerning irrigation, sewerage, waterworks and flood control.

KESC is privately owned but the government covers more than half of its investment so it has more or less the characteristics of a publicly owned corporation. KESC supplies electricity only to the Karachi area and the rest is supplied by WAPDA.

Supervising these electric utilities is the Ministry of Water and Power in Islamabad (MOWP).

Pakistan, as of December, 1985, has an electricity generating ability of 5,477 MW, with WAPDA 4,339 MW (79%) and KESC 1,138 MW (21%). WAPDA's facilities are hydro power 2,897 MW and thermal (including gas turbine) 1,442 MW.

The organization of MWP, WAPDA and KESC is shown in Fig. 2.1-3, respectively.

Fig. 2.1 MINISTRY OF WATER AND POWER

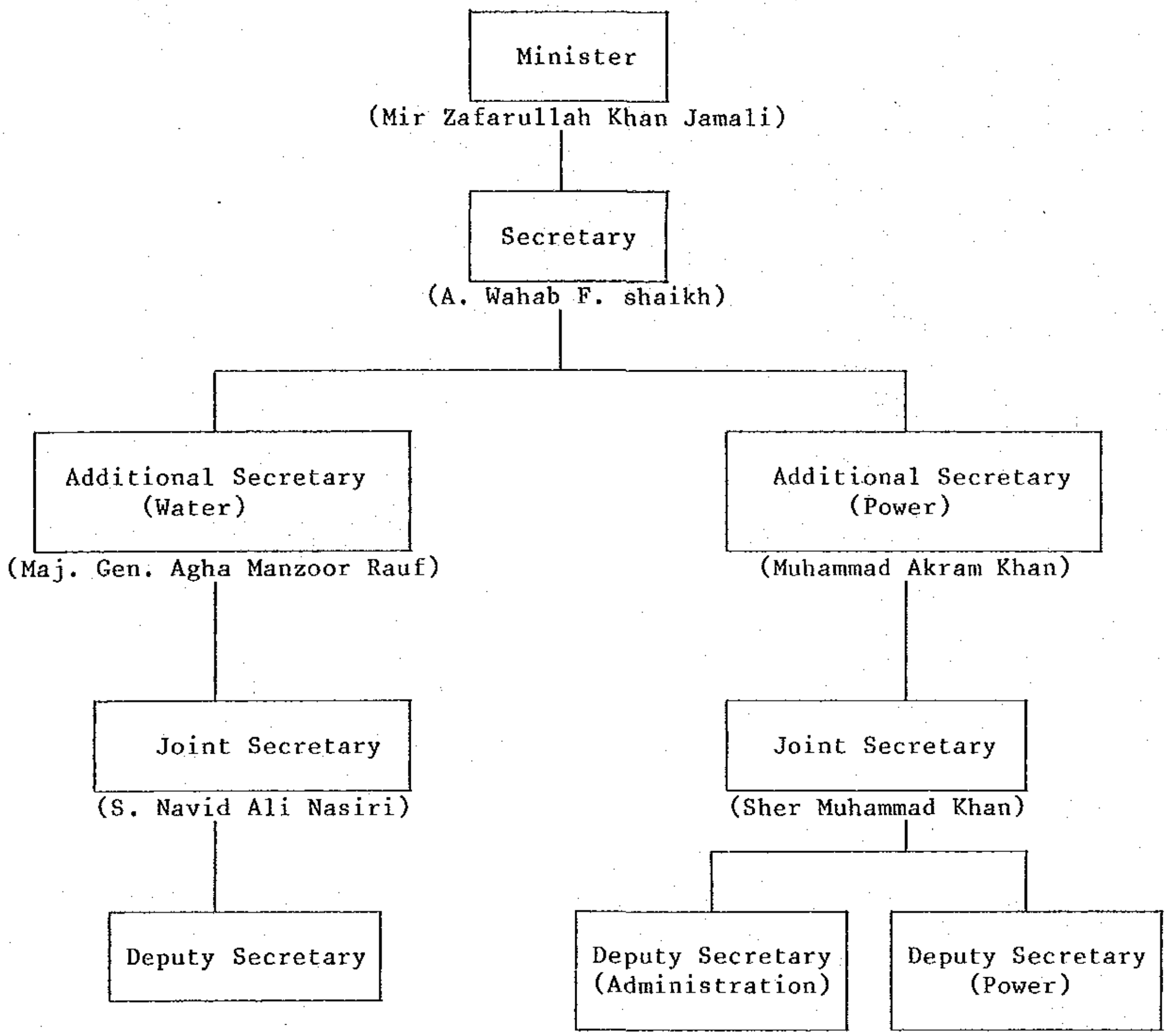


Fig. 2.2 ORGANIZATION CHART OF WAPDA

CHAIRMAN
Lt. -Gen. Dr. G.S. Butt
- Member (Finance)
  A.F. Serajul Haque
- Member (Power)
  M. Ayub Sadozai
- Member (Water)
  Asif H. Kazi

POWER WING

- Dy. M.D. (Distribution)
- Actg. G.M. (Coordination)
  A. Hafeez Ibrahim
- G.M. (Distribution)
  Rja Saeed Akhtar
- G.M. (Finance)
  Muhammad Rafiq
- G.M. (Hydel)
  M. Waseem Khan
- G.M. (Inventory Control)
  \- - - - -
- G.M. (Thermal)
  Khawaja Daood
- G.M. (Transmission & Grid Station)
  Javid Akhtar
- C.E. (Planning)
  S.M. Arshad/Badar-UD-Din
- D.G. (Training)
  A. Rehmatullah

Deputy General Manager, Inventory Control (T & G)
Chief Engineer, Headquarters T & G
Chief Engineer, (Civil) T/L and Grid Stations
Chief Engineer, Design, T & G
Chief Engineer, Extra High Voltage
Chief Engineer, 500 kV Transmission Lines
Chief Engineer, Grid System Construction (North)
Chief Engineer, Grid System Construction (South)
Chief Engineer, Grid System Operation, Islamabad
Chief Engineer, Grid System Operation, (North)
Chief Engineer, Grid System Operation, (South)
Chief Engineer, Secondary Transmission Grid Stations
Chief Engineer, Technical Services Group
Chief Engineer, Manager Finance (T & G)

WATER WING

- G.M. (Central)
  Brig. Khurshid Ghias Khan
- G.M. (Drams & Coordination)
  Sh. Maqsood Ali
- G.M. (Kalabagh Dam)
  Muhammad Hussain Chaudhry
- G.M. (North)
  Karim Khan
- G.M. (Planning)
  M. Badruddin
- G.M. (South)
  S. Mukarrum Ali
- G.M. (Tarbela)
  Muhammad Ashraf
- C.E. (Central Design Office)
  M. Aslam Qureshi
- Manager Finance (Water)
  M.Y. Khan

FINANCE & ADMINISTRATION

- M.F. (Coordination)
  Saeed Ahmad
- Chief Auditor
  Tajammal Hussain
- Principal Tarbela Academy
  M. Haziq Siddiqui
- D.G. (Wapda Audit)
  Aia-ul-Haq Khan ... on behalf of Government of Pakistan

AUTHORITY'S SECRETARIAT

- D.G. (Public Relations), Raziuddin Shaikh
- C.E. (Central Contracts Cell), S.M. Kazim
- D.G. (Computer Centre), Miss Mussarat-Abdullah
- Secretary, Col. Idrees Mohsin

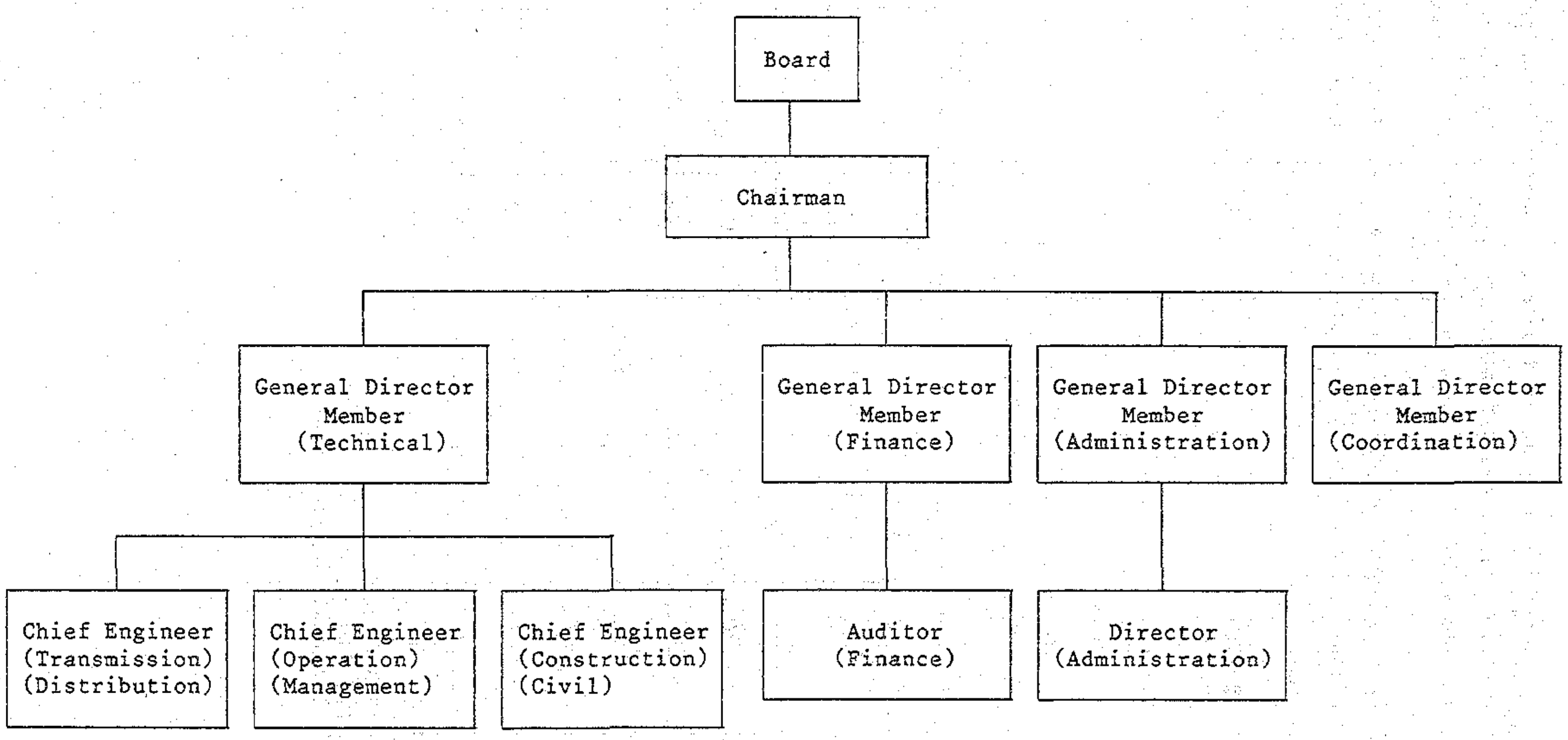
SERVICES & GENERAL ADMINISTRATION

- G.M. (Administration), Brig. (Retd) Asadullah Khan
- D.G. (Organisation & Methods), Sh. Abdul Hamid
- D.G. (Medical Services),Brig.(Retd) Agha TARIQ Ahmad Khan

Staff of Power Wing (WAPDA) FY 1984

Engineers	2,635
Agronomists, Economists, Statisticians, Soil Chemists, Geologists, Medical Staff etc.	88
Engineering supporting staff, etc.	8,144
Administration, Audit and Accounts, Supporting staff etc.	19,349
Skilled workers.	57,091
Unskilled workers.	6,303
Peons, Security guards, Stationary clerks Sweepers, Gardeners etc.	13,385
Miscellaneous	4,210
Total	111,205

Fig. 2.3 Organization of KESC



2-2-3 Present State and Future Plans of Electric Power Facilities

Pakistan's electric utilities as mentioned before, consist of the two large agencies (WAPDA and KESC), PAEC (Pakistan Atomic Energy Commission) and self supplying enterprises.

The outline and future plans for Pakistan's electric power facilities constructed by the end of December 1985 are summarized in the following figures and tables.

Table 2.4 GROWTH OF GENERATING FACILITIES

(MW)

Name / Year	WAPDA			KESC	Total
	Hydro	Thermal	Sub-total	Thermal	
1979/80	1,567	1,125	2,692	673	3,365
80/81	1,747	1,385	3,132	673	3,805
81/82	1,847	1,407	3,254	673	3,927
1983-3/31	2,547	1,441.4	3,988.6	673	4,661.6
82/83	2,547	1,407	3,954	810	4,764
83/84	2,547	1,407	3,954	1,020	4,974
84/85	2,897	1,442	4,339	1,138	5,477

Source: Energy Year Book 1983
WAPDA Annual Report 1984-85
KESC Annual Report 1982-6

Table 2.5 OUTLINE OF EXISTING MAJOR POWER PLANTS

(1) (Hydro - WAPDA)

(As of the end of December, 1985)

Name of Power Plant	Installed Capacity (MW)	No. x MW	Completion Date and Remarks
Tarbela (1-10 Unit)	1,750	10x175	No.1, No.2 1977-5 No.3 1977-6 No.4 1977-7 No.5 1977-8 No.6 1982-9 No.7 1982-11 No.8 1982-12 No.9 1985 No.10 1985
Mangla (1-8 Unit)	800	8x100	No.1, No.2 1967-6 No.3, No.4 No.5, No.6 1974-4 No.7 1981-5 No.8 1981-8
Warsak (1-6 Unit)	240	6x40	No.1,2,3,4 1960 No.5, No.6 1981-1
Rusul	22	2x11	1951
Malakand	19.6	3x3.2 2x5	1938 1951
Dargai	20	4x5	1954
Nandipur	13.8	3x4.6	1963
Chichoki	13.8	3x4.6	1959
Shadiwal	13.5	2x6.75	1961
Kurram Gorhi	4	1x4	1958
Renala	1.1	5x0.22	1925

(2) (Thermal - WAPDA.KESC)

Name of Power Plant	Installed Capacity (MW)	No. x MW	Completion Date and Remarks
Multan (Steam) " (Gas)	260 5.7	4x65 1x5.7	(WAPDA)
Guddu (Steam)	220 210	2x110 1x210	No.1, No.2 (WAPDA) No.3 1980-11
Faisalabad (Steam) (Gas)	132 200	2x66 8x25	(WAPDA)
Shahdara (Gas)	85	2x13.25 4x14.75	(WAPDA)
Sukkur (Steam)	50	4x12.5	(WAPDA)
Quetta (Steam) (Gas)	15 48	* 2x7.5 1x7.0 1x16 1x25	* Coal-fired thermal Power Plant (WAPDA)
Hydrerabad (Steam) (Gas)	15 28	2x7.5 1x5, 1x8 1x15	(WAPDA)
Korti (Gas)	130	2x15 4x25	No.3, No.4 1978/1979 (WAPDA) No.5, No.6 1981-4
Korangi (Steam) No.1, No.2 (Steam) No.3, No.4 (Gas)	132 250 60	2x66 2x125 3x20	1965 (KESC) No.3-1970, No.4-1977 1978
West Wharf A (Gas) B (Gas) B (Gas)	13 30 66	1x3.0 3x5.0 2x15 2x33	(KESC) 1956 1962
Dual Fuel Site Gas Turbine	15 100	10x1.5 5x20	1960 (KESC) 1979 (KESC)

Tab.e 2.6 EXPANSION PROGRAM OF POWER PLANT

Estimated Completion Date	Output (MW)	Name of Power Plant
1986/ 1	75	Guddu (Gas No.1)
1986/ 2	75	" (Gas No.2)
1986/ 3	75	" (Gas No.3)
1986/ 4	75	" (Gas No.4)
1986/11	200	Kot Addu (Gas No.1 & 3)
1987/ 7	75	Guddu combined cycle (Steam No.5)
1987/10	75	" (Steam No.6)
1987/10	210	Guddu (Steam No.4)
1987/11	200	Kot Addu (Gas No.2 & 4)
1988/ 4	400	Kot Addu (Gas No.5-8)
1988/12	210	KESC (Steam No.D-3)
1988/12	250	Jamshoro (Oil No.1)
1989/ 7	35	Mini-hydro (No.1)
1989/ 8	432	Tarbela (Hydro No.11)
1989/ 9	200	Mangla (Hydro No.9 & 10)
1989/12	432	Tarbela (Hydro No.12)
1989/12	210	Jamshoro (Oil No.2)
1989/12	210	KESC (Steam No.D-4)
1990/ 3	200	Kot Addu combined cycle (Steam No. 9 & 10)
1990/ 3	100	Faisalabad combined cycle (Steam No.9-12)
1990/ 5	432	Tarbela (Hydro No.13)
1990/ 8	432	" (" No.14)
1990/ 9	210	Multan Ext. (No.1)
1990/12	210	KESC (Steam No.D-5)

Table 2.7 EXISTING TRANSMISSION AND DISTRIBUTION FACILITIES

(km)

Year	500 kV	220 kV	132 kV	66 kV	Total
1980	849	1,219	6,666	6,560	5,294
1981	849	1,224	7,054	6,845	15,972
1982	849	1,302	7,710	7,045	16,906
1983	1,287	1,302	8,777	7,168	18,534
1984	1,287	1,437	9,239	7,389	19,352
1985	1,287	1,442	9,506	7,549	22,018

Table 2.8 TRANSMISSION LINE CONSTRUCTION PLAN

Year	Line Voltage	Name of Line Section
1985	220 kV	Faisalabad ∿ Sahiwal
1985	500 kV	Faisalabad ∿ Multan ∿ Guddu ∿ Karachi
1986	220 kV	Double Circuit Mardan ∿ Peshawar
1986	220 kV	D/C Kot Addu ∿ Multan
1987	220 kV	Dadu ∿ Khuzdar
1988	220 kV	Third Circuit Kot Addu∿Multan
1989	500 kV	Tarbela ∿ Lahore
1990	500 kV	Ludewala ∿ Dadukhel
1990	220 kV	Second 220 kV Guddu ∿ Sibi ∿ Quetta
1990	500 kV	Lahore ∿ Multan ∿ Guddu ∿ Jamshoro
1990	220 kV	4th Circuit Kot Addu ∿ Multan

Table 2.9 WAPDA'S EXISTING SUBSTATION

(As of June 30, 1985)

500 kV		220 kV		132 kV		66 kV		33 kV		Total	
No.	MVA	No.	MVA	No.	MVA	No.	MVA	No.	MVA	No.	MVA
1	900	10	3,182	240	7,379	205	3,014	1	18	457	14,493

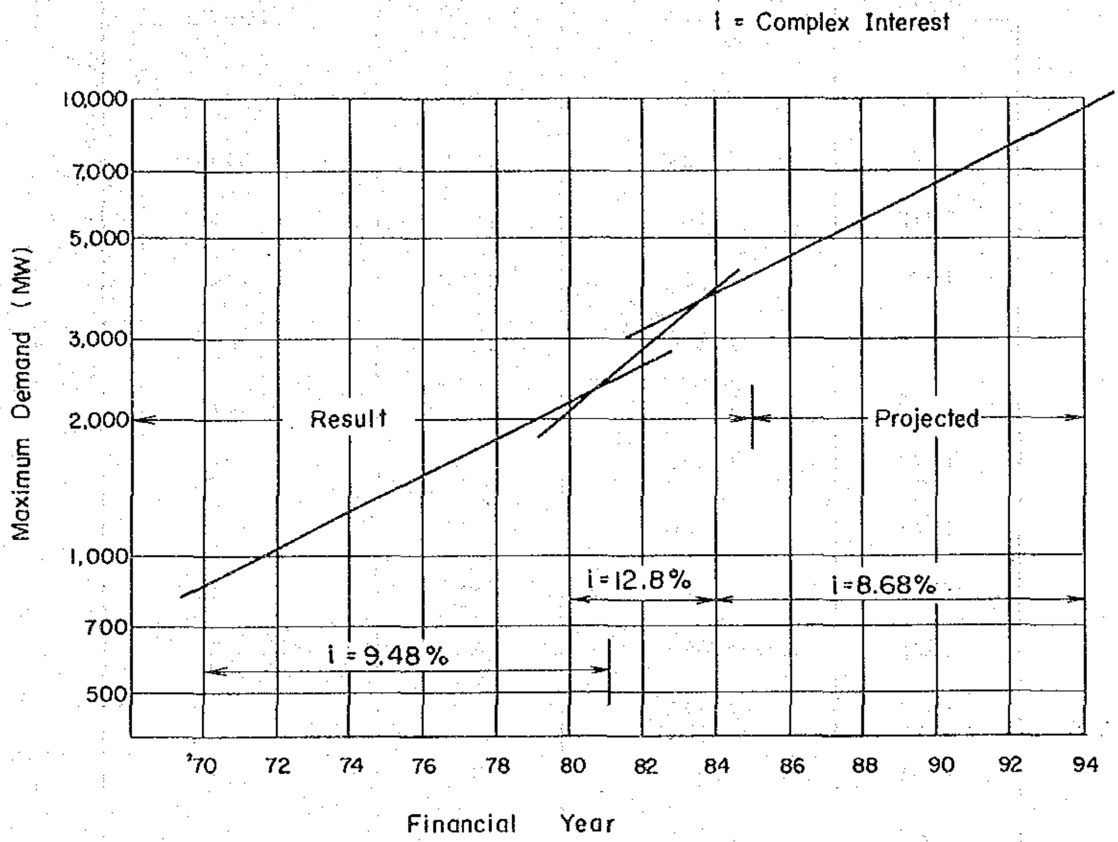
Table 2.10 GROWTH OF MAXIMUM DEMAND

Results (1)		Projected (2)	
Year (FY)	Maximum Demand (MW)	Year (FY)	Maximum Demand (MW)
1970	948	1985	4,121
1971	1,024	1986	4,517
1972	1,148	1987	4,955
1973	1,242	1988	5,436
1974	1,396	1989	5,963
1975	1,437	1990	6,541
1976	1,620	1991	7,176
1977	1,836	1992	7,872
1978	1,972	1993	8,636
1979	2,076	1994	9,473
1980	2,473		
1981	2,846		
1982	3,163		
1983	3,295		
1984	3,791		

Source: (1) Power System Statistic (Tenth issue) WAPDA

(2) WAPDA Annual Report 1984 - 95

Fig.2.4 Growth of Maximum Demand



Source : Result : Power System Statistics (tenth issue)
Projected: WAPDA Annual Report 1984~85

Table 2.11 ENERGY GENERATED, SOLD, CONSUMED IN AUXILIARIES AND SYSTEM LOSSES

Financial Year (FY)	Units Generated (GWh)	Consumption in Auxiliaries of the power system (GWh)	Units Sentout (GWh)	Units Sold (GWh)	System Losses	
					Total (GWh)	Percentage (%)
1969	5,162	179	4,983	3,600	1,383	27.75
1970	5,740	219	5,521	3,966	1,555	28.17
1971	6,029	174	5,855	4,137	1,718	29.34
1972	6,836	183	6,653	4,599	2,054	30.87
1973	7,179	218	6,961	4,742	2,219	31.88
1974	8,041	184	7,857	5,212	2,645	33.66
1975	8,276	222	8,054	5,315	2,739	34.01
1976	8,734	258	8,476	5,452	3,024	35.68
1977	10,089	221	9,868	6,490	3,378	34.23
1978	10,609	203	10,396	6,981	3,415	32.85
1979	12,124	269	11,855	8,160	3,695	31.17
1980	13,206	344	11,862	9,068	3,794	29.50
1981	14,768	390	14,378	10,288	4,090	28.45
1982	16,492	399	16,093	11,587	4,506	28.00
1983	18,052	400	17,652	12,762	4,890	27.70
1984	18,777	404	18,372	13,756	4,616	25.13

Source: Power System Statistics, Planning Department Power Wing 10th issue

Fig.2.5 Growth of Energy Sold by Economic Group

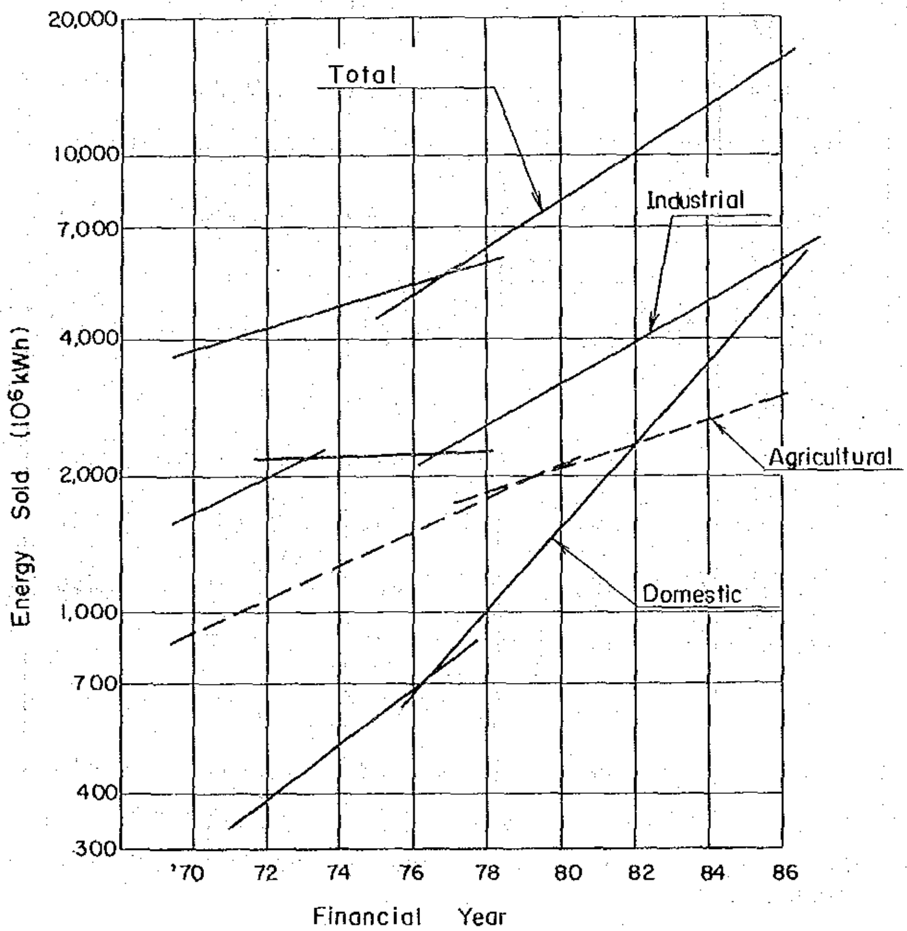


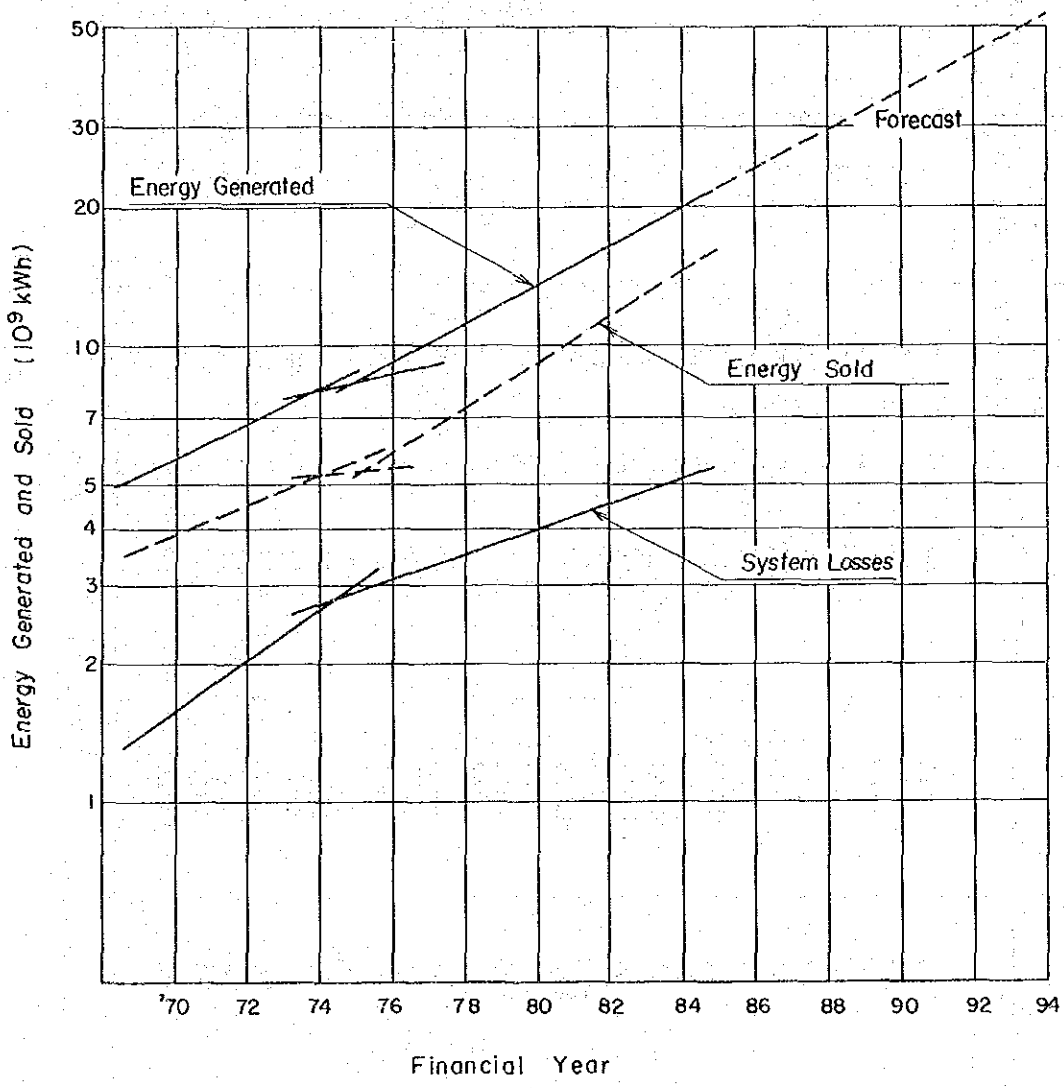
Table 2.12 CONSUMPTION OF ENERGY BY ECONOMIC GROUP

(Million kwh)

Year	Domestic	Commercial	Industrial	Agricultural	Public Lighting	Bulk Supply	Traction	Total
1959-60	81	18	390	67	5	42	-	603
1960-61	96	23	451	102	8	66	-	746
1961-62	126	28	505	178	10	82	-	929
1962-63	143	36	634	307	13	91	-	1224
1963-64	166	47	751	449	16	132	-	1561
1964-65	196	55	902	424	17	228	-	1822
1965-66	213	71	1041	481	17	266	-	2089
1966-67	232	72	1095	389	12	297	-	2097
1967-68	288	89	1242	502	27	338	-	2486
1968-69	308	93	1361	752	16	409	-	2939
1969-70	367	124	1646	956	20	487	*	3600
1970-71	388	146	1755	1072	22	583	*	3966
1971-72	392	142	2109	997	19	478	*	4137
1972-73	454	159	2222	1170	22	572	*	4599
1973-74	516	175	2251	1131	19	608	42	4742
1974-75	566	184	2244	1531	20	604	63	5212
1975-76	678	222	2261	1386	26	697	45	5315
1976-77	780	246	2295	1400	29	659	43	5452
1977-78	1004	305	2596	1717	42	784	42	6490
1978-79	1240	336	2770	1666	70	856	43	6981
1979-80	1564	389	3154	2056	50	901	46	8160
1980-81	1858	445	3482	2125	58	1056	44	9068
1981-82	2408	574	3960	2357	75	872	42	10288
1982-83	2866	634	4417	2546	78	1002	44	11587
1983-84	3470	739	4708	2663	75	1069	38	12762
1984-85	3888	796	5061	2782	77	1115	37	13756

* Separate figures not available

Fig. 2.6 Growth of Energy Generated and Sold



Source : Power System Statistics (tenth issue) WAPDA

2-2-4 Present State and Future Plans of Electric Power Equipment Manufacturers

Presently, in Pakistan electricity supplying equipment and materials such as cables and wires, electricity poles, insulators, distribution transformers and enclosed type switch boards are mostly manufactured domestically, and also transformers over 66 kV, as well as only 132 kV, 13 MVA transformers can be manufactured by a few makers, however, circuit breakers and line switching equipment above 66 kV depend on imports.

Recently, the Government made a plan to produce transformers of 66 and 132 kV class, domestically. The country's electric power equipment makers, in accordance with this policy, started a joint venture (JV) with Yugoslavian corporations for 132 kV circuit breakers (SF_6) and with French and Dutch corporations for 66 and 132 kV disconnecting switches, and it is scheduled to start manufacturing soon. Also, according to newspaper reports, the country's Heavy Electrical Complex announced that they will soon start manufacturing transformers with technical and financial assistance from China's C.M.E.C. (China Material Machinery and Equipment Import and Export Corporation).[1)] According to this report, it is planned to home-manufacture 148 units of transformers (about 2,885 MVA, 66 kV, 132 kV/11.5 kV) annually starting in 1988 or 1989.

Note: 1) Economic and Business Review of Dawn Dated Nov. 18, 1985.

2-2-5 Present State of Existing Testing Facilities

The outline of Pakistan's domestic testing facilities of electric utilities, electric power equipment makers and technical colleges is as follows:

(1) WAPDA Testing Laboratory

It is located in Faisalabad, about 140 km west of Lahor, and was completed in 1969 with assistance from the United States of America. The testing facility is equipped only with a transformer for testing with maximum voltage of 80 kV and equipment necessary for measurement.

Table 2.13 POWER FACILITIES POSSIBLE TO BE PRODUCED DOMESTICALLY

Items	Rating	Name of Company
1. Transformer		
For power transmission	up to 33, 66, 132kV/11.5kV, 13MVA up to 2MVA	Simens PEL
For distribution	WAPDA standard products	5 companies
2. Supporting structure		
Steel tower and structure	up to 220 kV up to 132 kV	PECO HMC
Concrete pole	11 kV, 132kV	WAPDA's subsidiary
3. Wires		
Control cable		4 companies
Power cables	below 1,000V	8 companies
HAℓ	WAPDA's standard products	5 companies
ACSR	WAPDA's standard products	5 companies
4. Insulator		
Low and high tension	WAPDA's standard products	EMCO
Suspension	-	"
5. Power Plant Equipment		
Circuit breaker	SF_6 CB, 132kV	PSL (JV) (1)
Disconnecting switch	132kV, 66kV	Pak Electron (JV) (2) Salo Dynamic (JV) (3)
Current Transfomrer	up to 11kV	Jhonson & Philips
11kV Metal-enclosed cubicle	For 11kV distribution with CB	5 companies
Watt-hour Meter		4 companies
6. Relay		5 companies
For control		
For auxiliary		
7. Battery		Chloride Pak
Lead acid type battery		
Charger		

Source: Summary of Questionnaire
Notes; (1) M/S Energoinvest Yugoslavia and Pakistan Switch Gear Ltd. (PLS)
(2) M/S Merlin Gerin France and M/S Pak Electron Ltd.
(3) M/S Hapom BV Holland and M/S solodynamic Corp.

It mainly conducts electric, mechanical and scientific testing of distribution insulators and metallic parts according to WAPDA specifications.

This facility handles 20,000 cases of testing annually (about Rs 550,000).

The test equipment and instruments of this laboratory are as follows:

(a) Relay test equipment
(b) WH meter test equipment
(c) PT, CT test equipment
(d) Max. demand meter
(e) 11 kV testing transformer
(f) Oil tester
(g) Pressure gauge calibration gauge
(h) Rubber gloves insulation tester
(i) Insulator rod test equipment
(j) AC test bay
(k) Compression test equipment
(l) Durometer

(2) Facilities at University of Engineering and Technology, Lahore

The University of Engineering and Technology LAHORE was founded in 1926 and is the largest university in Lahore. The number of students is 3,000 in total with 1,000 just in the department of electric technology.

As a testing facility in the university, there is a high voltage testing facility where presently all impulse tests for domestically made electric power equipment are conducted. The facility is equipped with a 500 kV impulse generator (transformer and other accessories).

Unfortunately, this facility was installed 20 years ago and the insulation is considerably worn out and presently it is only capable of conducting tests under 300 kV.

The facility is used on average 2-3 cases per day including experiments by students. In the future, there will be more and more domestic products and this facility will not be able to keep up with the demand.

(3) Electric Manufacutrers' Testing Facilities

There are about ten (10) large and small electric equipment manufactureres in Pakistan centered around Lahore and Karachi, like Climax Engineering Co. Ltd., Faizi Industries Ltd., Samco Industries Ltd., Pak Electron Ltd., Transpak Electro Cable Industries Ltd., Johnson & Phillips Ltd., Siemens (Pakistan) Engineering Co., Ltd. and AEG Telefunken (Pakistan) Ltd.

Of these, the Study Team observed testing facilities owned by Transpak Ltd., PEL (Lahore) and Siemens, J & P (Karachi). As a result, it was found out that each maker only has transformers for testing and various measuring equipment to conduct routine tests with the standardized test voltage to each product after manufacturing and they must entrust impulse tests to Lahore University and short-circuit tests, under the supervision of WAPDA, to KEMA in Holland.

2-2-6 Problems of Electric Utilities

(1) Load Shedding

Electric power plants owned by electricity utilities in Pakistan generate, as mentioned earlier, a total of 5,477 MW. The maximum electric power demand is 4,616 MW and there is 19% reserve. Therefore even if there is an accidental stop of large capacity unit or if it is stopped for routine inspection, it should be able to give steady supply of electricity to necessary households.

However, the hydro power plants, which generate 2,897 MW, or 53% of the total power generation, can not generate full output during winter because the water level in reservoirs lower due to the dry periods of winter, so at peak hours they must restrict electricity consumption.

During this fiscal year, load shedding was carried out from last December to March. Time of the load shedding depended on the city or district, but was at peak hours (18:00 hrs to 20:00 hrs), 2 to 3 hours, and the restricted power limit was about 1,500 MW.

(2) Excessive Loss of Transmission and Distribution Line, and Frequent Occurrence of Accidental Blackout

Although the rate of loss of transmission and distribution line in WAPDA electric power system is lowering, it is 26.7% as of end of 1984, which is very large. The main reasons are loss from resistance of transformers and service wires and other losses (electricity theft). These excessive losses can be reduced by improving the quality of transformers, shortening distribution line and improving electricity supply facilities.

Also, trouble with electric appliances due to excessive voltage and frequent occurrence of black-out due to breakdown of low quality electric power equipment such as electric supplying transformers and circuit breakers, badly influences the stability of people's lives and industrial development.

Concerned with these problems of Pakistan's electric utilities, WAPDA's Chairman Gnulam Safdar Butt announced in a statement on April 8, 1986, at the national congress as follows:

(a) WAPDA will additionally build by 1990 power plants to generate 3,000 MW, cancel the present load shedding, electrification of 3,000 villages every year and bring the rate of electrification up to 90% by 1990.

(b) Will conduct repair works on a large scale of electricity supplying facilities and strengthen the check system for electricity theft.

In order to promote these plans improvement and development of electric power equipment is a must, and high voltage and short-circuit test research centers, if utilized for product development research and planning, will greatly contribute to solving the above problems.

CHAPTER 3 CONTENTS OF THE PROJECT

CHAPTER 3 CONTENTS OF THE PROJECT

3-1 Project Objective

In the 6th Five-Year Economic Development Plan of Pakistan, a great emphasis was placed on the energy development. A national plan for supplying the electric loads essential to the industrial development, and for the rural electrification program is being implemented, to which as much as 38% of the national public investment is devoted. At the same time, a variety of electric power development programs have been formulated to meet the increasing domestic electric demand. As these plans and power development programs are implemented, a rapid increase of demand for power transmission and distribution equipments is expected to occur in Pakistan, and the Government of Pakistan is aggressively implementing programs for domestic manufacture of electric equipments with cooperation from foreign nations such as The People's Republic of China and Yugoslavia.

At present, however, there is no domestic facility in Pakistan with which the performance of electric equipment can be tested, and consequently the tests of important distribution equipment, such as power transformers and circuit breakers, are commissioned to foreign nations including Holland. The cost and time involved in the tests commissioned to foreign nations are substantial, and at the same time creating an issue from the viewpoint of foreign currency saving. Also it is pointed out that there is a problem from viewpoint of development of domestic technology, since the electric equipment tests commissioned to the foreign countries are conducted only on completed products.

In Pakistan, a program is being implemented to connect the hydroelectric power sources in the northern part of the nation and the thermal power sources in the southern part of the nation to the load centers of the central part by 500 kV extra-high voltage (EHV) transmission lines. A part of this transmission system is already in operation, and all facilities will be completed by the end of this fiscal year. However, many problems are encountered with the operation of such high technology power facilities, such as salt and dust hazards on insulators and the corona noise, placing heavy technical burden on the organizations involved.

Under the circumstances, the Government of Pakistan had the Water and Power Development Authority (WAPDA) formulate a plan for establishment of a high voltage and short-circuit testing and research laboratory having the following objectives, and requested the Government of Japan to provide a Grant Aid.

(1) Saving the foreign currency and the time consumed by commissioning to foreign nations for the performance test of electric power equipment

(2) Enhancing the domestic product qualities and manufacturing technology by having the domestic manufacturer utilize the testing laboratory

(3) Supplying optimal power equipment efficiently and economically to enhance the electric power technology of Pakistan and to improve the power supply situation of this country by improved qualities and standards of power equipment

3-2 Review of Scope of the Request

A Preliminary Study Team had already consulted with the interested parties of Pakistan to reach an agreement on the scope of request. However, the detailed scope of the request has been reviewed to confirm the outline of the laboratory with the Pakistani parties.

(1) Functions of Facilities

(a) High Voltage Test

(i) To be capable of conducting artificial contamination tests of 500 kV insulators.

(ii) To be capable of conducting the dielectric strength test on the electric power equipment to be manufactured in Pakistan in future.

(b) Short-Circuit Test

(i) To be capable of conducting the electric performance test of power distribution facilities

(ii) To be capable of conducting the synthetic test of 132 kV circuit breakers to be manufactured in the near future

(2) Administration Office Building

In the previous preliminary study, it had been agreed upon that the administration office for this testing laboratory would be constructed by Pakistani parties. In the discussion held by this Study Team, the Pakistani parties requested that the administration office, including a building (approximately 150 m^2) for the short circuit test monitoring and measurement, be constructed by the Japanese side.

To this request by Pakistan, the Study Team decided to accept this request, considering the fact that if the administration office were not constructed by the Pakistani parties for some reason after completion of this project, this testing laboratory would not be able to exhibit its full potential.

(3) Testing Facilities

(a) Capacity of Short-Circuit Generator

Concerning the capacity of the short-circuit generator for the rupturing test of the circuit breaker (245 kV, 40 kA), the Study Team explained that 1,500 MVA (instantaneous value) is sufficient, but the Pakistani parties stressed that 1,500 MVA (3 cycle value) is necessary.

As the capacity required for a short-circuit generator is affected by the testing items of the type tests of circuit breakers, the Study Team after returning back to Japan studied in detail the capacity based on the test items to be proposed by Pakistani parties, and it is decided to be 1,500 MVA (instantaneous).

(b) Computer

The Pakistani parties questioned the required capacity of the com- puter. The Study Team explained that the minicomputer proposed by the Preliminary Study Team is sufficient for the test data measurement and analysis to be conducted in this testing laboratory, which was agreed upon by the Pakistani parties.

In conducting a performance test, it is very important to precisely measure the voltage, current and other phenomena that change in transient manners. Consequently, 2 mini-computers, 1 for the short-circuit test and 1 for the high voltage test, are required for this testing laboratory.

(c) Synthetic Testing Facility

The synthetic test facility shall be able to conduct the synthetic short-circuit test of 140 kV, 20 kA gas circuit breaker, and shall be an outdoor type. Pakistan plans to produce the circuit breaker mentioned above by 1988 with license and fund provided by a foreign nation. The performance test facility for this circuit breaker is required.

Considering the plan to manufacture a 245 kV circuit breaker in future, the layout of the testing laboratory shall be such that it can be expanded in future.

(d) AC Voltage Test Facility

A single phase 500 kV testing transformer shall be installed to enable the AC voltage withstand test, the AC voltage test under water spray, the AC voltage breakdown test, etc. for 220 kV transformers. Also a single phase induction generator shall be installed to conduct the induced voltage test on the 220 kV, 75 MVA class transformers which are scheduled for domestic production in the near future.

(e) Impulse Voltage Test Facility

A 1,800 kV impulse voltage generator shall be installed to enable the lightning impulse voltage tests on 220 kV transformers and insulator strings. The impulse voltage generator shall be an outdoor type to save the necessity of building for a high voltage hall.

(f) Insulator String Artificial Contamination Test

A large fog room shall be provided to enable the artificial contamination tests on 500 kV class transmission line insulator strings. The testing transformer described in item (d) above shall be utilized as the voltage source of this test facility.

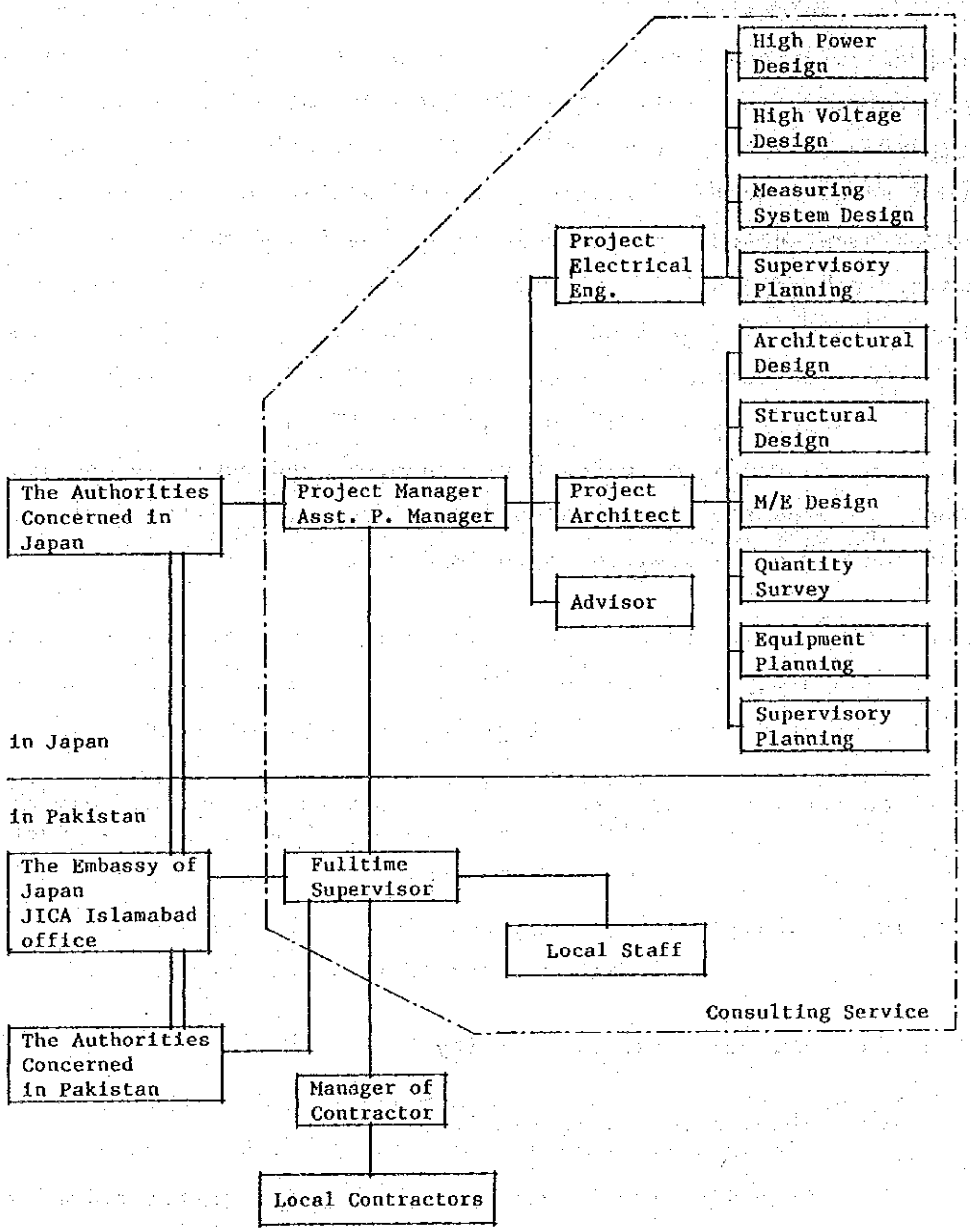
3-3 Project Outline

3-3-1 Implementation Systems

(1) Implementation Organizations

This project is to be implemented under the Japan's Grant Aid Program. The overall relations among the implementation organizations are illustrated in Fig. 3.1

Fig. 3.1 PROJECT IMPLEMENTATION SYSTEMS



(2) Implementation Organizations in Pakistan Government

The required formal liaison between the Governments of Pakistan and Japan and procedures involved in this project are to be implemented by the Ministry of Water and Power (MOWP), and matters related to the working designs and installation works are implemented by the Water and Power Development Authority (WAPDA).

3-3-2 Basic Plan

The percentage of the electric energy in the total energy consumption is ever increasing in Pakistan. Consequently, the role played by transmission and distribution lines that transmit the electric energy generated in power plants to the consumers efficiently and safely is very important. As the transmission and distribution lines are always exposed to severe natural environment, including salt contamination, lightning strokes, wind and snow, they must be provided with sufficient strength and maintained carefully. Generally speaking, the fault occurring in a transmission or distribution line creates short-circuit current which is ten times or several ten times the normal electric current, causing thermal and mechanical damages on the facility. Thus research and development efforts are required to enhance technology and equipment performance so that the expansion and/or secondary effect of the line fault is prevented and the damage is limited to the minimum.

The high voltage and short-circuit laboratory provides opportunities for such technology research and development activities, and enables the real-sized performance tests of electric equipment manufactured.

The testing facilities in this laboratory can be broadly divided into two groups.

Testing Facility: 1) Short-Circuit Testing Facility
2) High Voltage Testing Facility

(1) Short-Circuit Testing Facility

(a) Objective of This Facility

This facility is used for performance verification as well as research and development of electrical equipment and structures against short-circuit faults. The facility is mainly used for testing the rupturing characteristics of switching and protection devices such as the circuit breaker.

This facility is also used for testing the mechanical strength of equipment against the electromagnetic power created by short-circuiting, and the discharge characteristics of lightning arresters.

(b) Facility Outline

When a circuit breaker breaks the fault current, a high voltage is applied between its electrodes after the large current arc between the electrodes is quenched. Consequently, a large current and a large voltage are required for the circuit breaker rupturing test. As it is difficult to obtain this large current and voltage from a single power source when the large capacity circuit breaker is used in an extra-high voltage system, the large current source and the high voltage source are separated. The equivalent synthetic test is performed by combining these large current source and large voltage source.

A short-circuit generator is employed as the large current source because the commercial power system capacity is not sufficiently large.

A condenser bank is used as the high voltage source.

For measuring the test, there is a tendency to automate the necessary measuring with a computer, as the recording of circuit composition test data and the data analysis for a large variety of test conditions are getting more and more complicated.

(2) High Voltage Test Facility

(a) Objective of Facility

This facility is used for performance verification as well as research and development of electric equipment and structures working at high voltage.

(b) Facility Outline

This facility is planned to conduct the impulse test, AC voltage application test, induced voltage test, contamination test, etc. The facility comprises a high voltage hall, an impulse generator, an AC high voltage facility, and a contamination test facility.

The high voltage hall is used to attenuate the corona noise coming from outside, generally employing electromagnetic shield structures. The impulse generator can be either indoor type or outdoor type, in this case outdoor type is adopted to save the construction cost.

(3) Contribution of The Facilities

These testing facilities are indispensable for the verification of equipment performance in realizing domestic production of transmission and substation equipment such as circuit breakers.

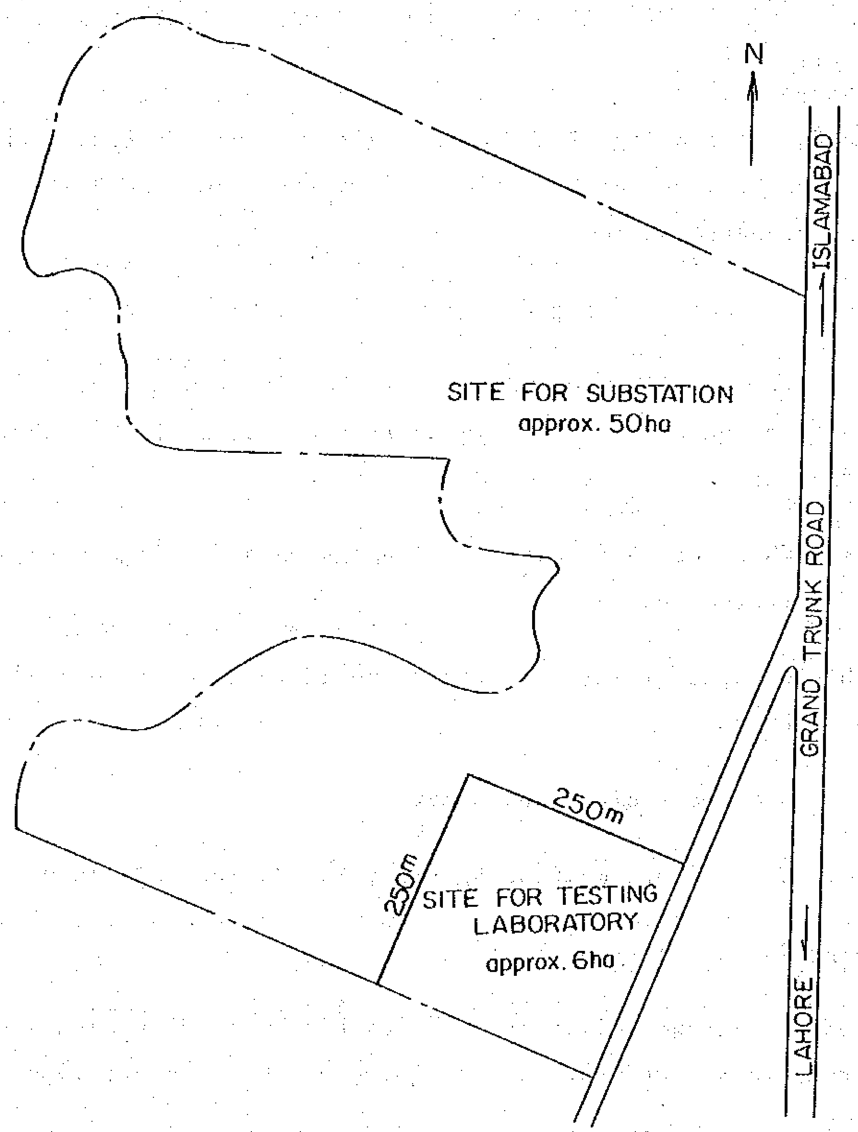
At the same time, practical tests and research and development activities must always be conducted on electric equipment and structures, as higher power system voltages are employed. Without the nation's own testing facilities, those in foreign countries, such as Holland, Canada, Italy and Japan must be resorted to. For the utilization of foreign testing facilities, many constraints are imposed such as the difficulty of adjusting the testing schedules, as well as waste of time and expenses for transportation, sometimes making it virtually impossible to conduct sufficient verification tests. For the same reason, the research and development of equipment are constrained, prohibiting the supply of products that meet the requirements for development of large capacity, high voltage power systems.

Such constraints can be eliminated if a domestic large power testing facility is established. Thus the contribution of this testing laboratory is quite substantial.

3-3-3 Proposed Project Site

The site for the laboratory has been selected in the south-eastern corner of the land on which WAPDA is planning to construct a 500 kV substation. This place is in the Riwat district, 25 km to the south-south east of Islamabad, the capital city of Pakistan.

Fig. 3.2 Proposed Project Site



This site was selected based on the following reasons.

(1) It is a land procured for construction of a substation, and the land elevation is the highest among the candidate sites.

(2) As the site faces a branched road, the laboratory is less likely to be affected by noise and vibration of traffic, while it is convenient for transportation of heavy equipment.

(3) The site has a rectangular shape, and it is possible to expand the premise in northern or western direction.

3-3-4 Plan Outline

The outline of the High Tension and Short-Circuit Testing Laboratory, agreed upon between the Government of Pakistan and the Basic Design Study Team, is presented below.

(1) Short-Circuit Testing Facility

This facility shall be sufficient for the direct short-circuit tests of distribution equipment. The synthetic test facility shall be added to the basic facility to enable the short-circuit tests of higher voltages.

(a) Short-circuit generator (including a driving motor, an excitation system, etc.)

(b) Current limiting reactors and line switches for switching operations

(c) Short-circuit transformer

(d) Control and monitoring board (including computers)

(2) High Voltage Testing Facility

Sufficient facilities for various high voltage testings of transmission and substation equipment shall be provided.

(a) AC testing transformer

(b) Impulse generator

(c) Water sprinkler equipment

(d) Contamination test equipment (fog room and artificial fog generating facilities, etc.)

(e) Measuring devices (voltage and current measurement devices, synchroscope, partial discharge measurement device, sphere gap, etc.)

(f) Measurement and control board (including a mini-computer)

(3) Power Receiving Facility (to be Born by Pakistan)

Power is supplied to the Laboratory from a nearby Riwat Substation by interconnecting distribution lines.

(a) Two interconnecting 11 kV distribution lines
(b) Incoming and outgoing line breakers with one bus coupler
(c) The power transformer
(d) Lightning arresters

(4) Buildings

The buildings accommodating the equipment described above and equipment foundations, etc. shall be constructed.

(a) Short-circuit generator building
(b) Short-circuit testing building
(c) Administration building
(d) Fog testing building

3-3-5 Management and Personnel

After this project is completed, the operation and management of the laboratory shall be conducted by WAPDA. WAPDA will place this laboratory under either the Transmission & Grid Station Division or Inventory Control Division, to have the Division operate this laboratory.

WAPDA plans to assign the personnel below for operation of this laboratory.

Chief Engineer/Project Director	1
Deputy Director	2
Professional and Technical	45
Clerical	19
Skilled	16
Unskilled	29
Total	112

The number of personnel in this plan looks a little larger for operation of this facility, when the number is compared to those in Japan and other foreign nations. WAPDA, however, is planning a large research center for electric power engineering, and this personnel plan is built with the idea that the personnel for the center is to be trained and educated by the operation of this laboratory.

As a fairly high technological level is required for the operation of this facility, WAPDA strongly requests the technical assistance by Japan. With a view to enable the WAPDA Engineers to develop indigenous expertise for tests of new equipment, the programme of training of Pakistani trainees including the research work training under JICA training programme though not a part of this project to be formulated.

3-4 Technical Cooperation

This laboratory is for high tension and short-circuit testing, and certain degrees of experience and technical calibre are required for the operation of this laboratory. Thus training of operation personnel is indispensable in this project. The following plan is suggested at this stage for the training of personnel for laboratory management operation.

(1) Training to be provided under the Contract

(a) Training during Shop Test at the Factory

The personnel can take part in the testing works of similar test facilities at the factory in Japan as apprentices, to learn jobs related to testing operations as well as operation and maintenance of test equipment.

Engineer for short-circuit test	1 person	2 months
Engineer for synthetic test	1 person	2 months
Engineer for high voltage test	1 person	2 months

(b) On-the-Job Training

The consulting engineers and the technical instructors of the equipment manufacturers can provide on-the-job training to the whole personnel of the laboratory.

(2) Training to be provided by JICA (when requested by the Government of Pakistan)

(a) Dispatching experts for Laboratory Operation

It is deemed necessary to dispatch several experts to act as advisers for about 2 years after completion of the Laboratory.

Engineer for short-circuit test	1 person	2 years
Engineer for synthetic test	1 person	2 years
Engineer for high voltage test	1 person	2 years

(b) Dispatching Trainees to Japan

Within 2 years after completion of the Laboratory, 2 or 3 trainees will be sent to Japan annually as counterpart for 3 months to learn jobs in connection with the Laboratory.

To provide the technical cooperation as itemized above on schedule during the construction and after the completion of the Laboratory, the Laboratory to be materialized under Japan's Grant Aid will be utilized more effectively.

CHAPTER 4 BASIC DESIGN

CHAPTER 4 BASIC DESIGN

4-1 Design Principle

4-1-1 Testing Facilities

Although there are great expectations on testing facilities which can enhance technological development, the following factors were taken into consideration in developing the design for this testing laboratory, based on the principle that the functions of the laboratory should be limited to those which can be of practical value immediately after completion of the facility, under the general technological and industrial status of Pakistan.

(a) The facility enables the performance tests on the 11 kV distribution equipment which are already being manufactured in Pakistan.

(b) The dielectric strength test of electric equipment and the artificial contaimination tests of 500 kV insulators can be conducted.

(c) The type tests for the 132 kV and 220 kV power equipment, which are to be manufactured domestically in the near future, especially the circuit breaker and transformer, have been taken into consideration in the basic design.

(d) The facilities are to be designed in such a way that it provides high safety and easy maintenance devices. The equipment used will be as simple as possible to facilitate operations.

(e) As this is the first facility of this kind in Pakistan, it should be designed with due considerations on its impact on natural environment, as well as on safety and high reliability.

(f) The testing facility equipment shall be standardized as much as possible, to reduce the equipment costs and to rationalize spare parts.

(g) The design shall be as economical as possible, provided that this does not conflict with the above design principles.

4-1-2 Buildings Accommodating Testing Facilities

This testing laboratory consists of the short-circuit test facility, the high voltage test facility, and the power receiving facility (the last to be born by Pakistan), and an administration office building for the management and overall operations.

Each equipment facility and buildings shall be designed with emphasis on functions, and the visual designs and finishing materials shall be simple and not be extravagant.

The visual designs and finishing materials of the administration building shall be so selected that it will match the designs of other test facility buildings and have the dignity which is suitable for the management of this laboratory. The islamic designs shall be incorporated as appropriate.

The construction materials shall be procured inside Pakistan as much as possible, unless there is problem with the material quality or availability.

In the building and equipment designs, systems and equipment types which facilitate maintenance shall be selected, to reduce the running cost and to realize energy conservation.

4-1-3 Description of Facilities

The large capacity short-circuit facility has a 15 kV, 1,500 MVA shortcircuit generator as its main power source, and short-circuits tests for a wide range of voltage classes, from the high voltage to the low voltage, can be performed by changing the connection of the transformer.

Technological development and various safety measures of electric power equipment, can not be achieved only by theoretical studies or small scale experiments, but a full-scale verification tests are required. This facility shall have performance which enables such tests.

The single line diagram of the large capacity short-circuit test facility is presented in Fig. 4.2.

The equipment to be tested is placed in the test bay, and the main electrical circuit is formed by the connecting conductors.

The total layout is presented in Fig. 4.7.

(a) Short-Circuit Generator (1 set of 3-phase generator)

This generator is a 4 pole, cylindrical rotating field, dual ventilation type, synchronous generator, which is directly connected to driving motor (capacity to be decided).

The short-circuit generator is basically the same as conventional generators, but the coils and busses are reinforced both thermally and mechanically, because the mechanical energy stored in the rotor is converted to the electric energy in a very short time. The main specifications of this short-circuit generator are as follows.

<Short-Circuit Generator Specification>

Short circuit capacity: 3 phase, 1,500 MVA.
(t = 0 cycle)

Rated voltage : 15 kV
Rated frequency: 50 Hz
Cooling : Air cooling

<Determination of Short-Circuit Generator Capacity>

A short-circuit generator of a smaller capacity is sufficient to perform short-circuit tests on the 11 kV distribution equipment (mainly circuit breakers and transformers) currently manufactured in Pakistan. The short-circuit capacity stated above was selected based on the idea that the generator will serve as the current source in the synthetic short-circuit test for the 245 kV circuit breaker which is being planned for manufacturing in Pakistan in future.

(b) High Voltage Short-Circuit Transformer (single phase, 3 units)

This equipment will be used most frequently in this laboratory, being capable of working as the power source for a variety of short-circuit tests with voltages from 10 kV to 15 kV. The secondary tap voltage of

3 units of transformers can be changed, and they can be connected in the way most suitable to the test to be performed, either in series to a single phase connection, or Delta or Star 3-phase connection.

The specifications of this transformer are given below.

Nominal capacity	:	50 MVA
Short-circuit capacity	:	700 MVA
Rated voltage	:	15 kV/10 - 15 kV

(c) Synthetic Short-Circuit Test Facility

Sometimes it is impossible to carry out a performance test of circuit breaker with a single short-circuit generator, when the breaker rupturing capacity increases with the increase of the power system short-circuit capacity.

One way of solving this difficulty is to supply the current from shortcircuit generator, and supply the transient recovery voltage after the current rupturing from a charged condenser. The short-circuit test is conducted by instantly switching from the current source to the voltage source. This method is generally called the synthetic short-circuit test.

<Selection of Capacity of Synthetic Short-Circuit Test Facility>

The capacity of this facility shall be such that a synthetic short-circuit test of 154 kV, 20 kA gas circuit breaker can be conducted.

In Pakistan, the technical license and fund for manufacturing such circuit breakers have been secured from a foreign country, and the production will be started in 1988. For these circuit breakers, a verification test facility is required.

Since there is a plan for manufacturing 245 kV circuit breakers, considerations are given on the facility design for possible expansion of facility in future.

Therefore, the facility was designed for outdoor installation.

(d) Measurement Devices

It is very important to perform precise measurement on the voltage, current and other variables that undergo transient states in a short-circuit test. It can be said that the quality of measurement controls the performance of the whole test and research.

For this reason, the following measurement devices shall be provided in this short-circuit test facility, to enable high accuracy measurements in a wide range.

(i) Automatic Measurement and Analysis System by Mini-Computer (1 set)

As the test conditions are diversified and circuit configurations and the method of data collection and analysis become more and more complex, it is a recent trend to automate the test operations by computers.

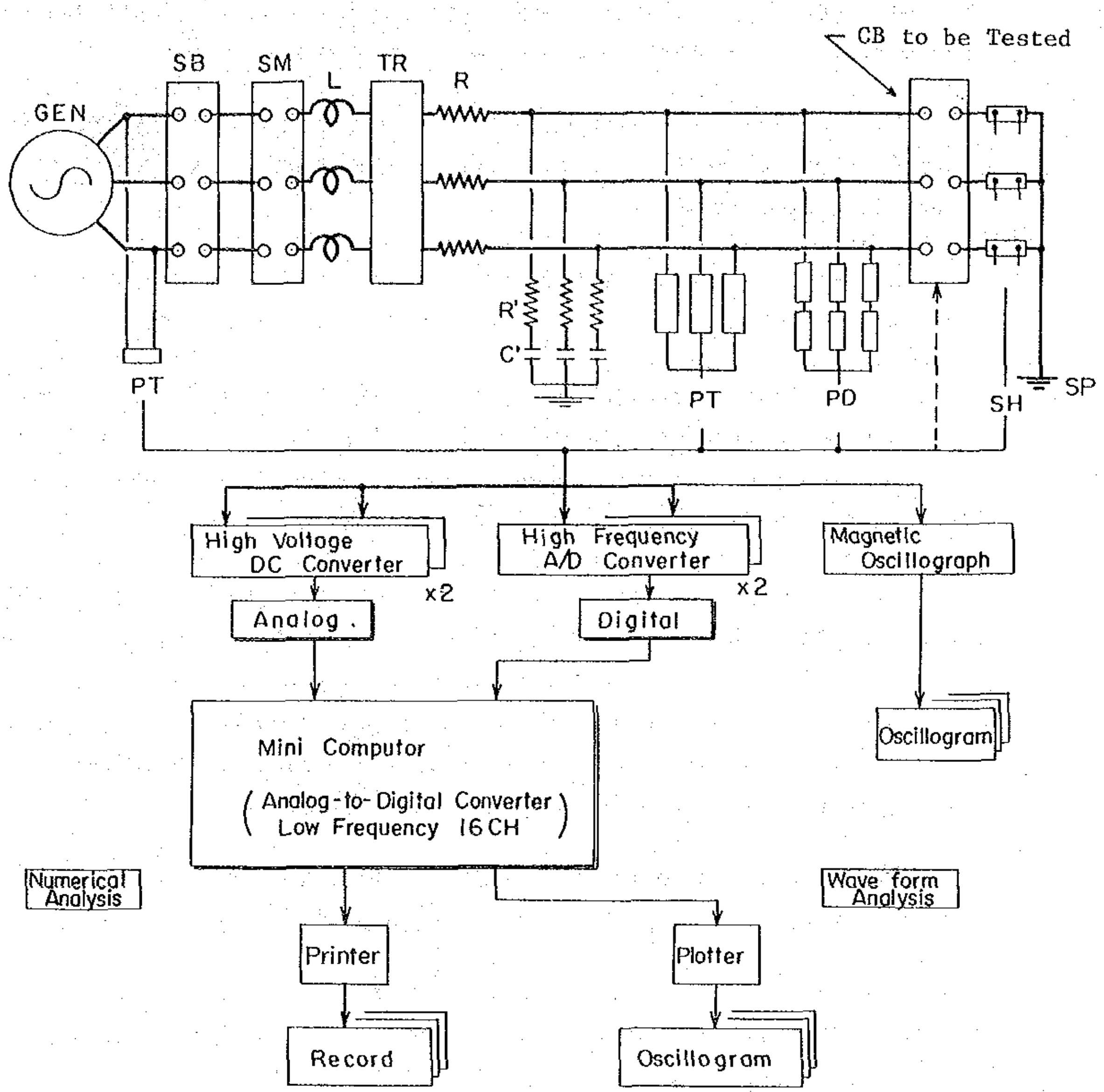
In the past, the analog measurement devices, such as Brown tube oscillograph, oscilloscope and electromagnetic oscillograph were generally employed in the measurement works related to large power electric tests. In such measurement works, a large amount of time and human labor were demanded, because a large volume of data had to be processed or analyzed at high precision.

With the recent advent of analog/digital conversion technique, computer technology and opto-electronics, measurement systems employing computers have been introduced.

For this test facility, a high speed multiple channel data processing system dedicated to the wave analysis will be provided. The optimal scale of this system depends on the number of input signals and the required processing time. In this case, the system was determined for 12 input elements and processing time of 5 to 6 minutes.

This is a relatively small system, as compared to equipment for similar facilities.

OUTLINE OF MEASURING SYSTEM (SHORT-CIRCUIT TEST)



Notation

GEN :	Short Circuit Generator	R',C' :	Transient Recovery Voltage Adjustor
SB :	Back-up Circuit Breaker	PT :	Potential Transformer
SM :	Making Switch	PD :	Potential Divider
L,R :	Current Adjustor L,R	SH :	Shunt
TR :	Transformer	SP :	Earthing Point

System Outline

- Input Units — Wide band input amplifiers ... 4 channels
  - Frequency characteristics; DC to 100 kHz
  - Medium band input amplifiers ... 16 channels
  - Frequency characteristics; DC to 10 kHz

- A/D Converters
  - Resolution; 12 bits
  - Conversion speed; 1.5 micro-seconds

- Floppy Disk Drivers
  - 8 inch floppy disk drive x 2, 1 M byte/unit

- Main CPU
  - Dynamic micro-programming system

- High Withstand Voltage DC Amplifier: 10 sets
  - Number of channel; 1

Capable of performing high precision measurement in a short-circuit test facility where a complete floating DC amplifier having high accuracy, wide bandwidth and high isolation are required.

Same phase allowable voltage (withstand voltage)±5,000 V DC
Frequency characteristics; DC to 100 kHz
Number of channels; 1

- A/D Converter: 2 sets
  - Number of channels; 2
  - A/D conversion speed; 20 ns/sample
  - A/D converter resolution; 10 bits
  - Writing memory length; 8,192 words (4,096 words/ channel)
  - With GP-IB interface (IEE-488)

- Printer: 1 set
  - Wire-dot matrix type, 24 pin printer
  - Paper width; 5 to 15 inches

- X-Y Plotter; 1 set

  Maximum recording area; 400 x 275 mm

  Paper; A3 size

(ii) Measurement Auxiliary Devices

The physical quantities including high voltage and large current that accompany the short-circuit test can by no means be directly put into the measurement devices above.

For this reason, it is necessary to convert those quantities into electrical signals of low voltage.

As the converters for this purpose controls the accuracy of the whole measurement systems, high accuracy conversion instruments for current and voltage are equipped on this large capacity short-circuit facility, as described below.

- Voltage Dividers

The high voltages encountered in the test is linearly reduced to an order less than several tens of volts. There are following different types depending on the kind of impedance used for voltage division.

* PT (potential transformer)
* CC (condenser type divider)
* CR (resistance and condenser divider)
* R.R. (resistance divider)

  (System addopted yet to be decided)

- Current Shunts

These are resistors having low resistance and producing voltage drops proportional to the large current. They are mainly the cage type and coaxial type, which have superior time characteristics.

* Cage type
* Coaxial type

Although shunts are usually placed on the grounding side of the circuit, it is necessary to connect them to the high voltage parts of circuits to obtain higher precision. For this purpose, the high potential shunt is developed, which is used to measure current at high voltage parts of circuit by employing the optical signal conversion method.

- Current Transformers

The current transformer is used when the shunt can not be used, such as in the case of measuring current of circuit having high voltage or short-circuit test of ungrounded system.

* 2.5 kA to 50 kA/5A

(e) Current Limiting Reactors

The current limiting reactor is used to control the short-circuit current, and usually have no iron core. The coil is embedded in reinforced concrete so that it can withstand the powerful electromagnetic force created. The desired value of short-circuit current is obtained by combining several units of reactors having different values for a phase.

The connection can be changed remotely by the calculation board in the measurement room.

(f) Switches

In order to utilize the electric power generated by the short-circuit generator, transformer, etc. for the test in a safe manner, a large current switches capable of closing and opening the short-circuit current are required. There are a variety of switches for performing this function, and outstanding switches are described below.

(i) Protective Circuit Breaker (3 phase, 1 set)

This circuit breaker is connected to the output terminal of the short-circuit generator, and having the backup protection function, capable of unerringly breaking any current occurring.

Indoor type vaccum circuit breaker with parallel resisters.
Rated voltage; 15 kV
Rated rupturing current; 80 kA

(ii) Making Switch (3 phase, 1 set)

The function of this switch is to close the circuit with high accuracy to produce the short-circuit condition. The making switch is provided in each phase. It has no capability of current breaking.

Rated voltage; 15 kV
Rated closing current; 200 kA (peak value)

(iii) Other Switches

Depending on the nature of test, several auxiliary switches other than the above are connected in series or in parallel, to form a circuit condition with high accuracy.

(2) High Voltage Test Facility

This facility enables verification, research and development of high voltage performance of electric equipment and structures, which in turn will make it possible to reduce the effect of electrical failures in the transmission and distribution lines as well as power equipment caused by lightning and other factors, to enhance the reliability and economy of electric power system components.

The rated test voltage of the 220 kV power equipment has been selected as 900 kV for lightning impulse, and 395 kV for AC voltage. The higher rating for the impulse voltage is a general rule based on the voltage withstand characteristics of power equipment.

(a) Testing Transformer

This transformer is used to conduct the insulation withstand test on electric power equipment such as circuit breakers and transformers. In this laboratory, this transformer will also be used for the artificial contamination test of transmission line insulator strings.

<Selection of Transformer Capacity>

In Pakistan, the 500 kV transmission line was recently completed, and put into commercial operation.

Thus it was decided to select a testing transformer with which both the AC contamination test of 500 kV class insulator strings and the AC withstand voltage test of 220 kV transformers can be conducted.

Rated voltage	:	3.3 to 6.6 kV/500 kV
Rated frequency	:	50 Hz
Short-circuit capacity	:	20 MVA

(b) Impulse Test Facility

This facility shall make it possible to conduct impulse tests on insulator strings and transformers having 220 kV class rated voltages. The facility shall be of an outdoor type.

<Selection of Rated Voltage>

The 500 kV power equipment were regarded as something to be dealt with in future, and not taken into consideration in the test equipment design.

Lightning impulse charging voltage: about 1,800 kV

(c) Measurement Systems

(i) Data Processing Computer

As there is only 1 measurement element in a high voltage test, the computer for this test is smaller in capacity than the one for the short-circuit test. At the same time, the requirement on the processing time is less severe.

- Auxiliary Memory
  - 5 inch floppy disk drive: 1.2 M bite x 1
  - 5 inch hard disk drive : 20 M bite x 1

- Interfaces
  - RS-232C interface
  - GP-IB interface (IEE-488)
  - Printer interface

- RAM (random access memory)
  - 512 k bite

- CPU 16 bits

(ii) Printer 1 set

Wire-dot matrix: 24 pin
Paper width : 5 to 15 inches

(iii) X-Y Plotter

Maximum effective paper area: 400 x 275 mm
Paper : A3 size

(iv) Digital Memory (with display)

Frequency band : no more than -3dB in DC to 12.5 MHz
Channel selection : dual, 1 channel or 2 channels
A/D conversion speed : 20 ns/sample
A/D conversion resolution: 10 bits

Reading memory length : 8,192 words
(4,096 words/channel)

With GP-IB interface (IEE-488)

4-2 Design Conditions

4-2-1 Equipment Design Conditions

(1) Natural Conditions

The natural conditions at the laboratory site is as below, according to materials collected and site survey by the Study Team.

(a) Elevation: 300 m

(b) Meteorological conditions

(i) Temperature: Maximum; 45°C
Minimum; -10°C

(ii) Relative humidity: Maximum 100%

(iii) Wind velocity: 45 m/sec

(iv) Precipitation: Annual; 1,275 (Islamabad)
Maximum; 333 (In July, Islamabad)

(c) Seismic condition Horizontal acceleration; 0.2 G

(d) Ground specific resistance: 50 to 100 ohms/m

(2) Standards to be Applied

In the design of this project, the internationally accepted IEC standards shall be applied in principle. The following Japanese standards may also be applied when necessary.

(a) Japanese Industrial Standard (JIS)

(b) The Institute of Electrical Engineers of Japan Standard (JEC)

(c) The Japan Electrical Manufacturers Association Standard (JEM)

(d) The Japanese Electrical Wire and Cable Maker's Association Standard (JCS)

(3) Equipments Subjected to Test

(a) Transformer
(b) Circuit breaker
(c) Disconnector
(d) Power fuse
(e) Power cable
(f) Insulator
(g) Bushing
(h) Others

(4) Type of Test

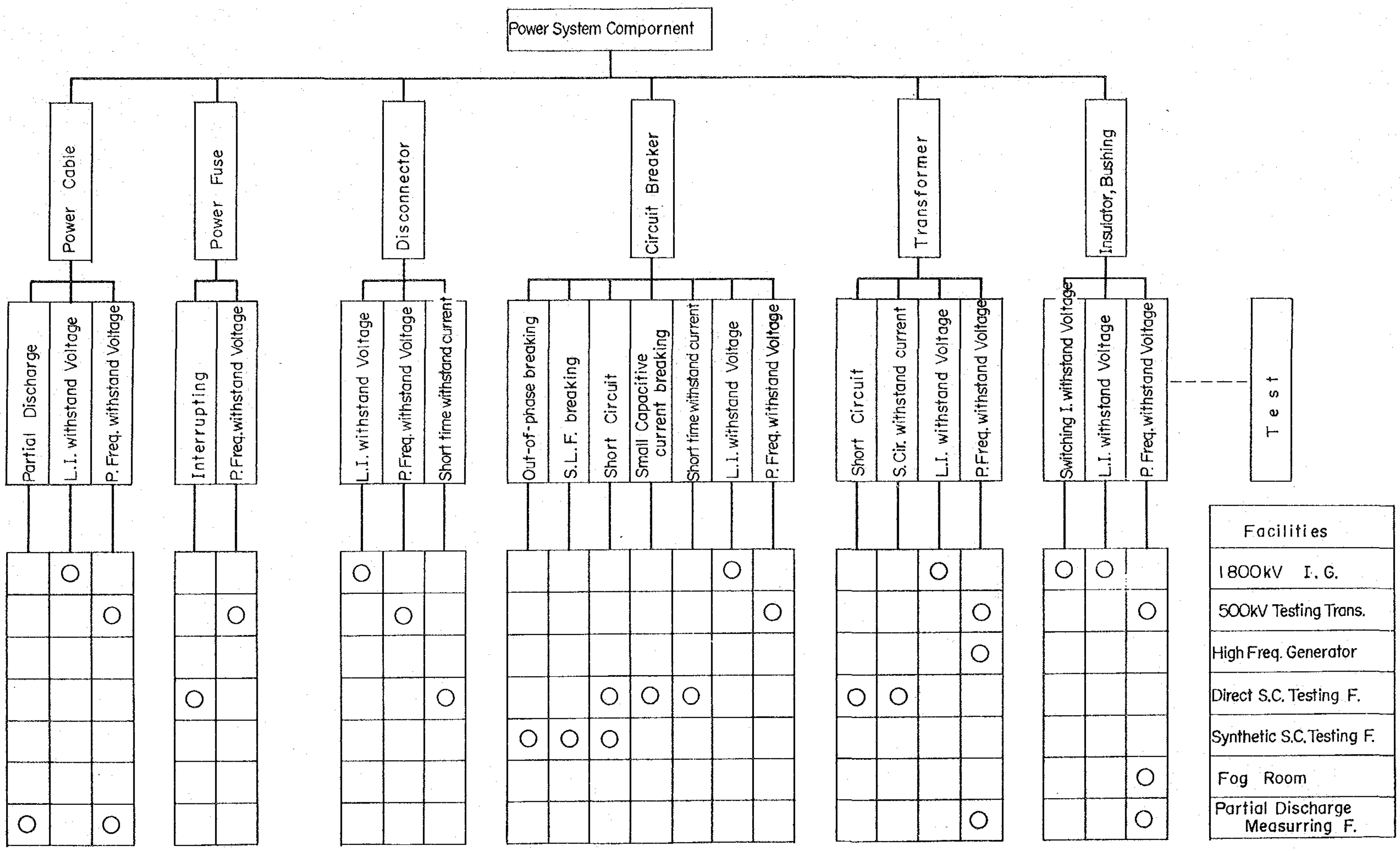
(a) Type Test

(i) Short-circuit test
(ii) AC voltage withstand test
(iii) Lightning impulse voltage withstand test
(iv) Switching impulse withstand test
(v) Short-circuit mechanical strength test
(vi) Short-time withstand current test
(vii) Small capacitive current breaking test
(viii) Short line fault breaking test
(ix) Out of phase breaking test
(x) Partial discharge test
(xi) Others

(b) Tests for Technical Researches

(i) AC voltage breakdown test
(ii) AC artificial pollution AC voltage test
(iii) Voltage/time curve test
(iv) Insulation characteristics test
(v) Others

Fig. 4.1 Testing Item and Facilities



(5) Basis for Selection of Facility Size

The basis for the selection of the facility size have been discussed with the Pakistani parties in reference to the study results prepared by the Preliminary Study Team.

(a) By this discussion, it was decided to set the following two cases.

Case	Number of Phase	Voltage	Short-circuit Current
1	3	12 kV	25 kA
2	1	12 kV	40 kA

In case 1, short-circuit tests can be conducted on the 11 kV distribution equipments manufactured in Pakistan (mainly circuit breakers and transformers). In case 2, the facility can be used as the current source for the synthetic short-circuit test to be conducted on the 245 kV circuit breakers to be manufactured in Pakistan in future.

(b) Synthetic Short-Circuit Testing Facilities

In selecting the size of the said testing facilities, the facilities can be used for the synthetic short-circuit test of gas circuit breaker with rating of 36 kV 25 kA upto 145 kV 25 kA possible to be produced in Pakistan domestically in future.

(c) Testing Transformer

It was decided to select a testing transformer with which the artificial contamination test of 500 kV class insulator strings and the AC withstand voltage test of 200 kV class power facilities including transformer.

In addition, the induction generating facilities are provided so as to carry out the induced voltage test of the reduced insulation type transformer.

4-2-2 Architectural Design Condition

(1) Weather Conditions

The summer of Islámabad is very hot (from May to July), the highest temperature recorded being 45.1°C. In winter, it snows although this is rare, the lowest temperature recorded being -2.8°C.

The prevailing wind direction is southwest in summer and northeast in winter, and sand storms are experienced in July. The precipitation is around 100 mm in the monthly average. This may be from 200 mm to 300 mm in the period from July to September.

The building shall be constructed along the east to west direction. To deal with the high temperature in summer, it will be designed to avoid strong sunshine and have a high ceiling providing good ventilation. The cold in the winter night shall be dealt with by heating.

(2) Construction Practices

The general architectural design and construction methods being practiced for office buildings in Pakistan are as described below.

(a) Structure and Material

* Column beam and floor: steel reinforced concrete
* Bearing wall, curtain wall and interior wall: brick construction

(b) External Finish and Structure

* Outside wall: painting or plastering on brick
* Pavement: brick with concrete side ends

(c) Internal Finish, etc.

* Floor : terrazzo finish
* Wall : plaster finish
* Ceiling : sound absorbing board with paint finish
* Ceiling height : 3.25 to 3.50 m
* Width of corridor : 2.4 to 3.0 m

(d) Office Floor per Person: 9.3 m^2 (100 square feet)

In accordance to this practice, the buildings will be made of steel reinforced concrete structure in principle, and nonbearing wall will be made of brick, and floors will be finished with terrazzo.

(3) Laws and Regulations Related to Architecture

As this site for construction of the laboratory is outside the capital city planning zone, the report to the Capital Development Authority (CDA) will not be required.

(4) Religious Customs

As Islam is the national religion of Pakistan, the direction of west, which is the direction of the holy city of Mecca, is regarded sacred. For this reason, the toilet facility can not be placed in such a way that the human body faces eastern or western direction when it is used. Also, a facility must be provided in the wash room for washing hands and feet before prayer.

4-3 Basic Plan

4-3-1 Premise and Layout Plan

The premise of the laboratory has the highest spot on the southeastern corner, gently sloping down by approximately 1° in the northern direction and by 2° in the western direction.

It has been confirmed that the power receiving facility, water supply facility including water storage tank, drainage system, septic tank and sewage pond (if required) and others as described in 4-6-2 (2) will be constructed at the expense of the Pakistani side.

The layout of the testing facilities and power receiving facility are determined by the functional requirements. The administration building is also determined by the functional requirement because the measurement and control room is accommodated in this building.

The periphery of the premise will be provided with tree planting create a green zone, to shield direct sight, noise and vibration, to create cozy atmosphere suitable to a research institute, and to stabilize soil and protect the laboratory from sand and dust on windy days.

4-3-2 Testing Facility Plan

(1) Short-Circuit Test Facility

(a) Test Items and Test Equipment Specification

The specification is such that the equipment short-circuit tests (direct test and synthetic test) can be conducted in accordance with the IEC standards.

The ratings of equipments subjected to tests and the test items are as presented in the table below.

Test Items	Power System Component	Rating
Short circuit tests (Direct)	Circuit breaker (VCB, GCB)	12kV: 8, 12.5, 16, 25kA
" (Synthetic)	" (VCB, GCB)	36kV: "
" (")	" (GCB)	72.5kV: 12.5, 20kA
" (")	" (GCB)	145kV: 12.5, 20kA
Short circuit withstand current tests	CB, DS	12kV ∿ 145kV
"	Transformer	Low voltage side: upto 11kV
"	CT	12kV ∿ 245kV
"	Cubicle	upto 12kV
"	Disconnecting switch	245kV
Small capacitive current breaking test	Circuit breaker	12kV ∿ 145kV

The specifications of major testing equipments are given in the next table.

NO.	APPARATUS	Q'TY	RATING	REMARK
1.	SHORT CIRCUIT GENERATOR			
	1. Short circuit generator	1	Horizontal, cylindrical rotor, rotating field, open air cooled type 3 Phases, 15kV 1500MVA t=0 cycles Connection Wye (Y) Insulation Class F	
	2. Excitation transformer	1	11kV/350V, 50Hz, 600kVA	
	3. Thyristor rectifier cubicle	1	Gate controled thyristor bridge 348kW, 1200A-290V	
	4. Field circuit breaker cubicle	1	DC 290V, 1,200A	
	5. Excitation control cubicle	1	Solid state type, automatic voltage control	
	6. Starting motor	1	Wound rotor, open ventilation, drip proof induction motor 3 Phases, 11kV, Insulation Class F	
	7. Bearing oil system	1	Oil tank capacity 10,000 lit. Max. cooling water temp. 35°C	
	8. Generator control panel	1		
2.	BACK-UP CIRCUIT BREAKER AND MAKING SWITCH			
	1. Back-up circuit breaker	1	Vacuum circuit breaker 3 Phases, 15kV, 80kA	
	2. Making switch	1	Air-blast circuit breaker 3 Phases, 15kV, 200kA (peak)	
3.	CURRENT LIMITTING REACTOR			
	1. Reactor	1 set	0.01-0.02-0.04-0.08-0.16-0.32-0.64-1.28-2.56-5.12 Ω (Total 10.23 Ω /phase) ... Three of each type	
	2. Disconnecting switch	45	Single phase, 15kV, 40kA	

NO.	APPARATUS	Q'TY	RATING	REMARK
	3. Steel structure, copper bars and supporting insulator etc.	1 set		
4.	DISCONNECTING SWITCHES FOR CONNECTION CHANGE			
	1. For main circuit	6	Single phase, 15kV, 40kA Manual operation type	
	2. For primary side of short circuit transformer	10	ditto	
	3. For high current testing room	16	ditto	
	4. For direct testing room	3	ditto	
	5. For pollution testing room	3	ditto	
	6. For secondary side of short circuit transformer	16	Single phase, 45kV, 40kA Manual operation type	
	7. For synthetic testing room	12	ditto	
5.	TESTING TRANSFORMER			
	1. Short circuit transformer	3	Single phase, 15kV/10-15kV, 50MVA, %Z=2%, short circuit capacity 700MVA	
	2. Low voltage high current transformer	3	Single phase, 15kV/250-500V, 3MVA, %z=4%	
6.	MISCELLANEOUS EQUIPMENTS			
	1. Surge absorber	3	Surge arrester : 18.6kV Capacitor : 22kV-0.15μF	
	2. Potential transformer	6	Single phase, 22kV/110V-200VA	
	3. Potential device	3	Single phase, 66kV/110V-200VA	
	4. Surge arrester	3	Single phase, 18.6kV	
	5. Surge arrester	3	Single phase, 42kV	

NO.	APPARATUS	Q'TY	RATING	REMARK
	6. High current making switch	1	Three phases, 460V, 100kA (220kA, peak)	
7.	<u>COMPRESSED AIR SUPPLY PLANT</u>			
	1. Control panel	1		
	2. Pressure reducing valve group	1	Pressure reduction from 30 kg/cm^2 to 15 kg/cm^2	
	3. Air compressor	2	400/230V, 50Hz, 22kW	
	4. Air receiver	3	1000 lit. air tank	
8.	<u>DC SUPPLY SYSTEM</u>			
	1. Battery and battery charger	1 set	DC 110V-1,000AH Charger output DC 250A	
	2. Battery and battery charger	1 set	DC 110V-100AH Charger output DC 75A	
9.	<u>STATION POWER SUPPLY SYSTEM</u>			
	1. Station transformer	2	3 Phases, 11kV/400-230V 50Hz, 200kVA	
	2. AC Distribution panel	2		
	3. DC Distribution panel	2		
10.	<u>TESTING CONTROL PANEL</u>			
	1. Digital sequence panel	1	Solid state type, 24 channels Time step: 10 channels ... 0.1 cycles 14 channels ... 0.25 cycles Max. time 999.99 cycles	
	2. Short circuit test control panel	1		
	3. Test circuit diagram indication panel	1		

NO.	APPARATUS	Q'TY	RATING	REMARK
11.	SYNTHETIC TESTING FACILITY			
11.1	MAIN CONDENCER BANK			
	1. Main condenser bank	1 set	400kV/3.75μF (300KJ) Composition : 4 stages of 100kV-15μF condenser blocks	
	2. Insulating structure	1 set	Neutral point insulation level : BIL 400kV Max. applied voltage: DC 400kV	
	3. Charging resistor	2	Insulation DC 250kV Testing voltage DC 250kV 100 kΩ	
	4 Disconnecting switch for charging	2	Testing voltage DC 250kV(0.5A) Insulation 1 set .. BIL 650kV 1 set .. BIL 400kV	
	5. Earthing device	2	Insulation BIL 650kV Testing voltage DC 250kV Capacity: Discharging of 150KJ through series resistors.	
	6. Resistor voltage divider for measuring of charging voltage	1	DC 250kV, 250 MΩ	
	7. Charging device	1	Input AC 230V Output DC ± 250kV (Max.) Polarity exchange method Charging of 12.5μF x 2 up to ± 200kV within 2 min.	
	8. Current zero point detective device	1	Pulse output range: 1kA-40kA Pulse output: 0-1 ms(variable) before current zero point	
	9. Gap starting device	1	For triggering gap	
	10. Triggering gap	2	High volt. side (Insulation BIL 650kV) and Low volt. side (Triggering gap) ... each 1	
	11. Neutral disconnecting switch	1	Test voltage: DC 250kV with series resistor (50 MΩ)	
	12. Synthetic test control panel	1		

NO.	APPARATUS	Q'TY	RATING	REMARK
	13. Auxiliary power distribution panel	1		
11.2	TRANSIENT RECOVERY VOLTAGE CIRCUIT FACILITY			
	1. Condenser bank	1 set	Max. voltage: 600kV Capacity: 0.473μF (85.2KJ) Composition: 6 stages of 100kV-2.84KJ condenser blocks	
	2. Insulating structure	1 set	Insulation BIL 650kV	
	3. Transient recovery voltage adjusting resistor	each 20	Non-inductive resistance 5-10-20-50-100 Ω-0.5-1-10 kΩ	
	4. Insulating structure	1 set	Insulation BIL 650kV	
	5. Time delay adjusting condenser	each 10	DC 100kV - 0.05μF DC 100kV - 0.1μF	
	6. Time delay adjusting resistor	each 10	0.5 Ω, 1 Ω	
	7. Insulating structure	1 set	Insulation BIL 650kV	
	8. Current source side condenser	1 set	Test voltage AC 15kV Two 4μF condensers series	
	9. Current source side resistor	1 set	AC 30kV 10 Ω(2x5 Ω)	
11.3	CURRENT LIMITTING REACTOR		Insulation level BIL 650kV 500HZ, Total 322 mH	
	1. Reactors	1 set	6kA ... Total 22mH	
	2. Reactors	1 set	3kA ... Total 100mH	
	3. Reactors	1 set	1.5kA ... Total 200mH	
	4. Insulating structure	7 sets	Insulation level BIL 650kV	
11.4	MULTI-LOOP ARC FACILITY			
	1. Condenser	1 set	Max. test voltage: DC 75kV Rating: DC 60kV Capacity: 12μF x 2 sets 30 KJ	
	2. Insulating structure	2 sets	Insulation DC 60kV + AC 30kV	

NO.	APPARATUS	Q'TY	RATING	REMARK
	3. Charging device	1	Input AC 230V Output DC ± 60kV Charging of 24μF x 2 up to ± 50kV within 2 min.	
	4. Disconnecting switch for charging	2	DC 60kV	
	5. Charging resistor	2	DC 60kV	
	6. Resistor voltage divider for measuring of charging voltage	2	DC 60kV, 60 MΩ	
	7. Discharging resistor	2	DC 60kV, 15 Ω	
	8. Discharging reactor	2	DC 60kV, 200μH (22 mm^2)	
	9. Current zero point detective device	2	Pulse output range: 1 kA - 40 kA Pulse output: 100μS before current zero point	
	10. Triggering gap	2	DC 60kV + AC 30kV Vacuum type trigger gap	
	11. Earthing device	2	DC 60kV + AC 30kV Capacity: Discharging of DC 60kV, 22kJ through series resistor	
	12. Gap starting device	2	For triggering gap with pulse selection and amplification functions	
11.5	<u>SHORT LINE FAULT CIRCUIT FACILITY</u>		(π-circuit : z=450 Ω)	
	1. Reactor	1 set	Insulation level BIL 650kV 500Hz - 4kA - 450 Ω Max. 14.4 mH	
	2. Condencer	1 set	AC 35kV Test voltage AC 42kV (750PF x 2), (1500PF x 2) ... each 32.	
	3. Parallel resistor	1 set	AC 40 kV	
	4. Disconnecting switch	1	For line short-circuit AC 40kV	
	5. Sphere gap	1	For line protection, ϕ150 mm	
	6. Insulating structure	1 set	Insulation level BIL 650kV	

NO.	APPARATUS	Q'TY	RATING	REMARK
11.6	AUXILIARY CIRCUIT BREAKER	1	SF_6 Gas circuit breaker 168kV, 40kA	
12.	POWER FACTOR ADJUSTING GRID RESISTOR			
	1. For high voltage side	3	Insulation 36kV 3 stages of 13.2 mΩ, 25kA, 0.2 sec rating grid resistors	
	2. For low voltage side	3	Insulation 15kV 4 stages of 25 mΩ, 5kA, 0.2sec rating grid resistors	
13.	AUXILIARY FACILITIES FOR MEASURING			
	1. Volage divider (Short circuit test)	6	Universal type (RCR type) 40kV, 1/1000, 1/4000 ± 5%, 0 - 100 kHz ± 5% (vs 1 kHz)	
	2. Voltage divider (Synthetic test)	2	Universal type (RCR type) 250kV, 1/5000, 1/10000 ± 5%, 0 - 1 MHz ± 5% (vs 1 kHz)	
	3. 100kA Shunt (Short time current test)	3	Single phase, 500Hz, 100kA/5V, 0.2 sec.	
	4. 30kA Shunt (Short circuit test)	3	Single phase, 500Hz, 30kA/5V, 0.6 sec.	
	5. 5kA Shunt (Short circuit test)	3	Single phase, 500Hz 5kA/5V, 0.2 sec.	
	6. 10A Shunt (for small current measuring)	3	Single phase, 500Hz core type, 10A/5V, continuous	
	7. 100A Shunt (for small current measuring)	3	Single phase, 500Hz core type, 100A/5V, continuous	
	8. Current transfomrer (Short circuit test, internal arc test)	3	Single phase, 50Hz 36kV, 5kA/5A, 15VA, 10 P10, 50kA (1 sec) Transient response (Time constant: 0.1 sec)	
	9. Current transformer (for small current measuring)	3	Single phase, 50Hz 24kV, 50A/5A, 15VA Class 1.0, 3.5kA (1 sec)	

NO.	APPARATUS	Q'TY	RATING	REMARK
	10.50kA Shunt	1	Coaxial type 50kA/5V, 0.6 sec.	
	11.Current transformer for high frequency current measuring (For power source current)	1	PEASON current monitor transformer 1000A/1V	
14.	<u>MEASURING INSTRUMENTS</u>			
	1. Oscillographs	2	18 channels Paper speed Max. 400 cm/sec.	
	2. Dual beam oscilloscope	1	DC - 100 MHz	
	3. Digital memory with display	4	10 Bit, 4K words	
	4. Oscilloscope	1	DC - 100 MHz	
	5. High speed motion picture camera	1		
	6. TV monitoring system	1		
	7. Measuring table	2		
	8. Cabinet	1		
	9. DC power source for oscilloscope calibration	2	0 - 100V variable, 1A	
	10.Calibration meter	2	3, 10, 30, 100, 300V Exchange, Class 0.5	
	11.Adjusting resistor (For oscillo)	2	0.1 Ω - 99.999 kΩ (0.1-1-10-100 Ω-1-10 kΩ 18 channels, each 9 steps notches	
	12.Instant camera (For Digital memory and oscilloscope)	4		
	13.Triggering pulse device (For phenomenon synchronizing)	1	Triggering (voltage pulse, contact signal) Output voltage 10V Pulse width 1 ms.	
	14.Contact resistance measuring device	1	DC 100A, 0 - 10 mΩ	

NO.	APPARATUS	Q'TY	RATING	REMARK
	15.Digital volt meter (For transformer impedance measuring)	2	Accuracy class 0.2% 0 - 200V	
	16.Power supply device for measuring instruments	8	Automatic voltage adjusting 0 - 130V, Insulation transformer 20A	
	17.Surge protection device (For oscillograph)	2 sets	Surge absorbing device for each channel	
15.	<u>DATA ANALYZING FACILITY</u>			
	1. High voltage withstanding DC amplifier	10	1 channel x 10 (for low and middle frequency	
	2. A/D converter	2	2 channels x 2 (for high frequency phenomenon)	
	3. Data analyzing computer	1		
	4. Printer	1		
	5. Plotter	1		

(2) High Voltage Test Facility

This high voltage test facility enables the AC voltage withstand test, the lightning impulse voltage test, the artificial pollution test of 500 kV insulator strings and the dielectric strength test of various equipments under the IEC Standards.

The ratings of equipments to be tested and the test items are presented in the table below.

Test Items	Power System Component	Rating
Lightning impulse voltage test	Insulator strings Circuit breaker Transformer Disconnecting switch etc.	Standard lightning impulse voltage: upto 900kV: (BIL 170) (Transformer: upto 220kV, 250 MVA)
AC withstand voltage test	ditto	AC withstand voltage: upto 395 kV (effective value) : BIL 170
Artificial pollution test (500kV suspension string)	280ϕ standard insulator 320ϕ fog insulators	Model pollution degree: 0.3 mg/cm^2 Fog withstand method
Dielectric characteristic test (Dielectric loss tangent test, Particl discharge test etc.)	Transformer AC generator	-
Induced voltage test	Transformer	Upto 220kV, 75 MVA

NO.	APPARATUS	Q'TY	RATING	REMARK
1.	POWER FREQUENCY WITHSTAND TEST FACILITY			
	1. Testing transformer	1	Single phase, 50Hz, 3.3-6.6kV/500kV, 2MVA (30 min. Rating) Short circuit capacity 20MVA	
	2. Compensating reactor	1	Single phase, 3.3kV 50Hz ... 160 - 400kVA (30 min. Rating) 200Hz .. 40 - 400kVA (30 min. Rating)	
	3. Current limiting reactor	1	Single phase, 3.3kV, 1 Ω	
	4. Voltage regulator	1	Single phase, 0 - 3.3 kV	
2.	IMPULSE TESTING FACILITY			
	1. Impulse generator	1	Max. charging voltage 1800kV, 180KJ	
	2. DC charging device	1		
	3. Automatic control console	1		
	4. Voltage divider	1	Universal type (RCR type)	
	5. Standard sphere gap For high voltage	1	Manual adjusting type, 1000 mm for 1800kV IG	
	For low voltage	1	Manual adjusting type, 250mm	
	6. Coupling capacitor	1		
3.	INDUCED TESTING FACILITY			
	1. Step-up transformer	1	Single phase, 200Hz, 1000kVA (5 min) 3.3kV/18.75-37.5-75-150kV	
	2. High freuquency generator	1	Single phase, 200Hz 3.3kV, 1000kVA	

NO.	APPARATUS	Q'TY	RATING	REMARK
	3. Driving motor	1	Three phase, 50Hz 400V, 600kW	
4.	ARTIFICIAL RAIN FACILITY			
	1. Nozzle and piping	1 set	IEC-60, Europian plain nozzle	
	2. Structure	1 set		
	3. Pump motor	1	37kW, Lift 200m	
	4. Feed motor tank	1	20 m^3	
	5. Control board	1		
5.	ARTIFICIAL FOG GENERATION FACILITY			
	1. Boiler	1	Evaporation quantity Max. 1200 kg/H	
	2. Fuel tank	1		
	3. Feed water tank			
	4. Nozzle and piping	1 set	Nozzle numbers 40 pcs	
6.	WALL BUSHING	1	500kV	
7.	PARTIAL DISCHARGE MEASURING DEVICE	1		
8.	DATA ANALYZING FACILITY			
	1. Digital memory with display	1		
	2. Data analyzing computor	1		
	3. Printer	1		
	4. Plotter	1		