APPENDIX

APPENDIX

KEY PERSONNEL WITH WHOME STUDY TEAM MET

(1) Ministry of Finance, Economic Affair Division (EAD)

Mr. Aftab KHAN	Joint Secretary
Mr. Mohammad FAHEEM	Deputy Secretary

(2) Ministry of Water and Power (MOWP)

Mr. sher Mohammad KHAN	Joint Secretary

(3) Water and Power Development Authority (WAPDA)

Mr. A. Hafeez IBRAHIM	General Manager (Coordination)
Mr. Javid AKHTAR	General Manager (T & G)
Mr. Badar UN-DIN	Chief Engineer (Project Planning)
Mr. Hasinul HAQUE	Chief Engineer (EHV)
Mr. Mian ASLAM	Director Plannig-Transmission-II
Mr. G.M CHAUDHRY	Director Civil Design
Mr. Aslam KHAN	Deputy Director Planning
Mr. Akbar KHAN	Project Director Grid System Construction

MEMBER LIST

1) Basic Design Survey Team (April 7 - 29, 1986)

Name	Designation	Organization
Mr. Kazuo Tanigawa	Leader	Manager Grant Aid Planning and Survey Department, JICA
Mr. Junzo Sago	Project Coordinator	Assistant Manager Grant Aid Division of Economic Cooperation Bureau, MOFA
Mr. Tsuneaki Mogi	Power Planning Engineer	Agency of Natural Resources and Energies, MITI
Mr. Moriichi Hisano	Senior Testing Laboratory Planning Engineer	EPDC International Ltd.
Mr. Hiroshi Kodani	Design Engineer for Control and Measuring System	EPDC International Ltd.
Mr. Minoru Noda	Design Engineer for Short-Circuit Testing Facilities	EPDC International Ltd.
Mr. Sadao Igarashi	Design Engineer for High Tension Testing Facilities	EPDC International Ltd.
Mr. Kenryo Tsuchida	Architectural Design	EPDC International Ltd.

2) Draft Report Team (July 25 - August 6, 1986)

Name	Designation	Organization
Mr. Toshio Nakamura	Leader	Deputy Head Grant Aid Planning and Survey Department, JICA
Mr. Moriichi Hisano	Senior Testing Laboratory Planning Engineer	EPDC International Ltd.
Mr. Hiroshi Kodani	Design Engineer for Control and Measuring System	EPDC International Ltd.
Mr. Ninosuke Kotani	Design Engineer for Short-Circuit Testing Facilities	EPDC International Ltd.
Mr. Sadao Igarashi	Design Engineer for High Tension Testing Facilities	EPDC International Ltd.
Mr. Kenryo Tsuchida	Architectural Design	EPDC International Ltd.

ITINERARY

1. Basic Design Study Team

	DATE	DESCRIPTION
1.	April 7th (Mon)	Leave Tokyo for Rawalpindi via Beijing (6 members only)
2.	8th (Tue)	Visit to JICA Islamabad Office and Discussion with them • Submission of Inception Report • Discussion on the Results of the Projects implemented under Japan's Grant Aid • Hearing on EAD and WAPDA organizations
3.	9th (Wed)	Visit to EAD with the members of Japanese Embassy and JICA Office stationed in Islamabad • Explanation of the scope of study based on the inception report • Submission of Questionnaire Discussion with Mr. Mian (WAPDA)
4.	10th (Thu)	Discussion with Mr. Mian (WAPDA) at JICA Office • Submission and explanation of the inception report and the questionnaire
5.	11th (Fri)	Mr. Tanigawa (Team leader) and Mr. Sago arrive in Islamabad. Internal meeting on the survey schedule
6.	12th (Sat)	Internal meeting to confirm the change of survey schedule
7.	13th (Sun)	Courtesy visits to Japanese Embassy, EAD and MOWP and discussion on the survey schedule with them After the discussions, leave Islamabad for Lahore

DATE		DESCRIPTION
8.	14th (Mon)	Visit to WAPDA Head Office, and explanation and discussion about the scope of study
9.	15th (Teu)	Discussion on the project scale of the Laboratory and the Minutes of Discussions with WAPDA Leave Lahore for Islamabad
10.	16th (Wed)	Preparation of the Minutes of Discussions at JICA Office
11.	17th (Thu)	Signing of the Minutes of Discussions at MOWP Investigation of the Construction machinary Trainning Center
12.	18th (Fri)	Visit to Tarbela Hydroelectric Power Plant
13.	19th (Sat)	Investigation of the Projects implemented under Japan's Grant Aid (1) Islamabad Hospital (2) College of Nuring and Paramedical Institute
14.	20th (Sun)	Internal meeting at JICA Office Mr. Tanigawa (team leader), Mr. Sago and Mr. Mogi returned back to Japan.
15.	21st (Mon)	Internal meeting and data collection Remaining 5 members leave Islamabad for Lahore
16.	22nd (Tue)	Discussions on Answers against questionnaire at WAPDA Head Office Visit to TRANSPAK's and PEL's factories (3 members)
17.	23rd (Wed)	Group A: Discussion with WAPDA at its office in Lahore Group B: Investigation of existing power facilities in Faisalabad

DATE		DESCRIPTION
18.	24th (Thu)	Group A: Discussion with WAPDA at its office in Lahore Group B: Investigation of testing facilities in the University of Engineering and Technology Lahore
19.	25th (Fri)	Internal meeting and data collection Leave Lahore for Islamabad
20.	26th (Sat)	Leave Lahore for Karachi Discussion with transportation agencies and data collection
21.	27th (Sun)	Investigation of Local Manufacturers (J & P, SIEMENS)
22.	28th (Mon)	Visit to KESC and discussion on the pollution of insulators used for transmission lines
23.	29th (Tue)	Return back to Japan from Karachi

ITINERARY

(2) Draft Report Team

DATE		DESCRIPTION
1	July 25 (Fri)	Tokyo (Lv. 12:00) → Karachi (Arr. 21:40) by PK-751
2	26 (Sat)	Karachi (Lv. 7:00) → Islamabad (Arr. 8:55) by PK-300 Courtesy visit to JICA Office
3	27 (Sun)	Courtesy visit to Japanese Embassy Explanation of Draft Report to MOWP and WAPDA
4	28 (Mon)	Islamabad (Lv. 9:30) → Lahore (Arr. 10:20) by PK-381 Explanation and Discussion with WAPDA
5	29 (Tue)	Explanation on Draft Report and Its Discussion with WAPDA
6	30 (Wed)	Summarization of WAPDA comments to Draft Report Mr. Nakamura arrives in Lahore (Arr. 10:10) by PK-830 Internal meeting
7	31 (Thu)	Explanation and Discussion with WAPDA
8	Aug. 1 (Fri)	Lahore (Lv. 10:45) → Islamabad (Arr. 11:35) by PK-332
9	2 (Sat)	Internal Meeting and Preparation of Minutes of Discussions
10	3 (Sun)	Visit to MOWP Explanation of Minutes of Discussions in draft form to MOWP
11	4 (Mon)	Signing of the Minutes of Discussions Courtesy visit to Japanese Embassy
12	5 (Tue)	Courtesy visit to JICA Office Islamabad (Lv. 19:05) → Karachi (Arr. 21:00) by PK-309
13	6 (Wed)	Karachi (Lv. 00:30) → Tokyo (Arr. 16:00) by JL-472

APPENDIX-4

MINUTES OF DISCUSSIONS
ON
THE HIGH TENSION & SHORT-CIRCUIT TESTING LABORATORY CONSTRUCTION PROJECT
IN
THE ISLAMIC REPUBLIC OF PAKISTAN

In response to the request of the Government of the Islamic Republic of Pakistan, the Government of Japan decided to conduct a basic design study on the High Tension & Short-Circuit Testing Laboratory Construction Project and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Pakistan the study team headed by Mr. Kazuo TANIGAWA, Head, 2nd Basic Design Study Division, Grant Aid Planning & Survey Department, JICA from April 7th to 29th, 1986.

The team had a series of discussions on the Project with the officials concerned of the Government of the Islamic Republic of Pakistan headed by Mr. Javid AKHTAR, General Manager (T&GS), Authorized Representative of Water and Power Development Authority and conducted a field survey in Riwat area.

As a result of the study, both parties agreed to recommend to their respective Governments that the major points of understanding reached between them, attached herewith, should be examined towards the realization of the Project.

Islamabad , April 17th, 1986.

Mr. Kazuo TANIGAWA
Leader, Basic Design Study Team
Japan International Cooperation Agency

Mr. Javid AKHTAR
General Manager (T & GS)
Authorized Representative of WAPDA

Mr. Sher Mohammad KHAN
Joint Secretary
Ministry of Water and Power

ATTACHMENT

1. The objective of the Japanese Grant Aid Program is to provide necessary facilities and equipment for the High Tension and Short Circuit Testing Laboratory (hereinafter referred to as "the Laboratory").

2. The basic concept for the Project is as follows :

1) With the improvement of quality of electric power equipment to be used for transmission and distribution facilities including grid stations, the following effects will be available:

- To prevent blackouts due to the faults and accidents of the above equipment.

- To lower the loss for transmission and distribution (KW loss and KWH loss).

- To enable the preparation of the optimum plans for power generation.

- To save fuel cost.

2) To save the foreign exchange spent by Pakistan on tests being carried out abroad in Holland and other countries.

3) To encourage the development of technology for electric power system in the country.

4) To provide facilities and guidelines to local manufacturers to improve and develop indigenously produced items.

3. The project site is located at Riwat approximately 25 km to the southeast of Islamabad, where about 6 ha of plot in square shape as shown in Annex 1 should be acquired at an early date by WAPDA based upon the Public Notice in the PUNJAB GAZETTE (Extraordinary) March 20th, 1985.

4. The Water and Power Development Authority (WAPDA) under the Ministry of Water and Power will be the executing agency for the Project and responsible for its operation and maintenance after completion of the Project.

5. The function of the Laboratory is as follows :

1) High Voltage Test
   a) To secure the pollution test for 500KV insulator
   b) To enable the test for high voltage equipment which will be manufactured
2) Short Circuit and Synthetic Short Circuit Test
   a) To enable the above tests for distribution equipment
   b) To enable the synthetic tests for 132KV circuit breaker which will be manufactured in Pakistan in near future.

6. The Japanese Study Team will convey to the Government of Japan the desire of the Government of Pakistan that the former will take the necessary measures to co-operate by providing the facilities and equipment listed in Annex 2 within the scope of Japanese economic co-operation program in grant form.

7. The Pakistan side has understood Japan's Grant Aid System explained by the Team which includes a principle of use of a Japanese consultant firm and Japanese contractors for the construction of the Laboratory.

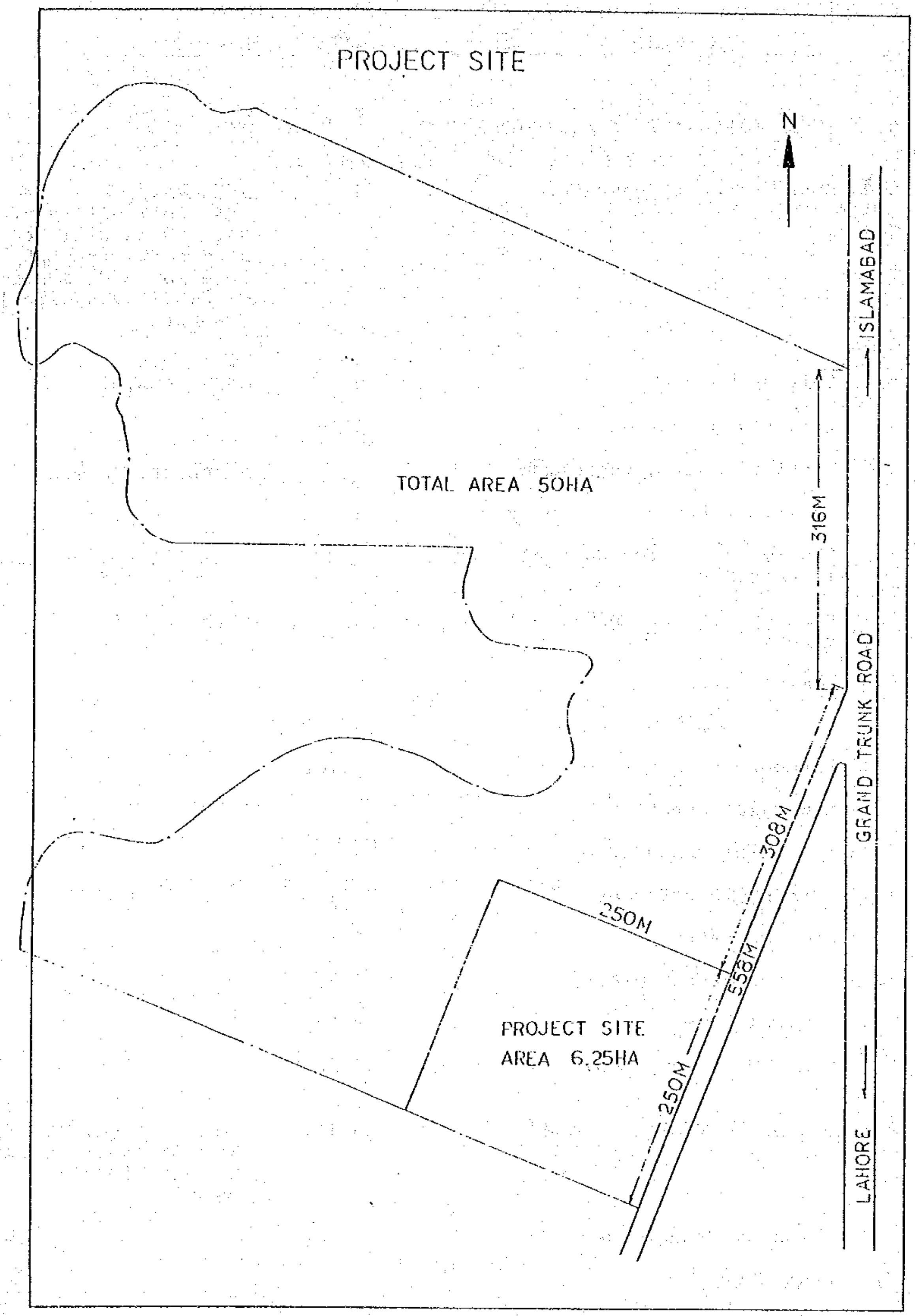
8. Necessary measures to be taken by the Government of Pakistan are shown in Annex 3.

9. The Pakistan side requested the need for a dispatch of Japanese experts as well as technical training of counterpart personnel in Japan in the field of maintenance and operation of the said facilities and equipment. The Pakistan side also understood that in case of the official request for the

above, A-1 form for the assignment of Japanese experts and A-2, A-3 Forms for technical training in Japan for the counterpart personnel should be submitted through diplomatic channels.

10. The Japanese side will prepare the Conceptual Design of the Laboratory based on the study and the discussions made with the Pakistan authorities.

Annex 1


PROJECT SITE
N
ISLAMABAD
TOTAL AREA 50HA
316M
GRAND TRUNK ROAD
308M
250M
558M
PROJECT SITE
AREA 6.25HA
250M
LAHORE

EQUIPMENT		Q'TY	REMARKS
1.	SHORT CIRCUIT TEST EQUIPMENT		
1.1	Short Circuit Generator	1	1500MVA, 50Hz The suitability of the T=0 ms will be studied by the B/D Team for S.C. testing of 245KV/40KA Circuit Breaker
1.2	Driving Motor	1	11KV, 50Hz
1.3	Excitation System	1 lot	
1.4	Short Circuit Transformer	3	secondary 12 & 24KV
1.5	Generator Protection Cubicle	1 lot	
1.6	Low Tension Large Current Transformer	1	Three phase, nominal capacity 3MVA
1.7	Back-up Protection Circuit Breaker	1	40KA, 2000A (three phase)
1.8	Making Switch	1	
1.9	Current Limiting Reactor	1 lot	
1.10	Disconnecting Switch	1 lot	
1.11	Lightning Arrestor	1 lot	
1.12	Potential Transformer	1 lot	
1.13	Current Transformer	1 lot	
1.14	Storage Battery	1 lot	
1.15	Compressor Equipment	1 lot	
1.16	Control Panel	1 lot	
1.17	Other Necessary Equipment	1 lot	
2.	SYNTHETIC TEST EQUIPMENT	1 lot	Outdoor type, 145KV, 20KA to enable tests for Gas Circuit Breaker
2.1	Charging Transformer		
2.2	Rectifier		
2.3	Condenser		
2.4	Computer for measuring and data analysis	1 lot	

	EQUIPMENT	Q'TY	REMARKS
3.	HIGH TENSION TEST EQUIPMENT		
3.1	Pollution Test Equipment	1 lot	
	1) Fog Chamber	1 lot	(With electromagnetic shield)
	2) Testing Transformer	1	500KV, 2MVA, out-door type
	3) Voltage Adjusting Transformer	1 lot	
	4) Cooling Chamber	1 lot	For 500KV Insulator
	5) Wall Bushing	1	500KV
	6) Measuring and Control Panel	1 lot	
3.2	Impulse Test Equipment	1 lot	outdoor type, for 245KV equipment (insulator/transformer
	1) Impluse Generator	1 lot	Lightning impluse test 1800KV Switching surge impluse 1200KV
4.	BUILDINGS		
4.1	Short circuit Generator Bldg.	1	
4.2	Short Circuit Test Bays	1	
4.3	Short Circuit Test Operation Rooms and Administration Offices	1	Approx. for 20 persons
4.4	Fog Bldg.	1	
4.5	Boiler Bldg.	1	

Necessary measures to be taken by the Government of Pakistan

1. To secure the land (Approx. 6 ha) aforementioned, demarcate the area and level the land for the construction of the facilities and buildings.

2. To construct the gate and fence in and around the site.

3. To construct the roads outside and inside the land.

4. To provide facilities for distribution of electricity, water supply including receiving water tank, outdoor drainage, septic tank and ground reservoir if any and other incidental facilities.

5. To supply adequate power for construction purposes before commencement of construction.

6. To construct either a 132/11KV substation or two 11KV incoming distribution lines for the power source of the Laboratory, as may be required in accordance with Annex IV.

7. To construct the residential colony.

8. To submit the results of test boring of the site and value of resistivity of the water to be utilized at the Laboratory.

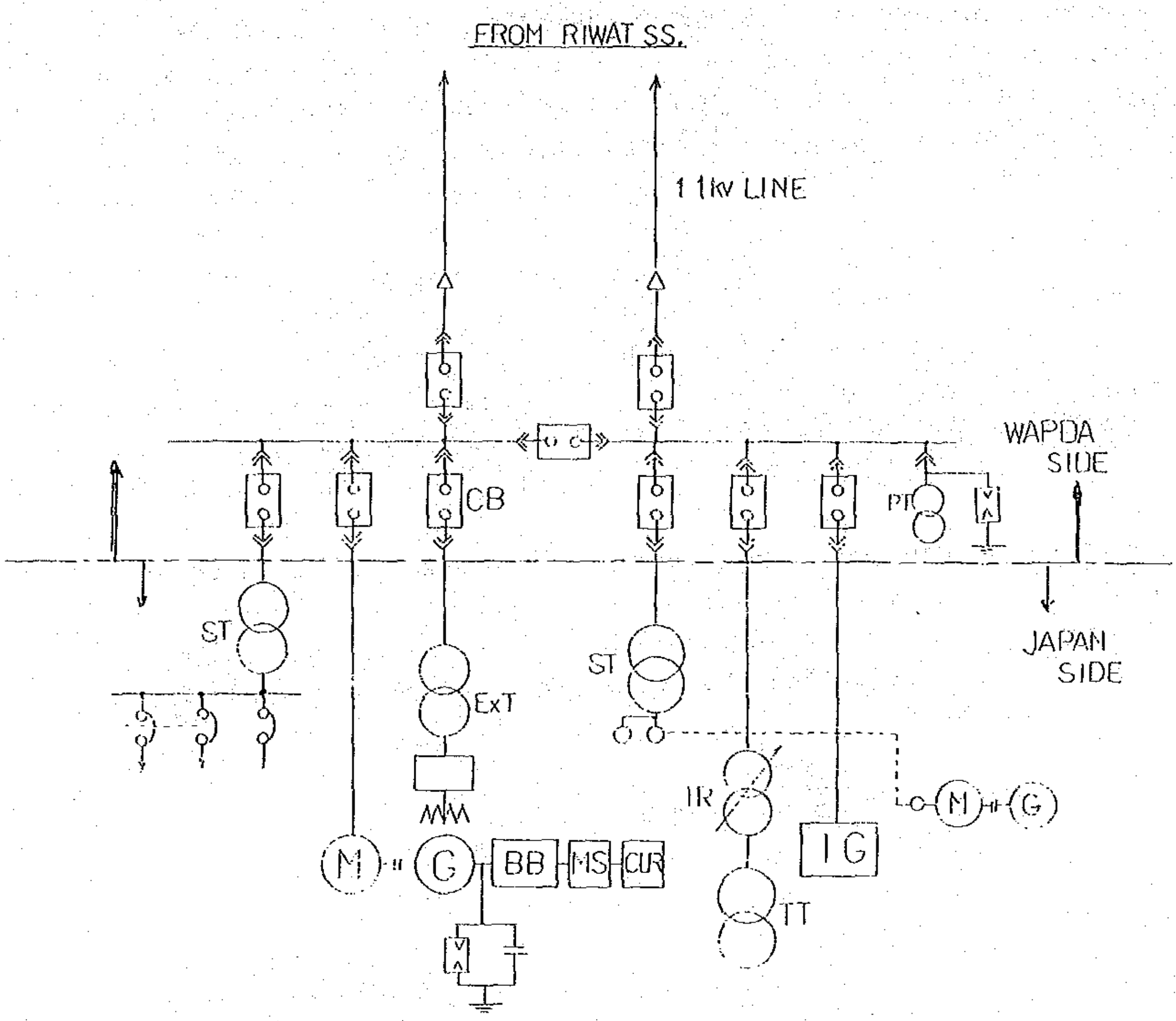
9. To exempt all taxes (duties, fees and charges including sales tax, corporation tax and stamp duty) levied by the Pakistan law on the equipment , materials and construction costs.

10. To provide general furnitures (carpets, curtain, table, chair and others).

11. To maintain and use properly and effectively the facilities constructed and equipment purchased under the Grant.

12. To bear all the expenses other than those to be borne by the Grant.

SCOPE OF CONSTRUCTION WORK



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MINUTES OF DISCUSSIONS
ON
THE HIGH TENSION & SHORT-CIRCUIT TESTING
LABORATORY CONSTRUCTION PROJECT
IN
THE ISLAMIC REPUBLIC OF PAKISTAN

In response to the request of the Government of the Islamic Republic of Pakistan for Grant Assistance for the High Tension & Short-Circuit Testing Laboratory Construction Project (hereinafter referred to as "the Project"), the Government of Japan decided to conduct a basic design study on the Project and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Pakistan the team headed by Mr. Kazuo TANIGAWA, Head, 2nd Basic Design Study Division, Grant Aid Planning & Survey Department, JICA, from April 7th to 29th, 1986.

As a result of the study, JICA prepared a draft report and dispatched a team headed by Mr. Toshio NAKAMURA, Deputy Head, 2nd Basic Design Study Division, JICA, to explain and discuss it from July 25th to August 6th, 1986.

Both parties had a series of discussions on the Report and agreed to recommend to their respective Governments that the major points of understanding reached between them, attached herewith, should be examined towards the realization of the Project.

Islamabad, August 4th, 1986.

中村俊男

Mr. Toshio NAKAMURA
Leader, Basic Design Study Team
Japan International Cooperation Agency

Mr. Javid AKHTAR
General Manager (T & GS)
Authorized Representative of WAPDA

Mr. Sher Mohammad Khan
Joint Secretary
Ministry of Water and Power

ATTACHMENT

1. The Report principally satisfies the Pakistan side and appropriate alterations as shown in Appendix-I will be incorporated in the Final Report.

2. The Pakistan side understood Japan's grant aid system and confirmed that the necessary measures will be taken by the Pakistan side as shown in APPENDIX-2 which are manifested in the ANNEX 3 of the Minutes of Discussions on the Project signed on April 17th, 1986, on condition that the grant aid by the Government of Japan would be extended to the Project.

3. The Pakistan side ensured that the necessary budget for the effective operation and maintenance of the Project constructed under the Grant Aid will be provided in line with the adequate number of the Pakistan personnel with sufficient knowledge and experiences.

4. The Final Report (10 copies in English) will be submitted to the Pakistan side by the end of September, 1986.

- 1 -

MEETING

Date : July 28th to 31st, 1986.

Place : Water and Power Development Authority
Head Office.

Participants:

WAPDA:

Mr. Javid Akhtar G.M. (T & GS)
Mr. Hafeez Ibrahim G.M. (Coord.)
Mr. Badar Ud Din Ahmed Khan
C.E. Project Planning
Mr. Mohammad Afzal Sheikh
C.E. Design (Power)
Mr. Mian Mohammad Aslam
Director Planning Power.
Mr. Manzoor Ahmed Langrial
Director Design
Mr. Masood Iqbal
Deputy Director Design
Mr. Aslam Khan
Deputy Director Planning

JICA

Mr. Toshio Nakamura
Mr. Moriichi Hisano
Mr. Hiroshi Kodani
Mr. Ninosuke Kotani
Mr. Sadao Igarashi
Mr. Kenryo Tsuchida

On July 28th 1986, the Team submitted ten (10) copies of draft final report of the above-mentioned project to WAPDA. The major comments given by WAPDA are as follows:

The Japanese side mentioned that these comments will be examined in Japan in consultation with the authorities concerned, and its results will be incorporated in the Final Report.

COMMENTS

Page	Paragraph	Comments
43	(3) Power Receiving facility (to be born by Pakistan)	The sentence of this sub-clause is amended as follows: 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
43	Para 3.3.5(Para-2... Page-44) Management & Personnel.	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.
82	4-4-3 Facility Plans (1) Electrical facility plan.	The sentence of this sub-clause is amended as follows:
	(a) Incoming Power line.	WAPDA will provide two incoming 11 KV power cable to its 8 panelboards consisting of 5 outgoing with 2 incoming and one bus coupler. This all shall be located in the short-circuit generator building at the location to be indicated by the Japan side.

Page	Paragraph	Comments
91	Fig 4.3 plan of short Circuit Test facilities.	1. Amended lay-out plan to be prepared showing the extension in dotted lines so as to accomodate the installation of additional generator at a later stage with the associated facilities. 2. Lay-out of synthetic test portion also to be incorporated with extension facilities shown in dotted lines. Note: The layout for extension to be designed as such that it facilitdes the placing of identical equipment and facilities alongwith the existing one.
100	Fig. 4.12 FOG BLDG Ground Floor plan.	To check the posibility of relocation of the boiler room close to the fog room.
A-22	New paragraph at the Bottom should be added	The testing equipment installed would be capable for testing as per I.E.C. standard and it would be possible to extend the facilities for testing of equipment upto 245 K V rating at a later stage.
	High Voltage Testing facilities.	1. The capacity of the transformer that can be tested to be mentioned. 2. The arrangement of un-loading and loading of heavy equipments brought for testing to be proposed.

Necessary measures to be taken by the Government of Pakistan

1. To secure the land (Approx. 6 ha) aforementioned, demarcate the area and level the land for the construction of the facilities and buildings.

2. To construct the gate and fence in and around the site.

3. To construct the roads outside and inside the land.

4. To provide facilities for distribution of electricity, water supply including receiving water tank, outdoor drainage, septic tank and ground reservoir if any and other incidental facilities.

5. To supply adequate power for construction purposes before commencement of construction.

6. To construct either a 132/11KV substation or two 11KV incoming distribution lines for the power source of the Laboratory, as may be required in accordance with Annex IV.

7. To construct the residential colony.

8. To submit the results of test boring of the site and value of resistivity of the water to be utilized at the Laboratory.

9. To exempt all taxes (duties, fees and charges including sales tax, corporation tax and stamp duty) levied by the Pakistan law on the equipment , materials and construction costs.

10. To provide general furnitures (carpets, curtain, table, chair and others).

11. To maintain and use properly and effectively the facilities constructed and equipment purchased under the Grant.

12. To bear all the expenses other than those to be borne by the Grant.

LIST OF RECEIVED DATA & INFORMATION EXCEPT ITEMS FILLED IN THE QUESTIONAIRE

REF. NO.	TITLE	NOTE
1.	THE SIXTH FIVE YEAR PLAN 1983-88	PLANNING COMMISSION, GOVERNMENT OF PAKISTAN
2.	PAKISTAN YEAR BOOK	EAST & WEST PUBLISHING COMPANY
3.	POWER SYSTEM STATISTICS TENTH ISSUE NOVEMBER 1985	PLANNING DEPARTMENT POWER WING. WAPDA.
4.	ENERGY YEAR BOOK 1984	GOVERNMENT OF PAKISTAN DIRECTORATE GENERAL OF RESOURCES, MINISTRY OF PETROLEUM & NATURAL RESOURCES
5.	WAPDA ANNUAL REPORT 1983-84	PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY
6.	PAKISTAN ECONOMIC SURVEY 1984-85	GOVERNMENT OF PAKISTAN ECONOMIC ADVISER'S WING FINANCE DIVISION
7.	A GEOGRAPHY OF PAKISTAN	K.U. KURESHY
8.	WAPDA ANNUAL REPORT 1984-85	PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY
9.	CONTRACT DOCUMENTS 216-11 DESIGN, MANUFACTURES, SUPPLY, ERECTION, TESTING AND COMMISSIONING OF THE 220 AND 132 kV PORTION OF JAMSHORO & DADU 500/220/132 kV SUBSTATIONS VOLUME 1	WAPDA PREPARED BY NATIONAL ENGINEERING SERVICE (PAKISTAN) LIMITED
10.	THIRD SECONDARY TRANSMISSION GRID PROJECT TENDER NO. 301 132 AND 66 kV CIRCUIT BREAKERS	WAPDA DESIGN DEPARTMENT POWER WING, JULY 1979
11.	PAKISTAN'S ENERGY POLICY TOWARDS A NEW STRATEGY	SAEED AHMED RASHED INSTITUTE OF POLICY STUDIES ISLAMABAD
12.	MAP OF PAKISTAN	MIRZA. BOOKS
13.	LAHORE GUIDE MAP	FEROZSONS LTD.

REF. NO.	TITLE	NOTE
14.	CATALOG. (SIEMENS) .TYPE PDB OIL CIRCUIT-BREAKERS .METAL-CLAD DISTRIBUTION SWITCHGEAR TYPES AG 16 AND FG 16 .DIESEL GENERATING SETS .POWER ENGINEERING IN PAKISTAN .DISTRIBUTION SYSTEM 8HK (GT-SYSTEM) .MOTOR CONTROL BOARDS FOR HOLLOW SHAFT PUMP MOTORS .THREE PHASE OIL IMMERSED DISTRIBUTION TRANSFORMER .POWER DIVISION MANUFACTURING AND SALES PROGRAMME .GT-SYSTEM 8HKO MODULAR SHEET-STEEL HOUSINGS FOR THE ASSEMBLY OF LOW TENSION DISTRIBUTION BOARDS UP TO 1,000A BUSBAR-RATING MOTOR CONTROL GEAR	SIEMENS PAKISTAN ENGINEERING CO. LTD.
15.	CATALOG TRANSPAK	TRANSPAK ELECTRO INDUSTRIES LTD. LAHORE
16.	CONTRACT DOCUMENTS 261-11 ADDENDUM-3	WAPDA
17.	PAKISTAN ELECTRICITY GRID 1980-95 DWG NO. POW/TL.56	WAPDA PLANNING DEPARTMENT(POWER)
18.	220/132/66KV TRANSMISSION LINES PHYSICAL DETAIL DWG. NO. OEM/B-26 31.7.1985	WAPDA
19.	PAKISTAN NATIONAL GRID SYSTEM LOAD DISPATCH CENTRE DWG. NO. LDC-701 1.1.1985	WAPDA
20.	CATALOG PEL	PEL. PAK ELECTRON LTD.
21.	CATALOG TUBUAR STEEL POLES	KARACHI PIPE MILLS LTD.

REF. NO.	TITLE	NOTE
22.	SURVEY OF PAKISTAN MAP OF PAKISTAN SCALE1:3,000,000	THE SURVEY OF PAKISTAN OFFICE
23.	POWER FLOW DIAGRAM LOAD DISPATCH CENTER	WAPDA
24.	LETTER CHIEF ENGINEER DESIGN T & G - CHIEF ENGINEER PROJECT (PLANNING POWER) JAPANESE DESIGN MISSION VISIT 13/04/1986	WAPDA
25.	ISLAMABAD GUIDE MAP	
26.	SURVEY OF PAKISTAN LAHORE GUIDE MAP 1:25,000	THE SURVEY OF PAKISTAN OFFICES RAWALPINDI
27.	WAPDA COMPOSITE SCHEDULE OF RATES 1979	WAPDA
28.	DRAFTING STANDARDS (GENERAL) VOLUME-I	WAPDA
29.	SOIL INVESTIGATION FOR PROPOSED HIGH TENSION AND SHORT CIRCUIT TESTING LABORATORY FOR WAPDA AT RIWAT	WAPDA
30.	ARCHITECTURAL DESIGN OF OFFICE BUILDING OF C.E.G.S.O ISLAMABAD	WAPDA
31.	KEMA REPORT OF PERFORMANCE NO.127-84	KEMA
32.	KEMA REPORT OF PERFORMANCE NO.642-82	KEMA
33.	TECHNICAL SPECIFICATIONS FOR POWER CIRCUIT BREAKER	
34.	MANUFACTURE AND ASSEMBLY OF HIGH VOLTAGE SWITCHGEAR IN PAKISTAN	
35.	NESPAK PRICE INDEX AUGUST 1984	

SELECTION OF FACILITY SCALE

(1) Short-Circuit Testing Facility

(a) Test Items

The facility provides direct and synthetic short-circuit tests on equipments under IEC Standards.

The equipments subjected to tests and the test items are as given in the table below.

Test Item	Tested Equipments	Ratings
Short-circuit test (direct)	Circuit breaker (VCB, GCB)	12kV: 8, 12.5, 16, 25 kA
Short-circuit test (synthetic)	Circuit breaker (VCB, GCB)	36 kV: 8, 12.5, 16, 25 kA
Short-circuit test (synthetic)	Circuit breaker (GCB)	72.5 kV: 12.5, 16, 25 kA
Short-circuit test (synthetic)	Circuit breaker (GCB)	145 kV: 12.5, 20, 40 kA
Short-circuit strength test	Circuit breaker, line switch	12 ∿ 145 kV
Short-circuit strength test	Transformer	Low voltage side 11 kV transformer
Short-circuit strength test	Instrument transformer	12 kV to 245 kV
Short-circuit strength test	Enclosed type switch board	up to 12 kV
Short-circuit strength test	Line switch	245 kV

(b) Calculation of Short Circuit Generator Capacity

(i) In Case of Direct Short-circuit Test

Generally speaking, the direct axis subtransient % reactance of a 4 pole, 1,500 rpm short-circuit generator having the rated capacity of 90 MVA is estimated to be 6% at the instant of short-circuiting (t = 0), and 8.5% at t = 3 cycles. Accordingly, the short-circuit capacity of this generator at the instance of 3 phase short-circuiting is 90 MVA/0.06 = 1,500 MVA, and 90 MVA/0.085 = 1060 MVA at t = 3 cycles. An example of the change of short-circuit capacity with time is illustrated by the attenuation curve in Attached Figure.

Assuming the impedance of the short-circuit transformer to be 2.0% and the total impedance of the bus to be 1.0%, the short-circuit capacity at t = 3 cycles can be expressed by the following equation.

$$\text{MVA } (t=3) = 90/(0.085 + 0.02 + 0.01) = 783 \text{ MVA}$$
$$Is = 783 \text{ MVA}/(\sqrt{3} \times 15 \text{ kV})\ 30.1 \text{ KA} > 25 \text{ kA}$$

That is, the short circuit generator has sufficient marginal capacity in the direct short-circuit test, and it is required to insert the series reactance to limit the current at 25 kA.

(ii) Synthetic Test

The short-circuit capacity in a single phase short-circuit can be calculated as below based on the impedance presented above.

$$\text{MVA } (t = 3, 1\ \phi) = 90/(0.085 \times 2 + 0.01 \times 2 + 0.02 \times 3/3) = 428.6 \text{ MVA}$$

The short circuit current in this case has the following value.

$$Is\ (t = 3, 1\ \phi) = 428 \text{ MVA}/10 \text{ kV} = 42.8 \text{ KA} > 20.0 \text{ (kA)} > 40.0 \text{ (kA)}$$

This value is sufficient for performing the synthetic short-circuit test duty No. 4 which is "0 - t_1 - C'0 - t_3 - C'0 or 0 - C'0 - t_1 - C'0 with the generator having the nominal capacity of 90 MVA.

In the synthetic test, the tap of the short-circuit transformer is set at 15/10 kV.

(iii) Calculation of Capacity of Synthetic Voltage Source Condenser

The main condenser voltage is calculated below for the test for 145 kV, 20 kA circuit breaker and 145 kV, 40 kA circuit breaker.

The maximum value of the line to earth voltage on 145 kV side is given by the calculation below.

$$V_A = 145 \text{ kV} \times 1.5/\sqrt{3} = 125.5 \text{ (kV, rms)}$$

Thus the condenser charging voltage is given by:

$$V_o = 125.5 \text{ kV} \times \sqrt{2} = 177 \text{ (kV);(DC)}$$

The value of the voltage source current regulating inductance is obtained as below.

$$Lx_{20} = 122.5 \text{ kV}/(2 \times \pi \times 50 \times 20 \text{ kA}) = 0.0195 \text{ H} = 19.5 \text{ mH: (20 kA)}$$

$$Lx_{40} = 122.5 \text{ kV}/(2 \times \pi \times 50 \times 40 \text{ kA}) = 9.7 \text{ mH: (40 kA)}$$

The frequency of the voltage source current is generally selected at around 10 times the commercial frequency. Thus, assuming the frequency f_V = 500 Hz, the condenser capacity of the voltage source can be determined by the calculation below.

$$Cv = 1 / ((2\pi \times 500)^2 \times 19.5 \times 10^{-3}) = 5.20 \ \mu\text{F: (20 kA)}$$

$$Cv = 1 / ((2\pi \times 500)^2 \times 9.7 \times 10^{-3}) = 10.4 \ \mu\text{F: (40 kA)}$$

The capacity of the condenser for the lower limit frequency of f_v = 300 Hz is given by the calculation below.

$$C_v = 1/[(2 \quad \times 300)^2 \times 19.5 \times 10^{-3}] = 14.4\ \mu F\text{: (20 kA)}$$

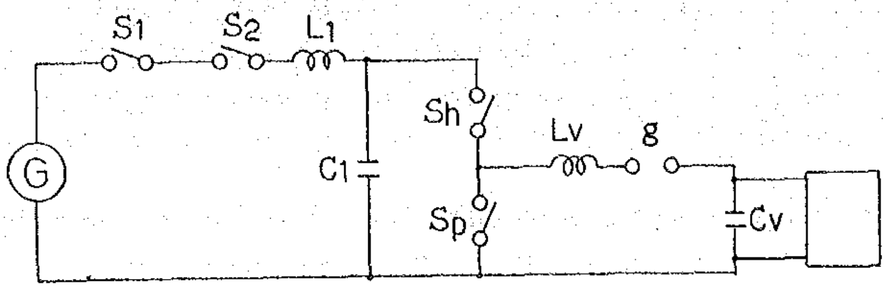
For the upper limit frequency of f_v = 1,100 Hz, the capacity is:

$$C_v = 1.1\ \mu F \text{ : (20 kA)}$$

Based on these calculations, the main condenser ratings of the synthetic test voltage source has been selected at the testing voltage of 100 kV and capacity of 15 μF.

The testing equipment installed would be capable for testing as per I.E.C. standard and it would be possible to extend the facilities for testing of equipment upto 245 kV rating at a later stage.

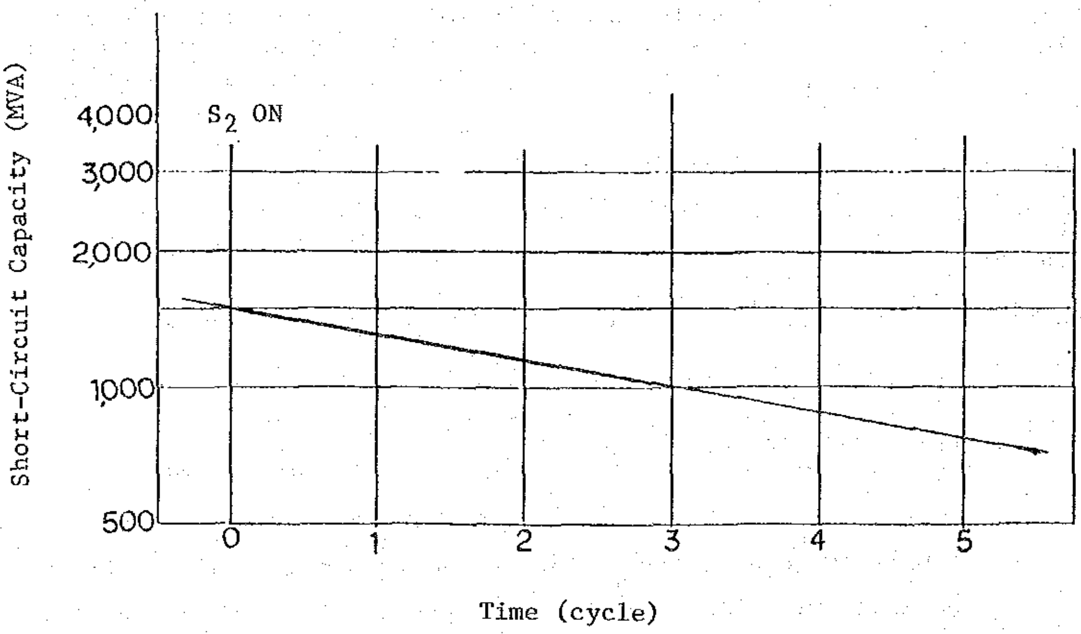
Fig. A.6.1 Variation of Short-Circuit Capacity



S_p:C.B undertest　　C_V;Voltage Source Condencer

S_h:Aux. C.B　　L_V:Current Adjusting Inductance

Example of Attenuation Curve (4P, 1,500 rpm 90 MVA Turbo-Generator)



(2) High Voltage Testing Facility

(a) Test Items

With this high voltage testing facility, the AC voltage withstand test, the lightning impulse voltage test, the artificial pollution test of 500 kV insulator strings, and the insulation characteristics tests of a variety of equipments can be performed under the IEC Standard.

The ratings of tested equipments and the test items are presented in the following table.

Test Item	Tested Equipments	Ratings
Lightning impluse voltage test	Insulator string, circuit breaker, transformer, etc.	Lightning impluse test with nominal voltage up to 220kV. (for transformer up to 220 kV and 250 MVA)
AC voltage withstand test	(same as above)	AC voltage withstand test up to 220 kV.
500 kV insulator string artificial pollution test	280 mm diameter standard insulator and 320 mm diameter fog insulator.	Insulator string pollution test with 0.3 mg/cm^2 contamination. (constant voltage withstand test in mist.)
Insulator characteristics test, tan δ, partial discharge	Transformer, AC generator.	
Induction voltage test	Transformer	up to 220 kV, 75 MVA.

(b) Needs for Test Facilities

In performing analysis of high voltage phenomena, the study must depend on experiments by real sized equipment models. Although mathematical models can be developed and have the mathematical equations solved by means of electronic computers to obtain solutions to clarify the phenomena in general electric circuits, this method is not always applicable to the high voltage phenomena, in which real sized models must be designed and constructed based on the knowledge related to the phenomena, and the solutions obtained by performing experiments on the models. Such experiment facilities are indispensable for the development of high voltage technology, and the electric power engineering which is useful in the particular local conditions can be enhanced drastically by use of such experiment facility.

(c) Scale of High Voltage Test Facility

The high voltage test facility is designed to conduct tests for commercialization of equipments or for research and development on such high-voltage, large-capacity facilities as transformer, circuit breaker, lightning arresters and insulator strings. The facility generally consists of impluse voltage generator, AC and DC high voltage generating equipments, instrumentations and the high voltage testing hall.

Today, there is no standard on the ratings of high voltage test facilities. However, the 33 Research Committee of CIGRE has recently proposed ratings for the UHV class testing facilities as presented in Table A.6.1. This proposal of CIGRE has been used as the basis in specifying the ratings for this high voltage test facility. This method used is to determine the rated voltage of the testing equipments by multiplying the equipment withstand voltage by certain coefficients. This is:

(Test facility rated voltage) = Withstand voltage x coefficient (k)

= Withstand voltage x k_1 x k_2 x k_3

Here, k_1 is the coefficient for research and development, k_2 for the voltage drop caused by the load connected to the test equipment, and k_3 is the safety factor to provide a margin in the ratings. Accordingly, the test equipment rated voltage is obtained by multiplying by k_2 and k_3 when it is used for the commercial tests only, making it possible to select a lower rated voltage for the test equipment. In this plan, however, it was assumed that research and development works would be conducted as well as the commercial test in determining the test equipment rated voltage. The generated voltage coefficients are presented in Table A.6.1.

Table A.6.1 Generated Voltage Coefficient

Test Type	Coefficient			
	Research k_1	Load k_2	Safety k_3	Total k
Lighning Impulse Test	1.3	1.4	1.1	2.0
Switching Impulse Test	1.3	1.8	1.1	2.6
AC Test	1.0	1.0	1.1	1.7
DC Test	1.2	1.25	1.1	1.7
AC Contamination Test	1.1	1.0	1.1	1.2

Note: $k = k_1 \times k_2 \times k_3$

Quoted from Proceedings of Institute of Electrical Engineering. "Recent trend in high voltage, large power testing facilities".

(d) Size of Impulse Voltage Generator

* Lightning Impulse Voltage Generator

The ratings of the impulse voltge generator stated in the preliminary study report are as below.

It is rated for conducting impulse test for such equipments as insulator strings and transformer (250 MVA) up to 220 kV, and the impulse generator is an outdoor type.

* Lightning impulse generated voltage; about 1,800 kV.
* Switching impulse voltage generated; (about 1,000 kV).

The test of 500 kV equipments is regarded as a task of future, and this is not taken into consideration.

In the current study and discussions with the Pakistan parties, it was decided to determine the ratings of the equipments within the framework of those in the preliminary study report in determining the impulse generator voltage and the storage energy.

The equipment test voltage ratings are as below according to JEC193-1974.

Nominal voltage;	220 kV.
Insulation class;	No. 170.
Lightning impulse withstand test voltage	900 kV.
Standard waveform;	1.2±50 μs

According to the recommendation for the test generated voltage by CIGRE cited above, the total multiplier coefficient is 2.0. With these values, the rated voltage for the impulse generator can be given by the following calculation.

$$\text{Lightning impulse testing voltage} = 900 \times 1.3 \times 1.4 \times 1.1 = 900 \times 2.0 = 1{,}800 \text{ kV}$$

The switching impulse test is not applicable to the commercial test of equipments having 220 kV nominal voltage. However, the following voltage was selected to make provision for research and development activities.

Switching impulse test voltage;	approximately 1,000 kV.
Standard waveform;	±250/2,500 μs

The lightning impulse generator can also provide the switching impulse voltage by changing the circuit elements.

In this plan, the impulse voltage generator was designed as an outdoor type in order to eliminate the need for the high voltage hall. As an outdoor type equipment can generate 70% of the full output even in rain, there is no problem in conducting the general commercial tests.

(e) Selection of Test Transformer Rating

The ratings of a test transformer are determined by the rated voltage and rated capacity. Generally, the voltage withstand test of a testing transformer is 110 to 120% of the rated voltage, having less margin than the common commercial power transformers. Thus a sufficient allowance must be provided for selecting the rated voltage.

(i) Rated Voltage

JEC-193-1974 stipulates a commercial withstand test voltage (effective value) of 395 kV for tests of equipment with nominal voltage of 220 kV and insulation class of No. 170. The rated voltage of the test transformer is determined by multiplying this value by the generated voltage coefficient 1.1 for AC voltage test recommended by CIGRE as cited above, that is;

$$\text{Rated voltage} = 395 \text{ kV} \times 1.1 = 435 \text{ kV}$$

As this test transformer is used for the artificial pollution test of 500 kV insulator strings, the required rated voltage for this test must also be studied. The maximum circuit voltage of a 500 kV transmission line is 550 kV for a long line, and maximum value of its line to ground voltage is $550/\sqrt{3}$ kV = 318 kV. As the generated voltage coefficient k of the artificial contamination test is 1.2, the rated voltage for the transformer for this test is given by the following calculation.

$$\text{Rated voltage} = 550/\sqrt{3} \times 1.2 = 381 \text{ kV}$$

According to these calculations, the rated voltage of the test transformer is determined by voltage required for the AC withstand voltage test, which is 435 kV. In this study, the rated voltage was selected at a standard value of 500 kV to provide some design margin.

(ii) Rated Current

The rated current of the test transformer is determined by the current that flows in the tested object. The capacity of the test transforemr W_c (kVA) is determined by the following equation.

$$W_c = VI_c = \omega c\ V^2 \times 10^{-9}\ (kVA)$$

where V (kV) is the test voltage, $C_{(PF)}$ the static capacitance of the tested object, I_c (A) is the charging current.

It is generally regarded that, when the capacitance of the tested object is unknown, the suitable value for the general test transformers is from 0.1 to 0.2 kVA for testing voltage of 100 kV or so, and from 0.4 to 0.5 kVA/kV for voltage of 500 kV or so. The capacity of the testing transformer under this study is, by assuming that it is of general type, given by the following calculation as the suitable value for general use.

$$\text{Continuous rated capacity} = (0.4 \sim 0.5)\ \text{kVA/kV} \times 500\ \text{kV} = 200 \sim 250\ \text{kVA}$$

The 30 minute rating given based on the continuous rating above is given by the following calculation.

$$\text{30 minute rating} = (200 \sim 250) \times 2 = 400 \sim 500\ \text{kVA}$$

The test transformer under this study is also used for the artificial pollution test of 500 kV suspension insulator strings. To conduct this test in a satisfactory manner, sufficient margin must be provided in the power source capacity so that the terminal voltage is not excessively reduced when flashover occurs on the insulator. It is generally regarded a short-circuit current of approximately 40 A must be maintained in order that phenomena such as destruction of insulator are created at flashover. This value of short-circuit current is the one adopted by the Central Research Institute for Electric Power Industry for its artificial contamination test facility. As the total impedance consisting of test transformer, voltage regulator and power source transformer can generally be regarded as approximately 10%, the rated capacity can be determined by the following calculation, based on the assumed rated current of 4A.

Rated capacity = 500 kV x 4A = 2,000 kVA

This capacity has enough margin as an artificial pollution test. It is expected that this facility can contribute to solving the salt pollution hazards not only in the Islamic Republic of Pakistan but also in the neighboring nations.

(3) Fog Room

(a) Artificial Pollution Test

(i) Pollution Flashover Test Method

It used to be, in Japan in the period after the second World War, frequent flashover faults were encountered in wide areas on transmission and distribution lines whenever a typhoon came, and it took a long time to restore the power supply every time this occurred. This event motivated establishment of the committee for effective countermeasures, and various testing methods were proposed by the committee. After deliberate studies and experiments, the pollution fashover test method have been established as the standard method because it has a distinctive advantage of not requiring the fog room. This testing method has been adopted as the standard method in JEC170 "General AC Voltage Insulation Tests". In this method, contaminated liquid is placed on the insulator, and voltage is applied 3 minutes afterwards in principle. The voltage is raised at a rate that the expected flashover voltage is reached in 10 to 30 seconds, and the flashover voltage is confirmed. The test is repeated 10 times in principle, and the 5% flashover voltage is determined from these 10 flashovers. This voltage is then defined as the artificial pollution test AC flashover voltage.

(ii) Fog Withstand Test Method

In this method, the insulator is treated with the contaminated liquid and dried as in the equivalent fog test. The contamination of the sample is renewed for every application of voltage. The sample is brought into the fog room, and artificial fog is created after a certain amount of voltage is applied. The artificial fog is created by spraying fog from the nozzle in the fog room. In this operation, it is so arranged that the sprayed fog does not attack the insulator directly. This status is maintained for 20 to 60 minutes, while observing the insulator until the leakage current decreases to confirm whether or not the flashover occurs. The voltage is raised or lowered with steps of 5 to 10% depending on the occurrence of flashover, and the withstand voltage is defined as the one with which the flashover does not occur for 4 applications of voltage.

The pollution flashover test method was generally sufficient for the standard suspension insulator strings because the variation of the flashover voltage was little even if the states of contamination is not even on the insulator string or if the method of applying voltage is changed. With the long rod insulator and bushing, however, the flashover voltage is high when the contamination is provided evenly, and the voltage is reduced substantially if the contamination is uneven. Further, a bushing having large diameter exhibits very low flashover voltage when contamination is uneven. Thus there have been problems associated with this method. In addition, under the influences of test results on insulator flashover voltage characteristics in the natural conditions and the international trend in the artificial pollution method, more emphasis are being placed recently on the constant voltage application fog withstand test method employing the fog room.

In the international scene, IEEE has been studying the fog withstand test method for about 10 years, and is planning to standardize the test method based on this study. The same test method is also being examined for standardization by IEC, and this test is being examined in many research institutions of the world as the step for formal adoption as a standard.

Thus, the artifical pollution test facility in this project has been planned as facility in which the artificial pollution test can be performed by means of the fog room and warm water fog, considering the world wide trend for adoption of the fog withstand test method as described above.

(b) Length of 500 kV Transmission Line Insulation

The Insulation of a transmission line is so designed that it withstands the commercial frequency overvoltage and the switching surges, but falshovers of certain frequency is allowed against the lightning surges.

For the commercial frequency overvoltages, an insulation strength sufficient to withstand the voltage rise when all the load is dropped, which is 428 kV (550 kV/$\sqrt{3}$ x 1.35). In taking into account the effect of wet contamination, the voltage standard is reduced from the above value of 428 kV becuase there is little probability of simulataneous occurrence of overvoltage and contamination, and the voltage occuring in an one-line-to ground fault of 380 to 412 kV is chosen as the target withstand voltage. Generally speaking, the number of insulators for a 500 kV transmission line is determined by the salt contamination design when the maximum salt contamination density of the insulator is approximately 0.06 mg/cm^2 or more. The insulators of 280 mm x 170 mm or 320 mm x 195 mm are usually used for the 500 kV transmission line. In an area where the salt hazard is class C, and the contamination density is 0.3 mg/cm^2, 40 insulators are required if 320 mm fog-proof insulators are used, and the total length of an insulator string is 6.8 m (170 mm x 40).

In the current study, no datum was available concerning the salt hazard in the Karachi area. There has been no measurement conducted in this area concerning the dust contamination and salt deposit density on pilot insulators, and there seems to be no such plan either for future. Accordingly, the design conditions for the 500 kV transmission line in Japan were referred to as basis and fog room was planned so that it is capable of testing insulator strings prevailing in Japan. These insulator strings have the maximum length of 6.1 m (170 mm x 35) consisting of 280 mm suspension insulators for the contamination condition of salt deposit density of 0.06 mm/cm^2 (design conditions for Boso Line, Fukushima Trunk Line and Ise Trunk Line), or 6.8 m long (170 mm x 40) in the heavily contaminated area where the salt density on insulator is 0.3 mg/cm^2 (to about 3 km inland from sea shore). The approximate dimensions of the facility is illustrated in Figure A.6.1.

(c) Required Insulation Clearance

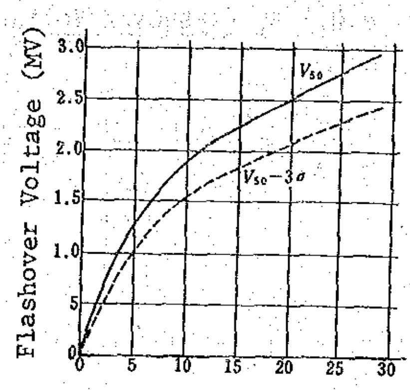
The high voltage test can not be conducted if there is possibility of occurrence of flashovers from the high voltage generator equipment or the tested object to the surrounding grounded object, such as the fog room ceiling and room walls. Because of this risk, it is required to study the required insulation clearance in the air. In general, the required insulation clearance is determined based on the flashover voltage characteristics when a switching impulse voltage is applied to the air gap between a rod and a plate electrodes, which have the lowest flashover voltage in the air.

The flashover characteristics between rod and plate electrodes for a positive polarity switching impulse flashover voltage is given in Figure A.6.2. In this figure, the 50% flashover voltage V-50 for a waveform having the wave front length of 100 to 300 μs and positive polarity, exhibits the lowest flashover voltage.
The broken line curve in the figure represent values which is V-50 minus 3, to provide the concept of the withstand voltage. The broken line curve in the figure indicates, for example, that the insulation clearance required for a stable generation of 1.2 MW switching impulse is approximately 6 m.

In Fig. A.6.3, "Minimum Clearance to Wall" presented on a catalogue prepared by ASEA is shown. This figure indicates the relation between the total charging voltage of the impulse voltage generator and the minimum clearance. The minimum clearance for a total charging voltage of 1,800 kV is 3.5 m.

The voltage applied in the artificial contamination test using a fog room has the commercial frequency, and the required rod to plate and rod to rod clearance for the test transformer terminal voltage of 500 kV is 150 cm (for 50 Hz peak value: Fig. A.6.4). Based on the overall considerations on the various distance requirements above, the fog room was designed with clearance of 5 m.

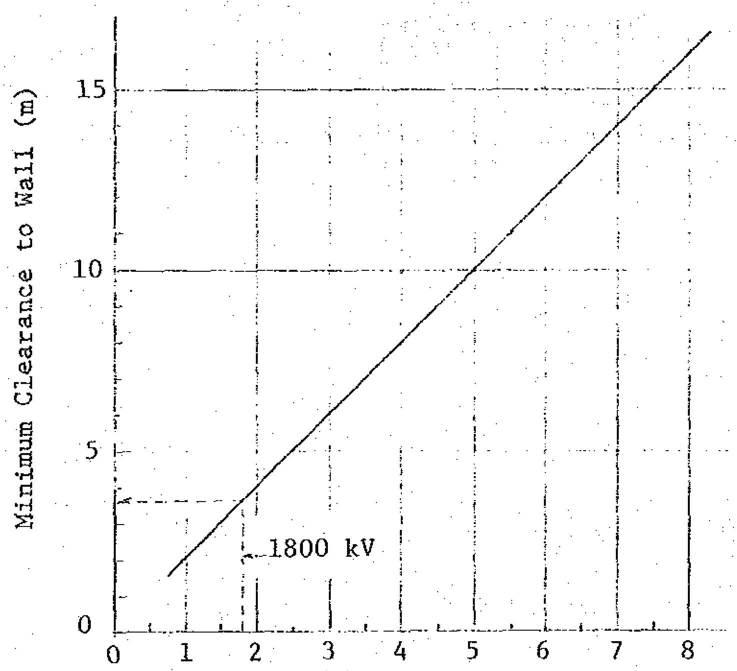
Fig. A.6.2 Switching Impulse Flashover Voltage
(positive, bar to plate)



Gap Clearance (m)

Source; Handbook of High-voltage Testing (J.I.E.E.)

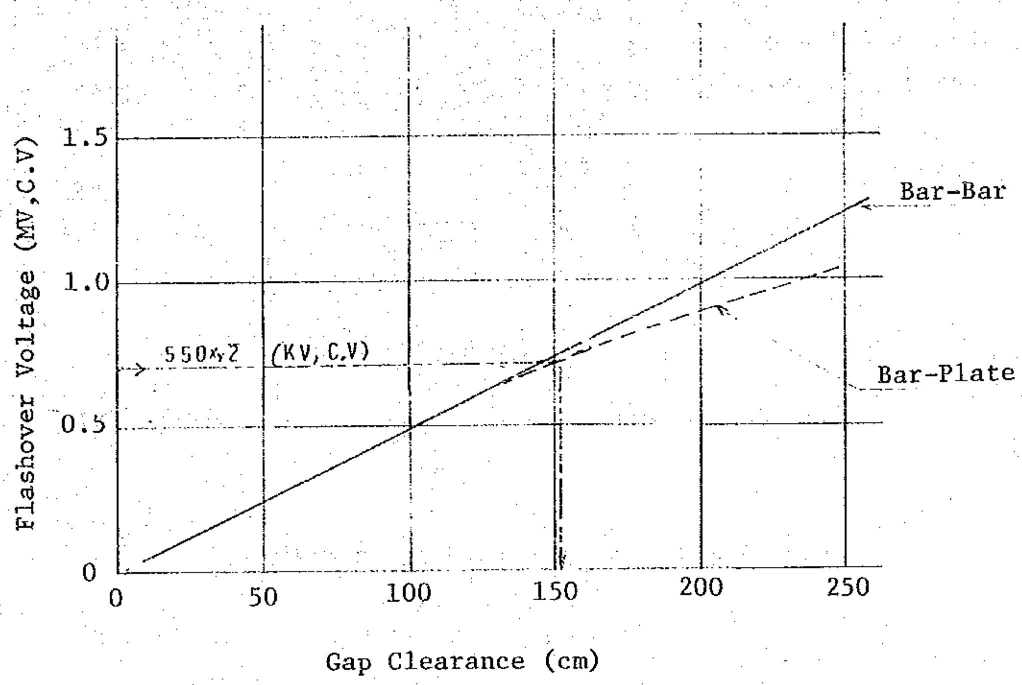
Fig. A.6.3 Minimum Clearance to Wall



Total Charging Voltage (MV)

Source; Impulse Voltage Generators Series
ASEA HAEFELY MICAFIL

Fig. A.6.4 AC Flashover Voltage



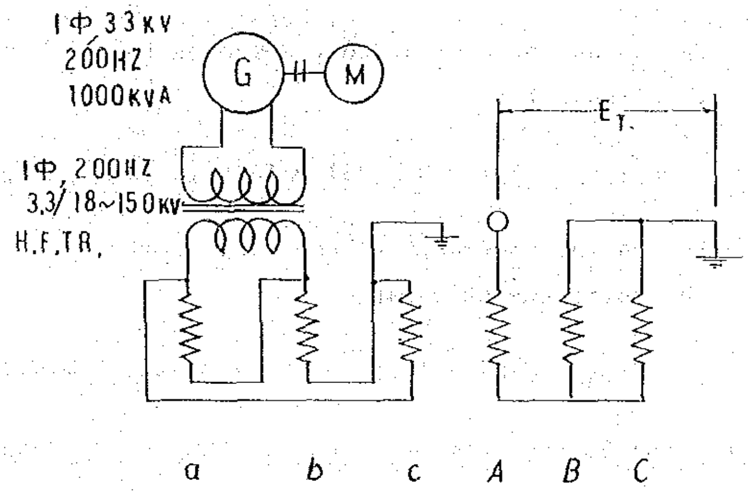
Source; Handbook of Electrical Engineering (J.I.E.E.)

(4) Determination of Induction Generator Capcacity

The following induced voltage test circuit was assumed for the 220 kV, 3-phase, 25,000 kVA transformers which are the standard transformer of WAPDA. The capacity of the induction generator was selected based on this circuit.

1. Connection diagram

Fig. A.6.5 Connection Diagram



2. Estimates of Excitation Current and Iron Loss at 50Hz

a) Excitation Current

The excitation current is assumed to be 2% of the full load current.

$$Ie_{50} = 25,000 \text{ kVA}/(\sqrt{3} \times 3.5 \text{ kV}) \times 0.02$$
$$= 88 \text{ (A/phase, r.m.s.)}$$

b) Iron Loss (rated voltage)

Assuming the transformer efficiency at 99%, the total loss Wt can be expressed by the following equation.

$$W_t = 25,000 \text{ kVA} \times 0.01 = 25 \text{ (kVA)}$$

Assuming that the iron loss is 1/3 of the total loss:

$$W_{f50} = 250/3 = 83 \text{ (KW)}$$

The amount of current corresponding to this iron loss on the 3.3 kV circuit is:

$$I_{f50} = 83/(3.3 \times \sqrt{3}) = 14.5 \text{ (A/phase, r.m.s.)}$$

c) The no load current (at the rated voltage) for 50Hz is given by the following calculation.

$$Io_{50} = \sqrt{88^2 + 14.5^2} = 89 \text{ (A/phase, r.m.s.)}$$

3. Excitation Current and Iron Loss at 200 Hz and Rated Voltage

a) Excitation Current

When the rated voltage is applied at 200 Hz, the magnetic flux of the transformer core B_{200} is 1/4 the amount with a 50 Hz rated voltage. that is, $B_{200} = B_{50}/4$. Accordingly, the excitation current is given by the following calculation.

$$Ie_{200} = Ie_{50}/4 = 88/4 = 22 \text{ (A/phase, r.m.s.)}$$

b) Current by Iron Loss

The iron loss with 50 Hz frequency is given by the following equation.

$$
\begin{aligned}
W_{f50} &= (Bc \times 10^{-4})^2[\sigma H f/100 + \sigma E\ d^2\ (f/100)^2] \\
&= (Bc \times 10^{-4})^2 [1.7 \times 50/100 + 8.1 \times 0.5^2 \times (50/100)^2] \\
&= (Bc \times 10^{-4})^2 \times (1.36)
\end{aligned}
$$

where;

- σH: hysteresis loss coefficient (S09 silicon steel: 1.7)
- σE: eddy current loss coeffieicnt (S09, silicon steel: 8.1)
- d : steel sheet thickness (mm)
- f : frequency

As the magnetic flux density for the 200 Hz rated voltage is 1/4 that with the 50 Hz voltage:

$$
\begin{aligned}
W_{f200} &= (\frac{Bc}{4} \times 10^{-4})^2 [\sigma H\ 200/100 + \sigma E \cdot 0.5^2\ (200/100)^2] \\
&= \frac{1}{16} (Bc \times 10^{-4})^2\ (1.7 \times 2.0 + 8.1 \times 0.25 \times 4) \\
&= \frac{1}{16} (Bc \times 10^{-4})^2 \times 115 \\
&= 0.71875\ (Bc \times 10^{-4})^2
\end{aligned}
$$

$$
\begin{aligned}
W_{f200}/W_{f50} &= 0.71875/1.36 \\
&= 0.53
\end{aligned}
$$

Consequently, the iron loss current I_{f200} is give by the following equation.

$$I_{f200} = I_{f50} \times \frac{W_{f200}}{W_{f50}} = 14.5 \times 0.53 = 7.7 \text{ (A/phase r.m.s)}$$

c) The no load current with the 200 Hz rated voltage is given by the following equation.

$$Io_{200} = \sqrt{Ie_{200}^2 + Io_{200}^2}$$
$$= \sqrt{22^2 + 7.7^2}$$
$$= 23.3 \text{ (P/phase r.m.s)}$$

4. Excitation Current and Iron Loss in Induction Tests

a) Excitation Current of the Phase to be Tested

The magnetic flux density B for the 50 Hz rated voltage is assumed as 1.3 [Wb/m^2]. In this case, the magetomotive force H is 8[AT/m]. consequently, the magnetic flux density at the 200 Hz rated voltage is 1.3/4 [Wb/m^2]. The flux density when the test is performed at twice the 200 Hz rated voltage is 1.3/2, the magnetomotive force H being 1.5 AT/cm as obtained by the B-H curve. Accordingly, the excitation current I'_{e200} is given by the following equation.

$$I'e_{200} = Ie_{50} \times 1.5/8 = 88 \times 1.5/8$$
$$= 16.5 = 17 \text{ (A/phase, r.m.s)}$$

b) Current of Iron Loss of the Tested Phase

As described above, the magnetic flux density for the test by 200 Hz rated voltage is $B'_{200} = 1.3/2$[Wb/m^2]. Consequently, the iron loss in the induction test is given by the following equation.

$$W'_{f200} = (\frac{BC}{2} \times 10^{-4})^2 \; [\sigma H(200/100) + \sigma E \cdot 0.5^2 \; (200/100)^2]$$
$$= \frac{1}{4} (BC \times 10^{-4})^2 \; (1.7 \times 2.0 + 8.1 \times 0.25 \times 4)$$
$$= 2.9 \cdot (BC \times 10^{-4})^2$$

The current I_{f200} corresponding to the iron loss is:

$$I'_{f200} = I_{f200} \times W'_{f200}/W_{f200} = 7.7 \times 2.875/0.719$$
$$= 31 \text{ (A/phase, r.m.s)}$$

c) No Load Current of the Tested Phase

The no load current at the 300 kV side with 200 Hz and twice the rated voltage is given by the equation below.

$$Io_{200} = \sqrt{17^2 + 31^2} = 35 \text{ (A/phase r.m.s)}$$

d) 3 Phase No Load Current

The value of current cited above is for 1 phase. As 1/2 of the test voltage is applied for phase B and phase C, the excitation current of each phase is equal to I_{200}.

Accordingly, the no load current Ie_{200} for the two phases of B and C is given by the following equation.

$$2 \times Io_{200} = 2 \times 23.3 = 47 \text{ (A/2phases r.m.s)}$$

Consequently, the total no load current I_{00} of the induction test is given by the following equation.

$$I_{00} = I'_{0200} + 2Io_{200} = 46 + 47$$
$$= 93 \text{ (A/3phases r.m.s)}$$

5. Determination of Induction Generator Capacity

The capacity of the single phase, 200 Hz, 3.3 kV generator has been estimated from the point of view of the no load loss.

The generator capacity P is given by the following equation,

$$P = 3.3 \text{ kV} \times 93 \text{ A} = 307 \text{ (kVA)}$$

Counting additional 10% loss as the step up transformer loss:

$$Po = 307 \times 1.1 = 338 \text{ kVA}$$

The calculations of excitation current and iron loss generally contains large amount of error because they are based on a veriety of assumed conditions. In addition, a large current flows when the high frequency is applied due to the stray capacitance present between the windings. Accordingly, this current must be compensated by reactors having the same amount of lagging current, or a high frequency generator of large capacity is required. In this plan, a 200 Hz, 400 VA compensation reactor will be employed in common with the AC voltage withstand test.

The standard transformer currently adopted by WAPDA, rated 220 kV, 3 phase, 50 Hz and 25,000 kVA, is much smaller than the standard transformers in Japan. Thus it is expected that the WAPDA's standard will be raised to 50,000 kVA or so as its power system loads are increased in future. Considering this and the factor as discussed above that the preliminary calculation of the current and loss of induction test contains large errors, the following equipment ratings were adopted with sufficient margin over the calculated value of the generator capacity presented above.

Generator; single phase, 200 Hz, 3.3 kv, 1,000 kVA.
Driving motor; 3 phase, 50 Hz, 600 kW, 400 V
Step up transformer; single phase, 200 Hz, 1,000 kVA (5 minute duty),
3.3 kV/18.75-37.5-75-150 kV.

INSTALLATION OF ADDITIONAL TRANSFORMER IN RIWAT SUBSTATION

The voltage fluctuation, which is expected when a 2,500 kW, 3 phase wound rotor type induction motor (for driving the short-circuit generator) is started in the circuit condition described in the attached figure. The calculation indicates that the voltage dip is approximately 4%, being within the allowable limit (± 5%) even when only 1 bank of main transformers (132 kV/11 kV, 13 MVA) is operating in Riwat Substation. However, there is possibility that the external disturbance is superimposed on this voltage fluctuation. Thus it was planned to provide a safety margin to stabilize the 11 kV bus voltage by installing an additional transformer.

The calculations for the basis of this plan is presented below.

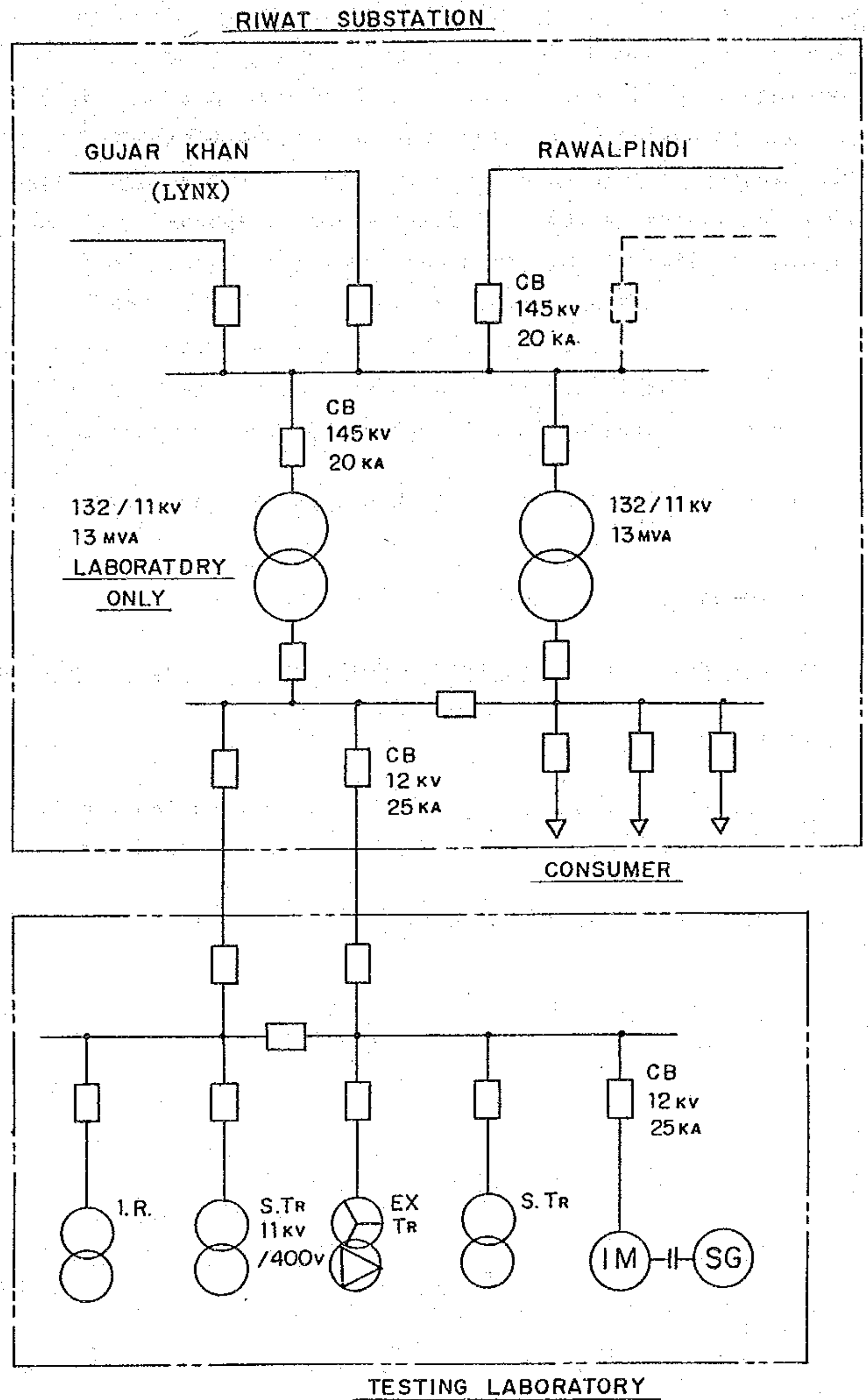
1. Determination of Circuit Impedance

Voltage Fluctuation on General Customers by Starting Current

Condition:

Voltage fluctuation limit; ± 5% (on distribution line).
± 10% (at motor terminals).

Distribution line; ACSR 120 mm^2, line length, 1.5 km, 2 circuits.


RIWAT SUBSTATION
GUJAR KHAN
(LYNX)
RAWALPINDI
CB
145KV
20 KA
CB
145KV
20KA
132/11KV
13MVA
LABORATDRY
ONLY
132/11KV
13MVA
CB
12KV
25KA
CONSUMER
CB
12KV
25KA
I.R.
S.TR
11KV
/400V
EX
TR
S.TR
IM
SG
TESTING LABORATORY

(1) Positive Sequence Impedance of 11 kV, 2 Circuit Distribution Line

Conductor: ACSR 120 mm^2, 30/2.3, D = 16.1/mm, R = 0.233 Ω/km (20°C)

Line structures; conductor clearance 1.0 m, horizontal layout, overhead line.

Line length; 1.5 km, 2 circuits (on a separate route).

$$L = 0.0411 + 0.4605 \log_{10} ((1.0 \times 1.1 \times 2.1)^{0.333}/(0.0161))$$
$$= 0.923 \text{ (mH)}$$

$$X = 2 fL = 2 \times \pi \times 50 \times 0.923 /1000 = 0.290 \text{ (}\Omega\text{/km)}$$

$$R = 0.233 \times 1.5/2 = 0.175 \text{ (}\Omega\text{)}: X = 0.290 \times 1.5/2 = 0.218 \text{ (}\Omega\text{)}$$

(2) Power Source Impedance

The circuit breaker on the receiving circuit of Riwat Substation has ratings of 145 kV and 20 kA. Assuming that 50% of the rupuring capacity of this circuit breaker is the short-circuit capacity of the power source, it is given by the following equation.

$$P = \sqrt{3} \times 145 \text{ kV} \times 20 \text{ kA}/2 = 2500 \text{ MVA}$$

Z_p, the percent impedance on 10 MVA base is:

$$Z_p = 10 \text{ MVA}/2500 \text{ MVA} \times 100 = 0.40\%$$

By the relation that:

Ohmic impedance = percent impedance x (base voltage)^2 x 10/(base capacity):

$$X_p = 0.40 \times 11^2 \times 10/10,000 = 0.0484 \text{ (}\Omega\text{)}$$

Assuming that the resistance component is 7% of the reactance component:

$$R_p = 0.0484 \times 0.07 = 0.0034 \text{ (}\Omega\text{)}$$

(3) Transformer Impedance (%Z=6%)

132 kV/11 kV, 13 MVA, %4 - 6%

$$\text{Ohmic impedance} = \frac{\text{percent impedance x (base voltage })^2 \text{ x } 10}{\text{(base capacity):}}$$

X_T = 6 x 11^2 x 10/13,000 = 0.5585 (Ω)
R_T = 0.5585 x 0.07 = 0.0391 (Ω)

(4) Motor Cable Impedance (100 m)

CV 100 mm^2; R = 0.18 (Ω/km) : R = 0.018 (Ω)
X = 0.0798 (Ω/km): X = 0.00798 (Ω)

(5) List of Impedance

	R	X
Motor Cable	0.018	0.00798
Distribution Line (11 kV, double circuit)	0.175	0.218
Transformer (6% 1 unit)	0.0391	0.5585
Power Source	0.0034	0.0484
Total	0.2355	0.8327

2. Calculation of Voltage Drop

(1) Motor Cable (CV 100 mm^2, 100 m)

Io = 2500 kW/($\sqrt{3}$ x 11 kV) = 131 (A)

Starting current I_s = 2 I_o (wound rotor type, 1.4 to 2.0 I_o)

Voltage drop;

$V_1 = \sqrt{3}$ (Rcos θ + Xsin θ) I
$= \sqrt{3}$ (0.018 x 0.2 + 0.00798 x 0.98) x 262
= 5V

(2) voltage Drop on distribution Line (ACSR 120 mm^2, 1.5 km)

R = 0.175 (Ω)

X = 0.218 (Ω)

Voltage drop = $\sqrt{3}\cdot(0.175 \times 0.2 + 0.218 \times 0.98) \times 262$

= 113 (V)

(3) Voltage Drop in Main Transformer in Riwat Substation

The new starting current = (starting current) x (motor rated voltage - voltage drop in cable)/(motor rated voltage)

262 (11.000 - (5 + 113))/11,000 = 259

Voltage drop V3 = $\sqrt{3}\cdot(0.0391 \times 0.2 + 0.5585 \times 0.98) \times 259$

= 249 (V) Z=6% 1 unit

Summary of voltage drop V_B

Transformer %Z	6%	4%
1 unit	249 (V)	166 (V)

(4) Total Voltage Drop (at motor terminal), target value; 10%

Transformer	6%		4%	
	V1	(%)	V	(%)
1 unit	367	(3.3)	284	(2.6)

6% 1 unit V = 5 + 113 + 249 = 367

4% " V = 5 + 113 + 166 = 284

The allowable limit of voltage drop in at the motor terminal is 10% or less. Thus there would be no trouble even if the transformer impedance is 6%.

In this case, however, the motor terminal voltage is as same level as the 11 kV bus voltage for the testing laboratory, from which power is supplied to various measuring instruments as well as the computer. Thus it is necessary that the voltage fluctuation remains within 5% even if the voltage change in the power source is superimposed. For this reason, it was planned to install an additional transformer in Riwat Substation to stabilize the voltage for the laboratory. The voltage fluctuation on the general customer is smaller than on the laboratory bus, and thus there is no problem at all.

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