Paper No. 402

WEST PAKISTAN 500 KV SUPER GRID

By

MAHMOOD AHMAD CHEEMA, B.Sc. Engg. (Hons.)
(Punjab). M. I. E. (Pak.), Fel. Int. E. E., P.S.E.I.

Director Super Grid.

I. EMERGENCE OF FUTURE TRANSMISSION SYSTEM

In order to plan on scientific basis the future Transmission System in West Pakistan, load flow and stability studies were carried out continually side by side with conducting Power Market Survey and exploitation of generation sources. From this load flow study it became quite apparent that an Extra High Voltage (E. H. V.) Transmission System would be required in the future. The requirements for EHV Transmission System are, however, affected by a number of important considerations, namely load growth, development of generation sources, the existing Transmission Voltage and last but not the least economic evaluation of alternative system. The estimation of the growth of load was made by assuming major substation loads for the years 1969, 1975, 1980 and 1985 which include both 'Basic Loads' and 'Tubewell Loads'. On account of several unavoidable factors such as technological, social and economic changes, it has been difficult to foresee accurately the future electrical loads. Even though the loads may actually grow at a faster or slower rate than anticipated, the net effect would only necessitate acceleration or de-acceleration of the programme of expansion of the Electrical System. A very important factor in the planning of a Transmission System is the size as well as the location of the generation, as not only it determines the power flows in the System but also affects the number of Transmission Lines and the voltage levels required to transmit the power satisfactorily to the load centres. The pattern for development of the generation, therefore, has a strong influence on the Transmission System. The major generating facilities in West Pakistan planned to meet the System Power demands, up to and including the year 1985 are Hydro Power at Mangla and Tarbela and the Thermal Power at Guddu, using natural gas from the nearby fields. For the purpose of a comparative economic studies Mangla was assumed to have a nominal capacity at full head of 800 MWs (8 Units 100 MW each) and Tarbela ultimate capacity at full head of 2100 MWs (12 Units 175 MW each). The Guddu Power Station was assumed to develop to an ultimate installed capacity of 1000 MW. There are

in addition to these major generating facilities small generation stations at other points in the System such as Karachi, Hyderabad, Sukkur, Shahdara, and Warsak.

The development of the Thermal Power at Guddu can meet the load growth of Karachi as well as upper and lower Indus regions provided of course enough quantity of gas is available at cheap rates. During the high water months surplus Hydro power from the North could be transmitted to the South whereas during the low water months Thermal power from Guddu is required to assist in supplying power to the Northern load centres. This pattern for developing generation does not preclude the development of other sides for an example it will be a good proposition to add generation to much greater extent in the Karachi Zone thus reducing the generation at Guddu. This would in turn reduce the power flows and Transmission requirements between Guddu, Hyderabad, and Karachi. A very important conscept in System planning, however, is to use more stringent requirements for developing the Transmission System so as to ensure its adequacy in all cases. It is on this account that Guddu was assumed to have installed capacity of over 1000 MWs for the purposes of determining the transmission requirements. In the coming years many other factors are likely to influence the pattern for developing generation such as new advances in Nuclear power, cost of Nuclear power fuel and discovery of new gas fields, coal deposits, or oil fields and all these would make it necessary to continually study and evaluate the System.

The 220 KV Transmission Lines are integral part of the Transmission System and the extent to which these lines are developed has an influence on the EHV System more so in the Northern zones. As a result of the investigation of various combinations of 220 KV and EHV Lines in the Load Flow studies the position emerged as follows :—

(1) Mangla—Kala Shah Kaku—Kot Lakhpat

The output from the first two units of Mangla can be carried to Lahore on the existing 132 KV Grid. The addition of subsequent units necessitate the building of 220 KV Lines from Mangla to Kot Lakhpat via Kala Shah Kaku in order to carry the main portion of power from Mangla Power Station to the Lahore load centres. There is a relatively larger flow of power on the 220 KV Line from Mangla to Kala Shah Kaku when the EHV Line between Tarbela and Lyallpur is out of service. The studies show that two double circuit 220 KV Lines from Mangla to Kala Shah Kaku are adequate for all cases, the actual construction shall depend on the unit additions at Mangla.

(2) Kala Shah Kaku—Lyallpur

As the transfer of load from EHV System to the 220 KV System at

Kala Shah Kaku Substation is about 100 MWs during the heavy load conditions of October, there is no justification for an EHV connection at Kala Shah Kaku. It is, however, noteworthy that a single circuit 220 KV Line would not provide adequate security because in case of an outage the 132 KV Line cannot satisfactorily carry the load to Lyallpur. Another consideration is that during low water months when the power of Mangla Station is reduced by approximately 300 MWs, it is necessary to supplement the Mangla Generation in order to meet the load requirements in Lahore area. The 220 KV Line between Kala Shah Kaku and Lyallpur will easily carry the additional power.

(3) Mangla—Wah—Tarbela

As explained above the Mangla Generation during the low water months has to be supplemented and for this purpose a 220 KV Link between Mangla and Tarbela through Wah also becomes necessary. Moreover the economic advantage of eliminating this line is partially offset by the earlier building of the more costly EHV Line to Tarbela.

II. ECONOMIC EVALUATION

The magnitude of the power flows for the conditions of 1985 makes it necessary to raise the voltage of Transmission in West Pakistan between Tarbela, Lyallpur, Multan, Guddu, Hyderabad, and Karachi. It is a practice in the developed countries of the world to approximately double the voltage for the next step. It has long been recognized by the Engineering profession that other things being equal no error is made in choosing the higher voltage since they do not lend themselves to change of voltage with increased load. There have been cases where the Voltage chosen appeared to be adequate at that time but in the later years, the error of not coming to the higher voltage became very apparent. The D. C. Transmission does offer some economic advantages and ease in operation but the cost both capital as well as operating of the terminal Stations is so excessively high that for our conditions it becomes very much unsuitable. The A. C. Transmission is, therefore, considered to be more advantageous in comparison with the D. C. Transmission.

Keeping all this in view, 500 KV A. C. and 380 KV A. C. were considered for a detailed economic appraisal. The economic comparison between the alternative systems were made by converting the yearly capital expenditure to the present worth values. The method of computing the present worth of source of capital expenditure is that the capital expenditure of each year are converted directly into the present worth for the basic year and accumulated over the period of years for which the analysis is to be made. The operating and maintenance costs are computed for each year and assumed

to continue thereafter. The present worth of the operating and maintenance costs are accumulated over the period of years specified and are added to the total present worth of capital expenditure. Since the Transmission Line losses are greater for 380 KV than for 500 KV, the present worth of the loss differential is added to the present worth of the equipment cost for the 380 KV System. The economic evaluation was made on an IBM 1620 Computor and the present worth curves (See Figure I) were drawn on the basis of the results of the computor programme, which show the effect of the interest rate on the economic comparison.

In order to make a more realistic comparison, the capital expenditures for the 500 KV as well as 380 KV are shown in Fig. 2.

It will be seen from the curves in Figure 1 that there is a slight advantage for 500 KV when the value of the loss differential is included. A reference to Figure 2, however, reveals, that the capital expenditure for the 500 KV are higher than for 380 KV in early years but the total expenditures for 500 KV are relatively small and do not appear to give any big advantage to either voltage at least up to the year 1985. The continued load growth beyond 1985 will of course necessitate additional generating facilities to meet the system power demand. It is essential that the Transmission System be capable of handling the power requirements, which will be imposed on it in the years beyond 1985 and also before if the power market develops at the rate higher than estimated. For this reason it was decided by WAPDA to project and investigate the System requirements to the year 1990 before making a decision of which EHV Voltage should be used. The present worth calculations for the year 1985 System namely 500 KV and 380 KV were extended to include the transmission equipment costs up to and including the year 1990. In order to make the exercise simpler, items common to both the 500 KV and 380 KV Schemes such as all 220 KV equipment costs were omitted. The results of the present worth analysis presented by curves showing the effect of interest rates are shown in Figure 3.

The evaluation of the results shows that the 500 KV tends to be more economical than 380 KV for interest rates of 6% or below. For interest rates between 6 and 8% the present worth of 500 KV and 380 KV System are comparable. The 380 KV will involve the use of series compensation perhaps in the very early stages which apart from having effect on the cost is likely to present difficultires, in the maintenance of this sophisticated equipment. The 500 KV will also ensure that on account of error arising out of the load growth estimate being approximate, the necessity of taking yet another stride in the Voltage before 1985 would not be necessary.

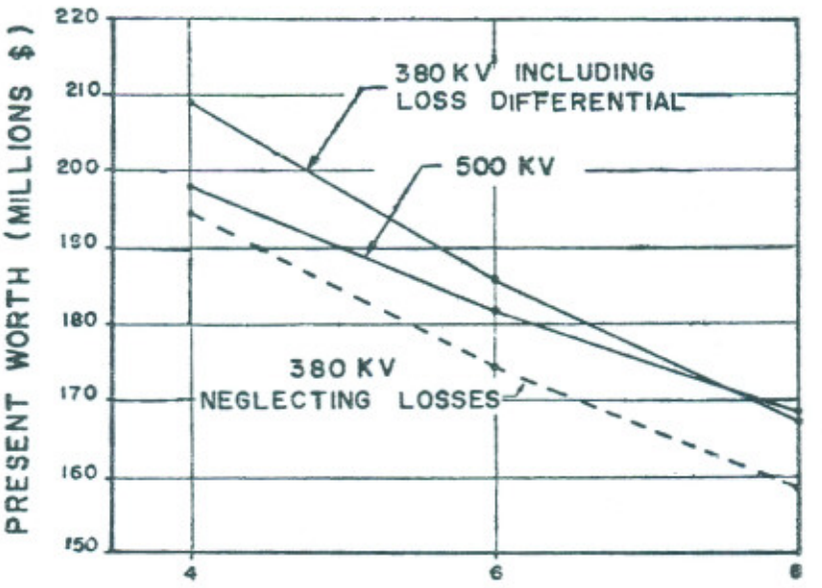

PRESENT WORTH (MILLIONS $)
220
210
200
190
180
170
160
150
380 KV INCLUDING
LOSS DIFFERENTIAL
500 KV
380 KV
NEGLECTING LOSSES
4
6
8
INTEREST (PERCENT)

FIG : 1

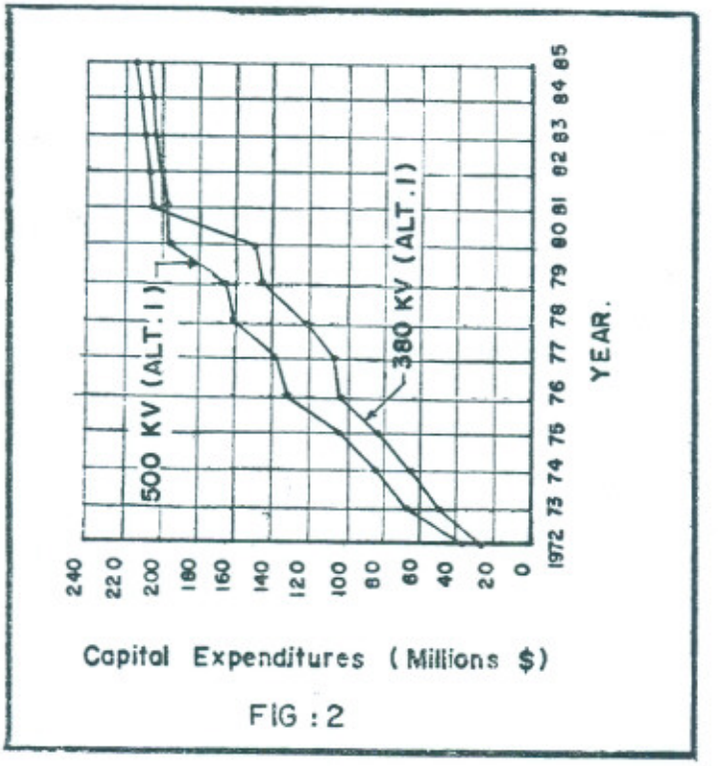
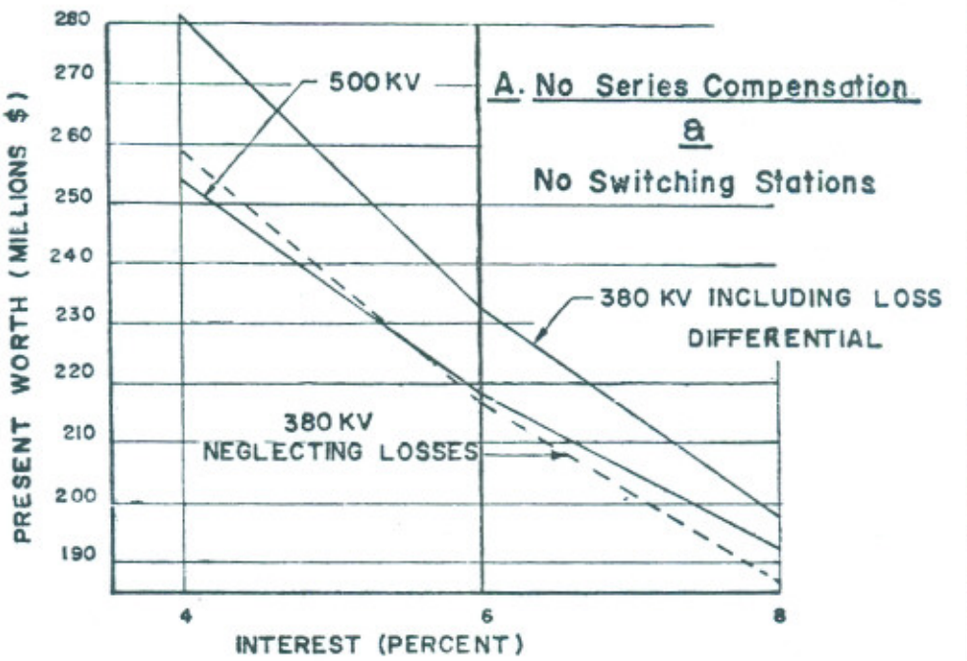

500 KV (ALT. I)
380 KV (ALT. I)
1972 73 74 75 76 77 78 79 80 81 82 83 84 85
YEAR.
240 220 200 180 160 140 120 100 80 60 40 20 0
Capital Expenditures (Millions $)

FIG : 2


A. No Series Compensation
&
No Switching Stations
500 KV
380 KV INCLUDING LOSS DIFFERENTIAL
380 KV NEGLECTING LOSSES
PRESENT WORTH (MILLIONS $)
INTEREST (PERCENT)

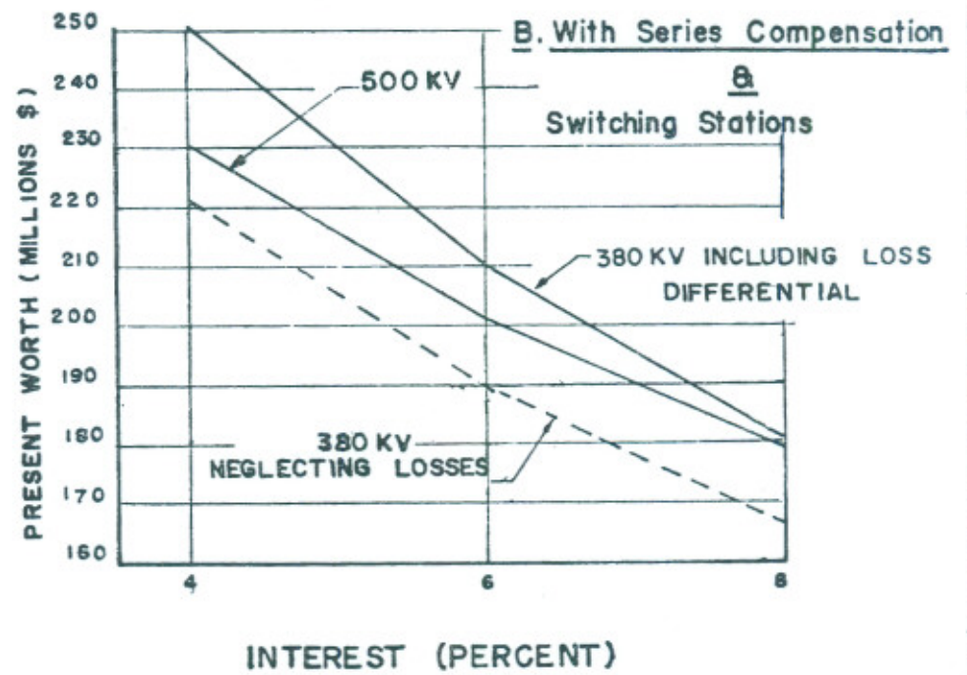

B. With Series Compensation
&
Switching Stations
500 KV
380 KV INCLUDING LOSS DIFFERENTIAL
380 KV NEGLECTING LOSSES
PRESENT WORTH (MILLIONS $)
INTEREST (PERCENT)

FIG : 3

III SCHEDULES OF COMMISSIONING

The generation from the two units of 110 MW each at Natural Gas Power Station at Guddu could be utilized with the help of 132 KV Circuits leading to Multan and Sukkur. As soon as the third unit of 200 MW is commissioned at Guddu, it will be necessary to make use of the 500 KV for its dispersal. The first circuit between Guddu and Lyallpur of the 500 KV Line is, therefore, indicated in the year 1973. In order to ensure that load requirements in the South are properly satisfied, it becomes necessary to instal the first circuit of the 500 KV between Guddu, Hyderabad and Karachi in the year 1974. The non-availability of reliable data on the effects of corrosion, erosion and pollution in the Hyderabad area is likely to present difficulties in keeping up with the schedule. The comprehensive research studies are to be started in the very near future, which are likely to be completed over a period of approximately two years. The line between Guddu and Karachi is likely to be delayed on this account.

Whereas the generation from Mangla and that of first four Machines at Tarbela could be transmitted to the load centres over the 220 KV network, it will be necessary to instal two circuits of the 500 KV between Lyallpur and Tarbela in 1977. In order to ensure security and stability of the system operation it is considered advisable to have one circuit between Lyallpur and Tarbela of the 500 KV in the year 1975. The second circuit will have to follow closely as generation at Tarbela is to develop faster. The second circuit between Lyallpur and Karachi will depend upon the growth of the load and development of greneration and is likely to be needed around 1980. The work on the installation of the first two units at Guddu is already underway and, therefore, the first circuit between Guddu and Lyallpur was allotted the first priority and the section between Guddu and Karachi the second priority.

IV. DESIGN AND CONSTRUCTION

The available sources of financing the foreign currency cost of this Project were considered keeping in view the experience of the Aid giving country in the field of EHV. It was therefore decided by the Government of Pakistan that the Super Grid between Lyallpur and Karachi will be financed from the Russian Credit. A contract, therefore, was signed between WAPDA and V/O Technopromexport of USSR on the 8th of December, 1967 for carrying out the Electrical studies, designing the Transmission Line as well as the Substation at Lyallpur, Hyderabad and Karachi (Guddu Substation being the part of the Guddu N. G. Power Station Scheme) and for rendering technical assistance for carrying out the Geodesic, Geological, Hydrological and Meteorological survey

along the 650 miles long Transmission Line Route. It was originally estimated that the survey would be completed in a year and a half in all reserving nine months for each of the two sections, but on account of various difficulties such as delays in initial commencement and testing of soil samples it has taken 2½ years. The Project Report comprising of the results of work done under the contract of 8th December 1967 for the Lyallpur-Guddu Section is due on the 31st of March, 1971. The prices of materials and equipment to be supplied from USSR will be received immediately thereafter. The supplies will be commenced after WAPDA has satisfied itself with regard to the reasonability of the prices, adequacy of the design and suitability of the time schedule and entered into a formal contract with USSR indicating acceptance. The Project Report for the Guddu-Karachi section is to be received on the 15th of April, 1972. The formal contract for the supply, delivery of the materials and the equipment will be signed by the end of June, 1972 in a manner similar to the one adopted for the first section.

The West Pakistan WAPDA has taken upon itself to carry out the construction and installation work with the Pakistan means and resources. Messrs. Technopromexport, however, will supply construction equipment, Tools and Plants, as well as key supervisory personnel. A comprehensive training programme has been prepared and is already underway for affording training to the Pakistani Engineers in the design, construction and operation of the 500 KV Transmission System. So far one Director, and, two Assistant Directors have received advanced training in the EHV techniques in the USA. Similarly a batch of 10 Engineers comprising of three Senior and seven Junior Engineers has returned from USSR recently after having received training in that country for a period of six months in construction and operation of EHV Transmission Lines. Another batch of 12 Pakistani Engineers left for Moscow for the same purpose on the 16th of January, 1971, and they are scheduled to return to Pakistan by the 15th of July this year. WAPDA intends to depute two more batches of 14 and 12 Engineers respectively for training in USSR. These 51 engineers will form a nucleus of the construction forces to be deployed on this Project costing 62 crore Pakistani Rupees.

In the month of June, 1968 a team of Russian Design Engineers was deputed to collect initial data for designing of the 500 KV Transmission Line and Substations and seek clarifications and elaborations on the information already supplied to them in the Technical task. The Soviet side indicated that the design of all the equipment and materials for this project has to be according to the Soviet Norms and Rules (Russian Standards). While the design criteria and the methods adopted for raising a Transmission System in West Pakistan were explained in great detail to the Soviet Specialists, a clause was put in the

agreement that the designing of the System will be accomplished keeping in view the special climatic conditions prevailing in Pakistan and also the Pakistani Standards evolved in some of the cases. In order that none of our requirements was overlooked, the main parameters for designing were, therefore, agreed and made part of the agreement. Some of the salient features of the proposed 500 KV Transmission Line are as under :—

1. Traffic capacity of the Single Circuit 500 KV T/L: 1000 MW.

2. Conductors :

3-Conductors Bundle per phase
ACSR Code Name ASO, 500 (500 Sq. mm).

Diamer of the Wire :	30.2 mm
Number of Aluminium Strands :	54
Diameter of Aluminium Strands :	3.37 mm
Number of Steel Strands :	19
Diameter of Steel Strand :	2 mm
Weight per kilometer :	1836 kgs.
Ultimate Tensile Strength :	14,630 kgs.
Inductive Reactance per Kilometer :	0.304 Ohms.
Permissible Continuous current rating per conductor:	945 Amperes.

3. Overhead Ground Wire :

Type :	C-70
Number of Strands :	19
Diameter of Strand.	2.3 mm
Ultimate Tensile Strength :	4620 Kgs.
Shielding Angle :	25°
Weight per Kilometer.	631.6 Kgs.

4. Galvanized Steel Towers :

Type :	Wine-Glass.
Material :	Galvanized Structural Steel, high tensile as well as mild.
Approximate height :	33 Meters.
Categories :	Straight Line. 0-2° Suspension. 0-30° Angle-Anchor. 0-60° Angle-Anchor.

Approximate Weight of the Normal Tower :	10.5 Tons.
Ruling Span:	420 Meters.
Wind Span:	420 Meters.
Weight Span:	420 Meters+20%
Factor of Safety :	—in normal conditions: 1.5
	—for emergency conditions for all types except Suspension : 1.33
	—under emergency conditions for Suspension Towers : 1.2

5. Foundations :

Type:

Reinforced, Concrete, Block Type.

Categories:

The foundations will be designed for varying conditions of soil and loading requirements. The properties of Soil will be determined from the Geological and Hydrological investigations.

Factors of Safety:

—SUSPENSION TOWERS:

—Under Normal Conditions of the T/Line:	1.5
—under broken wire conditions:	1.3

—ANGLE AND TERMINAL TOWERS

—under normal operation conditions:	2.0
—under broken wire conditions:	1.8

—SPECIAL TOWERS:

—under normal operation conditions :	2.5
—under broken wire conditions :	2.0

Combination of designed load under different operation conditions of the Transmission Line will be considered and the most severe conditions applied in the design of foundations.

—CONCRETE :

The ratio of the concrete will be 1: 2: 4. The foundations will be made at site by using the local materials like cement, shingle or crushed stone and sand, M. S. Bars for the reinforcement. The concrete will acquire 3500 Lbs. P.S.I. strength in 28 days and 2500 Lbs. P.S.I. in seven days.

6. INSULATORS:

The Insulator String will comprise of disc Insulators with ball and socket arrangement, made of very high quality porcelain or hardened glass dependent upon economic considerations. The main technical characteristics of the Insulators will be as under :—

—Number of the Insulators in one Suspension String	32
—Number of Insulators in a Tension String	34
—Diameter of the Insulator Disc :	320 mm
—Leakage distance :	2.25 cm. per KV.
—Length of leakage path:	384 mm
—Dry Flash over Voltage:	85 KV.
—Wet Flash Over Voltage:	55 KV
—Electrical, Mechanical Strength :	
For Suspension :	14,500 Kgs.
For Tension :	20,000 Kgs.

In order to ensure good performance in Pakistan conditions, experiments will be performed in order to determine the dry and wet flash-over Voltages, with reference to the switching, lightening and impulse surges. The tests will be performed on the full-scale towers and at simulation models for different length of the strings.

—Factors of Safety:

The ratio of electrical and mechanical breakdown load and the working load of the Insulator will be not less than 2.7 at maximum, designed wind velocity of 45 Meters per second (100 m.p.h.) and minimum temperature of 30°C and will be not less than 5.0 at mean annual temperature of 25°C and No Wind.

Studies are envisaged for working out the comparative advantages and disadvantages based on technical and economical aspects of the hardened glass and porcelain insulators keeping in view the facility in maintenance.

7. Hardwares:

SUSPENSION CLAMPS

The use of Release Type Suspension Clamps is envisaged on this Transmission Line. These clamps are capable of releasing the Conductor automati-

cally when the unbalanced tension exceeds 700 Kgs. This type of clamp will reduce the longitudinal loading on the towers to a great extent, thus affording saving in the tower cost. The release clamps will be designed to withstand full vertical load. This type of clamps is in wide use in USSR but is unknown in the Western world. It is of great importance that the clamps are properly maintained so as to avoid possible sticking during the periods when the corrosion has taken place. These clamps become ineffective in the area where very steep ground slopes ase encountered but as such conditions do not exist in the area between Lyallpur and Karachi, it is expected that release type clamps will be the well suited to our system.

TENSION CLAMPS

It has been proposed that bolted or Compression type tension clamps will be used. The clamps will be designed according to the tension in the conductor keeping the factor of safety as 2.5 in worst conditions.

MISCELLANEOUS ITEMS

All the other items of hardwares like the balls, sockets, hooks, yokes, etc., will be manufactured according to the Russian Norms and Rules but comparable with international standards.

SPACERS

The spacers are rigid type and will be able to withstand the short circuits during the emergency conditions. The spacers will not let the conductors clash, roll over each other or wrap during the conditions of short circuit. The spacers will be placed at a distance of 250 feet from each other and 150 feet from the suspension clamps.

METEOROLOGICAL DATA

The following climatic conditions have been adopted in our design which have been based on the 32 years recordings in the meteorological stations nearest to the route of the Transmission Line.

(*a*) The minimum design ambient temperature taking the heating of the conductor due to the summer radiation into account : +65°C

(*b*) Consideration has been given to the effects of temperature rise under operation conditions of thermal stability, maximum operating condition limits, and for the conditions of parallel operation with faults on circuit.

(*c*) Ambient Air Temperature in shade : +50°C

(*d*) Minimum ambient Air Temperature : −3°C

(*e*) Mean annual ambient Air Temperature : +25°C

(*f*) Maximum designed wind velocity 45 m/second (100 m.p.h.) This wind speed has been escalated for heights above 30 meters.

(*g*) The data available on relative humidity and rain has been processed, compiled, and evaluated, and conclusions drawn, for consideration in the design of the Insulation and Conductor and Coordination of air gaps for the Tower configuration.

V: SURVEY: AND FIELD INVESTIGATIONS:

(i) Geodesic Survey

The tentative route of Transmission Line was laid on the Survey of Pakistan Maps after field reconnaisance and deciding about the important points such as location of River Crossings, maintenance of minimum distance from air fields and Defence installations. The aerial photographs were a great help. The clearance of the Defence Department was then obtained. The necessary clearance from the owners of the installations such as Radio Transmitters, Telephone Exchanges etc., were also arranged. The route was then laid out in the field and tied with main objects, important features, and triangulation points in the vicinity. The coordination of the triangulation points were taken into consideration while carrying out the survey along the route. The mapping of a strip of 50 meters either side of the route were carried out planetabling the details and important features. The route of the Transmission Line was plotted from field books at the scale of 1 : 50,000. The scale used in the plane table survey is 1 : 500. Unlike the Transmission Lines of voltages up to 220,000 Volts, the voltage induced in the communication lines, power lines, and objects like metal fencings assumes such proportions as are not only harmful for all kinds of life coming in contact with them but also can cause serious danger to the equipment connected to such lines. In order to study in detail the effect of induction on the communication circuits in particular and other installations in general and design the necessary protective arrangements all the communication lines as well as power lines existing or planned for future in the "Zone of Influence" extending over a strip of 5 km either side of the central line were plotted on a map to the scale of 1 : 50,000.

The levels of the ground along the route line were taken at intervals of 100 meters and also at all angles, Rail Road and Road Crossings, Crossings over Rivers and Canals and where topography under-went abrupt changes. The first run of levelling was followed by control levelling. The levels thus obtained were correlated with Bench Marks at reasonable intervals. The Bench Marks were also established along the route at intervals of 8 kilometers. The topo-

graphic profile was constructed from processed field data at horizontal and vertical scales of 1: 5000 and 1: 500 respectively.

For maintaining the accuracy the permissible limits in respect of both the field work as well as the office plotting work the Russian Norms and Rules were followed which specify as follows :—

Accuracy in the open traverse of the Route $=50\sqrt{L}$ in mm/KM
where L=route length in kilometers:

Accuracy in precision level : $=20\sqrt{L}$ in mm/KM

The topographic survey was also carried out in greater detail for special sites such as River Crossings, Angle Points, points where there was abrupt change in topography such as hilly areas and also in the desert. The details in respect of such crossings as well as Rail Road Crossings, Canal Crossings, were also prepared in the Scale: 1: 500. In order to choose a minimum of 600×600 meters area for installation of the Switchyard and complementary works of the Substation a piece of land measuring 700×900 meters was selected and maps thereof were prepared with the help of plane-table in the scale of 1: 500.

(ii) Geological Works

In order to ascertain the properties and behaviour of the soil which is necessary for designing a proper type of foundation, geological survey along the route of the Transmission Line was carried out by making bore-holes every 500 meters and also at all the Angle and Crossing points. The depth of the bore-hole at Angle and Crossing points over the Roads and Railways, as also the Canals was 10 meters and for the normal conditions, the depth of the bore-hole was kept at 5 meters. For the Crossings over the three Rivers, namely, Ravi, Chenab and Indus, drilling of up to an approximate depth of 30 meters was done. In the case of open pits logging of the soil was done by visual inspection and in the case of drilling the data was compiled on the basis of excavated materials. The disturbed samples were drawn from the test pits and bore-holes at every two feet whereas only one undisturbed sample was collected per bore-hole. The samples collected in the field were transported to Lahore for complete soil analysis comprising of determination of shear strength angle of repose, internal friction, compressive and tensile strength, the displacement, de-formation, plasticity limits, void ratio, and classification of the soil. An elaborate programme of determination of the characteristics of the soil was drawn up in order that the soil was evaluated completely so that the conclusions could be drawn for use in the preparation of the most economical and technically sound designs of the foundations. In order to achieve economy, the bore-holes were spaced $2\frac{1}{2}$ km apart in the second varient of the Transmission Line in the Muzaffargarh—D. G. Khan section. Side by side with these

investigations, a superficial inspection of the ground 0.5 km either side of the route was carried in order to determine the geological features on the surface which were considered to be representative of the geological conditions of the soil up to a depth of one meter. The information was compiled, compared with the logging done, and plotting to form the geologic maps.

The geological data collected from the field, processed in the office and the results of the soil analysis were plotted on the topographic profiles so as to indicate the geological profile along the axis of the Transmission Line. The vertical and horizontal scales used for all the profiles are the same as adopted for the construction of topographical profiles.

(iii) Meteorological and Hydrological Survey

The meteorological data collected from the Department of Meteorology, Government of Pakistan was compiled, processed and possed on to the Designers in Russia. This data was considered to be inadequate particularly in the Southern part of the Transmission Line in the Hyderabad-Karachi area, in respect of the speed, direction of the wind as well as the phenomenon of Dew formation because the information was available only for the stations of Hyderabad and Karachi. It has, therefore, been decided to set up one or two meteorological stations along the route of the Transmission Line in this area so as to obtain more authenticated information regarding weather conditions which would prevail in the close vicinity of the Transmission Line. In order to study and establish the characteristics of the under-ground water and the behaviour of the Rivers, Canals and seasonal water-courses, crossing the Transmission Line, a detailed Hydrological survey was carried out in accordance with the specifications laid down by the Soviet Designers. The information and data such as yearly River survey maps, discharge and velocity of water and water levels, gradients, maps of the flood area and the scouring of the bed and banks was collected from the Department of Hydrology, Government of West Pakistan. This information was processed and slope of water and scouring effects taking place in the bed, as well as erosion of the banks of the Rivers and other water-courses was calculated. The water samples were drawn from all the water objects and subjected to the chemical analysis for the purpose of determining the aggressiveness of the water on the concrete and also for finding out the suitability of water for making the concrete. The ground water has a great influence on the designing of the foundations on account of its hydrostatic and hydrodynamic properties which fixes the limits of the forces acting on the foundations as well as the chemical composition which effects and helps in predetermination of the quality of the concrete to be used in the foundations. The effect of the seepage from the Canals including the rise of the underground

water levels in the adjoining areas were also studied in detail. In order to determine as accurately as possible the behaviour of the Rivers in respect of the errosion of banks, scouring in the bed, trends in the change of the course and combined effect of water velocity and discharges was determined in order to fix the most economical and technically sound depth of the foundations of the Towers to be installed either in the bed of the River or behind the protective embankment built near the bridges and barrages.

(iv) Geophysical Survey

In order that the flow of the currents through the Earth which affects the neighbouring communication as well as the power lines, geophysical properties were determined. The geophysical survey for finding out the resistivity of the earth was carried out up to the depth of 100 meters and every five kilometers along the route of the Transmssion Line. The Soviet Designers, however, desired that some probes be made up to a depth of 1500 meters and for this purpose equipment and experts were imported from USSR and studies made along the route of the Transmission Line. The data collected from the field was processed and calculations made on computor in USSR and the interpretations of the curves drawn were accomplished with the help of Russian Experts.