PAPER No. 392

Railway Electrification

(POWER SUPPLY SYSTEM)

By

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As a part of its modernization programme, Pakistan Western Railway, has embarked upon the introduction of 25 KV, Single Phase, A. C. Electrification on its Lahore-Khanewal Section extending over 178 miles, *ab initio*. The Project which started in June 1966, is gaining momentum with the passage of each day. While the Lahore-Raiwind Section is planned for trial runs initially, apprehensions are expressed often by laymen as to the viability of the Project in regard to power supply system dependent as it would be on an external source outside the control of Railway *viz*., WAPDA supply. Frequency of failure of ordinary low tension power supply in cities or fluctuations in voltages in a locality is probably the criterion and as a basis would perhaps justify such misgivings and in consequence has caused reflections on the thinkings of many. It may be stated at the outset that power in-feed to the P.W.R. Electric Overhead Traction System would be from the WAPDA High Tension integrated Grid Supply where incidence of outages, interruptions is rather rare and almost negligible.

P. W. R. Electrification Cell, however, as Engineers and WAPDA's prospective consumers have looked into every aspect of the proposed supply system as has WAPDA itself to meet its responsibilities. Before power system as it would stand ultimately is delineated, it would be pertinent to mention that design considerations have been a function of the economics and maximum use has been made of the existing facilities to avoid extra costs both in foreign exchange and local currency. To that extent a limit was imposed on the planners to what could have been catered for otherwise. Ideally P.W.R. should have envisaged a system of power generation based at the load centres along with the concomitant High Tension Transmission Lines to meet both Traction requirements as well as its own which could have been justified if all the isolated power requirements of Railway from Lahore to Khanewal were integrated. Railway already maintains Power Houses at Lahore and Khanewal as at other important junctions which could be augmented and modernised by the provision of quick starting, efficient gas turbine sets at each end with the availability of gas. This, however, besides conflicting with WAPDA's jurisdiction as a

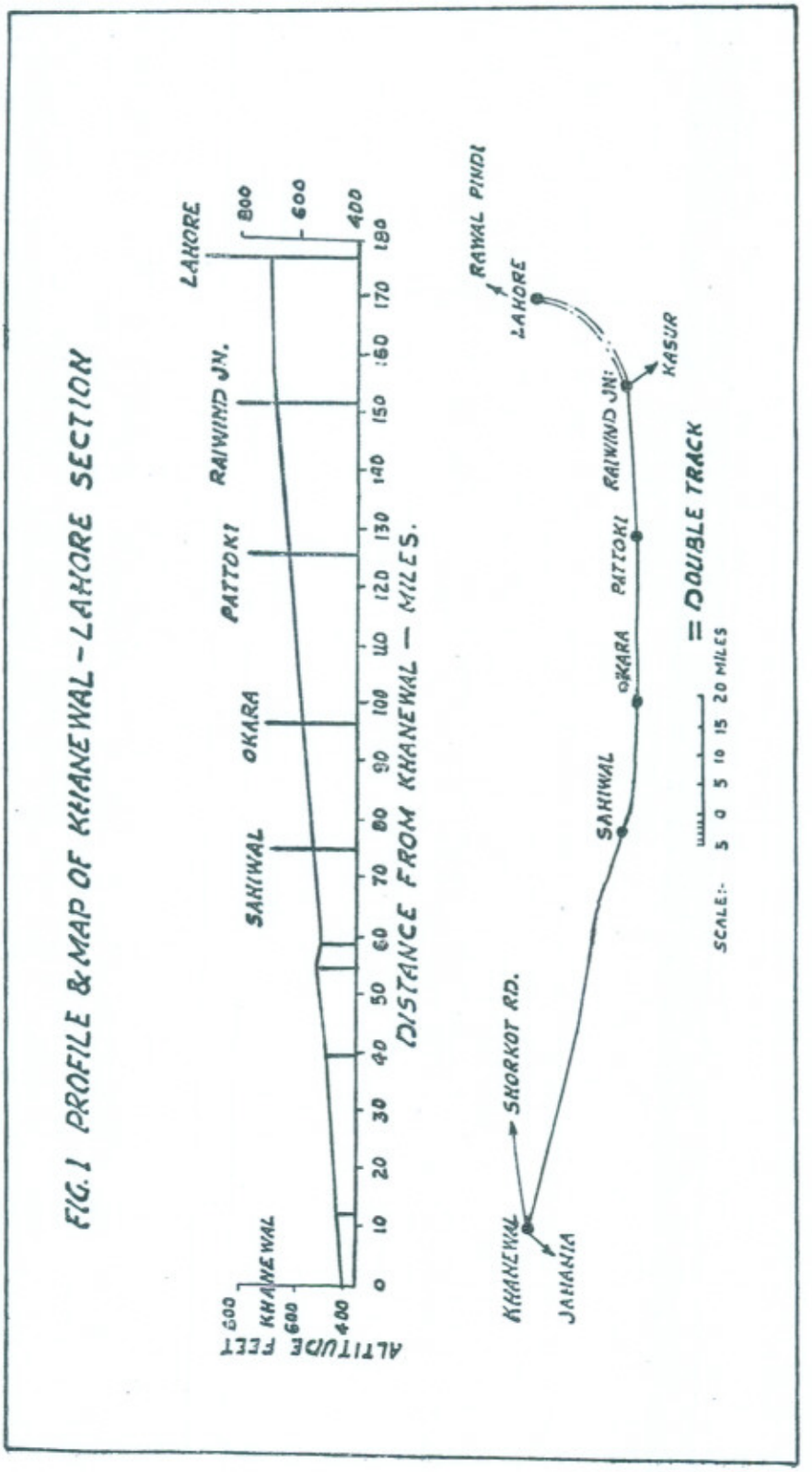
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liencee, would have upset the economics of Electrification although providing the much needed relief to WAPDA's distribution system. Another alternative was to arrange at extra cost for a 132 KV Transmission Line along the Track exclusively for Electrification, looped into WAPDA's Grid Stations enroute so that a more reliable and trouble free system could be guaranteed. All this though very well is extravagant. It is necessary to carefully balance the traction requirements against power availability, if most economic scheme is to be designed. WAPDA's Grid on the other hand has developed sufficiently and attained a good measure of advancement and this reassurance forms the basic parameters for the justification of electric traction. A properly conceived system for Electric Traction should be one which besides making use of existing facilities, does not throw excessive demand on the facilities obtaining. It should have feeding points such that in the event of outage of one of these, the track can be fed from the adjacent track sections. In keeping with this, a best possible power system for Electric Traction services has been evolved which is described in detail hereafter.

System of High Tension Supply

A profile of the section to be electrified is shown in Fig. 1. Based on the location of important WAPDA Grid Stations contiguous to Railway track from Lahore to Khanewal, Five Track Feeder Stations have been determined *viz.*, at Kot Lakhpat, Wan Radha Ram, Sahiwal, Mian Channun and Khanewal. WAPDA has 132 KV Grid Stations at Kot Lakhpat and Sahiwal, while 66 KV Grid Stations at Mian Channun and Khanewal. For tapping 25 KV supply at the five Track Feeder Stations, Railway will provide and erect complete 132/66 KV step-down equipment in WAPDA Yards, such as Isolators, Transformers and Circuit Breakers, extension of Bays and Gantries, besides putting up a completely new 66 KV Sub-Station at Wan Radha Ram with provision for incoming and outgoing circuit Breakers for use and ultimate extension by WAPDA. Based on the anticipated train operating conditions and consequent net-work analyser studies carried out, the power requirements at the various proposed inter-connection points is detailed as on next page.

The ratings of transformers located at each of the WAPDA Grid Stations have been decided upon Railway demand under normal and outage conditions and load thrown over from one feeding point to the other on account of emergency or failure of a transformer. Sahiwal is the most heavily loaded feeding point and since feeds on either side of Sahiwal are at 66 KV, it was necessary to limit demand on these sections while suitably re-inforcing Sahiwal. Sahiwal under outage conditions would have maximum demand of 18 MVA, $\frac{1}{2}$ hour maximum of 12 MVA and RMS figure of 7.7 MVA, based on which 2×7.5 MVA,


FIG. 1 PROFILE & MAP OF KHANEWAL - LAHORE SECTION
ALTITUDE FEET
600
600
400
KHANEWAL
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
SAHIWAL
OKARA
PATTOKI
RAIWIND JN.
LAHORE
800
600
400
DISTANCE FROM KHANEWAL — MILES.
RAWAL PINDI
LAHORE
KASUR
RAIWIND JN.
PATTOKI
OKARA
SAHIWAL
SHORKOT RD.
KHANEWAL
JAHANIA
= DOUBLE TRACK
SCALE:- 5 0 5 10 15 20 MILES

S. No.	LOCATION		7½ Minute 7½ Max. Demand MVA*	Min. p. f.	0.5 hr. Max. Demand MVA	RMS Demand MVA	Max. Demand + 3 ph. Sc. level %
1.	Kot Lakhpat	..	11.1	.785	7.8	5.0	1.06
2.	Wan Radha Ram	..	6.7	.782	4.3	2.3	4.79
3.	Wan Radha Ram	..	7.9	.795	4.8	2.8	5.64
4.	Sahiwal	..	14.5	.777	10.0	5.9	1.88
5.	Mian Channun	..	5.8	.782	4.1	2.4	4.14
6.	Khanewal	..	5.7	.781	3.6	2.2	3.35
	Total	..	26.1	..	..	20.6	..

132/25 KV Trasformers have been provided there. Kot Lakhpat is another relatively loaded point but RMS demand under worst conditions would not exceed 7.4 MVA (with failure of a Transformer at Wan Radha Ram) which can be suitably catered for by one Transformer of 7.5 MVA, although provision here of another has also been made purely as a standby with 66 KV tapping for use as a spare transformer for whole of the system. For the rest of the 66 KV feeding points, RMS demand under normal and outage conditions is not expected to exceed 3.0 MVA at any time per circuit and dependent on the economics of manufacturing, 5 MVA Units have been selected and standardized. Transformer capacities at various Grid Stations provided to meet the Railway load are therefore, as under :—

1. Kot Lakhpat = 2×7.5 MVA, 132/25 KV (One spare with 66 KV Tap).
2. Wan Radha Ram = 2×5 MVA, 66/25 KV.
3. Sahiwal = 2×7.5 MVA, 132/25 KV.
4. Mian Channun = 1×5 MVA, 66/25 KV.
5. Khanewal = 1×5 MVA, 66/25 KV.

Selection of 7.5 MVA Transformer for 132 KV primary system and 5 MVA for 66 KV, besides meeting present load requirements envisages suitable margin for load growth also. Pattern of power demand and Transformer loading at Sahiwal and Kot Lakhpat is shown in Figs. 2 and 3.

*It is anticipated that the instaneous max. demand under worst conditions will be 1.3 to 1.5 times the 7½ minute maximum demands quoted above.

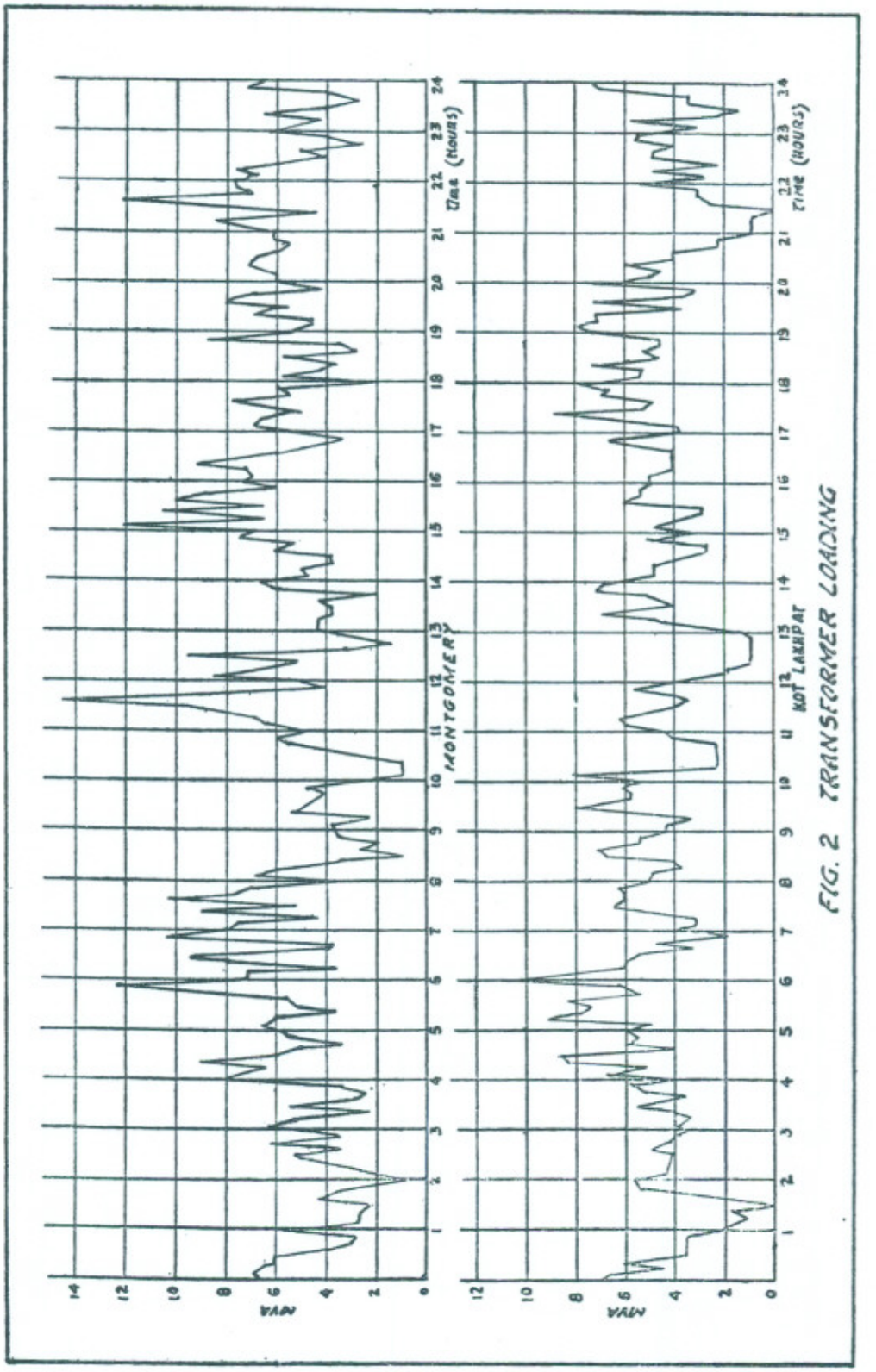


FIG. 2 TRANSFORMER LOADING

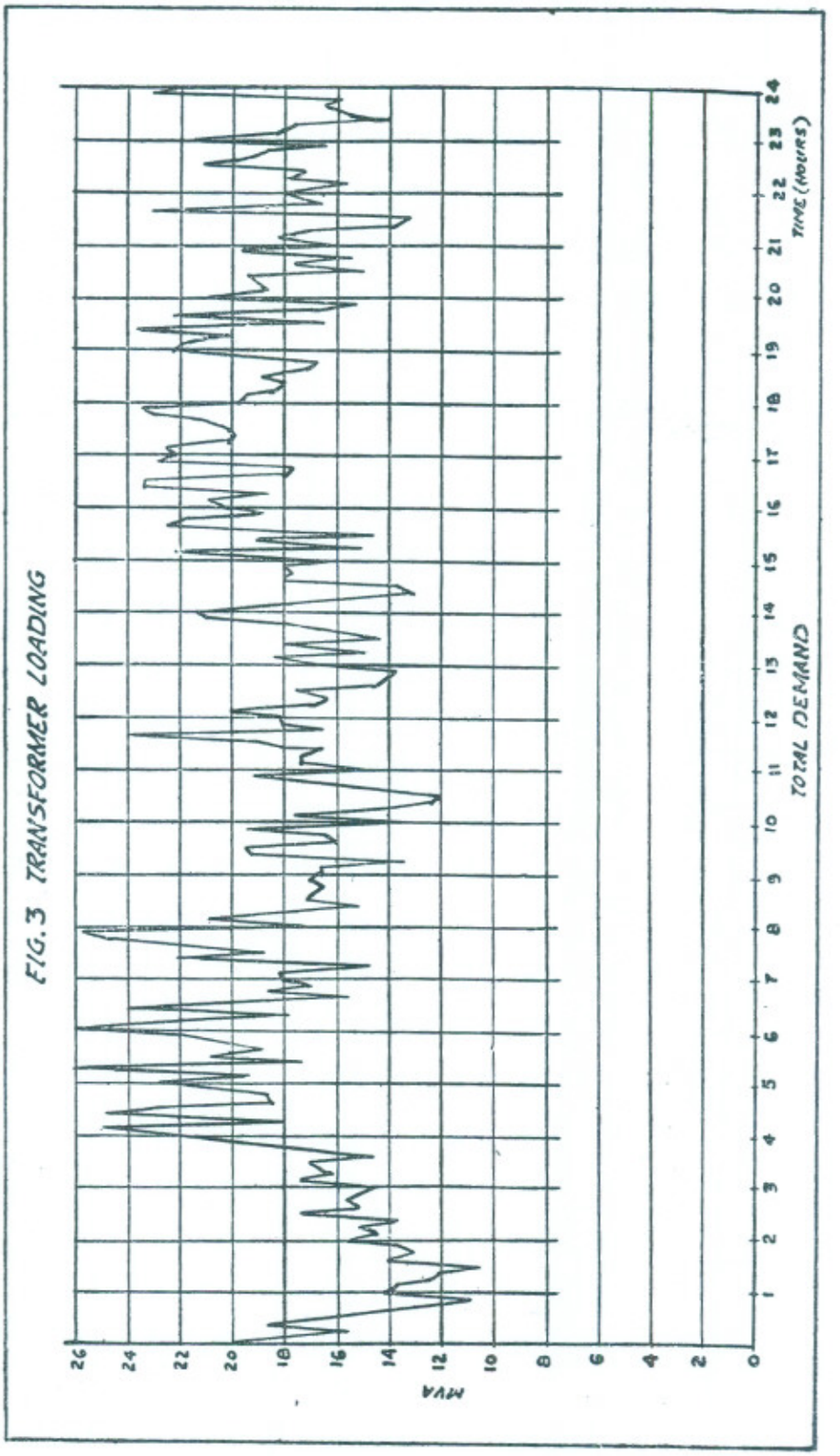


FIG. 3 TRANSFORMER LOADING

Primary Equipment and Feeding Arrangements

Fig. 4 gives the schematic diagram of the 132 KV and 66 KV equipment being installed in the various WAPDA Grid Sub-Stations. For 132 KV, circuit breaker rupturing capacity of 3500 MVA has been chosen while for the 66 KV, the breaking capacity would be 2500 MVA. Briefly the equipment being installed at the various WAPDA Grid Sub-Stations would be as under :—

Kot Lakhpat

(*i*) Two, double pole 132 KV, 3500 MVA, 600 Amps site rating type 'OS.10', small oil volume, pneumatically closed, compression spring opened, circuit breakers with local and remote control served by a common air compressor to control two main stepdown transformers.

(*ii*) Set of two, separately mounted current transformer posts for each circuit breaker, each post accommodating :

One current transformer, ratio 75/1 amp. 15 VA, for ammeter service and for overcurrent protection.

One current transformer ratio 75/1 amp. 15 VA, for restricted earth fault protection.

One current transformer ratio 100/5 amp. 15 VA, for integrated metering by KWH meter with maximum demand indicator per circuit.

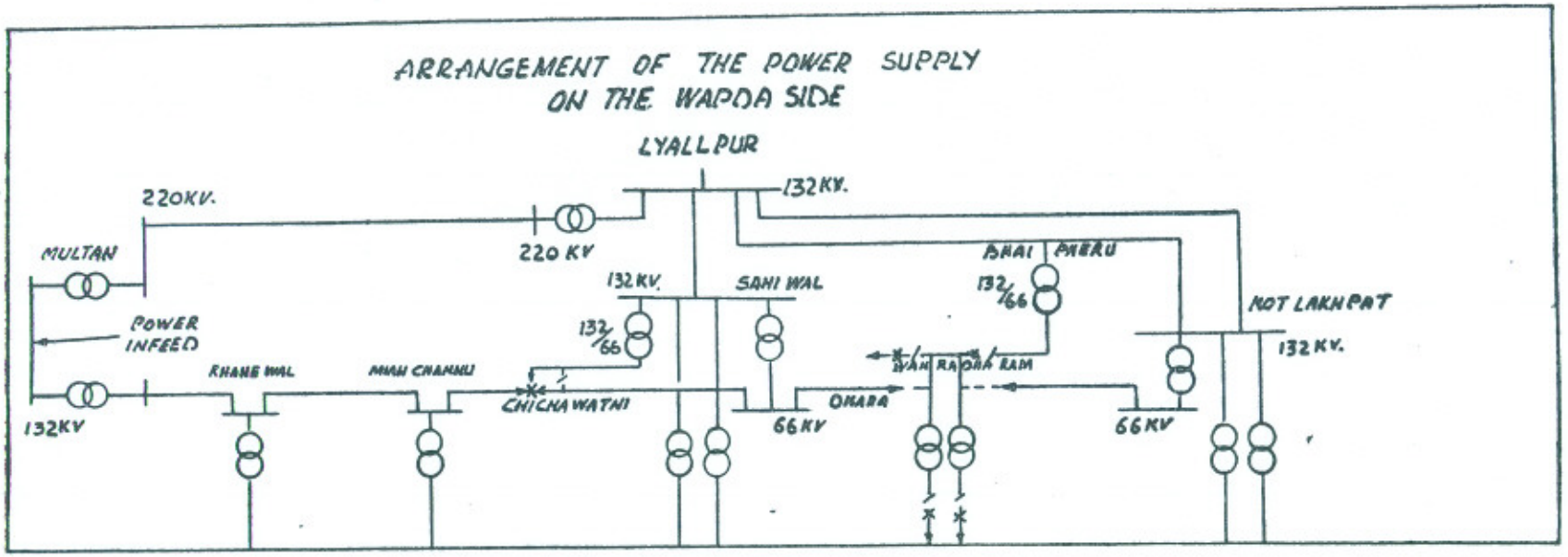
Two double pole, double change over type (5 post) 132 KV, 600 amp. horizontal double break busbar isolators complete with their own galvanized steel supporting structures.

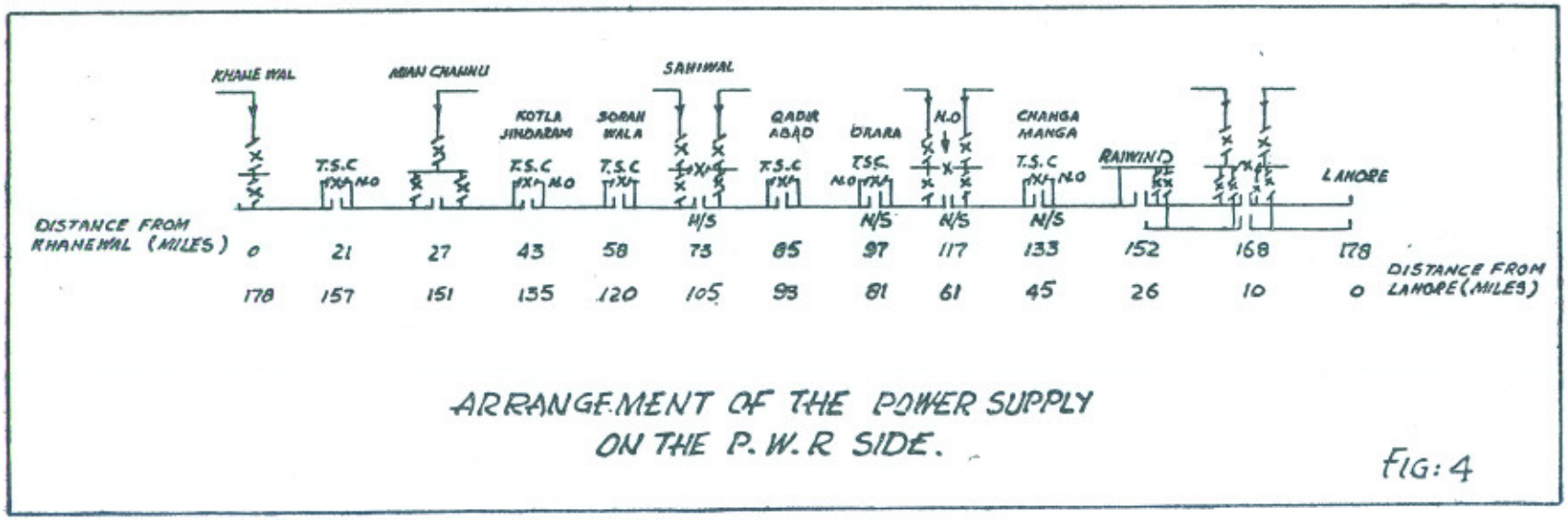
(*iii*) Two, 7.5 MVA, 132/25 KV, single phase, 50 c/s, oil immersed, naturally cooled, outdoor pattern, core type, main stepdown power transformers, complete with all necessary current transformers protection equipment and fittings alongwith mounted surge divertors. One transformer would have tertiary winding (132/66/25 KV) for standby purposes.

Wan Radha Ram Sub-Station (66 KV, New Station)

(*i*) Two, 3 phase, 66 KV, 600 ampere site rating, 2500 MVA breaking capacity, type 'OSM.10', outdoor pattern small oil volume, automatic motorised charging, spring closed, compression spring opened, circuit breaker units, to be used to control the 66 KV incoming grid feeders.

(*ii*) One set of three separately mounted current transformer posts for each circuit breaker, each posts accommodating :—





ARRANGEMENT OF THE POWER SUPPLY
ON THE P.W.R SIDE.

FIG: 4

One current transformer ratio 300/5-amp. of suitable output and accuracy for 2 stage distance protection.

One current transformer ratio 300/100/5-amp. 15 MVA output for ammeter service and back-up overcurrent protection.

(*iii*) Two, 2 phase, 66 KV, 600 ampere, 2500 MVA, type 'OSM.4', outdoor pattern circuit breakers, each to control one main step-down power transformer.

(*iv*) One set of two separately mounted current transformer posts for each of the above circuit breakers, each post accommodating :—

One current transformer ratio 100/1-amp. 15 VA, for ammeter service and overcurrent protection.

One current transformer ratio 100/1-amp. 15 VA for restricted earth fault protection.

One current transformer ratio 100/1-amp. 15 VA output for integrated metering by KWH/Maximum demand meter per circuit.

(*v*) One set of 66 KV Isolating Switches consisting of :—

Two, Triple pole 66 KV, 600 amp. line Isolators each with single earth switches, for control of the incoming grid feeders.

Two, Triple pole 66 KV, 600 amp busbar Isolators suitable for control of the busbar side of the 66 KV circuit breaker on the incoming grid feeders.

Two, double pole, 66 KV, 600 amp. busbar Isolators for the 5 MVA, 66/25 KV, transformer circuits.

(*vi*) One set of galvanised steel structures, consisting of :—

Four High-level structures for two 66 KV triple pole line isolators and two 66 KV busbar isolators.

Two structures for two double pole 66 KV isolators for the transformer circuits.

One set of three, busbar connected, 66 KV voltage transformers, output 200 VA per phase.

(*vii*) Two 5 MVA, 66/25 KV, single phase, 50 c/s, oil immersed, naturally cooled outdoor pattern, core type, main stepdown power transformers, complete with all necessary current transformers, protection equipment and fittings with mounted surge divertors.

Sahiwal

The equipments at this station would be identical to that installed at Kot Lakhpat except that the stepdown transformers would be both 132/25 KV, apart from feeding arrangements and busbar connections.

Mian Channun

(*i*) One, Two phase, 66 KV, 600 ampere site rating, 2500 MVA breaking capacity, type 'OSM.10', outdoor pattern small oil volume circuit breaker, complete with a motor charged, spring closing, compression spring opening mechanism. The circuit breaker would be suitable for local and for remote control.

(*ii*) Two separately mounted current transformer posts, each post accommodating :—

One current transformer ratio 100/1-ampere, 15 VA output, for ammeter service and for overcurrent protection.

One current transformer ratio 100/1-ampere, 15 VA output, for restricted earth fault protection.

One current transformer ratio 100/1-ampere, 15 VA output, for integrated metering by KWH/MD meter per circuit.

One double pole, 66 KV, 600 ampere busbar isolator.

(*iii*) One, 5 MVA, 66/25 KV, single phase, 50 c/s. oil immersed, naturally cooled, outdoor pattern, core type, main stepdown power transformer, complete with all necessary current transformers, protection equipment and fittings with mounted surge divertors.

The circuit breakers, current transformer posts and isolating switches would have their own supporting, galvanised steel frameworks.

Khanewal

The equipment at this station would be in accordance with the requirements to form an extension bay to an existing 66 KV switching station and would be generally the same as for Mian Channun described above.

In addition to the above, auxiliary equipment *viz*. relay and control panels would be provided at each Grid Sub-Station which would be of the indoor pattern for accommodation within the sub-station control buildings. The extension bays would be earthed through 19/.083'' (0.1 Sq. Inch) copper and connected with the existing sub-station earthing as also double earth would be provided to all the H. T. equipment.

25 KV, Overhead Transmission Lines

P. W. R. would also provide for the installation of an estimated total of 7¼ miles of single circuit 25 KV overhead Transmission Lines from various WAPDA Grid Sub-Stations to the connecting Track Feeder Stations as detailed hereunder :—

Transmission Line		No. of wires	Actual length of route (feet)
Kot Lakhpat	..	4	11,277
Wan Radha Ram	..	4	1,271
Sahiwal	..	4	1,367
Mian Channun	..	2	6,826
Khanewal	..	2	1,154

It was originally intended to use all aluminium conductors but to conform with WAPDA standards and facilitate eventual maintenance, it was decided to use A.C.S.R. 'Lynx' conductor. The 25 KV lines would be on steel poles. Single circuit/double circuit construction with phase conductor of 0.35 sq. inch cross section, together with an adequate combined earth/Return wire. At Kot Lakhpat and Sahiwal and Wan Radha Ram double circuit lines would be used. Typical 25 KV towers are shown in Fig. 5 enclosed.

Protection Scheme

Lot of thinking has gone into the subject of protection system and the equipment has been so designed as to be sufficiently sensitive to detect all faults as also to ensure adequately stability and discrimination in the light of the peculiar requirements of railway working. Conventional inverse time over current protection alone, (unless as back up protection) is unsuitable for use with railway track feeder circuit breakers because high speed fault clearances is essential to assist discrimination and to avoid arcing damage to the contact wire. Simple protective arrangements have, therefore, been envisaged in conjunction with a closely co-ordinated system of circuit breakers and highly discriminative protective equipment with inherent back up features. The protection system proposed for the various 132 and 66 KV Grid Sub-Stations as also for 25 KV Track Feeder Stations, is shown in Fig. 6, Broad features of the protection Scheme are given below:

High Tension Equipment in WAPDA Grid Stations

(*i*) *Instantaneous Restricted Earth Fault Relay Type* 2B3 *Voltage Operated*:

The C.Ts are so positioned that earth faults occurring on the busbar and primary winding of the transformers would be detected.

(*ii*) *High Set Instantaneous Overcurrent Relay and Low Set Over Current Set with Timer Type BC/BI/TCD.*

The over current protection would trip the breaker instantaneously for primary faults and after a suitable time delay for secondary

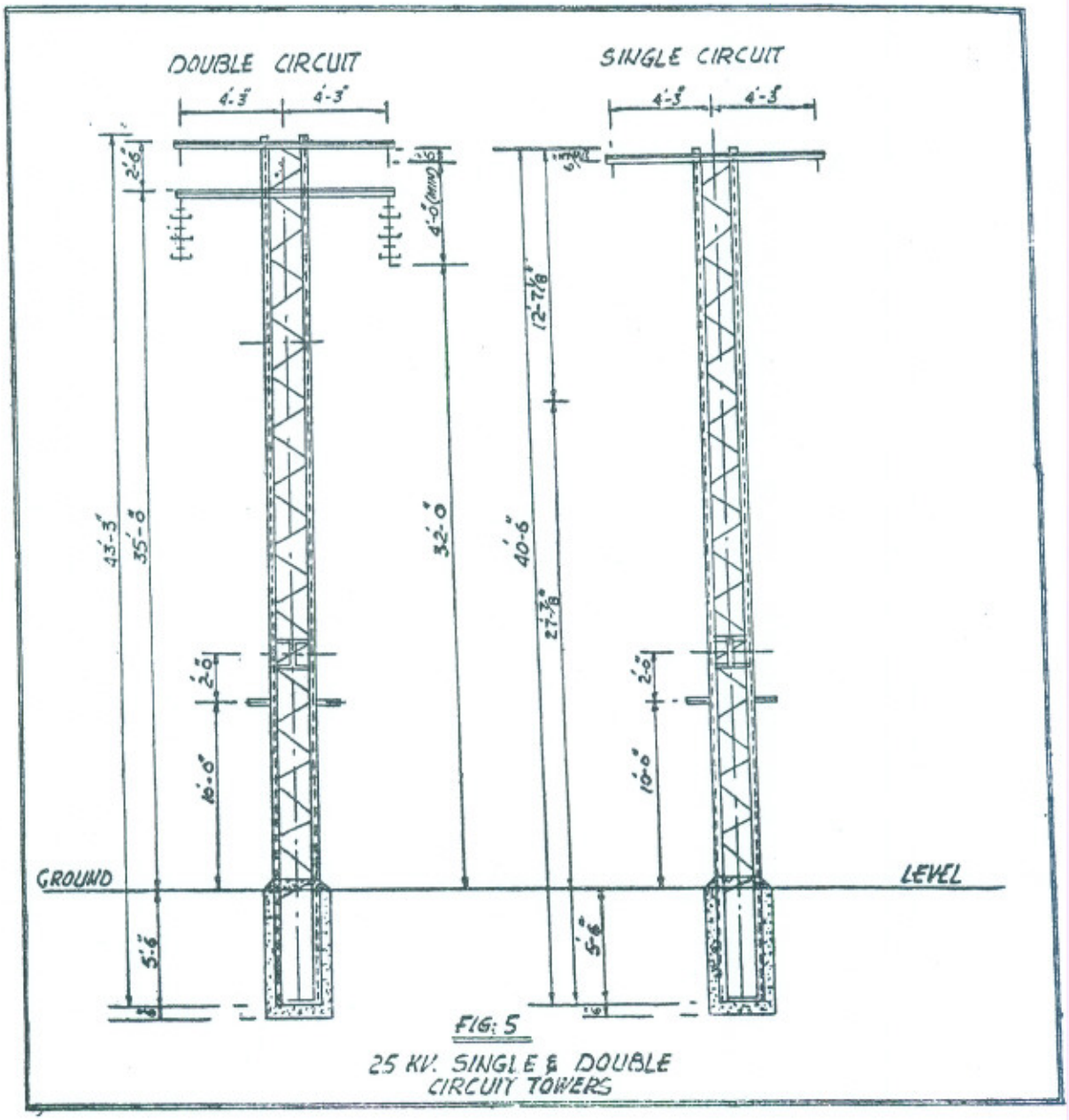
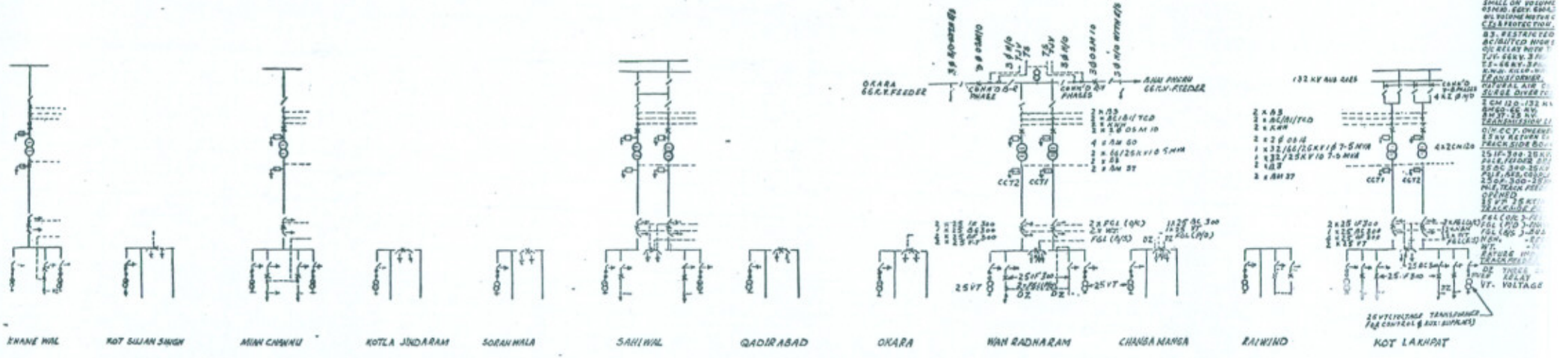


FIG: 5

25 KV. SINGLE & DOUBLE CIRCUIT TOWERS

PROTECTION SCHEMATIC FOR H.T AND L.T. (25K.V) SIDE



PROTECTION SCHEMATIC FOR H.T AND L.T. (25K.V) SIDE

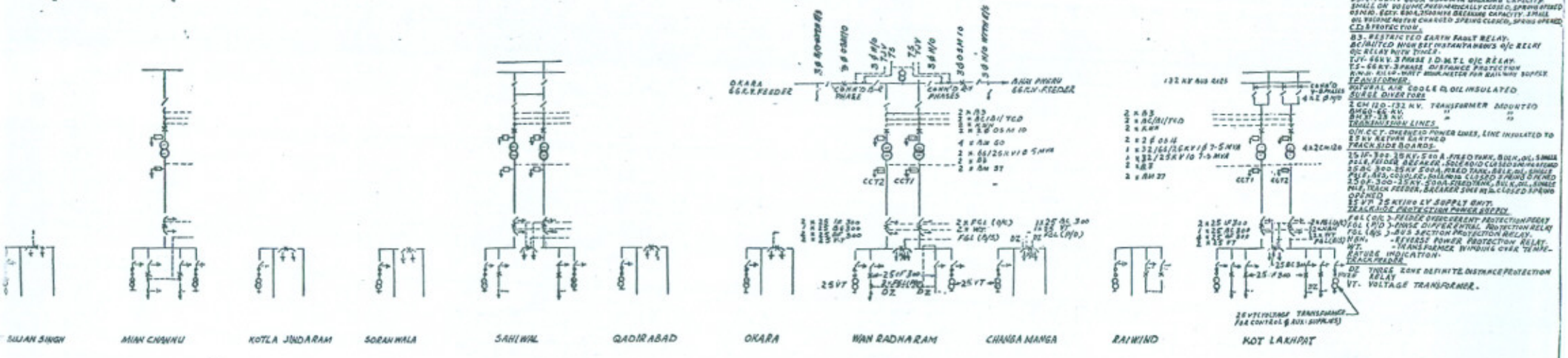


FIG: 6

faults. The range for high setting is from 400 to 1000% of the full load current while the low setting is from 100% to 400% with a timer of 0.1 to 3 seconds.

(*iii*) *Surge Divertors*

Transformer mounted surge divertors of the following type have been provided :

(*a*) 2 CM 120 for 132 KV.
(*b*) BM 60 for 66 KV.
(*c*) BM 37 for 25 KV.

(While surge divertors in the two phases have been provided on the primary side, on the LV side only one surge divertor has been provided in the phase and the other phase has been solidly earthed).

(*iv*) *Transformer Protection*

Single Transformer circuit protection scheme is shown in Fig. 7, both for 132 KV and 66 KV systems. The earth fault relays E/F, are connected to protect the transformer primary circuit and the secondary windings. Further protection is provided by the use of gas operated relays which is a standard device of the Buchholoz type giving an alarm on gassing and trips the breaker on gas or oil surging. Oil and winding temperature thermometers are provided, mounted in a sheet steel cubical on the side of the transformer. Both work on the liquid expansion principle and have variable alarm and trip mercury switches. The winding temperature thermometer has the addition of a heater arranged to bias operating mechanism. The heater is energized by a current transformer in proportion to the load on the main transformer such that its thermometer corresponds to the winding temperature. The recommended settings for the alarm and trip switches on both thermometers based on British Standard Code of practice are given as under :—

Oil Alarm	...	...	...	75°C
Temperature Trip	...	...	...	82°C
Winding Alarm	...	...	...	105°C
Temperature Trip	...	..	...	115°C

25 KV Line Protection

Protection for the 25 KV Single Phase Lines and the associated 25 KV Transformers would be of the overall differential type initiating tripping of the connected H. V. Circuit Breakers. The primary over current protection

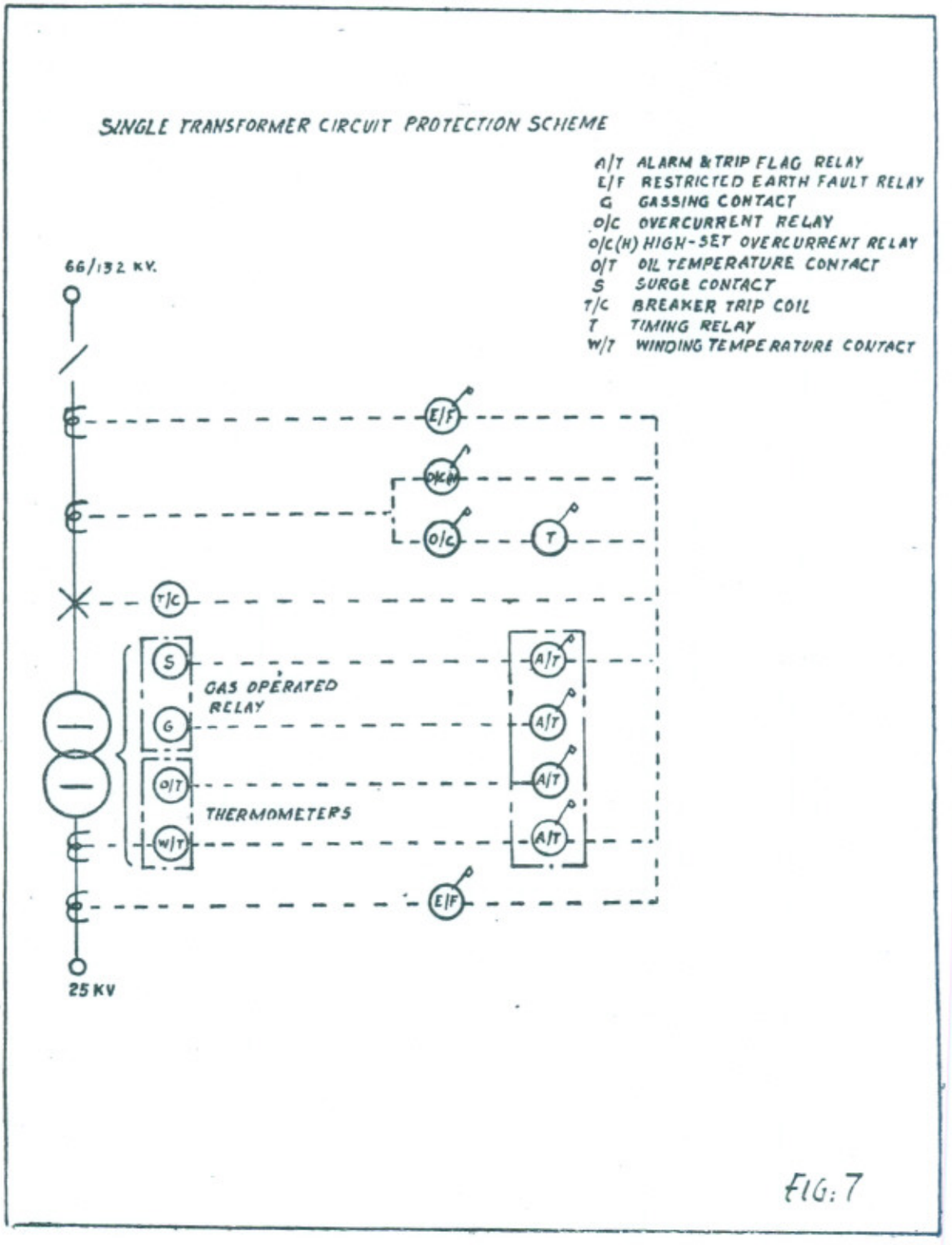

SINGLE TRANSFORMER CIRCUIT PROTECTION SCHEME
A/T ALARM & TRIP FLAG RELAY
E/F RESTRICTED EARTH FAULT RELAY
G GASSING CONTACT
O/C OVERCURRENT RELAY
O/C(H) HIGH-SET OVERCURRENT RELAY
O/T OIL TEMPERATURE CONTACT
S SURGE CONTACT
T/C BREAKER TRIP COIL
T TIMING RELAY
W/T WINDING TEMPERATURE CONTACT
66/132 KV.
E/F
O/C(H)
O/C
T
T/C
S
G
O/T
W/T
A/T
A/T
A/T
A/T
GAS OPERATED RELAY
THERMOMETERS
E/F
25 KV

FIG: 7

is arranged to trip the breaker instantaneously for primary faults and after a suitable time delay for secondary faults, the differentiation being obtained by settings the instantaneous element to a value of current above the calculated secondary fault level of the transformer. This system allows full time/current grading with the track side protection while providing over current and earth protection for the 25 KV Transmission Lines, where a low earth return impedence is obtained by solidly connecting the return conductor to each support tower. The setting of the earth fault relays type 2B3 and over current relays type BC/BI/TCD would be determined by the 25 KV track side protection, the current setting being higher than the equivalent relays on the track side equipment and the time lag relay setting longer than the total operation time of the track side equipment plus the reset time of the over current element. These relays being on the primary side of the transformer would protect against faults below the high set over current relays setting as well as 25 KV transmission line faults. Under normal operating conditions transformer switch-on surges and Railway Track faults may cause operation of the over current element flags without tripping the HV breaker. In the case of a trip occurring the time delay relay flag would operate and thus indicate fault on the supply side of the 25 KV switch board.

Track Feeder Stations and Track Sectioning Cabins

Depending on the points of supply, the consideration of the traffic to be handled and the electrical characteristics of the overhead and supply system, an optimum spacing of the track feeder stations is determined. For the Lahore-Khanewal Section, however, the pre-dominant consideration has been the locations of the allied Grid Sub-Stations; Track Feeder Stations have, therefore, been located at the site of the track at the following places :—

(1) Kot Lakhpat.
(2) Wan Radha Ram.
(3) Sahiwal.
(4) Mian Channun.
(5) Khanewal.

The distance between Kot Lakhpat and Wan Radha Ram is 51 miles, between Wan Radha Ram and Sahiwal 43 miles, Sahiwal and Mian Channun 46 miles and Mian Channun and Khanewal 27 miles. Simultaneously Seven Track Sectioning Cabins have been provided along the track for the purpose of inter-connecting adjacent track overhead supply sections under various conditions whenever warranted. These track sectioning cabins have been

located at :

(*a*) Raiwind.
(*b*) Chhanga Manga.
(*c*) Okara.
(*d*) Qadirabad.
(*e*) Soranwala.
(*f*) Kotla Jinda Ram.
(*g*) Kot Sujan Singh.

Based on the experience of British Railways and the recommendations of the consultants, choice between Air or Oil insulated equipment for these track feeder stations and track sectioning cabins equipment has been made in favour of Switchgear and Cowans outdoor oil linsulated equipment. The circuit breakers for the 25 KV system would be of the single phase, oil insulated out-door pattern having a breaking capacity of 250 MVA and arranged for motor wound spring closed, compression spring opened operation. These would be remote controlled through supervisory Control System based at Lahore and fitted with fully inter-locked operated Isolators on both incoming and outgoing sides.

Protective System

Track Feeder Stations. The overall system is divided into Incoming Power Supply Protection and Track Feeder Protection.

(A) **Incoming Power Supply Protection**

The incoming feeder are supplied from Grid Sub-Stations either from two 7.5 MVA Transformer to the same pair of supply phases such as at Kot Lakhpat and Sahiwal, in which case the Bus-coupler is normally closed to run the supplies in parallel and, therefore, a balance over current system is required or where the supply Transformers are of 5 MVA capacity, no parallel operation is required and, therefore, simple incoming feeder over current protection is provided. As an instance there are two supplies at Wan Radha Ram tapped from different supply phases and are not to be paralleled; a system of Electrical inter-locking is fitted on this switch board to prevent closure of the two feeder breakers and the bus-coupler at the same time.

(*i*) *Over-current Protection*

There are two basic type of over current systems utilizing FGL over current instantaneous relays with the following specifications :—

		5 MVA		7.5 MVA
CT's	..	200/1		300/1
Relay			F. G. L.	
Coil Current	..		IA	
Setting Range	..		100%—400%	
Timing Relay	..	AKA2		AKB2
Setting Range	..			0.2-2 Secs.

(*ii*) *Transformer Winding Temperature Indication Relay Type W. T.*

This relay is connccted to the Supervisory Control to give an indication of the winding temperature of the Transformer on load.

(*iii*) *Reverse Power Protection Type NBN2.*

Where two supply transformers are connected in parallel, power could flow in the reverse direction through one of the incoming feeder circuit breakers, should the HV circuit breaker supplying that circuit open for any reason. In order to stop the flow in the reverse direction, the NBN2 relay is connected to trip associated circuit breaker instantaneously. The details of setting are :

CT's	300/1
V. T. supply	110V
Relay	NBN2
Setting Range	0.6%—1.2%

(*iv*) *Phase Differential Protection*

The single phase power supplies are obtained from different pair of phases of the Grid Supply System and on certain points on the Railway system, voltages 120° out of phase *i.e.*, 44 KV can occur and if the circuit breaker, at such a point were closed, an effective phase fault would be applied to the high voltage power supply system. To ensure that such a condition is cleared quickly, phase differential protection relays are applied to all circuit breakers across which 44 KV is likely to appear under operating or emergency conditions. These phase differential relays are normally at some of the track sectioning cabins. The protection is basically through a FGL instantaneous over-current relay and is detailed as under :—

CT's	400/1
Relay	F. G. L.
Coil Current	IA
Setting Range	50%—200%

(B) Track Feeder Protection

Adequate and reliable track feeder protection is most vital for efficient maintenance of services as also high speed clearance of short circuits to minimise arcing damage to the overhead contact wire system. With a normal supply system, loading points are fixed geographically whereas in the Railway system, the loading points are constantly moving. Thus the train loading currents would be seen by the conventional protection equipment such as inverse time over-current type as fault currents. To overcome this difficulty definite distance type protection schemes have been developed both by AEI and ASEA for 25 KV system and are presently used on the British Railways. For P.W.R. a three Zone definite distance scheme of protection has been utilized. The underlying principle of protection is based on measurement of fault/path impedance and operation of the relay is dependent upon the quotation $\frac{V}{I} = Z$, fault impedance, which corresponds to a definite length of track feeder termed as Zone.

The application of each set of Distance Protection is such that the Zone 1 is set to measure 85% of the first track section *i.e.*, distance between sub-stations, Zone 2 operates for faults occurring within the remaining 15% and also extending into 50% of the second track section, and Zone 3 operates for faults occurring within the remaining 50% and approximately 25% of the third track section.

The approximate operating times for faults appearing in the various zones are :—

Zone	Relay Time Seconds	O.C.B. Operation Seconds	Total Time Seconds
1.	0.06 to 0.2	0.15	0.21 to 0.35
2.	0.5*	0.15	0.65
3.	1*	0.15	1.15

Remote Control Supervisory System

Central Electric Traction Remote Control Centre has been established at Lahore with a view to ensuring continuity of power supply as also to have a comprehensive picture of supply conditions and the means to operate switch-gear at all Feeder Stations and Track Sectioning Cabins. The control centre would comprise Control Room, Apparatus Room, Battery Room and other facilities. The Supervisory Control will be exercised by Traction Controllers through a common Diagram System. The system would be capable of control

*Dependent on the setting of Timer Relay.

and indication of any one Track Feeder or sectioning stations at a time with provision for registering on a mimic diagram by means of set up keys, the individual indication for all Track Side Stations. Each controlled circuit breaker and motorized switch is represented on the diagram and switches and lamps have been provided for the following purposes :—

(*i*) Operating Circuit Breaker and Switches.
(*ii*) Accepting and cancelling alarm.
(*iii*) Checking indication.
(*iv*) Testing the indicating lamps.
(*v*) Operating and indicating dummy circuit breaker.

Through the Tele-communication cable systems, the control and indication of the position of circuit breakers and switches is transmitted over pilot cables from the Feeder Stations and Track Sectioning Cabins to the Control Centre.

Emergency Power Supply Arrangements

Under normal feeding arrangements, Kot Lakhpat Track Feeder Station will feed through the Track Sectioning Cabin at Raiwind upto Chhanga Manga. While one 5 MVA Transformer at Wan Radha Ram will feed from the other side up to Chhanga Manga and the second 5 MVA Transformer up to Okara. Sahiwal will feed through Qadirabad Track Sectioning Cabin up to Okara and on the other side up to Kotla Jinda Ram through Soranwala Track Sectioning Cabin. Mian Channun Track Feeder Station will feed up to Kotla Jinda Ram on one side and Kot Sujan Singh on the other side, while Khanewal will feed up to Kot Sujan Singh on the one side and up to the limit of energisation towards Multan end. These arrangements are shown in Figure 8.

Emergency Arrangements under Outage Conditions

Case 1 :—*Complete Failure of Mian Channun and One 5 MVA Transformer out at Wan Radha Ram* :

Diagram 'C' in Figure 8, shows the feeding arrangements, should situation arise resulting in complete failure of Mian Channun Power Supply and outage of one Transformer at Wan Radha Ram. It may be seen that Kot Lakhpat would be able to supply up to Wan Radha Ram through closing of both Raiwind and Chhanga Manga Track Sectioning Cabins and Sahiwal would supply up to to Mian Channun through Soranwala and Kotla Jinda Ram Track Sectioning Cabins, while Khanewal would meet the requirements up to the other side of the neutral section of Mian Channun through Kot Sujan Singh Track Sectioning Cabin.

Case 2. :—*Complete Failure of both Wan Radha Ram and Mian Channun* :

This is a rather severe case as with complete outage at Wan Radha Ram and Mian Channun, although Kot Lakhpat and Sahiwal would be able to meet the demand of Wan Radha Ram, a section about 16 miles between Kotla Jinda Ram and Mian Channun will be out of operation. Arrangements proposed are shown in Diagram 'D' of Figure 8. Traffic could, however, be regulated to overcome this.

The main back stay of the power supply requirements for Railway operation are Kot Lakhpat and Sahiwal Track Feeder Stations and in case of a complete outage on any one of these, train operation would be seriously disturbed. It is, however, anticipated that situation of this kind would not arise as WAPDA has sufficiently re-inforced their 132 KV net-work at these two places.

Other Features

There is often mention of unbalance loading and harmonics caused to the supply system through the use of single phase traction requirements. Considerable research has been carried out on the subject and generally it is concluded that impact of single phase traction requirements of a system subject to certain conditions is invariably within permissible limits and no undue adverse effect is manifested on the supply system as a result thereof. Briefly unbalanced loading can cause :

(*i*) Unbalanced voltages and currents.
(*ii*) Reduction in capacity of 3 phase net works.
(*iii*) Over heating generators.

A check and control of these conditions is ensured by various means. In the first instance where single phase demand as a function of 3 phase short circuit capacity of the supply system at that point is within 5% as is mostly the case for Lahore-Khanewal Electrification except at Wan Radha Ram, the unbalance expected is within safe limits. In conclusion, the higher the primary supply voltage, the lesser the unbalance. To obviate any restriction in the capacity of 3 phase network, arrangements have been made to connect supply to different pair of phases: To that end at Kot Lakhpat, the two transformers are connected to Yellow and Blue phases of the 132 KV system, at Wan Radha Ram to Red and Yellow phases of the 66 KV system, at Sahiwal to Red and Yellow phases of 132 KV system, at Mian Channun to Yellow and Blue phases of 66 KV Busbar while at Khanewal to Blue and Red phases of 66 KV WAPDA in feed. Lastly as the single phase demand would be tapped from the integrated

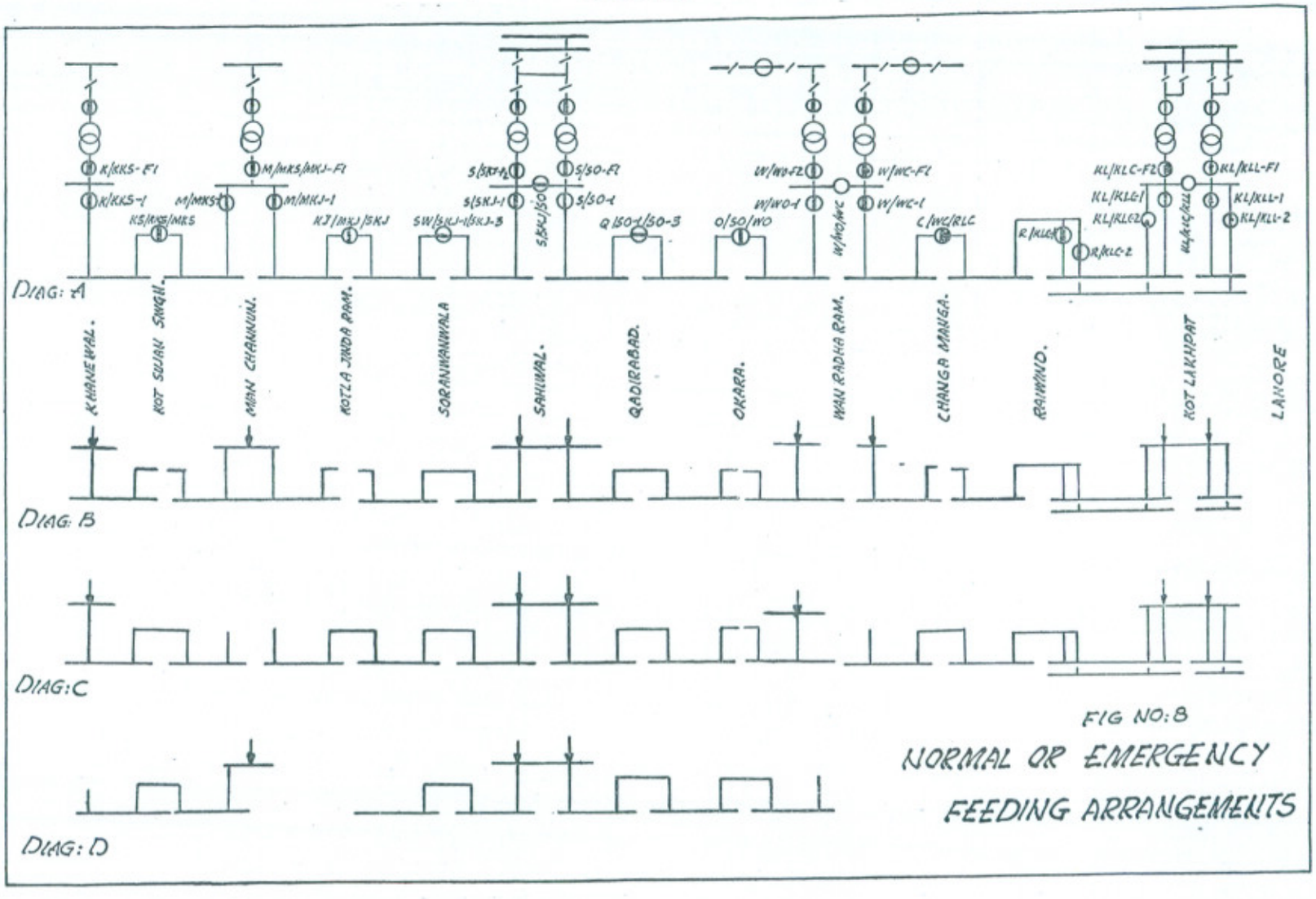


FIG NO: 8

NORMAL OR EMERGENCY FEEDING ARRANGEMENTS

Grid system and would be spread on the various generators, it is expected that Turbo Generators particularly at Multan would not supply continuous single phase load in excess of 10% of their normal rating based as it is, on the present demand conditions of the traction system designed. Effect of harmonies is also appreciably reduced where the system short circuit level is high and it is expected that these would not interfere at the 132 KV supply system *viz.*, at Kot Lakhpat and Sahiwal, which forms the backbone of the Traction requirements.

Conclusion

Lahore - Khanewal Electrification Scheme has been designed allowing maximum use of indigenous power supply facilities without throwing excessive burden on the WAPDA supply system. Continuity of train operation is ensured even under adverse conditions when two of the five Grid Stations supplying power to the Track Feeder Stations fail, while banking heavily on the 132 KV Grid Supply at Kot Lakhpat and Sahiwal.