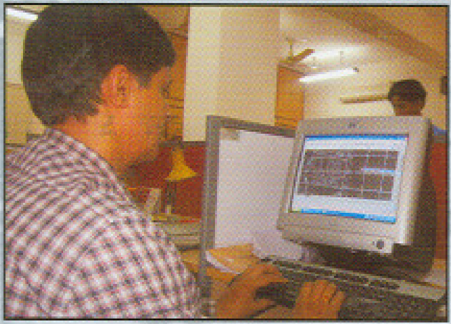
Manual on

SUBSTATION LAYOUT



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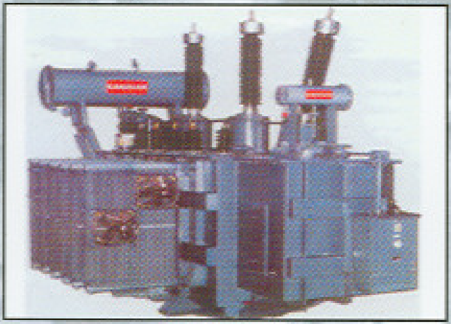

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Central Board of Irrigation and Power

New Delhi

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G.N. Mathur
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CENTRAL BOARD OF IRRIGATION AND POWER
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Foreword

India is on the threshold of high economic growth and the country's initiatives in the infrastructure sector particularly the power sector are moving fast towards a higher growth trajectory.

Substations are vital links in the power systems and their improved availability based on well thought of design parameters / lay out, etc., play major role in power delivery system.

The primary requirements of a good substation lay out are flexibility, reliability, ease of operation and maintenance and safety of operating personnel and equipment.

Keeping in view the importance of the subject and to disseminate the practices being adopted by the various utilities for substation layout and to enable them to decide the best layout suitable to their set conditions the Central Board of Irrigation and Power Published a **Manual on Layout of Sub Station** for the first time in 1967. The Publication was revised four times from 1967 to 1996.

In view of very fast technological developments in power sector it was felt desirable to comprehensively review and revise the manual once again taking into consideration the latest developments and technologies on the sub station equipment etc. The revised edition covers the basic requirements and for the sake of illustration contains typical layout for various types of bus-bar systems. This Manual includes brief discussion on the various components of auxiliary facilities required in a substation to the extent these affect station layout. It also covers other aspects such as minimum clearances and requirements of inspection and maintenance also.

I am sure that the present publication will prove to be a very useful guide for the Power Utilities, Manufacturers, and concerned engineers.

I appreciate the efforts made by Expert committee in bringing out this comprehensive document. I congratulate CBIP, for their initiative and also commend the invaluable contribution of the authors, members of the Expert Group & Central Board of Irrigation and Power.

(RAKESH NATH)

New Delhi
November, 2006

PREFACE

The country's transmission perspective plan for Tenth & Eleventh Plan focuses on the creation of the National Grid so that present Generation capacity as well as future addition are optimally utilized. For this purpose, the massive transmission system comprising of several EHV substations and transmission lines is being planned in the years ahead. Keeping this in view, all out efforts are required to be made by the planners, designers/ engineers in the country to ensure that these substations perform in the best possible manner with minimum down time. Beside this aspect, the economic considerations and parameters relating to the safety of the working personnel have to be ensured. To achieve this goal, the latest technological developments/ requirements have to be kept in view while designing these vital installations/ substations.

One of the objective of existence of Central Board of Irrigation & Power is to work as a platform for the experts in the field to prepare vital technical publications in Power & Water Resources sectors for reference of practicing engineers and other users.

The First Manual on Substation Layout was published by the CBI&P in the year 1967. The publication was revised four times during the period 1967 - 1996. Since last edition was published about a decade back, a feed back was received that this publication is required to be comprehensively reviewed and revised taking in to consideration the developments in the technologies on the sub station equipment and utilizing experience of the professional engineers involved in planning, design, development, operation and maintenance of the EHV sub stations.

Accordingly a committee of experts from state utilities and PSU's was constituted under the chairmanship of Shri S.C. Misra, the then Director (Projects) POWERGRID for preparation of this revised "Manual on Substation Layout".

In this publication, a serious attempt has been made to cover the basic requirements and illustrations containing typical layout for various bus-bar systems beside brief discussion on the various components of auxiliary facilities required for a modern EHV substation including other aspects such as minimum required clearances with respect to safety, inspection and maintenance of the substation.

This manual is out come of ceaseless efforts made during last three years by all members of the expert group. The Central Board of Irrigation & Power wishes to acknowledge its grateful thanks to the authors of this manual for their valuable contribution. I acknowledge with thanks the tremendous contribution made by late Shri A.K. Kapur, Retd. Executive Director (POWERGRID) beside the contribution by other members of the Expert group representing CEA, NHPC, A.P. TRANSCO., GEB, BBMB, RRVPNL, KPTCL, WBSEB, MSEB, PSEB, TNEB, BHEL, ALSTOM & KEC in finalizing the manual. Special thanks

are due to Shri S.C. Misra, Chairman of the expert group for his tremendous input and directions given. I would like to add that but for the untiring efforts of Shri V.B. Prasad, Executive Director (Retd), NHPC, Shri R.S. Chadha, the then Director (IT) CBIP, Shri M.M. Goswami, POWERGRID, Shri S.K. Mohapatra (CEA) and Shri R.K. Gupta (POWERGRID) it would not have been possible to bring out this updated manual in this form.

I hope that the publication will be of immense use and shall have excellent reference value to the practicing engineers and other professionals of power utilities, manufacturers, researchers, testing stations, faculty members and students of engineering Institutes in India and abroad.

G.N. Mathur

New Delhi *Secretary*

November 2006 *Central Board of Irrigation & Power*

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INTRODUCTION

Substations form an important element of transmission and distribution network of electric power system. Basically, these provide points for controlling the supply of power on different routes by means of various equipment such as transformers, compensating equipment, circuit breakers, isolators etc. The various circuits are joined together through these components to bus-bar systems at the substations. While the bus-bar systems have followed certain definite patterns, thus limiting scope for variation, there is practically no standardisation regarding the physical arrangement of the various components in the layout. For the same type of bus-bar system, different layouts have been used in different countries, and, in fact, in India there are variations in this regard among the various Power utilities and State Electricity Boards etc. Although standardisation to a great extent is feasible, some variations in layout are inevitable in view of varying climatic and other conditions in various parts of the country. This Manual gives the basic requirement, and, for the sake of illustration, contains typical layouts for various types of bus-bar systems up to 400 kV system voltage.

One of the primary requirements of a good substation layout is that it should be as economical as possible, which is particularly important in view of the paucity of land and rising cost of land, material and labour. To meet the large programme for expansion of transmission and distribution facilities, the layout should ensure the desired degree of flexibility,–reliability, ease of operation and maintenance, and safety of the operation and maintenance personnel. Besides, the layout should not lead to breakdowns in power supply due to faults within the substation, as such faults are more severe than those occurring on the lines away from the substations. This Manual includes brief details about the various components of auxiliary facilities required in substation to the extent they relate to substation layout. It also covers minimum clearances and other related aspects.

The Bureau of Indian Standards are periodically publishing Indian standards, Codes of Practice and Guides. It is essential that the equipment actually used and the practices followed conform to these standards. For the convenience of users, a list of the relevant latest Indian Standards, Codes, Guides etc. is enclosed as Appendix 1.1, and the list of relevant IEC Standard enclosed as Appendix 1.2.

Appendix 1.1

List of Indian Standards, Guides, Codes etc. required for Reference

IS:325	Three-phase induction motors
IS:398(Pt-1)	Aluminium conductors for overhead transmission purposes; Pt 1- Aluminium stranded conductors
IS: 398(Pt-2)	Aluminium conductors for overhead transmission purposes : Pt.2- Aluminium conductors, galvanized steel reinforced
IS: 398(Pt-5)	Aluminium conductors - galvanized steel reinforced for extra high voltage (400 kV and above)
IS: 692	Paper insulated lead sheathed cables for rated voltage upto and including 33 kV - specification
IS: 694	PVC insulated cables for working voltages upto and including 1100 volts.
IS: 731	Porcelain insulators for overhead power lines with a nominal voltage greater than 1000 volts
IS: 802	Use of structural steel in overhead transmission line towers – Code of practices.
IS: 875 (Pt 1-5)	Code of practice for design loads (other than earthquake) for buildings and structures
IS:933	Portable chemical fire extinguisher, foam type
IS:934	Portable chemical fire extinguisher, soda acid type
IS: 1180	Three-phase distribution transformers upto and including 100 kVA, 11 kV, outdoor type
IS:1248	Direct acting indicating analogue electrical measuring instruments and their accessories
IS: 1255	Code of practice for installation and maintenance of paper insulated power cables (Upto and including 33 kV)
IS: 1554 (Pt-1)	PVC insulated (heavy duty) electric cables Part-1, for working voltages upto and including 1100 volts
IS: 1554 (Pt-2)	Specification for PVC insulated (heavy duty) electric cables Part-2, for working voltages from 3.3 kV upto and including 11 kV
IS: 1646	Code of practice for fire safety of buildings (General) electrical installation
IS: 1651	Stationary cells and batteries - Lead acid type (with tubular positive plates)
IS: 1652	Plante positive plate stationery cell lead acid batteries
IS: 1866	Code of practice for maintenance and supervision of mineral insulating oil in equipment
IS: 2026	Power transformer
IS: 2062	Steel for general structural purposes - Specification
IS: 2099	Bushings for alternating voltages above 1000 volts

IS: 2121	Conductors and earth wire accessories for overhead power lines
IS: 2165	Insulation coordination
IS: 2190	Code of practice for selection, Installation and maintenance of portable first-aid fire extinguishers
IS: 2309	Code of practice for protection of buildings and allied structure against lightning
IS: 2486	Insulator fittings for overhead power lines with nominal voltage greater than 1000 V
IS: 2544	Porcelain post insulators for systems with nominal voltages greater than 1000 volts
IS: 2629	Recommended practice for hot-dip galvanizing of iron and steel
IS: 2633	Methods for testing uniformity of coating of zinc coated articles
IS: 2705	Current transformers
IS: 3034	Code of practice for fire safety of industrial building, electrical generating and distributing stations
IS: 3043	Code of practice for earthing
IS: 3070 (Pt.1)	Lightning arresters for alternating current systems non-linear resistor type lightning arrester
IS: 3070 (Pt.2)	Metal oxide surge arresters without gaps for alternating current systems
IS: 3151	Earthing transformers
IS: 3156	Voltage transformers
IS: 3646 (Pt.1,2)	Principles for good lighting and aspects of designs, code of practice
IS: 3646 (Pt.3)	Code of practice for interior illumination
IS: 3716	Application guide for insulation coordination
IS: 4004	Application guide for non-linear resister type surge arrestors without series gap for AC system
IS: 4146	Application guide for voltage transformers
IS: 4201	Application guide for current transformers
IS: 4691	Degrees of protection provided by enclosure for rotating electrical machinery
IS: 5082	Wrought aluminium and aluminium alloy bars, rods, tubes and sections for electrical purposes
IS: 5216 (Pt.1&2)	Guide for safety procedures and practices in electrical work
IS: 5547	Application guide for capacitor voltage transformers
IS: 5553 (Pt.1&2)	Shunt reactors
IS: 5561	Specifications for electrical power connectors
IS: 5578	Guide for marking of insulated conductors
IS: 6005	Code of practice for phosphating of iron and steel

IS: 7098 (Pt-1)	Cross linked polyethylene insulated PVC sheathed cables: Part 1 For working voltage upto and including 1 100 V
IS: 7098 (Pt-2)	Cross linked polyethylene insulated PVC sheathed cables: Part 2 For working voltages from 3.3 kV upto and including 33 kV
IS: 7098 (Pt-3)	Cross-linked polyethylene insulated thermoplastic sheathed cables: Part 3 for working voltages from 66 kV upto and including 220 kV
IS: 8437(Pt.1&2)	Guide on effects of currents passing through human body
IS: 9921	Alternating current disconnections (isolators) for voltages above 1000 volt
IS: 10028 (Pt-1, Pt 2&3)	Code of practice for selection, installation and maintenance of transformers
IS:10118	Code of practice for selection, installation and maintenance of switchgear and control gear
IS:10136	Code of practice for selection of disc insulator fittings for highest system voltages of 72.5 kV and above
IS:10162	Spacers and spacer dampers for twin horizontal bundle conductors.
IS:10561-	Application guide for power transformers
IS: 12032 (Pt-2)	Graphical symbols used in electro-technology : conductors and connecting devices
IS: 12032 (Pt-4)	Graphical symbols used in electro-technology : Passive components
IS: 12032 (Pt-6)	Graphical symbols used in electro-technology : Production and Conversion of electrical energy
IS: 12032 (Pt-7)	Graphical symbols used in electro-technology : Switchgear, control gear and protective devices
IS: 12360	Voltage bands for electrical installations including preferred voltages and frequency
IS: 12063	Classification of degrees of protection provided by enclosures of electrical equipment
IS: 13134	Guide for selection of Insulators in respect of pollution conditions.
IS: 13118	Specification for high voltage AC circuits breakers
IS: 13516	Methods of synthetic testing of high voltage AC circuit breakers
IS: 13947 (Pt.1 to 5)	LV switchgear and control gear
ANSI/IEEE:80	IEEE guide for safety in AC substation grounding

Appendix 1.2

List of IEC Standards

IEC-60034 (P1 to P19:)	Rotating electrical machines
IEC-60044-1	Current transformers.
IEC-60044-2	Voltage Transformers
IEC-60044-4	Instrument Transformers: Measurement of Partial Discharges
IEC-60051 : (P1 to P9)	Recommendations for Direct Acting indicating analogue electrical measuring instruments and their accessories.
IEC-60076 (Part 1 to Part 5)	Power Transformers
IEC-60076-10	Determination of Transformer and Reactor Sound Levels
IEC-61095	Electromechanical Contactors for household and similar purposes
IEC-60099-4 25	Metal oxide surge arrestors without gaps
IEC-60129	Alternating Current Disconnectors (Isolators) and Earthing switches
IEC-1129	Alternating Current Earthing Switches Induced Current switching
IEC-60137	Insulated bushings for alternating voltages above 1000 V.
IEC-60168	Tests on indoor and outdoor post insulators of ceramic material or glass for Systems with Nominal Voltages Greater than 1000 V
IEC-60183	Guide to the Selection of High Voltage Cables
IEC-60189 (P1 to P7)	Low frequency cables and wires with PVC insulation and PVC sheath
IEC-60214	On-Load Tap-Changers
IEC-60233	Tests on Hollow Insulators for use in electrical equipment.
IEC-60255 (Part 1 to part 23)	Electrical relays
IEC-60265 (Part 1 & Part 2)	High Voltage switches
IEC-60273	Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000V
IEC-60289	Reactors
IEC IEC-60297 (P1 to P4)	Dimensions of mechanical structures of the 482.6mm (19 inches) series
IEC -60376	Specification and Acceptance of New Sulphur Hexafloride
IEC -60437	Radio Interference Test on High Voltage Insulators
IEC -60507	Artificial Pollution Tests on High Voltage Insulators to be used on AC Systems
IEC -60694	Common Specification for High Voltage Switchgear & Control gear Standards
IEC -60815	Guide for the Selection of Insulators in respect of Polluted Conditions
IEC -60865 (P1 & P2)	Short Circuit Current - Calculation of effects
IEC - 60354	Loading Guide for Oil - Immersed power transformers
IEC-62271-100	High Voltage Alternating Current Circuit Breakers
IEC -60427	Synthetic Testing of High Voltage alternating current circuit Breakers

IEC-61264	Pressurized Hollow Column Insulators
IEC-60358	Coupling capacitors and capacitor dividers
IEC-60481	Coupling Devices for power Line Carrier Systems
IEC-60529	Degree of Protection provided by enclosures
IEC-60947-4-1	Low voltage switchgear and control gear
IEC-60439 (P1 & 2)	Low Voltage Switchgear and control gear assemblies
IEC-60353	Line traps for A.C. power systems
IEC-60481	Coupling Devices for power line carrier systems
IEC-60495	Single sideboard power line carrier terminals
IEC-60683	Planning of (single Side-Band) power line carrier systems
IEC-60359	Expression of the performance of electrical & electronic measuring equipment
IEC-60387	Symbols for Alternating-Current Electricity meters
IEC-60447	Man machine interface (MMI) - Actuating principles
IEC-60521	Class 0.5, 1 and 2 alternating current watt hour metres
IEC-60547	Modular plug-in Unit and standard 19-inch rack mounting unit based on NIM Standard (for electronic nuclear instruments)
IEC-60305	Insulators for overhead lines with nominal voltage above 1000 V-ceramic or glass insulator units for a.c. systems Characteristics of String Insulator Units of the cap and pintype
IEC-60372 (1984)	Locking devices for ball and socket couplings of string insulator units: dimensions and tests.
IEC-60383 (P1 and P2)	Insulators for overhead lines with a nominal voltage above 1000 V.
IEC-60433	Characteristics of string insulator units of the long rod type
IEC-60471	Dimensions of Clevis and tongue couplings of string insulator units
IEC-60227 (P1 to P7)	Polyvinyl Chloride insulated cables of rated voltages up to and including 450/750V
IEC-60228	Conductors of insulated cables
IEC-60230	Impulse tests on cables and their accessories
IEC-60287 (P1 to P3)	Calculation of the continuous current rating of cables (100% load factor)
IEC-60304	Standard colours for insulation for low-frequency cables and wires
IEC-60331	Fire resisting characteristics of Electric cables
IEC-60332 (P1 to P3)	Tests on electric cables under fire conditions
IEC-60502	Extruded solid dielectric insulated power cables for rated voltages from 1 kV upto to 30 kV
IEC-754 (P1 and P2)	Tests on gases evolved during combustion of electric cables

Chapter 2

SUBSTATION EQUIPMENT

2.1 The substation layout is influenced to a great extent by the dimensions of the various equipment and their accessories within the substation. A detailed specification for various equipment is outside the scope of this Manual. However, in this chapter only the brief details of the various equipment to the extent they relate to the Substation layout, have been included.

2.2 BUS-BARS

Substations include bus-bars and are divided into bays.

2.2.1 Types of Bus-bars

2.2.1.1 The outdoor bus-bars are either of the rigid type or the strain / flexible type.

2.2.1.2 In the rigid type, pipes are used for bus-bars and also for making connections to the various equipment wherever required. The bus-bars and the connections are supported on pedestal mounted insulators. This leads to a low level type of switchyard, wherein equipment as well as the bus-bars are spread out. Since the bus-bars are rigid, the clearances remain constant. However as the bus-bars and connections are not very high from the ground, the maintenance is easy. Due to large diameter of the pipes, the corona loss is also substantially less. It is also claimed that this system is more reliable than the strain / flexible bus. In case of a rigid type bus, special care has to be taken in respect of aeolian vibration.

2.2.1.3 The the strain / flexible type of bus bars is on overhead system conductors strung between supporting structures and strain / tension type insulators. The stringing tension may be in the range of 500-900 kg per conductor / sub-conductor (of a bundle conductor) for installations upto 132 kV. For 220 kV and 400 kV installations, stringing tension may be in the range of 1000 - 2000 kg per conductor / sub-conductor (of a bundle conductor) depending upon span. The conductor tension, which strongly influences the design and weight of structure has to be specified carefully with reference to span, ambient temperature, wind velocity and relevant site conditions.

2.2.1.4 The design of structures can be economised by suitably locating spacers in bundle conductor bus bars for 245 kV and higher voltage substations.

2.2.2 Bus-bar Material

2.2.2.1 For the rigid bus bar arrangement, aluminium pipes of Grade 63401 WP conforming to IS:5082 are commonly used. The commonly used sizes of pipes are given in Table 2.1.

Table 2.1 : Commonly Used Size of Pipes

System voltage (kV)	Nominal diameter	
	External (mm)	Internal (mm)
72.5	42	35
145	60 60	52 49.25
245	89 89 101.6 101.6 114.3 114.3	78 74 90.1 85.4 102.3 97.2
400	114.3 114.3 127 127	102.3 97.2 114.5 109

2.2.2.2 The material commonly used for bus-bars and connections of the strain / flexible type bus-bars are ACSR/AAC. The following sizes are commonly used either as single conductors or as bundles (Table 2.2) :

Table 2.2 : Commonly Used Size of Conductors

System voltage (kV)	Type	Stranding (Al / St.) / Dia (mm)	Diameter of complete conductor (mm)
72.5	ACSR AAC	30/7/2.79 19/-/3.53	19.53 17.65
145	ACSR AAC	30/7/3.00 19/-/4.22	21.00 21.10
245	ACSR AAC 	54/7/3.18 30/7/4.27 54/7/3.35 19/-/5.36 37/-/5.23	28.62 29.89 30.15 26.80 36.61
400	ACSR	54/7/3.53	31.77

2.2.2.3 Since aluminium oxidises rapidly, great care is necessary in making connections. In case of long spans, expansion joints should be provided to avoid strain on the supporting insulators due to thermal expansion or contraction of pipes.

2.2.2.4 The bus-bar sizes should meet the electrical and mechanical requirements of the specific application for which these are chosen.

2.3 CIRCUIT BREAKERS

2.3.1 Circuit breaker is a mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions. Circuit Breakers of the types indicated below have been used in India.

36 kV Minimum oil. Bulk oil, Vacuum, SF_6

72.5 kV Minimum oil. Bulk oil, SF_6

145 kV	Minimum oil. Bulk oil, SF_6
245 kV	Minimum oil. Bulk oil, Air Blast, SF_6
420 kV	Minimum oil. Bulk oil, Air Blast, SF_6

However, minimum oil, bulk oil and air blast circuit breakers are being phased out due to advancement in technology. SF_6 circuit breakers are generally the present day choice at transmission voltages.

The circuit breakers may be of live tank or dead tank design. The circuit breakers of the "live tank" type for outdoor substations have the interrupters housed in porcelain weather-shields on the top of an insulated support column. The circuit breakers of the "dead tank" type have interrupters housed in an earthed metal container with their connections taken out through porcelain bushings and the bushings may be used to house the current transformers.

2.3.2 The circuit breakers are normally mounted on individual structures.

2.3.3 245 kV and higher voltage outdoor circuit breakers, generally necessitate the provision of approach roads for breaker maintenance.

2.3.4 The commonly used operating mechanisms are pneumatic, spring, hydraulic or their combinations.

2.4 DISCONNECTORS AND EARTHING SWITCHES

2.4.1 A disconnector is a mechanical switching device, which provides in the open position, an isolating distance meeting the specified requirements. A disconnector can open and close a circuit when either a negligible current has to be broken or made or when no significant change in voltage across the terminals of each pole of the disconnector occurs. It can also carry current under normal circuit conditions and carry for a specified time the short circuit currents. Disconnectors are used for transfer of load from one bus to another and also to isolate equipment for maintenance. Although a variety of disconnectors are available, the factor which has the maximum influence on the station layout is whether the disconnector is of the vertical break type, pantograph or horizontal break type. Horizontal break type normally occupies more space than the vertical break type. Out of the horizontal centre break and horizontal double break type, the former requires a greater phase to phase clearance.

2.4.2 The location of disconnecting switches in substations affects not only the substation layouts but maintenance of the disconnectors contacts also. In some substations, the disconnects are mounted at higher positions either vertically or horizontally. Although such substations occupy smaller space, the maintenance of disconnecting switches in such substations is more difficult and time consuming.

2.4.3 Earthing switch is a mechanical switching device for earthing parts of a circuit, capable of withstanding for a specified time short-circuit currents, but not required to carry normal rated currents of the circuit.

2.4.4 It is usual for disconnectors to be motorized. Earthing switches may be motorized or operated manually.

2.4.5 In case of double circuit lines the earthing switches shall be capable of switching inductive current (electromagnetically induced) and capacitive currents (electrostatically induced) as per the values specified in IEC 62271-102 when parallel circuit is energized. The disconnector must also be capable of interrupting and making parallel circuits when transferring load between main and reserve bus bars according to IEC requirements

2.5 INSTRUMENT TRANSFORMERS

2.5.1 Instrument transformers are devices used to transform the values of current and voltage in the primary system to values suitable for the measuring instruments, meters, protective relays, etc. These also serve the purpose of isolating the primary system from the secondary system.

2.5.2 Current Transformers (CT) may be either of the bushing type or wound type. The bushing types are normally accommodated within the transformer bushings and the wound types are invariably separately mounted. The location of the current transformer with respect to associated circuit breaker has an important bearing upon the protection scheme as well as layout of substation. So far, the wound type current transformers with dead tank construction have been used. However, current transformers with live-tank construction also are being used.

2.5.3 Voltage Transformer (VT) may be either of the electro-magnetic type or the capacitor type. The electro-magnetic type VTs are more costly than the capacitor type and are commonly used where higher accuracy is required as in the case of revenue metering. Capacitor type is preferred particularly at high voltages due to lower cost and it serves the purpose of a coupling capacitor also for the carrier equipment. For ground fault relaying, an additional core or a winding is required in the VTs which can be connected in open delta. The voltage transformers are connected on the feeder side of the circuit breaker. However, another set of voltage transformer is normally required on the bus-bars for synchronisation.

2.5.4 The tank of the instrument transformers may preferably be galvanized as this would require least maintenance.

2.6 Compact Air-Insulated Substation (CAIS) / Intelligent Air-Insulated Substation (IAIS)

2.6.1 Compact Air-Insulated Substation (CAIS) / Intelligent Air-Insulated Substation (IAIS) based on modular concept has been developed by various manufacturers offering advantages in compactness, easy in installation, lower maintenance requirement etc. A single module can include breaker, disconnector, DOIT (Digital Optical Instrument Transformer- current and voltage transformer, i.e., DOCT, DOVT) for metering and protection, surge arrester, and earthing switch. In some modules, with a trolley mounted Circuit Breaker (CB), i.e., drawout type, disconnector function is achieved by the movement of the complete breaker unit. Composite modules are pre-manufactured, pre-tested and then integrated to replace the functions of number of conventional components. In a compact design, all primary and secondary functions required for a line or transformer bay in one pre-manufactured and pre-tested switching module (for all voltage levels) can be integrated. The concept also allows to build, upgrade or extend substation more efficiently.

2.6.2 Hybrid type switchgear could also be considered for reducing space and from reliability consideration

2.7 TRANSFORMERS

2.7.1 Transformer is the largest piece of equipment in a substation and it is, therefore, important from the point of view of station layout. For instance, on account of large dimensions, it is generally not possible to accommodate two transformers in adjacent bays. One of the problems is the installation of radiators, which makes the width of the transformer much more than bay width. In order to reduce the risk of spread of fire, large transformers are provided with stone pebble filled soaking pits and oil collecting pit. In addition to above provision, separation walls are provided in-between the transformers and also between the transformer and the control room building, if required road-cum-rail tracks is also provided for movement of transformer. Relevant, sections of CBIP Manual on Transformers may be referred to in this context.

2.7.2 One of the important factors governing the layout of the substation is whether the transformer is a three-phase unit or a bank of 3 single-phase transformers. The space requirements with single – phase banks are much larger than those with three-phase transformers. Besides, in the case of single-phase banks, it is usual to provide one spare single-phase transformer, and used in case of a fault or maintenance of one of the single phase units. The spare unit may be permanently installed in the switchyard ready to replace the unit, which is out of service.

2.8 REACTIVE COMPENSATION EQUIPMENT

2.8.1 Reactive compensation may be of switched or non-switched type as indicated by system studies of the network in which the substations are located.

The non-switched type compensation usually comprises shunt reactors permanently connected to transmission line or to bus bars at the substations as per the requirements. Next to the transformer, shunt reactors constitute large pieces of equipment. These also can be in the form of single-phase units or three phase units. Often another reactor called neutral grounding reactor, which is connected between the neutral bushing of the line shunt reactor and earth, is provided to facilitate single pole auto-reclosing. However in case of bus reactor neutral is solidly grounded. Since these equipment also contain oil, the provisions valid for transformers apply to shunt reactors too.

The switched compensation can comprise switched reactors, switched capacitors or thyristor controlled reactors and thyristor switched capacitors known as Static Var Compensations (SVC). These are selected according to the system requirements and connected directly to their own discrete transformers.

2.8.2 Flexible AC Transmission Systems (FACTS)

Flexible AC Transmission Systems (FACTS) technology is an evolving technology based solution for enhancing the power transmission capability of existing transmission system. FACTS is defined as "Alternating Current Transmission systems incorporating power electronics based and other static controllers to enhance controllability and increase power transfer capability." Thus, FACTS increases the flexibility of power systems, make them more controllable and allow increased utilization of existing network closer to its thermal loading capacity without jeopardizing the stability. FACTS technology can boost power transfer capability in stability limited system by about 20 to 30%. By the process not only capacity is increased but also design and installation cost is saved. Several types of FACTS controller / devices e.g. Static VAR Compensator (SVC), Static Compensator (STATCOM), Thyristor Controlled Series Compensation (TCSC), Unified Power Flow Controller (UPFC), Inter-line Power Flow Controller (IPFC) etc. can be adopted to achieve the goal.

2.8.2.1 *Static Var Systems*

The following are the basic types of reactive power control elements, which make up all or part of any Static VAR system :

- Saturated Reactor (SR)
- Controlled Shunt Reactor (CSR)
- Thyristor-switched Capacitor (TSC)
- Thyristor-switched Reactor (TSR)

Static VAR Compensators (SVCs) are shunt connected static reactive power generators and/or absorbers whose output are varied so as to control specific parameters of the electric power systems.

2.8.3 Series Compensation

Series capacitors are connected in series with the line conductors to compensate for the inductive reactance of the line. They reduce the transfer reactance between the buses of which the line is connected, increase maximum power that can be transmitted and reduce the effective reactive power losses. The series compensation can be variable type with control by Thyristor (also called as Thyristor Controlled Series Compensation – TCSC). Depending upon system requirement, a line can be compensated with fixed series compensation or fixed series compensation and TCSC.

2.8.4 The substation lay out should be such as can accommodate the required compensation equipments. Many-a-time only some of these may be required in the initial stage and may undergo alteration as the system develops. Typical layout space requirement series compensation equipment is given in Chapter-7.

2.9 LIGHTNING PROTECTION

2.9.1 A substation has to be shielded against direct lightning strokes either by provision of overhead shield wire/earthwire or spikes (masts). The methodology followed for systems upto 145 kV is by suitable placement of earthwires/masts so as to provide coverage to the entire station equipment. Generally, an angle of shield of 60° for zones covered by two or more wires/masts and 45° for single wire/mast is considered adequate. For 245 kV installations and above, normally use of electromagnetic methods is resorted to. The most used method for determining shielded zones are the Mousa Method and Razevig Method. The detailed design of shielding system is outside the scope of this publication.

2.9.2 Besides direct strokes, the substation equipment has also to be protected against travelling waves due to lightning strokes on the lines entering the substation.

The apparatus most commonly used for this purpose is the Surge arrester.

Advances in material technology has resulted in the development of metal oxide gapless type surge arrestors, which are being most widely used because of better protection level, higher energy handling / discharge capability and low power loss under normal operating conditions.

The most important and costly equipment in a substation is the transformer and the normal practice is to install Surge arresters as near the transformer as far as possible. The fixing up of insulation level for various equipments within a substation requires a detailed study of insulation coordination with lightning arrester as the focal point for providing protection to the equipment from power frequency over-voltage exceeding the rating of the arrester. In the EHV range, there is also the problem of switching over-voltages and the life of the arrester may be considerably reduced due to frequent operations because of such overvoltages. Sometimes it is not possible to locate the lightning arrester very near the transformer. However, there is no problem so long as the transformer is within the protective distance from the Surge arrester. Besides protecting the transformers, the lightning arresters also provide protection to the equipment on the bus side located within certain distance. In the case of very large substations where the Surge arrester for the transformer does not provide adequate protection to the other equipment, additional Surge arresters either on the bus or on various lines have to be provided. For determination of number of Surge arresters and their locations, each case has to be studied taking the size and importance of the substation, isoceraunic level, anticipated overvoltages etc. into consideration.

2.10 INSULATORS

2.10.1 Provision of adequate insulation in a substation is of primary importance from the point of view of reliability of supply and safety of personnel. However, the station design should be so evolved that the quantity of insulators required is minimum commensurate with the expected security of supply. An important consideration in determining the insulation in a substation, particularly if it is located near sea or a thermal power generating station or an industrial plant is the level of pollution. As a first step to combat this problem, special insulators with higher creepage distance should be used. In case this does not suffice, washing the insulators by using live line equipment has to be resorted to and this aspect has to be kept in mind while deciding the layout of the substation. Another method, which has proved to be successful in other countries, involves the application of suitable type of greases or Room Temperature Vulcanization (RTV) compounds on the surface of the insulators. This, however, also requires cleaning of insulation, the frequency depending upon the degree and the type of pollution.

2.10.2 The creepage distances for the different pollution levels are provided according to Table 2.3.

Table 2.3 : Creepage Distance for Different Pollution Levels

Pollution level	Creepage distance (mm/kV of highest system voltage)
Light	16
Medium	20
Heavy	25
Very heavy	31

For determining the creepage distance requirement, the highest line-to-line voltage of the system forms the basis.

2.10.3 The following types of insulators are normally used:

(A) Bus Support Insulators

(i) Cap and Pin type

(ii) Solidcore type

(iii) Polycone type

(B) Strain Insulators

(i) Disc insulators

(ii) Long rod porcelain insulators

(iii) Polymer insulators

2.11 STRUCTURES

2.11.1 The cost of structures also is a major consideration while deciding the layout of a substation. For instance, in the case of the strain / flexible bus-bar arrangement, cost of structures is much higher than in the case of rigid bus type. Similarly the form of structures also plays an important part and the choice is usually between using a few heavy structures or a large number of smaller structures. While finalizing the design, size, and single line diagram of structures, safety clearance requirements should be ensured.

2.11.2 Steel is the most commonly used material in India for substation structures. Normally the steel structures are hot-dip galvanised so as to protect them against corrosion. However, galvanising sometimes has not proved effective, particularly in substations located in coastal or industrial areas and in such cases painting also becomes essential. In other countries special paints have been developed which are applied within the shop and these paints have proved quite effective.

2.12 POWER LINE CARRIER EQUIPMENT

2.12.1 The carrier equipment required for communication, relaying and telemetering is connected to line through high frequency cable, coupling capacitor and wave trap. The wave trap is installed at the line entrance. The coupling capacitors are installed on the line side of the wave trap and are normally base mounted. The wave traps for voltage levels upto 145 kV can be mounted on the gantry structure on which the line is terminated at the substation or mounted on top of the capacitor voltage transformer. However, the wave traps for voltage levels of 245 kV and above generally require separate supporting insulator stacks mounted on structures of appropriate heights.

Chapter 3

SUBSTATION AUXILIARY FACILITIES

3.1 Besides the main equipment discussed in Chapter 2 a number of auxiliary facilities such as earthing, cabling, oil handling system, illumination system, fire fighting, crane and other unloading facilities, oil filtration, AC/DC auxiliary system etc., have to be provided within a substation. These requirements have been briefly discussed in this chapter to the extent these relate to the substation layout.

3.2 EARTHING

3.2.1 Provision of adequate earthing system in a substation is extremely important for safety of the operating personnel as well as for proper system operation and performance of the protection devices. The primary requirement of a good earthing system in a substation are:

(a) The impedance to ground should be as low as possible. In general it should not exceed 1 ohm for substations with high fault levels (EHV substation) and 5 ohms for substations with low fault levels (Distribution substation).

(b) The step and touch potentials should be within safe limits.

3.2.2 To meet these requirements, an earthing system comprising an earthing mat buried at a suitable depth below ground, supplemented with ground rods at suitable points is provided in the substations. All the non-current carrying metal parts of the equipment in the substation are connected to the earthing mat so as to ensure that under fault conditions, none of these parts is at a potential higher than that of the earthing mat. Under normal condition, the ground rods make little contribution in lowering the earth resistance. These are, however, helpful in maintaining low value of résistance under all weather conditions which is particularly important for installations with high system earth fault currents.

3.2.3 All substations should have provision for earthing the following:

(a) The neutral points of equipment in each separate system. There should be independent earth for the different systems. Each of these earthed points should be interconnected with the station earthing mat by two different diagonally opposite connectors to avoid common mode failure.

(b) Equipment framework and other non-current carrying metal parts.

(c) All extraneous metal frameworks not associated with equipment.

(d) Lightning arresters: These should have independent earthing which should in turn be connected to the station grounding grid or earthmat.

3.2.4 The earthing of substation fence has to be considered from the viewpoint of touch and step potentials in the peripheral area outside the fence. Normally the earth mat has to be extended by 1m to 1.5m beyond the fence so as to ensure that the area in the vicinity of the substation fence is safe.

Where the fenced area is large and mat area is small, in that case fence earthing should be isolated from the main earth mat so that person touching the fence is protected from danger due to transfer voltage.

3.2.5 Earthing in a substation must conform to the requirements of the Indian Electricity Rules and the provisions of the relevant sections of latest IS: 3043 and IEEE Std - 80. The earthing system should be designed to have low overall impedance, and a current carrying capacity consistent with the fault current magnitude. The major parameters which influence design of earth mat are:

(a) Magnitude of fault current:

(b) Duration of fault:

(c) Soil resistivity:

(d) Resistivity of surface material:

(e) Shock duration:

(f) Material of earth conductor, and

(g) Earth mat grid geometry

3.2.6 Bare stranded copper conductor or copper strip used to find extensive application in the construction of earth mat in the past. However, on account of high cost of copper and the need to economise in the use of copper, current practice in the country is based on the use of steel conductor for earth mat.

In view of fast deterioration of GI pipe electrode, cast iron pipe electrode is preferred for earthing. The minimum distance between the electrodes shall be twice the length of electrode.

3.2.7 *Design Procedure*

For detailed design of earth mat reference may be made to the latest edition of IEEE-80, CBIP Technical Report No. 5 on 'Steel Grounding Systems where Grounding Mat is not needed' and CBIP Publication No. 223.

3.3 CABLING

3.3.1 Trenches and cable ducts are normally laid for cable runs. In very large substations, particularly those associated with power plants, tunnels have also been used. Except where cables enter and take off from trench, directly buried cables are generally avoided to facilitate locating faults and rapidly restoring the supply.

3.3.2 The substation area should be properly graded so that the rainwater is drained away form the cables trenches. For draining off any water that may enter the trenches, these should be sloped in their run to drain freely and necessary arrangements made to remove the accumulated water as and when required. Cable trenches should be provided with strong and effective covers. Cables should not be laid directly in the trench floor. A typical cable trench is shown in Fig. 1. At points of entry into indoor areas, termination chambers etc., waterproof and fireproof sealing arrangements should be made. Cable trenches should not run through oil rooms.

3.3.3 Conduits should have the minimum number of bends in their run. Pull boxes to facilitate cable pulling should be provided at suitable locations. Conduits should be sloped and drained at low points. Care must be exercised to see that water does not accumulate within the conduits or drain into the equipment at the end.

3.3.4 In indoor areas, cable may be laid in racks supported on walls, ceiling or floor, floor trenches or clamped to walls or ceiling. Wherever a large number of cables are involved and conditions so permit, a system of racks is preferable as it gives quick access. Particular care should be taken in substation design to permit easy entry of cable in to switchgear with convenience of handling even afterwards.

3.3.5 Cable laying should be done in accordance with systematically prepared cable schedules. In major substation thousands of separate cables will be involved and quick tracing of defects will depend very much on the orderliness exercised while laying. All cable ends should be suitably labeled to facilitate easy identification.

3.3.6 Power cables and control cables should be segregated by running in separate trenches or on separate racks so that in the event of a fire, the control cables are not affected. Segregation of AC and DC control cables to the extent possible is also useful. Separate cables should be used for each CT and PT. In the case of *400 kV substations and substations having numerical/digital relays,* shielded cables should be used for CT and PT circuits and armoured cables for other circuits. These should not be included in the cores of other multicore control cables. While arranging cable runs it should be kept in mind that the arrangement should be such that a fire at any point will not lead to complete shutdown of the whole substation for a long time. Flexible conduits should be used at terminal connections to motors, pumps, etc. The main trenches should be formed such that heavy current carrying conductors do not run parallel to the control cables.

The cable ducts should be laid away from lightning arresters to minimize the effect of high discharge current flow.

In main trenches a heavy current carrying conductor should not be run parallel to control cables. This conductor should be clamped at suitable intervals to the support angles earthed to rod electrodes at every 20/25-meter intervals. *This shield conductor drain all induced current and minimizes induction of high voltage in the control cables.*

Power cables are placed in the top rack. Lower racks contain control cables. If unarmoured cables are used these should find place in the bottom most rack.

3.3.7 XLPE/PVC insulated cables conforming to the Indian Standards listed in Appendix 1.1 in Chapter 1 should be used up to 11 kV.

3.3.8 Multicore control cables should also be PVC / XLPE insulated and colour coded. Adequate number of spare cores should be included in all control cables. Wherever fiber optic cable are used they should be armoured type.

3.3.9 Wherever insulated cables are used reference should be made to latest IS: 1554 and IS: 694. Earthing of cables sheaths, provision of earth continuity conductors etc., should be as per latest IS: 1255. "Code of Practice for Installation and Maintenance of Paper Insulated Cables" (upto and including 33 kV) and latest IS: 3043 Code of Practice on Earthing.

3.3.10 Wherever application demands, FRLS cables and fittings should be used. For mechanical protection, armoured cables are used in case these are laid on ladder type trays. For 400 kV switchyards, irrespective of the type of cable trays, armoured cable should be used. Armoured cables can be buried directly. However the unarmoured cables can be laid in conduits.

3.4 OIL HANDLING SYSTEM

3.4.1 The oil handling system is required for treatment of insulating oil in transformers, reactors etc. Details regarding handling and treatment of oil are given in latest IS: 1866 – "Code of Practice for Maintenance and Supervision of Insulating Oils in service.

3.4.2 Oil may be stored in clean drums. *The drums should be stored horizontally with caps below oil level.* It should be tested periodically for dielectric strength and kept in good condition.

3.4.3 Portable oil filtration set of adequate capacity *mounted on trucks* may be provided to cater to the requirements of group of substations. A typical layout of oil handling system for a centrally located or a large substation is shown in Fig. 2.

3.5 ILLUMINATION SYSTEM

3.5.1 Good lighting in a substation is necessary to facilitate normal operation and maintenance activities and at the same time to ensure safety of the working personnel. As per latest IS: 3646 (Pt. II) "Schedule for values of illumination and Glare Index" recommends values of intensity of illumination. Table 3.1 contains the recommended values for different parts of substations.

Table 3.1 : Recommended Illuminator Values

Sl. No.	Particulars	Average illumination level 'Lux'	Limiting Glare Index
1.	Control rooms: Vertical control panels Rear of control panels Control desks Switch houses	 200 to 300 150 300 150	 19 19 19 25
2.	Battery room	100	-
3.	Carrier room	300	-
4.	Offices and reception	300	19
5.	Cloak rooms	100	-
6.	Workshop/Repair bay	300	25
7.	Test room	450	19
8.	Outdoor switchyard	20	-
9.	Stairs	100	-
10	Corridors	70	16
11	Approach roads	20	-
12	Pathways	20	-
13	Car parks	20	-
14	Conference room	300	19
15	Store room	100	-
16	Cable gallery/floor	70	-
17	AC plant/DG set room	150	-

Out door switchyard average illumination level shall be 50 lux on main equipment and 20 lux on balance area of switchyard. In the out door switchyard, the area covered by transformer/reactor should have 50 lux.

3.5.2 The lighting system of a particular area whether outdoor or indoor should be designed in such a way that uniform illumination is achieved. As far as possible any dark spots should be avoided. This requires careful placing of the luminaries, selection of proper mounting heights and provision of sockets in the marshalling kiosks and mechanism boxes of circuit breakers/disconnect switches for providing supplementary lighting wherever required. In outdoor switchyards, only the equipment/bus bar areas are illuminated. In outdoor area, luminaries should be directed as far as possible towards transformers, circuit breakers/disconnect switches, their mechanism boxes etc., where some operations may be necessary during emergency at night.

3.5.3 There are several classifications of the types of lighting such as direct, indirect, semi-indirect, diffusion, etc., The types of lighting or the combinations should be so chosen as would provide adequate level of glare-free illumination without creating undesirable shadows.

3.5.4 Direct lighting system is the most commonly used and it employs open dispersive reflectors, silver glass reflectors and angle reflectors. The simplest form of general diffusion fitting is the plain sphere of opal glass. The spherical form may be modified and any form, which the designer can think of may be used. The efficiency of the general diffusion fitting depends partly on shape but much more on the properties of the diffusing material used.

3.5.5 The typical indirect fitting is and opaque bowl with lamp suspended in it at such a depth that all the direct light from the lamp as well as form the bowl is emitted in the upper hemisphere. The semi direct fittings lie in between the indirect and the general diffusion fittings.

3.5.6 Flood light fittings are in essence, projectors with parabolic reflectors. There are two types of floodlights: the wide beam type and the narrow beam type. Wide beam type is suitable where accurate control is not necessary and the light is projected only over a short distance. The narrow beam type is used where light is required to be projected over longer distances.

3.5.7 The choice of lamps, i.e., incandescent, *fluorescent*, mercury vapour, sodium vapour halogen etc., depends mainly on the nature of work, the number of hour of utilization annually, the cost of energy and the power available for illumination. Table 3.2 gives different types of lamps and fittings that may be used in different area of a substation.

3.5.8 The foremost criterion in the design of illumination system of indoor area such as control room, workshop, repair bay, offices, etc., is that illumination at the working height throughout the area should be as uniform as possible so as to avoid eye fatigue. In practice, complete uniformity of illumination is difficult to achieve and a ratio of the minimum intensity to the maximum equal to about 70 percent is usually considered acceptable.

3.5.9 Energy conservation requirement has to be kept in view while selecting type of lamp and type of fitting. While designing the lux level requirement Utilization co-efficient factor may be considered to take care effect of dust, pollution etc. on reflectors used in the lighting fixtures.

The night time lighting of exterior areas is necessitated by operational requirement, security or decorative purposes or a combination of these. It is used for illuminating outdoor switchyards transformer yards, approach roads to substations, etc., Use of flood lights has been in practice for illumination of switchyards. However, floor lights generally cause glare, if not properly positioned and mounted at proper heights. As the lumen output of mercury/sodium vapour lamps is quite appreciable as compared to incandescent lamps, flood light units having mercury/sodium vapour lamps with medium and wide angle coverage, mounted at suitable heights are preferred. If the floor light is mounted at a height of 6 to 10m it would be away from the normal vision angle (8^0) of a man approaching it and therefore, there would be no problem of glare. If the design of the flood lighting is followed in an orderly fashion, it is easy to obtain uniform illumination in the outdoor switchyard. The spillover light from flood lights provided in the switchyard is generally sufficient for fence lighting. Separate fence lighting is provided only in exceptional cases. Light fittings in the switchyards are mounted on substation structure/lighting masts. Typical lamps and fittings generally provided in some identified areas are given in Table 3.2

Table 3.2 : Typical Lamps & Fittings in Some Identified Areas

Sl. No.	Particulars of area	Type of lamps	Type of fittings
1.	Unloading-cum-repair bay	Mercury vapour sodium	High bay
2.	Store rooms, workshops	Fluorescent	Industrial
3.	Control room, offices carrier room	Fluorescent	Decorative
4.	Battery room	Fluorescent	Acid proof, Industrial
5.	Compressor room etc.,	Fluorescent	Industrial
6.	External lighting on building	Mercury vapour sodium vapour	Water tight flood light
7.	Outdoor switchyard	Mercury vapour sodium vapour	Water tight flood light
8.	Fence lighting	Mercury vapour sodium vapour	Post type water tight, flood light
9.	Roads	Mercury vapour sodium vapour	Post type water tight street light fittings

3.5.10 The purpose of street lighting in substations is to promote safety and convenience on the approach roads, service roads and side walls inside switchyard, etc., The aim should be to provide conditions of visibility adequate for accurate, certain and comfortable seeing.

3.5.11 Emergency lighting is called for in case of AC supply failure in substations. In indoor installations such as a control room, switchgear rooms, etc., DC lamps connected to the DC supply system should be provided at suitable locations. These are brought into service in case of AC supply failure. These are normally wired through automatic changeover contactor at the DC distribution board. In workshops/ repair shops and machine hall, where mercury/sodium vapour lamps are employed, provision should be made for one incandescent lamp fitting of suitable power for a group of 4 to 6 mercury/sodium vapour lamps. This would avoid *an extended* total blackout in the event of a voltage dip or momentary interruption of AC supply, as the discharge lamps take a few minutes to give full light output again.

3.6 COMPRESSED AIR SYSTEM

3.6.1 Compressed air system in substation may be required for the operation of air blast circuit breaker and pneumatically operated circuit breakers and disconnect switches. A reliable source of supply of compressed air is very essential for successful operation of the equipment.

3.6.2 Compressed air requirement of a substation can be met by either a central compressor system or a unit compressor receiver system.

3.6.2.1 *Central Compressor System*

3.6.2.1.1 This arrangement is generally provided in substation, where the number of circuit breakers to be served is large. The central compressor normally works at a high pressure and through reducing valves, the pressure is reduced at local receiver of each circuit breaker to a working level. The values of high or low pressure vary from manufacturer to manufacturer.

However, generally the rated pressure of the central air receiver is kept about twice the rated pressure for breaker operation. The advantages of choosing higher pressure for the central receiver are:

(i) Ensured availability of working pressure in the circuit breaker received immediately after one specified duty operation.

(ii) Elimination of moisture in the compressed air, as expansion takes place from high pressure in the central receiver to working pressure in the circuit breaker receiver.

(iii) Reduction in storage volume.

3.6.2.1.2 The central compressor system should comprise at least two compressors, each capable of charging the central air receiver to its rated pressure within prescribed time. The capacity of the local receiver should be adequate for the breaker to perform one standard duty cycle. The capacity of the air receiver should be adequate for the total number of breakers likely to perform one standard duty cycle simultaneously. The capacity of the air compressor should be adequate so that the time required for the first charging or charging under normal running conditions or charging after one standard duty cycle whichever is more critical, does not exceed the specified limits.

3.6.2.2 *Unit Compressor Receiver System*

3.6.2.2.1 This system may be provided in the substations, where the number of circuit breakers to be served is small. In this arrangement, each circuit breaker shall have its own compressor and receiver. A single compressor is used but a connector is provided to allow a portable compressor to be coupled for maintenance purposes or in emergency. In such an arrangement, the storage capacity of the local receiver should be sufficient for two or three operations without recharging. The usual practice is that the time to restore 95 percent pressure following a break operation is 3-5 minutes or even less.

3.6.3 Compressed air always contains moisture to some extent which must be eliminated so as to ensure the safety of operation.

3.6.4 The pipe from the air supply system to the circuit breaker should be normally of ring main or double bus type to ensure continuity of supply. Formerly, solid drawn copper piping was used for compressed air but, in view of the acute shortage of copper, it is not economical to use copper piping. Instead black steel or galvanized iron piping may be used. Screwed malleable iron fittings should be used for low pressure (7atm. and lower). Where high pressures are encountered, flanged forged black steel fittings may be used.

3.6.5 A typical central compressor arrangement for a substation using air blast circuit breakers is shown in Fig. 3.

3.7 CRANE FACILITIES

3.7.1 Large substation sometimes has the facilities of repair bay along with a crane of adequate capacity for handling the heaviest equipment which is usually the transformer. In view of heavy cost and infrequent use, however, this facility is not provided in all substations. In the case of substations near the generating stations, the service bay and crane facilities normally available at the generating station are utilized. In the case of substations, which are not near a generating stations, crane and service bay facilities may be provided at one centrally located substation to serve a group of nearby substations connected by road or rail.

3.7.2 Provision of a rail track should be made for movement of transformer from switchyard to the repair bay. Point for jacking pad should be provided at the transformer foundation, to facilitate 90^0 turn on the rail track for changing the direction of wheels.

3.8 FIRE PROTECTION FACILITIES

3.8.1 In view of a large number of oil-filled equipments in a substation, it is very important that proper attention is given to isolation, limitation and extinguishing of fire so as to avoid damage to costly equipment, reduce chances of serious dislocation of power supply and ensure safety of personnel. The first step in this direction is inherent in the design and layout of the substation itself, which should be such that if fire occurs in any equipment it should be limited and isolated so that it does not spread to other equipments. For this purpose the following are the general guidelines:

(i) The spacing of the equipment should be considered. Extra space is not usually provided for fire isolation, but the space available is taken into account in deciding other isolation measures.

(ii) Fire isolation walls should be provided between large oil-filled equipments such as two or more transformers placed adjacent to each other. These should be of adequate strength and of such size that the adjacent equipment is reasonably safe from fire risk due to burning oil flying from the equipment on fire.

(iii) In indoor areas automatic fireproof doors should be provided for rooms which house major oil-filled equipment. The rooms should also be constructed with a view to isolating the fire.

(iv) Soak pits or drain pits should be provided below large oil-filled equipment to drain off the burning oil falling below the equipment.

(v) Minor items of oil-filled equipment should be placed in beds of gravel or pebbles which will quench and prevent the spread of burning oil.

(vi) Care should be exercised that any prospective fire can be easily approached for quenching. In closed spaces and buildings attention should also be given to evacuation of personnel (Refer IS: 1646).

(vii) All oil pipes and cable trenches should be sectionalised by means of cross walls.

3.8.2 A well coordinated system of fire protection should be provided to cover all areas of the substation and all types of likely fires. The details of fire protection have to be worked out on the basis of size, type and location of the substation, accessibility and degree of attendance. Care should be taken that any fire can be fought from more than one source and dependence is not placed on single equipment for this purpose.

3.8.3 The subject of fire safety involving electrical equipment is exhaustively covered in latest IS: 1646, IS: 3034 and CBIP Manual on Transformer.

3.8.4 Fire Fighting System

3.8.4.1 All substations should be equipped with fire fighting systems conforming to the requirements given in latest IS:1646 and Fire Protection Manual Part-I issued by Tariff Advisory Committee of Insurance Companies.

3.8.4.2 Trailer pumps where provided should draw their water supply from ground tanks of suitable sizes, the location and distribution of which shall be such that no item to be protected is more than about 90m away from any ground tank.

3.8.4.3 The more valuable equipment or areas forming concentrated fire risk should be covered by special fire protective systems. In this class are:

(a) Transformers, both indoor and outdoor:

(b) Oil-filled reactors:

(c) Oil-filled switchgear:

(d) Oil tanks and oil pumps:

(e) Oil, grease and paint stores: and

(f) Synchronous condensers.

3.8.4.4 Although the substitution of bulk-oil and minimum oil circuit breakers by SF_6 gas circuit breakers has reduced the risk of fires in electrical installations, considerable risk still exists on account of transformers, reactors, cables etc., which contain combustible insulating materials. Fires in live electrical equipment, motors, machinery etc. fall in class C according to the Tariff Advisory Committee Classification of Fires. It is necessary to provide efficient Fire Protection Systems in the Electrical Installations. Fire Protection System consists of the following:

(i) Fire Prevention

(ii) Fire Detection and annunciation

(iii) Fire Extinguishing.

3.8.5 Fire Prevention

3.8.5.1 Fire prevention is of utmost importance and should be given its due if risk of occurrence of fires has to be eliminated/minimized. The safety and preventive measures applicable for substations as recommended by the relevant authorities must be strictly followed while planning the substations.

3.8.5.2 All fire fighting equipment and systems should be properly maintained. Regular mock drills should be conducted and substation staff made aware of importance of fire prevention and imparted training in proper use of the fire fighting equipment provided in various parts of the substation, control room building etc.

3.8.6 Fire Detection and Annunciation

3.8.6.1 Fire detection if carried out at the incipient stage can help in timely containment and extinguishing of fire speedily. Detection can either be done visually by the personnel present in vicinity of the site of occurrence or automatically with the use of detectors operating on the principles of fixed temperature, resistance variation, differential thermal expansion, rate of rise of temperature, presence of smoke, gas, flame etc. Fire detectors of the following types are usually used:

(i) Ionisation type

(ii) Smoke type

(iii) Photoelectric type

(iv) Bimetal type

(v) Linear heat detection type

3.8.6.2 Ionisation type detectors are used more commonly. However in areas like cable vaults, Ionisation smoke and linear heat detection type detectors are used. Smoke type detector is effective for invisible smoke, and photoelectric type for visible smoke. Smoke type detectors incorporate LEDs, which start glowing in the event of fire.

3.8.6.3 Detectors are located at strategic positions and arranged in zones to facilitate proper indication of fire location, transmission of Audio-visual signals to Fire control panels and actuation of the appropriate Fire Fighting Systems. In the rooms with false ceilings, these are provided above the ceiling as well as below it. For the detectors located above the false ceilings, remote response indicators should also be provided.

3.8.6.4 Detectors are provided at the rate of one for a maximum area of 80 m^2 in the zones to be covered by the Fire Protection System

3.8.7 Fire Extinguishing

3.8.7.1 The Fire Extinguishing Systems used for fire protection of the various equipments/building in substations are the following:

(i) Hydrant system.

(ii) High velocity water spray system.

(iii) Portable fire extinguishers.

(iv) Nitrogen injection fire prevention method for transformer only

These are described below briefly.

3.8.8 Hydrant System

3.8.8.1 Hydrant System is installed for the protection of the following areas from fire:

(i) Control room building

(ii) L.T. transformer area

(iii) Diesel generator set building

(iv) Fire water pump house

(v) Suitable location in the switchyard.

3.8.8.2 Hydrants are the backbone of Fire Fighting System as these can help fighting fires of all intensities in all classes of fires and continue to be in service even if the affected buildings/structures have collapsed. These keep the adjoining properties/buildings cool and thereby save them from the serious effects of fire and minimize the risk of explosions.

3.8.8.3 The Hydrant System is supplied water from Fire Water Pump House. Fire Water Pump House is located by the side of Fire Water Storage Tanks constructed within the substation boundary limits. These tanks are made of RCC above ground such that these are easily accessible. Water from these tanks is pumped into the Fire Hydrant System with horizontal centrifugal pumps.

3.8.8.4 The Hydrant System essentially consists of a network of pipes, laid both above ground and underground, which feed water under pressure to a number of hydrant valves located at strategic locations throughout the substation. Pressure in the piping is maintained with the help of hydro-pneumatic tanks and jockey pumps. Jockey pumps compensate for minor leakages also. The hydro-pneumatic tanks are pressurized with compressed air supplied by two air-compressors of which one is working at a time and other acts as standby.

Adjacent to the Hydrants, hosepipes, branch pipes and nozzles are kept in Hose Boxes. In case of fire, the hoses with nozzles are coupled to the respective hydrants and water jet is directed towards the seat of fire.

3.8.8.5 On drop of pressure in the piping network below a preset value, the Hydrant Pump starts automatically and continues to run till it is stopped manually after fire has been extinguished.

3.8.8.6 The quantity of water to be available for fire protection and the number of fire water pumps depend on the total number of hydrants which are provided as per guidelines of Tariff Advisory Committee Manual, according to which substations fall in "Light Fire Hazard" category. The parameters of Fire Water Pumps as per TAC guidelines are given below.

(a) For the total number of hydrants upto twenty, one no pump of 96 m^3/hr capacity with a pressure of 5.6 kg/cm^2 (gauge)

(b) For the total number of hydrants exceeding twenty upto fifty five, one no. pump of 137 m^3/hr capacity with a pressure of 7.0 kg/cm^2 (gauge)

(c) For the total number of hydrants exceeding fifty five, upto hundred, one no. pump of 171 m^3/hr with a pressure of 7.0 kg/cm^2 (gauge)

3.8.8.7 As per TAC guidelines, the jockey pump should have a capacity of 10.8 m^3/hr. and the hydro-pneumatic tank should have a capacity of 18 m^3. The effective capacity of the Fire Water Tank should be not less than one hour of aggregate pumping capacity, with a minimum of 135 m^3.

3.8.8.8 All components of the Hydrant System such as piping, valves, fittings, hoses, branch pipes, nozzles etc. should be of approved make acceptable to TAC.

3.8.9 High Velocity Water (HVW) Spray System

3.8.9.1 This type of Fire Protection System is provided for the following types of equipment:

(i) Power Transformer, both auto and multi-winding

(ii) Shunt Reactors

This system is designed on the assumption that one reactor/transformer is on fire at a time. For this assumption, the largest piece of equipment forms the basis.

3.8.9.2 High Velocity Water Spray System consists of a network of projectors arranged around the equipment to be protected. Water under pressure is directed into the projector network through a deluge valve from a piping network exclusively laid for the Spray System. Water leaves the projectors in the form of conical spray of water droplets travelling at high velocity.

3.8.9.3 The high velocity droplets bombard the surface of oil and form an emulsion of oil and water which does not support combustion. This emulsion converts a flammable liquid into a non-inflammable one. However, this emulsion is not of a stable character and therefore shortly after the water is shut off, oil starts to separate out from water which can be drained away, leaving the oil behind unimpaired.

3.8.9.4 The rate of burning of a flammable liquid depends upon the rate at which it vaporizes and the supply of oxygen to support combustion. It is the maximum when the rate of burning of the flammable liquid is the maximum and the surface of the liquid is near boiling point. The high velocity water spray system while forming an emulsion, intersperses cold water with the liquid, cools it and lowers down the rate of vapourisation which prevents further escape of flammable vapours. During passage of water droplets through flames, some of the water gets converted into steam, which dilutes oxygen in the air supporting the fire and creates a smoothering effect, which aids in extinguishing the fire.

3.8.9.5 An automatic deluge valve triggered by a separate system of quartzoid bulb detector heads mounted on a pipe work array charged with water, at HVW spray mains pressure, initiates the HVW Spray System operation. When a fire causes one or more of the quartzoid bulbs to operate, pressure in the detector pipe work falls and this allows the deluge valve to open thereby permitting water to flow to all the projectors in the open pipe array covering the risk.

3.8.9.6 *Water Supply to HVW Spray System*

(a) Two pumps are provided for HVW Spray System. Of these, one is electric motor driven and the other diesel engine driven. The capacity and head of the pumps is selected to protect the biggest risk. It has been experienced that each pump having a capacity of 410 m^3/hr is usually adequate for the biggest risk in substations.

(b) These pumps are located in Fire Water Pump House. Suitable connection with the Hydrant System is provided so as to allow flow of water from Hydrant System to HVW Spray System but not in the reverse direction.

(c) Standby diesel engine driven pump is a common standby facility for HVW spray as well as Hydrant System.

(d) These pumps are automatically started through pressure switches located sequentially in headers. However, stopping of the pumps is done manually after the fire gets extinguished.

(e) The values of pressure of running water and discharge density given below are recommended for HVW Spray System :

(i)	Minimum pressure of running at any projector at any instance.	=	3.5 Bar
(ii)	Maximum pressure of running water at any projector at any instance	=	5.0 Bar
(iii)	Discharge density on ground surface	=	6.1 lpm/m^2
(iv)	Discharge density on other surface	=	Not less than 10.2 lpm/m^2

3.8.10 Water Supplies

3.8.10.1 Water for fire fighting purposes should be supplied from the water storage tanks meant exclusively for the purpose. The aggregate storage capacity of these tanks should be equal to the sum of the following:

(i) One-hour pumping capacity of Hydrant System or 135 m^3 which over is more.

(ii) Half-an-hour water requirement for single largest risk covered by HVW Spray System.

The water storage tank made of RCC construction over ground should be in two parts.

3.8.10.2 Fire Water pumps located in the Fire Water Pump House should have pumping head suitable to cover the facilities for future stages also. The piping system should be designed to permit extensions without disruption in the existing system. The material of piping is mild steel as per IS: 1239/IS: 3589 medium grade. The piping laid underground is coated and wrapped against corrosion as per IS: 10221 and the piping laid over ground consists of galvanised mild steel.

3.8.10.3 All equipment and accessories, constituting the HVW Spray System, such as flow control valve, heat detectors, projector nozzles, piping, valves, fittings, instrumentation etc., should be of approved makes acceptable to TAC.

3.8.11 Portable and Mobile Fire Extinguishers

3.8.11.1 Portable and Mobile Fire Extinguishers are provided at suitable locations for indoor/outdoor applications. These extinguishers are used during early stages of localised fires to prevent them from spreading. Following types of these extinguishers are usually provided.

(i)	Pressurised Water Type	in 9.01 kg size
(ii)	Carbon Dioxide Type	in 4.5 kg size
(iii)	Dry Chemical Type	in 5.0 kg size
(iv)	Halon type	in 5.0 kg size
(v)	Mechanical foam Type	in 50ltrs, 90ltrs.

For the quantities of these types and their applications, the norms given in TAC manual should be followed.

- The make of these extinguishers should also be acceptable to TAC.
- Halon type fire extinguishers are now getting phased out on account of their negative effect on the atmosphere.
- The transformers shall be protected by automatic high velocity water spray system or by carbon dioxide or BCF (Bromochloro-difluromethane) or BTM (Bromotrifluromethane) fixed installation system or Nitrogen injection and drain method.
- Nitrogen injection fire prevention method is being used by a few utilities at present.

3.8.12 Instrumentation and Control

3.8.12.1 Fire Protection System should include suitable instrumentation and necessary controls to render the system efficient and reliable. There should be local control panels for each of the pumps individually as also for the operation of deluge valve of the HVW Spray System. There should be a common control panel for the Jockey Pump and Air Compressors. Main annunciation panel should be provided in the control room for the facilities provided in the control room and for repeating some annunciation from pump house.

3.8.12.2 The following Annunciation is usually provided in the Fire Water Pump House :

(i) Electric motor driven HVW spray pump running/fails to start

(ii) Diesel engine driven HVW spray pump running/fails to start

(iii) Hydrant pump running/fails to start

(iv) Jockey pump running/fails to start

(v) Air compressor fails to start

(vi) Hydro-pneumatic tank pressure low

(vii) Hydro-pneumatic tank pressure high

(viii) System header pressure low

(ix) Fire in transformer/reactor.

(x) Fire in smoke detection system

(xi) Water storage tank water level low

(xii) High speed diesel oil tank level low

3.8.12.3 The following Annunciations should be available in the control room also:

(i) Fire in transformer/reactor

(ii) Hydrant pump/diesel engine operated HVW spray pump in operation

(iii) Motor operated HVW spray pump in operation

(iv) Fire/Fault in Zone 1

(v) Fire/Fault in Zone 2

(vi) Fire/Fault in Zone 3

(vii) Fire/Fault in Zone 4(depending on the number of zones)

3.8.12.4 All fire protection equipment should be covered by a regular and strict maintenance and test routine. The hydrant systems should be checked every week which may be possible during night shifts. Sprinkler systems should be checked at regular intervals. Portable equipment should be charged at specified intervals and checked regularly for loss of charge, damage, etc. Records of all tests and checks must be maintained.

3.8.12.5 Provision should be made to switch off the air conditioning equipment in case of fire.

3.8.12.6 Cable entry openings shall be sealed to prevent the spreading of fire.

3.8.13 Diagram of Fire Fighting System

A flow diagram of a typical HVW Spray and Hydrant System is enclosed as Fig. 5.

3.9 DC AUXILARY SUPPLY

3.9.1 DC Auxiliary supply is required for relays, instrumentation, closing and tripping of circuit breakers, emergency lighting, control board indications, etc. During normal operation, battery charger (rectifier bridge with Silicon diodes and Silicon control rectifiers) provides the required DC supply. However, to take care of failure of the AC supply (rectifier), a storage battery of adequate capacity is provided to meet the DC requirement. Normally, the storage battery merely keeps floating on the direct current system and supplies current in case of failure of the rectifier in substation. It is desirable to provide duplicate rectifiers to meet the contingency of rectifier failure. An arrangement shall be made to supply an uninterrupted DC supply to load wherever the battery charger is facilitated with float/trickle/boost charging.

3.9.2 The voltage commonly used for the DC auxiliary supply is 110 or 220 volts batteries for substations and 48 volts for PLCC. Generally lead acid batteries are used.

3.9.3 Capacity of the battery should be adequate to supply.

(a) Momentary current required for the operation of switchgear.

(b) The continuous load of indicating lamps, holding coils for relays contactors, etc.,

(c) Emergency lighting load.

3.9.4 Complete DC equipment for a substation may be divided into three parts i.e., storage battery and accessories, charging equipment and distribution board.

3.9.5 The charging equipment generally consists of float charger and boost charger. In major substations, twin float chargers and twin boost chargers or with float cum boost charges with a suitable switching cubicle are generally used for reliability.

3.9.6 The distribution board has an incoming circuit from the DC battery and a number of out going circuits for closing and tripping, alarm and indication for control and relay panels. A separate circuit is provided for the emergency load normally fed from AC supply but is automatically switched on to DC supply in the event of AC power failure.

3.10 AC AUXILIARY SUPPLY

3.10.1 AC supply both single and three-phase, are needed in a substation for internal use for several functions such as:

(a) Illumination.

(b) Battery charging

(c) Transformer cooling system

(d) Oil filtration plant

(e) Transformer tap-changer drives

(f) Air compressors

(g) Power supplies for communication equipment

(h) Crane

(i) Breakers/disconnect switch motors

(j) Fire protection system

(k) Space heaters in cubicles and marshalling kiosks

(l) Air-conditioning/ventilation equipment

3.10.2 Auxiliary Transformer

The design of AC auxiliary supply system must be such that it ensures continuity of supply under all conditions, as far as practicable, reliability being the basic requirement. In a substation, it is normally provided from a station transformer connected to the 11 kV or 33 kV station bus. Its capacity should be adequate to meet the demands of all the essential connected loads. Generally, two such transformers are provided in all major substations.

3.10.3 In case of transformers where tertiary winding is available one auxiliary transformer can be connected to tertiary of transformer for station power supply with adequate insulation margin and protection to save the damage to main transformers from the Secondary system faults.

3.10.4 The station transformer is connected to the indoor AC distribution panel through duplicate cables. Duplicate feeds to important loads are made from the AC distribution panels through outlets, which are controlled, by switch fuses or circuit breakers.

In the event of shutdown of the entire station, ensure availability of AC auxiliary supply for charging of protective equipments, DG set shall preferably be provided in major substations with Auto Main Fail (AMF) panel preferably. Change over scheme shall be provided in AC distribution panel, to feed important loads by DG set.

3.10.5 Incomer of AC distribution panel shall be provided with 4-pole breaker either it may be from auxiliary transformer or from DG set.

3.11 VENTILATION

3.11.1 Battery Room Ventilation

Exhaust fans should be provided. Further it is necessary to ensure sufficient air inlet to the battery room by providing blowers, if necessary. Exhaust alone without air inlet, a negative pressure will be created in the battery room which will cause

(a) Evaporation of electrolyte even at the normal room temperature and the fine spray of electrolyte will settle on cells, stands etc., reducing the electrical insulation of the battery from the ground.

(b) The hydrogen evolved from the battery may form an explosive mixture if the room pressure has reduced.

Chapter 4

BUS-BAR SCHEMES

4.1 TYPES OF BUS BAR SCHEMES

The various types of bus-bar schemes generally considered in this Manual are:

(a) Single bus-bar

(b) Main and transfer bus-bar

(c) Double bus-bar

(d) Double main and transfer bus

(e) Ring bus-bar and mesh bus-bar

(f) One-and-half circuit breaker

(g) Double-bus double-breaker scheme

4.2 SELECTION OF BUS-BAR SCHEME

4.2.1 The selection of a bus-bar scheme and its possible extension is an important initial step in substation design. The aspects which influence this decision are operational flexibility, system safety, reliability, availability, ability to facilitate system control and cost. Figure 6 (A to J) shows the various bus-bar arrangements and Fig. 6 (K) shows the graphic symbols for various equipment. An important factor in selection of bus-bar scheme is the degree of reliability of supply expected during maintenance or faults. Careful consideration has also to be given regarding the amount of redundancy to be provided so as to determine the equipment, which can be permitted out of use on account of maintenance or faults. Certain amount of sectionalisation has also to be provided in a substation so as to ensure that in the event of a fault, a large power source does not get disconnected. In the case of step-up substations associated with large generating stations a fault within the substation may have serious repercussions from the point of view of the system operating as a whole and, therefore, a very high degree of reliability is required in such cases as compared to step down or switching stations. Similarly, the exposure of a substation to atmospheric hazards such as lightning, marine and industrial pollution etc., also plays an important part in deciding the type of the bus-bar system. Future expansion of the bus-bar system at least in a foreseable future may also be considered.

4.3 Single Bus-Bar Scheme

4.3.1 This is the simplest scheme, in which each circuit is provided with one circuit breaker (Fig. 6 (A)). This arrangement offers little security against bus bar isolator maintenance. The entire substation is lost in case of a fault on the bus bar or any bus-bar isolator and also in case of maintenance thereof. Another disadvantage is that in case of maintenance of circuit breaker associated feeder has also to be shutdown. One of the methods for reducing the number of circuits lost in case of a bus fault is to sectionalise the bus as shown in Fig. 6 (B).

4.3.2 The arrangement in Fig. 6 (C) is a improvement over that shown in Fig. 6 (B), as additional by-pass isolators are provided to permit feeder circuit breakers to be taken out for maintenance without switching out the associated feeder. On occurrence of a fault on the feeder connected to bus bar through by-pass isolator, the other feeder on that bus section will also be lost.

4.4 MAIN AND TRANSFER BUS ARRANGEMENT (Fig. 6 (D))

This is technically a single bus bar arrangement with an additional bus bar called "Transfer bus" energised from main bus bars through a bus coupler circuit, i.e., for 'n' number of circuits it employs n+1 circuit breakers. The additional provision of transfer bays and bus coupler circuit facilitates taking out one circuit breaker at a time for routine overhaul and maintenance without de-energising the circuit controlled by that breaker as that circuit then gets energised through bus coupler breaker and transfer bus bar. Each circuit is connected to the main bus-bar through a circuit breaker with isolators on both side and through an isolator to the transfer bus-bar.

As in the case of single bus arrangement, this scheme also suffers from the disadvantage that in the event of a fault on the main bus bar or the associated isolator, there is a complete shutdown of the substation. Complete shut down can be avoided through sectionalizing the main bus with the provision of additional one single phase bus PT for synchronization in case of more than eight bays. This scheme has been used in India, USA and also in some of the European countries, particularly for step-down substations, as bus-bar faults are rare.

4.5 DOUBLE BUS-BAR SCHEME

4.5.1 In this scheme a double bus bar is provided and each circuit can be connected to either one of these bus-bar isolators as shown in Fig. 6 (E). Bus coupler breaker is also provided so that the circuits can be switched on from one bus to the other on-load. The scheme suffers from the disadvantage that when the circuit breaker is taken out for maintenance, the associated feeder has to be shutdown. This can be avoided by providing, a by-pass isolator across circuit breaker as shown in Fig. 6 (E). But under this condition all the circuits have to be transferred to one bus and protection of feeder has to be transferred to bus coupler. This scheme has the limitation that only one bus is available when any breaker has to be taken out for maintenance. The double bus-bar scheme with by-pass is available when any breaker has to be taken out of maintenance. The double bus-bar scheme with by-pass isolator across circuit breakers is very suitable for large generating stations as well as large grid substations forming part of a well interconnected system wherein a variety of grouping of circuits is required, Fig. 6 (F) shows another alternative of this scheme. In this alternative the by-pass isolators are connected to one of the main bus bars as shown. This scheme constitutes double bus-bar Scheme with main reserve and transfer bus-bars.

In both these schemes, use of temporary earthing device is called for during breaker maintenance. As temporary earthing drives can result in serious accidents, if not removed, it is preferable to provide the isolators on either sides of the circuit breakers across which bypass isolators are provided with integral earthing switches having mechanical interlocking features.

4.6 DOUBLE MAIN AND TRANSFER BUS-BAR SCHEME

The limitation of scheme Fig. 6 (F) can be overcome by using additional transfer bus, transfer bus breaker and isolators as shown in Fig. 6 (G). In this arrangement, the feeder, the breaker of which is to be maintained is transferred to the transfer bus without affecting the other circuits. This scheme has been widely used for the highly interconnected power networks where switching flexibility is important and multiple supply routes are available. This scheme is also used for splitting networks, which are only connected in emergencies.

4.7 MESH BUS-BAR SCHEME (Fig. 6 (H))

4.7.1 Each circuit is controlled by two circuit breakers and therefore, any one circuit breaker can be taken out for maintenance without affecting the security of supply. A circuit fault also is cleared by opening of two breakers. In both cases the ring is broken and the bus-bar is reduced to sectionalised single bus-bar scheme. In the case of a feeder fault, the circuit isolator can be opened, the faulty feeder disconnected and both the breakers closed which would close the ring. This system has got a number of advantages such as maintenance of a circuit breaker without loss of supply and without providing by-pass facilities, loss of only the faulty feeder in case of a feeder fault, and loss of only two circuits in case of a circuit breaker fault. There are, however, some problems such as occurrence of a fault when a circuit breaker is being maintained resulting in a double break in the mesh and capacity limitation of the equipment to pass the maximum current that may flow round the mesh. If these are provided for, it adds to cost of the station. In view of these problems, it is considered desirable to limit the number of circuits on the mesh.

4.7.2 The mesh scheme is very suitable where the number of circuits is comparatively small and chances of future expansion are less such as substations associated with generating plants and also step-down substations operating at extra high voltages. This scheme has been used on many of our early installations. However, during the recent past there have not been many installations of this type as this scheme does not lend itself easily to further expansion. However, the mesh arrangement has been widely used in UK for their 275 kV and 400 kV substations and also in USA for their high voltage installations operating at 230 kV and above.

4.8 ONE-AND-HALF BREAKER SCHEME (FIG. 6 (I & J))

4.8.1 In this scheme three circuit breakers are used for controlling two circuits as shown in Fig. 6 (I & J). Normally, both the bus-bars are in service.

A fault on any bus is cleared by the opening of the associated circuit breakers without affecting continuity for supply. Similarly, any circuit breaker can be taken out for maintenance without causing interruption. All load transfer is done by the breakers and therefore, the operation is simple. However relaying is somewhat more involved as the third breaker has to be responsive to troubles on either feeder in the correct sequence. Besides, each breaker has to be suitable for carrying the currents of two circuits to meet the requirements of various switching operations, which may in some cases increase the cost. The breaker and a half scheme is suitable for those substations which handle large amounts of power on each circuit. The scheme has been widely used in USA particularly for their EHV substations operating at 330 kV and above. This scheme has been applied widely in the 420 kV systems in this country also.

4.9 DOUBLE-BUS AND DOUBLE-BREAKER SCHEME

In this scheme two circuit breakers are used for controlling one circuit as shown in Fig. 6 (K). Normally both bus-bars are in service. Similar to breaker and half scheme, a fault on any bus is cleared by opening of the associated circuit breakers without affecting continuity of supply. Similarly any circuit breaker can be taken out of maintenance without causing interruption. All load transfer is done by breaker and therefore, the operation is simple and relaying is also simpler compared to breaker and half scheme. Because of increase in number of breakers per bay and higher cost, double bus double breaker scheme is suitable for those substations, which handle large amount of power.

Chapter 5

SAFETY CLEARANCES

5.1 OVER-VOLTAGE AND INSULATION LEVEL

5.1.1 All equipment installed in a substation are designed to take into account of the rated power frequency voltage of network; temporary over voltages at power frequency caused by e.g. sudden loss of load and / or earth faults; switching over voltages and lightning over voltages. Accordingly equipment is subject to following voltage tests.

(a) Lightning impulse withstand voltage (1.2/50 micro sec.)

(b) Switching impulse withstand voltage (250/2500 micro sec.)

(c) Short duration power frequency withstand voltage (50 Hz) (wet and / or dry)

(d) Combined voltage test

Additionally an oscillating voltage or chopped wave test may be required.

5.1.2 The set of test voltage values determines the insulation level. Standard insulating levels are defined in IEC: 60071-1, -2 or relevant IS. For equipment voltage upto 245 kV, IEC60071-1 specifies standard rated short duration power frequency and lightning impulse withstand voltages. For equipment voltage beyond 245 kV, IEC60071-1 specifies standard rated switching and lightning impulse withstand voltages. The necessary insulation level depends on the insulation co-ordination, i.e., on the properties of different components of the network (mainly lines), the protection used against overvoltages (ZnO surge arrester are very effective), on altitude and also on the required reliability of the substation (permissible probability of flashover) and may vary in different parts of the same substation.

5.1.3 All EHV apparatus are generally protected against lightning as well as switching over voltage. The equipment used for protection are coordinated with protected apparatus to ensure safe operation as well as to maintain the stability of the interconnected units of the power system.

5.2 SOME DEFINITIONS

5.2.1 Insulation Co-ordination

The selection of the dielectric strength of equipment in relation to the voltages which can appear on the system for which the equipment is intended and taking into account the service environment and the characteristic of the available protective devices.

Note : "Dielectric strength" of the equipment, is meant here its rated or its standard insulation level

The primary objectives of insulation co-ordination are :

- To establish the maximum steady state, temporary and transient over-voltage levels to which the various components of a system may be subjected in practice.
- To select the insulation strength and characteristics of equipment, including those for protective devices, used in order to ensure a safe, economic and reliable installation in the event of the above over-voltages.

5.2.2 Rated Insulation Level

A set of standard withstand voltages which characterize the electric strength of the insulation.

The selection of the rated insulation level consists of the selection of the most economical set of standard withstand voltages (U_w) of the insulation sufficient to prove that all the required withstand voltages are met.

5.2.3 Standard Insulation Level

A rated insulation level, the standard withstand voltages which are associated to highest voltage (U_m) as recommended in IEC.

5.2.4 "Installation" means any composite electrical unit used for the purpose of generating, transforming, transmitting, converting, distribution or utilizing energy.

5.2.5 Safety Clearance

Minimum clearance from any point on or about the permanent equipment where a man may be required to stand (measured from position of the feet) to the nearest unscreened live conductor in air.

5.2.6 "Earthed" or "Connected with Earth": means connected with the general mass of earth in such manner as to ensure at all times an immediate discharge of energy without danger.

5.2.7 "Earthing system" means an electrical system in which all the conductors are earthed.

5.3 ELECTRICAL CLEARANCE

5.3.1 As per Indian Electricity Rules, all electric supply lines and apparatus shall be of sufficient rating for power, insulation and estimated fault current and of sufficient mechanical strength, for the duty which they may be required to perform under the environmental conditions of installation and shall be constructed, installed, protected, worked and maintained in such manner as to ensure safety of human being, animal and property.

5.3.2 It is not possible to test the whole HV installation by corresponding test voltages. Steps are to be taken to avoid flashover occurring below the impulse withstand level. Therefore minimum clearance in air between live parts or between live and dead parts are stated, to obtain the required insulation level in arrangements which have not been tested. Smaller clearances are permissible if the particular arrangement has been tested by the prescribed insulation test (IEC:60071-1, -2) taking into account all relevant environmental condition e.g. rain, pollution. The specified electrical clearance must be maintained under all normal conditions.

5.3.3 The clearances may also be lower, where it has been confirmed by operating experience that the over voltages are lower than those expected in the selection of the standard withstand voltages or that the gap configuration is more favourable than that assumed for the recommended clearances.

5.3.4 The various equipments and other facilities discussed in Chapters 2, 3 and 4 have to be so arranged within the substation that certain minimum clearances are always available from the point of view of the system reliability and safety of operating personnel.

The following parameters are usually defined:

(a) Minimum height of live parts above the accessible surface.

(b) Minimum height of lowest parts of insulators above the accessible surface.

(c) Minimum horizontal distance between a live part and protective rails, fences, etc.

(d) Minimum distance between a live part and human body (or conductive tools) during the work in the substation.

5.3.5 Clearances as per Indian Standard Code are provided for electrical apparatus so that sufficient space is available for easy operation and maintenance without any hazard to operating and maintenance personnel working near the equipment and for ensuring adequate ventilation. These include the minimum clearances from live parts to earth, between live parts of adjacent phases and sectional clearances between live parts and work section required for maintenances of an equipment. Besides, it is also necessary that sufficient clearance to ground is also available within the substation so as to ensure safety of the personnel moving about within the switchyard.

5.3.6 The minimum air clearance to ground and between phases are function of switching, lightning impulse withstand voltage, environmental condition and gap factor which depends on electrode configuration. For voltage upto 245 kV, usually lightning over voltages are considered the governing factor whereas for 420 kV and higher voltage switching over voltage are considered the governing factor.

5.3.7 For determination of phase-to-ground air clearance, the **"rod-structure"** configuration is the worst electrode configuration normally encountered in practice; the **"conductor-structure"** configuration covers a large range of normally used configuration. But the necessary inter-phase clearance is more related to the **"rod-conductor"** and **"conductor- conductor"** configuration. The unsymmetrical **"rod-conductor"** configuration is the worst electrode configuration normally encountered in service. The **"conductor-conductor"** configuration covers all symmetrical configurations with similar electrode shapes on the two phases.

5.3.8 For voltage upto 245 kV, the air clearance phase-to-earth and phase-to-phase is determined from for the rated lightning impulse withstand voltage. For voltage greater than 245 kV, the phase-to-earth clearances is the higher value of the clearances determined for the rod-structure configuration for the standard lightning impulse and for the standard switching impulse withstand voltages. The phase-to-phase clearance is the higher value of the clearance determined for the rod-structure configuration for the standard lightning impulse and for the standard switching impulse withstand voltage.

5.3.9 Table 5.1 gives the recommended values of clearance required for substation up to 800 kV.

Table 5.1 : Recommended Clearances

Highest system voltage (kV)	Lightning impulse voltage (kVp)	Switching impulse voltage (kVp)	Minimum clearances $		Safety clearances (mm)
			Between Phase and Earth(mm)	Between Phases (mm)	
36	170	-	320	320	2800
72.5	325	-	630	630	3100
123	450 550	-	900 1100	900 1100	3400 3700
145	550 650	-	1100 1300	1100 1300	3700 3800
245	950 1050	-	1900 2100	1900 2100	4300 4600
420	1425	1050 (Ph-E) 1575 (Ph-Ph)	3400* -	- 4200**	6400
800	2100	1550 (Ph-E) 2550 (Ph-Ph)	6400*	9400**	10300

* Based on Rod-structure air gap.

** Based on Rod-Conductor air gap.

$ This value of air clearances are the minimum values dictated by electrical consideration and do not include any addition for construction tolerances, effect of short circuits, wind effects and safety of personnel, etc.

Notes:

- Safety clearances are based on the insulation height of 2.44 m which is the height of lowest point on the insulator where it meets the earthed Metal.
- The distances indicated above are not applicable to equipment which has been subjected to impulse test since mandatory clearances might hamper the design of the equipment, increase its cost.
- The values in Table refer to an attitude not exceeding 1000 m and take into account the most unfavourable conditions which may result from the atmospheric pressure variation, temperature and moisture. A correction factor of 1.25% per 100 m is to be applied for increasing the air clearance for altitudes more than 1000 m and upto 3000 m.
- No safety clearance is required between the bus-bar isolator or the bus-bar insulators. However, safety clearance is necessary between the section isolator or the bus-bar itself and the circuit breaker.
- For the purpose of computing the vertical clearance of an overhead strung conductor the maximum sag of any conductor shall be calculated on the basis of the maximum sag in still air and the maximum temperature as specified.

5.3.10 As an alternative to maintain safety clearances in some substation earthed barriers are used to ensure safety of the maintenance personnel. The use of earthed barriers is quite common at lower voltages of 36 kV 72.5 kV. However, as the voltage increases, the saving in space decreases and at 420 kV level, normally earthed barriers are not provided. In case paucity of space if 2.44 m clearance is not available then localized earthed fencing with safety clearance can be considered by the designer.

Chapter 6

GAS-INSULATED SWITCHGEAR

6.1 SF_6 gas-insulated switchgear (GIS) is now widely used for construction of compact substations. Some of the applications for which GIS is eminently suited are listed below:

(i) Installations for which stringent demands regarding security must be met.

(ii) Indoor substations to occupy the minimum space in densely populated urban areas.

(iii) Installations in areas with high risk of pollution and corrosion from industrial plants or by marine and desert climates.

(iv) Extension of conventional outdoor installations where space is at a premium.

(v) Replacement of conventional switchgear by SF_6 metal clad switchgear for a higher system voltage without increasing the space occupied.

(vi) Applications involving use of metal clad switchgear with components of conventional design to minimize area requirement.

(vii) Underground substations for pumped storage and other hydroelectric power stations.

(viii) Outdoor installation where surface is not easily available.

(ix) Installations in difficult site conditions (e.g., seismically active areas, high altitude areas etc.).

6.2 CONSTRUCTIONAL DETAILS

6.2.1 For any single line diagram, there are usually a number of possible physical arrangements. The shape of the site of installation and the nature of interconnections, i.e., lines and/or cables are to be considered. Most GIS designs were developed initially for double bus, single breaker arrangement. This has been widely used and provides good reliability, simplicity in operation, easy protective relaying and excellent economy.

6.2.2 It is found economical to adopt 3-phase enclosure up to 145 kV system voltage. For system voltages above 145 kV, single-phase enclosure designs are preferred. Functionally, the performance does not differ between 3-phase enclosure and single-phase enclosure of GIS but, it could depend on users choices.

6.2.3 The GIS components like circuit breakers, load break switches, earthing switches, isolators, voltage transformers, current transformers, surge arresters and connectors are functionally separate modules of a standardized modular system.

6.2.4 The enclosure of GIS could be made of aluminium alloy or stainless steel. The selection of material largely depends on temperature rise considerations and permissible limits depending on emissivity (solar radiation) and/or temperature rise of conductor).

6.2.5 SF_6 is five times as dense as air. It is used in GIS on pressures from 3.5 - 7 bars absolute. The pressure is so selected that gas will not condense into liquid at the lowest temperature, the equipment could experience. This gas is about 100 times better than air in terms of interrupting arcs.

6.2.6 Cone or disc shaped insulators moulded from high quality resin support to active parts in side the enclosures and serve as barriers between adjacent gas-filled compartments.

6.2.7 Silver-plated plus contacts provide connections between individual components and bolted flanges between the enclosures.

6.2.8 The operating mechanism for circuit breaker could be electro-hydraulically (hydraulic spring drive) operated or spring-spring operated for least maintenance.

6.2.9 The load break switches and high speed earthing switches are operated by motor charged spring mechanism and the safety earthing switches and disconnects are operated by motor operated mechanism.

6.2.10 Manual operation of safety earthing switches is also possible as an alternative to motor operation.

6.2.11 Connectors enable straight line, 90 deg, 120 deg to 180 deg, four way and T-connections between the various elements.

6.2.12 The modules include compensating units to permit lateral mounting, axial compensation, parallel compensation, tolerance compensation, vibration compensation etc. The lateral mounting units enable sections of switchgear to be removed and re-inserted without interfering with adjacent parts. Axial compensators take-up the changes in bus bar length due to temperature variation. Parallel compensators are intended for accommodating large linear expansions and angle tolerances. Tolerance compensators are intended to take up manufacturing and assembly tolerances. Vibration compensators absorb vibrations caused by transformers connected directly to SF_6 switchgear by oil/SF_6 bushings.

6.2.13 Approximate space requirements for double bus lay out with vertical breaker scheme can be estimated approximately by assuming the width (3.0 m x 8.5 m x 8.0 m) leaving 1.5 m along the depth, for panels, 2.0 m for movement on either side along the length of bus bar for 400 kV system

6.2.14 Depending on the bus bar arrangement, the various elements are assembled to constitute various bays in the desired sequence.

6.3 CONTROL CABINETS

6.3.1 The elements for control, indication and alarms are contained in local control cabinets mounted close to bays. The elements normally mounted in the control cabinets consist of the following:

(i) Mimic diagram with control switches for electrically operated breakers, load break switches, disconnects and earthing switches and indicators for all components provided with auxiliary switches.

(ii) Local/Remote Selector Switches.

(iii) Alarm facia with indicating lamps for monitoring operating system, gas density and auxiliary supplies.

(iv) Contactors, timing relays etc.

(v) Terminal blocks.

(vi) Interior lighting, heater, cable glands.

(vii) Lockable bypass switches for defeating the interlocks to facilitate maintenance work.

6.4 INTERLOCKS

6.4.1 GIS control cabinet includes electrical interlocks to prevent incorrect switching sequence and ensure correct operations of isolators, circuit breakers and earthing switches from local control cabinet or from the control room.

6.5 SAFETY LOCKS

6.5.1 Safety locks for locking the disconnects and earthing switches in the positions "Operation" or "Maintenance" are also provided. In the "Maintenance" position these locks interrupt the control circuits of motor drives for disconnects and earhing switches. In the manually operated earthing switches, these locks in the "Operation" position do not permit engagement of manual operating handle with the earthing switches operating shaft.

6.6 SUPPORTING STRUCTURES

6.6.1 Depending on the design of installation, the GIS can be self supporting or erected on steel supporting structures of simple design anchored to the substation floor.

6.7 GROUNDING

The three enclosures of single phase GIS are required to be bonded to each other at the ends of GIS to ensure to flow circulating currents. These circulated enclosures currents cancel the magnetic field that would otherwise exist outside the enclosure out to conductor current. 3-phase enclosures GIS does not have circulating currents but does have eddy currents in the enclosure and should also be multi point grounded. Although multi point grounding leads to some losses in the enclosure due to circulating current multi point grounding results in many parallel path for the current from an internal path to flow to the switchyard ground grid. The recommendations of manufacturers and multi point grounding concept normally ensures touch and step potentials within safe levels prescribed by IEEE 80.

6.8 The GIS should be extendable to meet the requirement of addition of bays in future. The side on which the extension is to be made should be provided with suitable extension bellows/flanges with blanking plates. The building that is to house the GIS should have space provision for future extension.

6.9 GIS TERMINATIONS

GIS terminations could be any of the following:

- SF_6 to air bushings
- SF_6 to cable termination
- SF_6 to oil bushings for direct connection to transformer
- SF_6 bus duct

All termination modules are commonly used to connect the GIS with transformer. Overhead lines could be connected to GIS either though cables or through SF_6 to air bushings. Type of terminations has also bearing on the size of substations. If cable or SF_6 bus ducts are used, substation can be kept quite compact. SF_6 to air bushings, on the other hand, requires minimum clearance in air and thus requires more space and in addition, they are subject to environmental conditions. Especially in cities/ industrial areas where space is both restricted and expensive and the surrounding environment has impact on type of termination, preference should be for cable termination or SF_6 bus duct. Selection of cable termination will have to be judiciously done keeping in view the specific requirement.

Chapter 7

PHYSICAL LAYOUT

7.1 STATION SITE

7.1.1 Site limitation is one of the important considerations in deciding the type of layout of a substation. It should be free from all obstructions from the point of view of convenience of terminating high voltage transmission lines. At the same time it should be accessible to the public road to facilitate transport of plant and equipment. As far as possible, it should be near a town and away from municipal dumping grounds/ areas and also away from police and military rifle ranges. The site should have good drinking water for station staff. Outdoor substation should not be within 3 km from aerodrome or should be as per aviation guidelines.

7.1.2 Type of isolators has great influence in bay width and level of the substation. Using double break type of Isolators compared to Horizontal Centre Break Isolators, bay width can be reduced by 10-15%. Pantograph isolators are best suited for Double Main and Transfer (DMT) scheme (with flexible bus arrangement) but it requires proper and careful erection of isolator and stringing of buses. By using vertical break isolators, the height of levels increases but vertical break isolators are more economical for voltages more than 400 kV due to lesser length of beam, bay width and ultimately lesser requirement of land.

7.1.3 While planning the layout and orientation of an EHV sub station in order to avoid right of way problem in future, approximate provision should be made for installation of towers for incoming/ outgoing lines and this aspect should be considered simultaneously and provision made accordingly in the construction of emanating transmission lines. It is necessary to consider in the layout design, the possibility of extension of substation. The line and transformer bays sequence should, if possible, be fixed minimizing the possibility of overloading bus bars and connecting conductor.

7.2 SELECTION OF LAND

The land for substation should be selected on the basis of size of substation. switchyard layout design depends on switching scheme, shape and size of land. A substation requires land for consist of switchyard, control and administrative building, stores, security barrack, colony, etc. Considering increasing cost of land but keeping provision for future extension, following size of lands are required for a substation

- 400/220/132 kV : 45-60 acres
- 220/132/33 kV : 15-18 acres
- 132/33/11 kV : 8-10 acres
- 33/11 kV : 2-3 acres

7.3 ILLUSTRATIONS

7.3.1 Figure 7 (a) to 34 illustrates some typical layouts of 420, 245, 145, 72.5 and 36 kV substations as mentioned in Table 7.1 including some typical layouts adopted recently commissioned substations. These layouts are being given for general guidance only and are not intended to serve as standard layouts. The various types of layouts included herein are as follows:

Table 7.1 : Various Types of Layouts Generally Adopted

Figure No.	Description			
Figure 1	Typical cable trench section			
Figure 2	Switchyard and substation oil handling system schematic piping diagram			
Figure 3	Typical compressed air system for air blast circuit breaker			
Figure 4A.	Typical 400/220 kV control room (ground floor)			
Figure 4B	Typical 400/220 kV control room (first floor)			
Figure 5	Details of High Velocity Water (HVW) spray system			
Figure 6	Single line diagram for various types of switching schemes			
Figure No.	**Voltage kV**	**Bus system**	**Bay width (typical)**	**Bus level**
Figure 7 (a)	420	Double main and transfer bus (Plan)	27 m	Low
Figure 7 (b)	420	Double main and transfer bus (Section)	27 m	Low
Figure 8(a)	420	Breaker and half, D-type arrangement (Plan)	27 m	Low
Figure 8(b)	420	Breaker and half, D-type arrangement (Section)	27 m	Low
Figure 8(c)	420	Breaker and half, D-type arrangement (SLD)	27 m	Low
Figure 8(d)	420	Breaker and half with 1-Ph Transformer with auxiliary bus arrangement	27 m	Low
Figure 8(d), Sheet 1 of 6	420	Single line diagram	27 m	Low
Figure 8(d) , Sheet 2of 6	420	Plan	27 m	Low
Figure 8(d) , Sheet 3 &4 of 6	420	Sections	27 m	Low
Figure 8(d) , Sheet 5 of 6	420	Plan of transformer area	27 m	Low
Figure 8(d) , Sheet 6 of 6	420	Section of transformer area	27 m	Low
Figure 8(e)	420	Breaker and half	24 m	Low
Figure 9A	245	Double main and transfer	15 m	Low
Figure 9B	245	Main and transfer with provision for conversion to double main and transfer	15 m	Low
Figure 9C	245	Double main and transfer	16 m	Low
Figure 10A	245	Double bus	15 m	Low
Figure 10A , Sheet 1 of 2	245	Single line diagram and plan	15 m	Low
Figure 10A, Sheet 2 of 2	245	Sections	15 m	Low
Figure 10B	245	Double bus	16 m	High
Figure 10C	245	Double bus	17 m	High

Figure 11	245	Double bus	17 m	Low
Figure 12 A	245	Double bus GIS	NA	-
Figure 12 B	245	Double bus GIS	NA	-
Figure 13	245	Main transfer	17 m	High
Figure 14	245	Main and transfer	17 m	Low
Figure 15	245	Single bus	17 m	High
Figure 16	245	Single bus	17 m	Low
Figure 17	145	Double bus	10.4 m	High
Figure 18	145	Double bus	10.4 m	Low
Figure 19	145	Main and transfer	10.4 m	High
Figure 19A	145	Main and transfer	12 m	Low
Figure 19A, Sheet 1 of 4	145	Single line diagram	12 m	Low
Figure 19A, Sheet 2 of 4	145	Plan	12 m	Low
Figure 19A, Sheet 3&4 of 4	145	Sections	12 m	Low
Figure 20	145	Main and transfer	10.4 m	Low
Figure 20A	145	Main and transfer	10.5 m	Low
Figure 21	145	Single bus	10.4 m	High
Figure 22	145	Single bus	10.4 m	Low
Figure 23	72.5	Double bus	7.6 m	High
Figure 24	72.5	Double bus	7.6 m	Low
Figure 24A	72.5	Double bus	7.6 m	Low
Figure 25	72.5	Main and transfer	7.6 m	High
Figure 26	72.5	Main and transfer	7.6 m	Low
Figure 27	72.5	Single bus	7.8 m	High
Figure 28	72.5	Single bus	7.6 m	Low
Figure 29	36	Double bus	5.5 m	High
Figure 30	36	Double bus	5.5 m	Low
Figure 31	36	Main and transfer	5.5 m	High
Figure 32	36	Main and transfer	5.5 m	Low
Figure 33	36	Single bus	5.5 m	High
Figure 34	36	Single bus	5.5 m	Low

Note : Layouts shown in this Manual are the ones generally adopted by the utilities

7.4 It is recommended that based on the equipment selected, the basic data included in this manual and the operating experience, the layouts may be standardized so that a uniform design is obtained which would reduce the cost as well as construction period.

7.5 LAYOUT OF CONTROL ROOM BUILDING

The size of the control room building is dependant on the number of rooms, equipments in the room and varies from utility to utility. Typical sizes for different rooms of the control room building for a 400/220 kV substation with conventional control and relay panels having the following number of bays is given in Table 7.2.

400 kV system – One and half breaker bus scheme having 8 nos. diameters to accommodate 12 nos. line feeders, 2 nos. 400/220 kV transformers, 2 nos. bus reactors.

220 kV system – Double main and transfer bus scheme to accommodate 7 nos. line feeders, 2 nos. 400/220 kV transfotmers, 1 nos. bus transfer and 1 nos. bus coupler bay.

Table 7.2 : Typical Sizes of the Different Rooms in Control Room Building

Sl. No.	Control room	Approximate size (length x breadth)
1.	Control Room	15 m x 10 m
2.	Relay and PLCC Room	20 m x 15 m
3.	MCC Room (Main Switchboard, ACDB, DCDB, Battery Charger)	15 m x 14 m
4.	Battery Room (Accommodation of 2 nos. 220 V & 2 nos. 50V Battery Bank in Single Row Single Tier Arrangement)	15 m x 8 m
5.	Communication Room	15 m x 7 m
6.	Shift-in-Charge's Room	5 m x 4 m
7.	Engineer's Room	7 m x 5 m
8.	Conference Room	7 m x 5 m
9.	Maintenance Room	6 m x 5 m
10.	Library cum Record Room	6 m x 5 m
11.	Electronics Test Lab	9 m x 5 m
12.	Maintenance Staff Room	6 m x 5 m
13.	Toilets	As per requirement
14.	Pantry	As per requirement

For an automated substation, relays and PLCC equipments may be accommodated in a weather proof bay controller unit located in the outdoor switchyard. Hence Relay, PLCC room and communication room are not required and size of control room can be reduced as the control room for such type of application should be suitable for accommodation of Computer peripherals and communication equipment.

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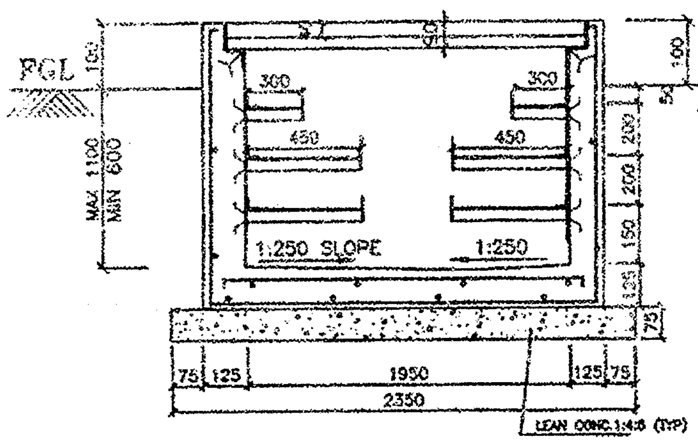

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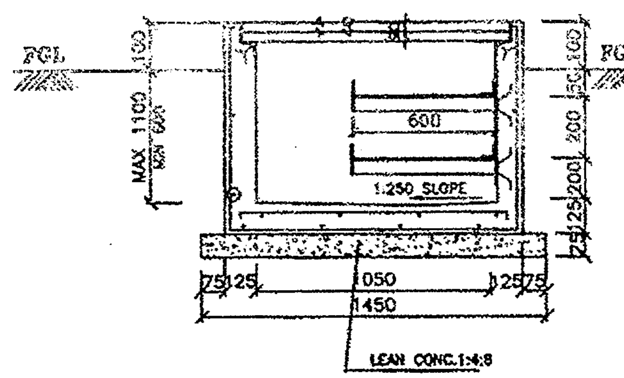

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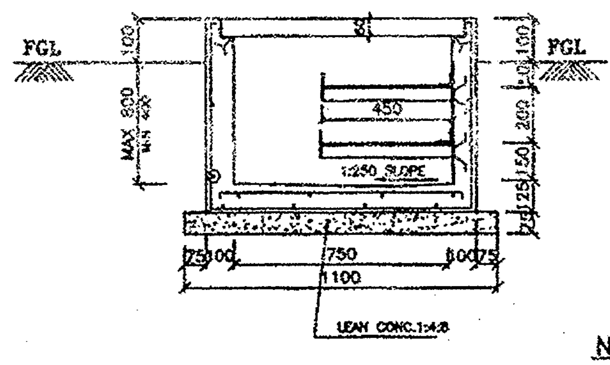

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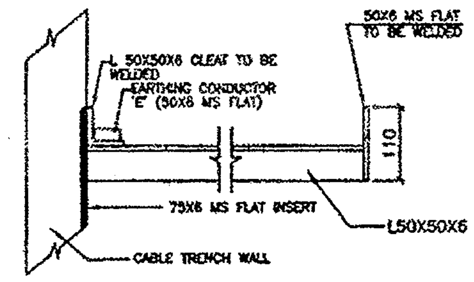
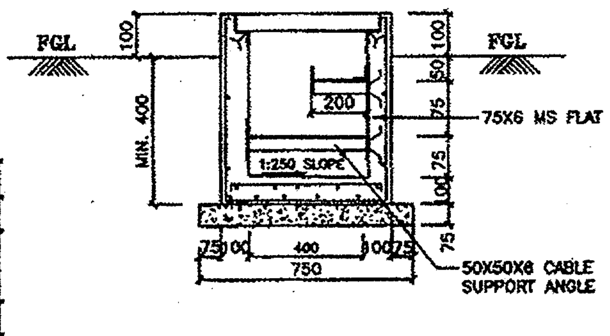


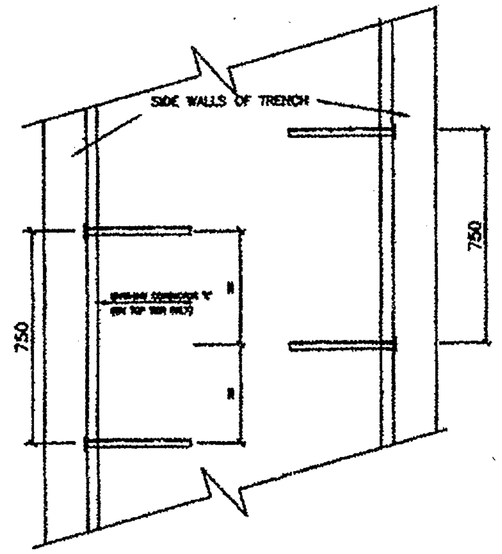
TYP. CABLE SUPPORT



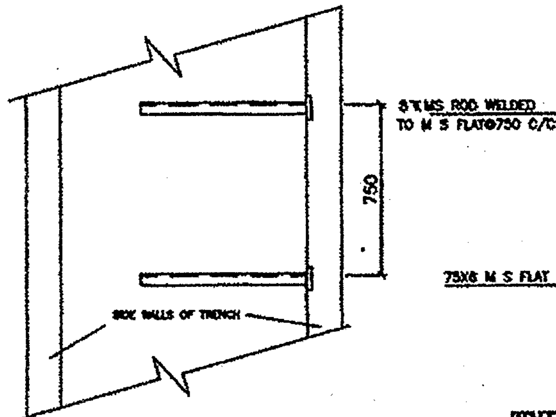
SECTION 4-4

NOTE

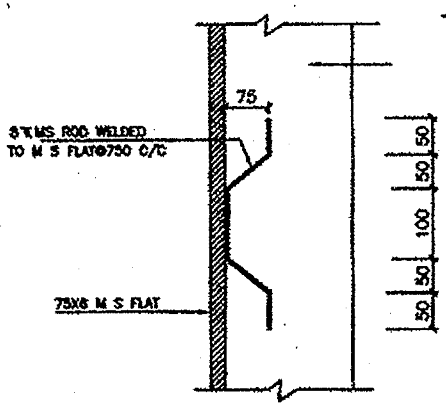
1. ALL DIMENSIONS ARE IN MM UNLESS OTHERWISE SPECIFIED.
2. DO NOT SCALE THE DRG. FOLLOW WRITTEN DIMENSIONS ONLY.
3. R.C.C MIX. SHOULD BE M20 GRADE.
4. LEAN CONCRETE SHALL BE 1:4:8.
5. CLEAR COVER FOR BOTTOM SLAB REINF. ON TOP SIDE IS 25MM.
6. LIFTING HOOK ARE TO BE PROVIDED IN EVERY TENTH SLAB.
7. NECESSARY OPENING SHALL BE PROVIDED AT APPROPRIATE LOCATIOPN TO TAKE OUT CABLES.
8. FOR ACTUAL DEPTH OF TRENCHES REFER CABLE TRENCH LAYOUT.
9. F.G.L DENOTES FINISHED GRADED LEVEL (FORMATION LEVEL).
10. F.G.L TO BE TAKEN FROM LAYOUT DRG.
11. A SLOPE OF 1:250 SHALL BE GIVEN IN THE DIRECTION PERPENDICULAR TO THE RUN OF THE TRENCH FOR ALL SECTIONS.
12. ALL CABLE TRENCHES SHALL BE GIVEN A SLOPE OF 1:500 IN THE DIRECTION OF MAIN RUN.
13. EARTHING CONDUCTOR 'E' 50X6 MS FLAT WOULD BE WELDED ON THE CABLE SUPPORTING STRUCTURES BEFORE INSTALLATION OF CABLES.
14. ALL STEEL STRUCTURE PLATES WOULD BE PAINTED WITH NON CORROSIVE PAINT ON A SUITABLE PRIMER BEFORE INSTALLATION OF CABLES EARTHING CONDUCTORS WOULD HAVE RED PAINT.
15. TRENCH WALL SHALL CLEAR THE EQUIPMENT FOUNDATION BY 100 MM.
16. NECESSARY CONSTRUCTION JOINTSHALL BE PROVIDED AT EVERY 30M (MIN.) OR AS PER SITE CONDITION.
17. 40 MM CLEAR COVER FOR WALL AND BOTTOM SLAB REINFORCEMENT WHICH IS TOWARDS EARTH SIDE SHALL BE PROVIDED.
18. ALL SUPPORT ANGLE SHALL BE L50X50X6.
19. ANCHORING FLAT (75X6 MM) SHALL BE PROVIDED AT EACH SUPPORT ANGLE POINT.
20. EARTHING CONDUCTOR MKD 'E' SHALL BE PROVIDED ON THE TOP TIER OF EACH CABLE TRENCH SECTIONS.



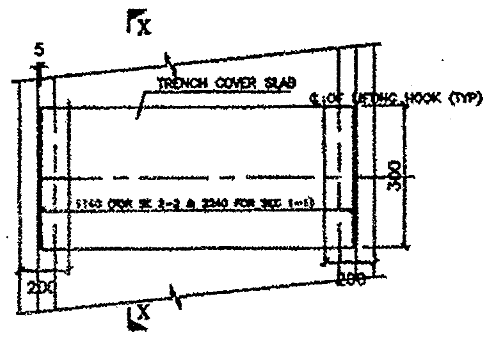
PLAN
CABLE TRAY SUPPORT FOR SECTION 1-1



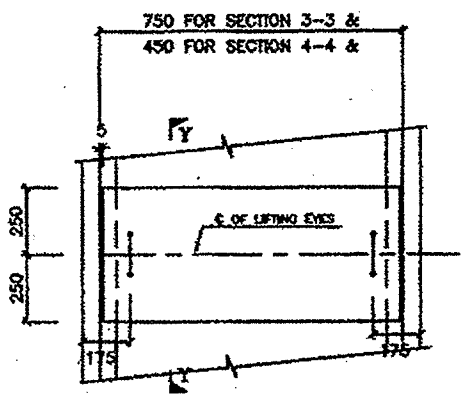
PLAN
CABLE TRAY SUPPORT FOR SECTION 2-2 & 3-3



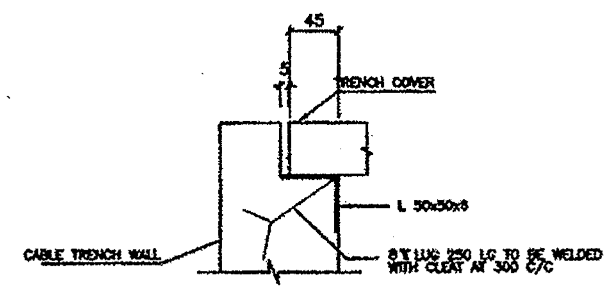
TYP DETAIL OF ANCHORING
75X6 M S FLAT



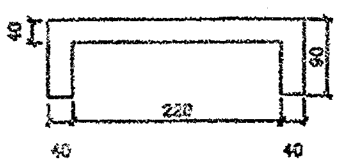
DETAIL OF TRENCH COVER SLAB
FOR SECTION (1-1) & (2-2)



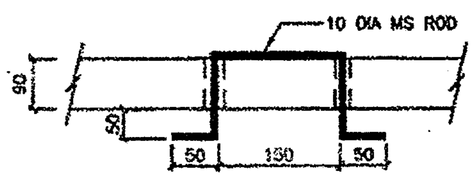
DETAIL OF TRENCH COVER
FOR SECTION 3-3 & 4-4



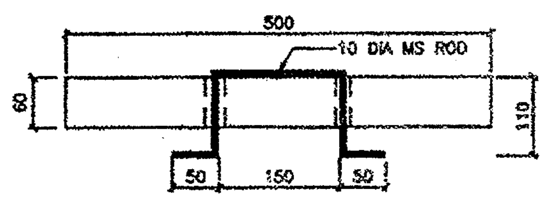
TYP. DETAIL OF SLAB SUPPORT



SECTION X-X



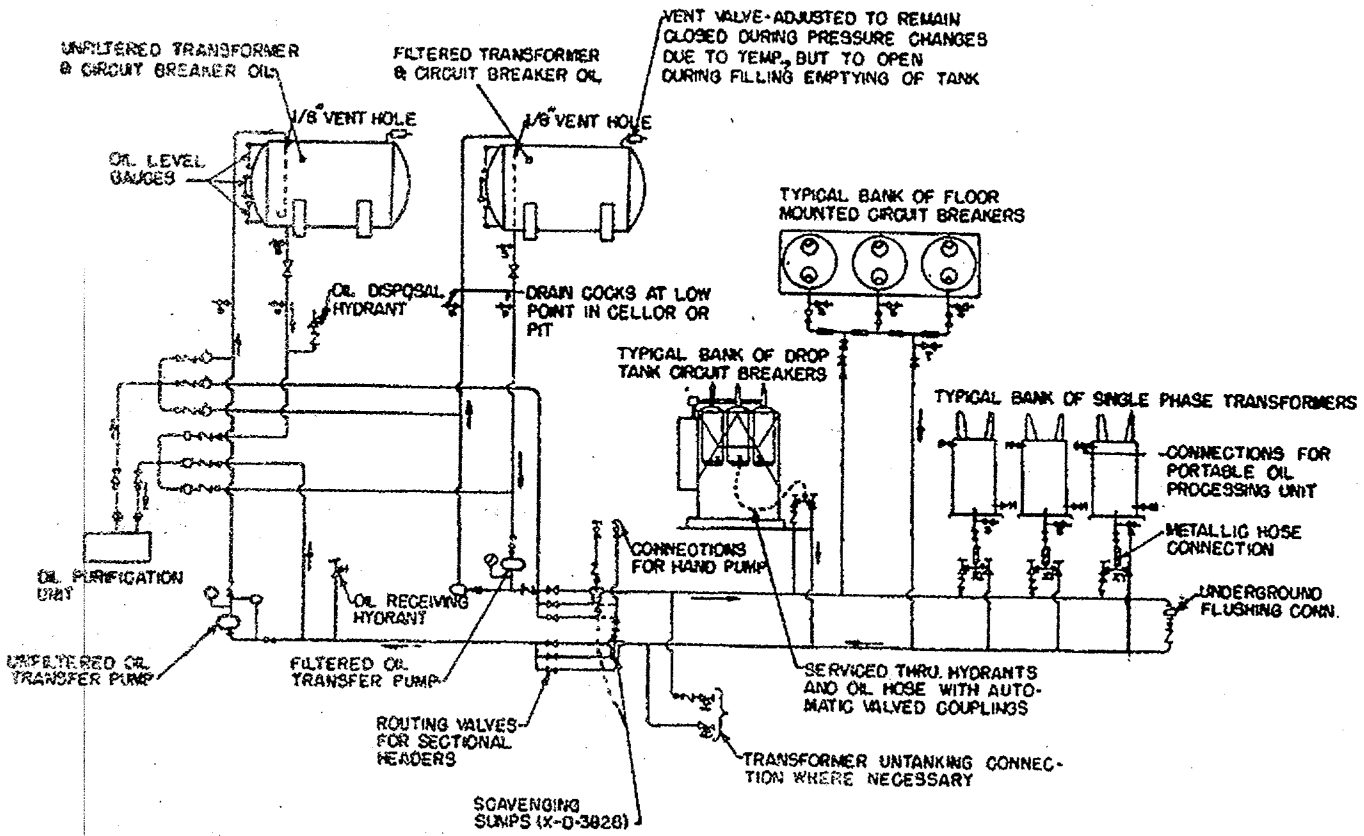
DETAIL OF LIFTING HOOK
FOR SECTION 1-1 & 2-2



SECTION Y-Y

FIGURE-1

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
TYPICAL CABLE TRENCH SECTIONS		
	SHEET 1 OF 1	SCALE: NTS



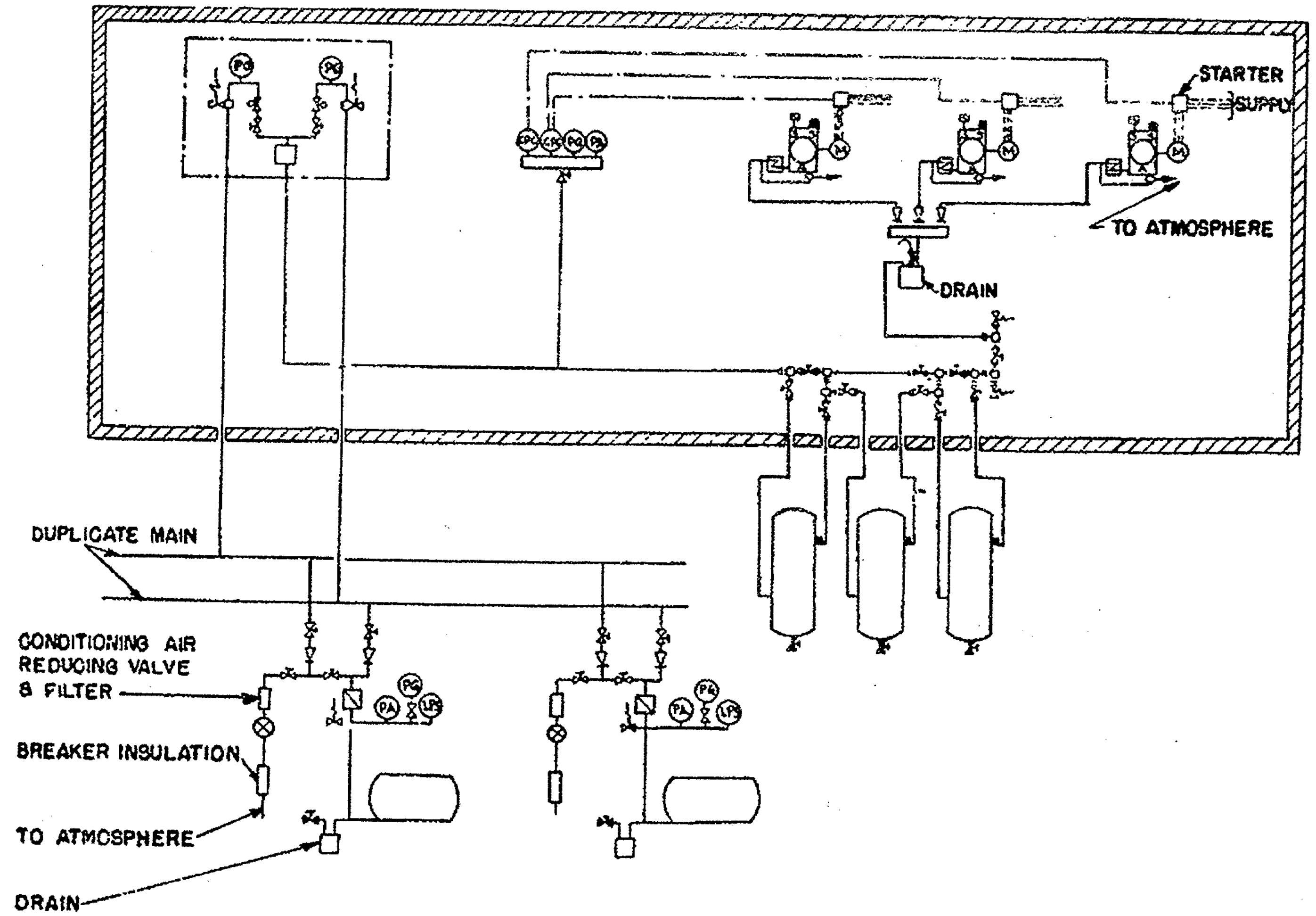
EXPLANATION

- GATE VALVE
- CHECK VALVE
- SAMPLING COCK
- DRAIN VALVE
- FLEXIBLE METALLIC HOSE (X-D-3825)
- HOSE COUPLING AND CAP
- PRESSURE RELIEF VALVE
- ROTARY PUMP
- UNION
- PLUG COCK
- TELLTALE
- ANGLE GLOBE VALVE

SUB-STATION MANUAL

SWITCH YARD & SUB-STATION
OIL HANDLING SYSTEM
SCHEMATIC PIPING DIAGRAM

FIGURE-2



LEGEND

- 3-STAGE AIR COOLED RECIPROCATING COMPRESSOR
- MOTOR
- AIR FILTER
- FUSIBLE PLUG
- AFTER COOLER
- UNLOADER, (PART OF COMPRESSOR)
- COMPRESSOR PRESSURE CONTROL
- PRESSURE ALARM
- LOW PRESSURE SWITCH
- PRESSURE GAUGE
- RELIEF VALVE
- PRESSURE REDUCING VALVE
- NON RETURN VALVE
- STOP VALVE NORMALLY OPEN (WHEEL OPERATED)
- STOP VALVE, NORMALLY CLOSED
- FLOW INDICATOR
- AIR-PIPE CONNECTION
- ELECTRICAL CONNECTION
- MANIFOLD

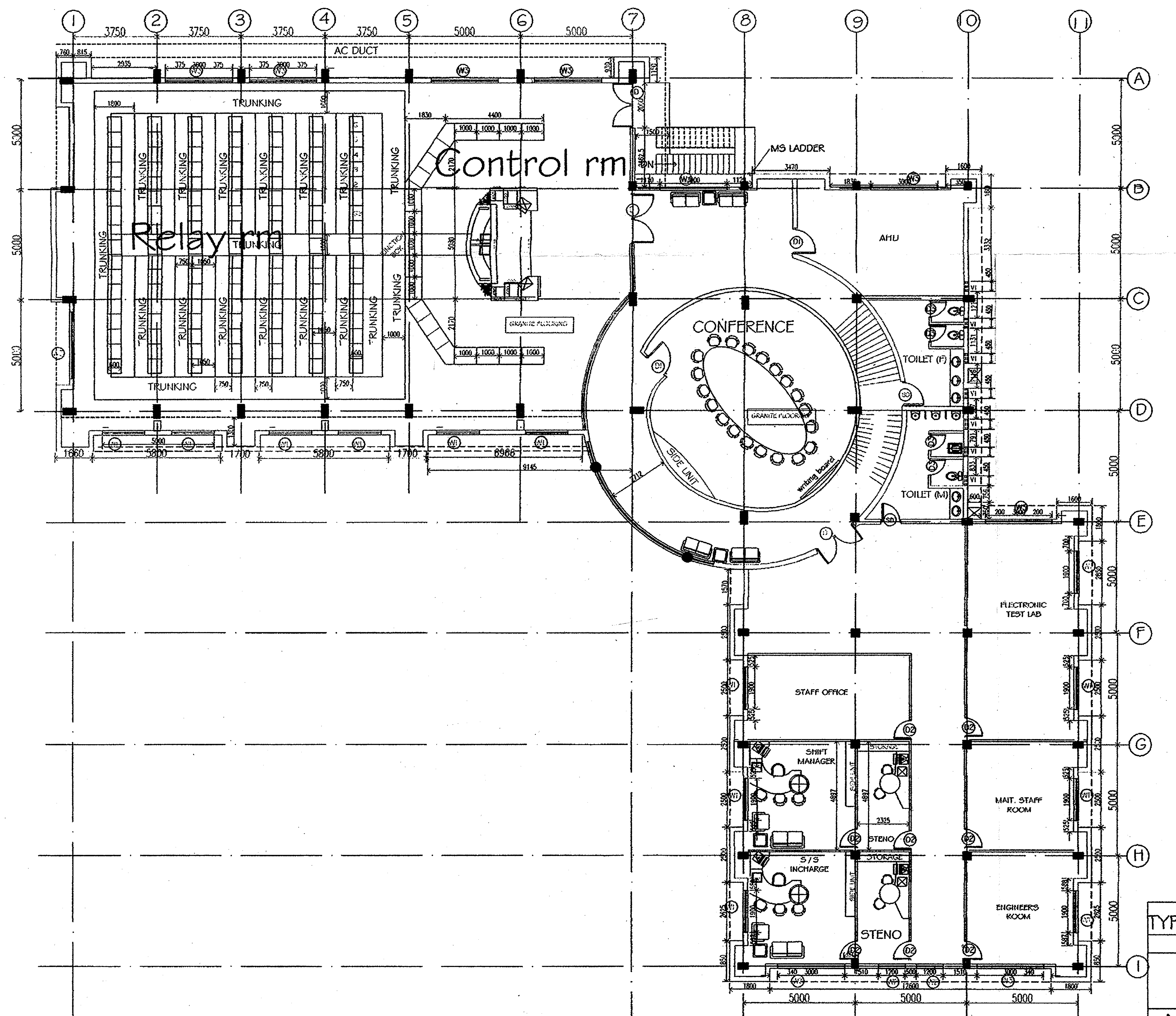
SUB-STATION MANUAL

TYPICAL COMPRESSED AIR SYSTEM
FOR AIR BLAST CIRCUIT BREAKERS

FIGURE- 3

SCHEDULE OF OPENINGS

TYPE	SIZE	NOS.	DESCRIPTION
DOORS			
D	2.0M X 2.4M	3	DOOR WITH ALUMINIUM FRAME AND GLAZED DOUBLE SHUTTER.
D1	1.2M X 2.4M	2	DOOR WITH ALUMINIUM FRAME AND GLAZED SHUTTER
D2	0.9M X 2.4M	8	DOOR WITH ALUMINIUM FRAME AND GLAZED SHUTTER
D3	0.8M X 2.4M	4	TEAK WOOD FRAMEWORK WITH FLUSH DOOR OST.
SD	0.9M X 2.4M	2	TEAK WOOD FRAMEWORK WITH FLUSH DOOR OST.
WINDOWS			
W1	1.9M X 1.68M	13	ALUMINIUM GLAZED WINDOW.
W2	1.2M X 1.68M	3	ALUMINIUM GLAZED WINDOW.
W3	3.0M X 1.68M	10	ALUMINIUM GLAZED WINDOW.
VENTILATORS			
V1	0.45M X 0.9M	6	ALUMINIUM GLAZED LOUVERED VENTILATORS.



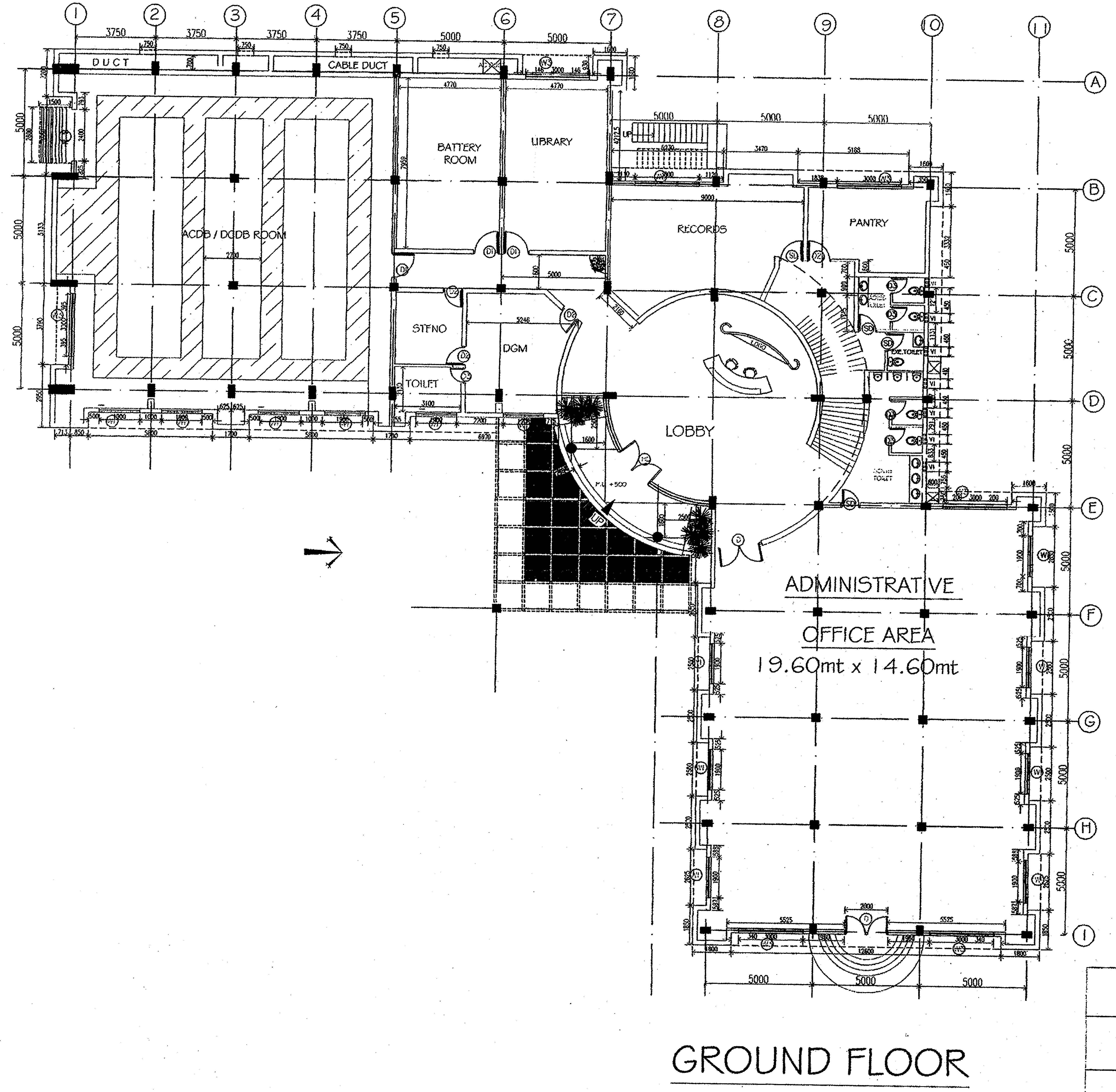
FIRST FLOOR

FIGURE-4B

TYPICAL 400/220KV CONTROL ROOM

FIRST FLOOR

MANUAL ON SUB STATION LAYOUT & DESIGN



SCHEDULE OF OPENINGS

TYPE	SIZE	NOS.	DESCRIPTION
DOORS			
MD	2.2M X 2.4M	1	ALUMINIUM DOOR WITH DORMA BTS80 - UNIVERSAL FLOOR SPRING, DOUBLE DOOR WITH MECHANICAL BACK CHECK, HYDRAULIC HOLD OPEN OR DELAYED ACTION.
D	2.0M X 2.4M	2	DOOR WITH ALUMINIUM FRAME AND GLAZED SHUTTER.
D1	1.2M X 2.4M	3	DOOR WITH ALUMINIUM FRAME AND GLAZED SHUTTER.
D2	0.9M X 2.4M	4	DOOR WITH ALUMINIUM FRAME AND GLAZED SHUTTER.
D3	0.8M X 2.4M	5	TEAK WOOD FRAMEWORK WITH FLUSH DOOR OST.
SD	0.9M X 2.4M	4	TEAK WOOD FRAMEWORK WITH FLUSH DOOR OST.
RS	2.4M X 2.4M	1	MS ROLLING SHUTTERS
WINDOWS			
W1	1.9M X 1.68M	13	ALUMINIUM GLAZED WINDOW.
W3	1.5M X 1.68M	7	ALUMINIUM GLAZED WINDOW.
VENTILATORS			
V1	0.45M X 0.9M	7	ALUMINIUM GLAZED LOUVERED VENTILATORS.

FIGURE 4A

TYPICAL 400/220KV CONTROL ROOM

GROUND FLOOR

MANUAL ON SUB STATION LAYOUT & DESIGN

APPENDIX-III TO TECHNICAL SPECIFICATION FOR FIRE PROTECTION SYSTEM

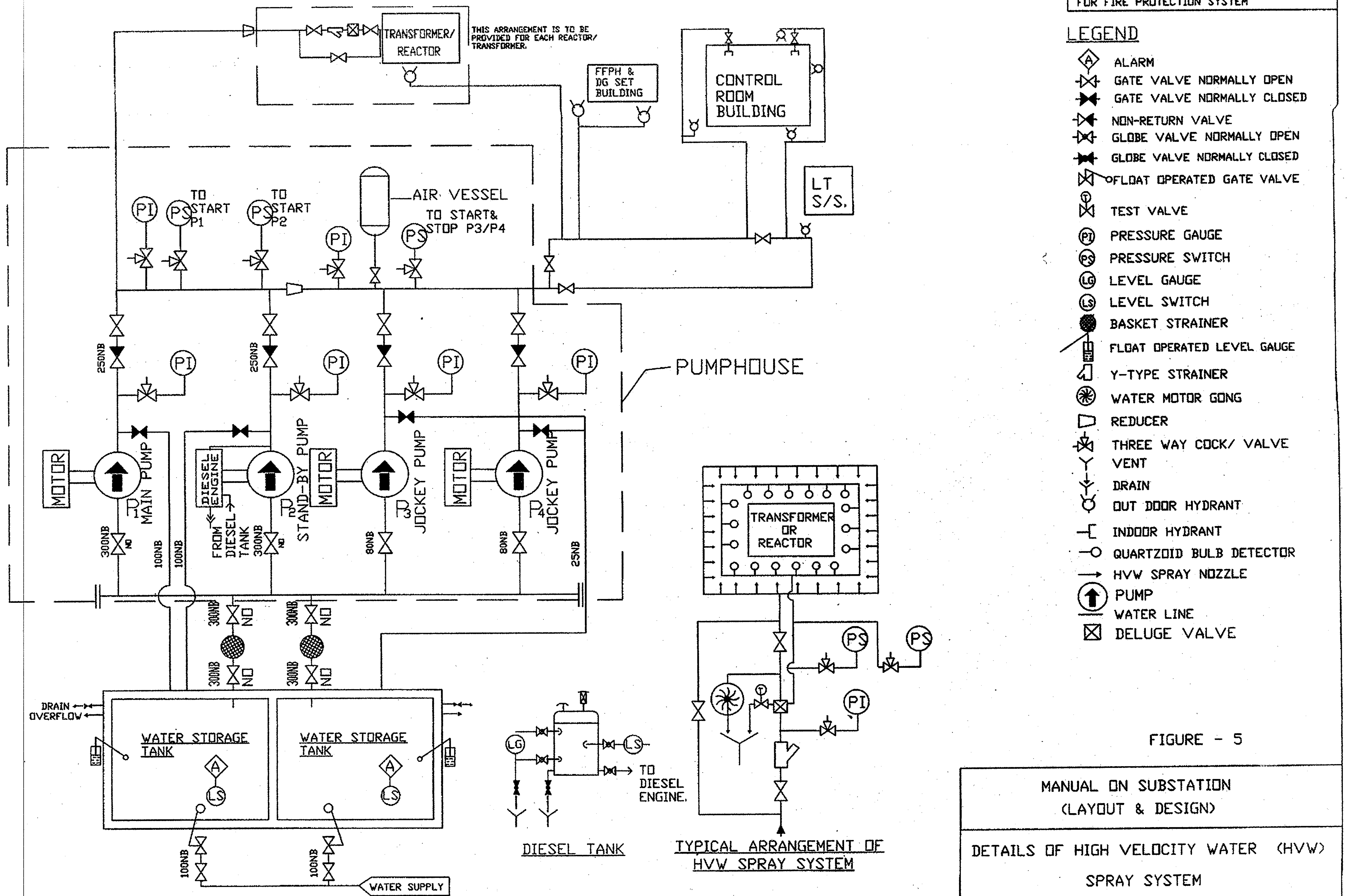
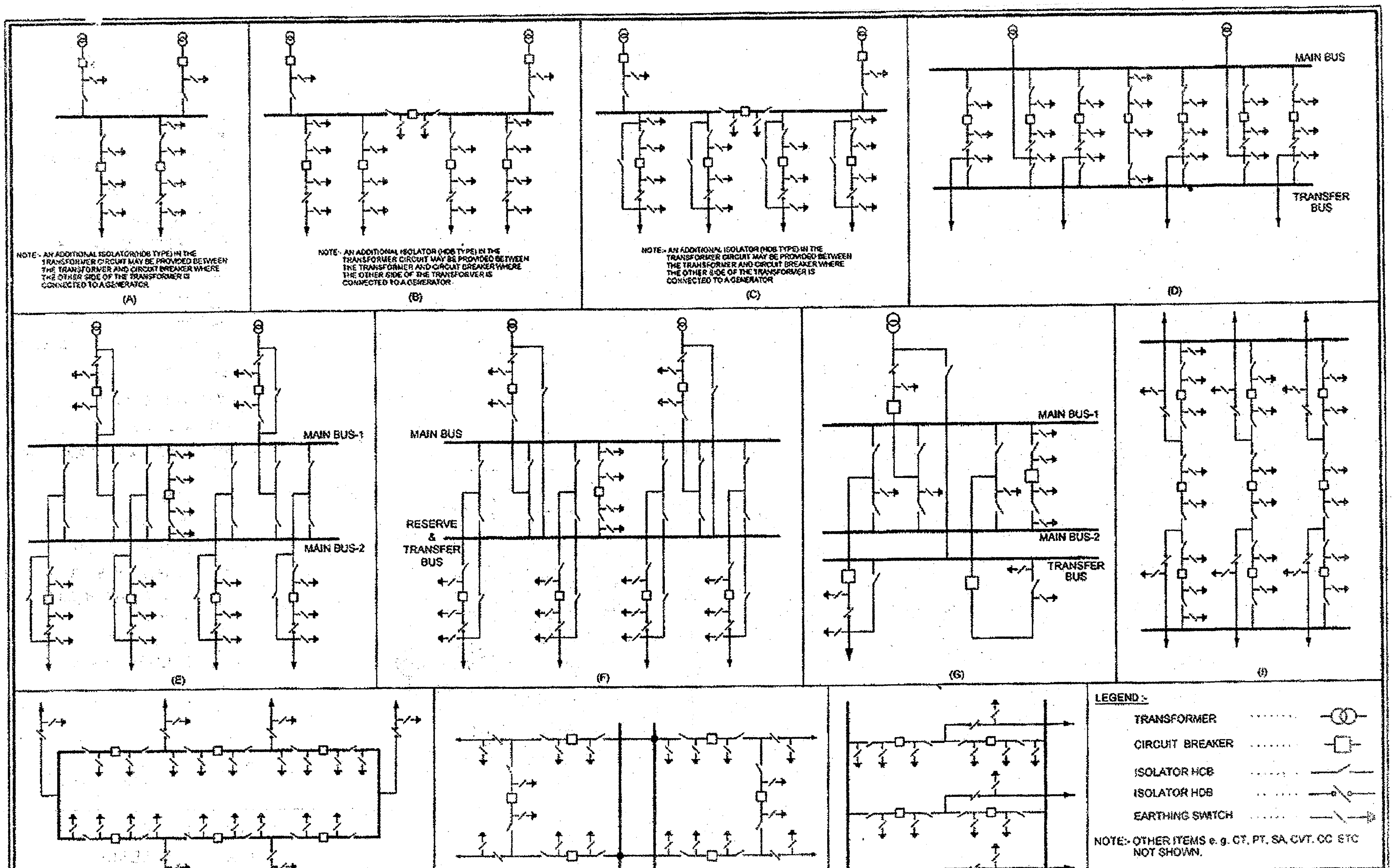


FIGURE - 5

NOTES: 1. THE HYDRANT POINTS FOR TRANSFORMER/ REACTOR SHALL BE LOCATED AT LEAST 20M AWAY FROM THEM.

2. AS SAFETY MEASURE, A WARNING PLATE SHALL BE PLACED NEAR HYDRANT POINTS FOR TRANSFORMER/ REACTOR TO CLEARLY INDICATE THAT WATER SHALL BE SPRAYED ONLY AFTER ENSURING THAT THE POWER TO THE TRANSFORMER/ REACTOR WHICH IS ON FIRE IS SWITCHED OFF AND THERE ARE NO LIVE PART WITHIN 20 M. DISTANCE OF THE PERSONNEL USING THE HYDRANT.

MANUAL ON SUBSTATION (LAYOUT & DESIGN)	
DETAILS OF HIGH VELOCITY WATER (HVW) SPRAY SYSTEM	
	NTS



SUB-STATION MANUAL
BUS BAR ARRANGEMENTS
FIGURE - 6 (A TO K)

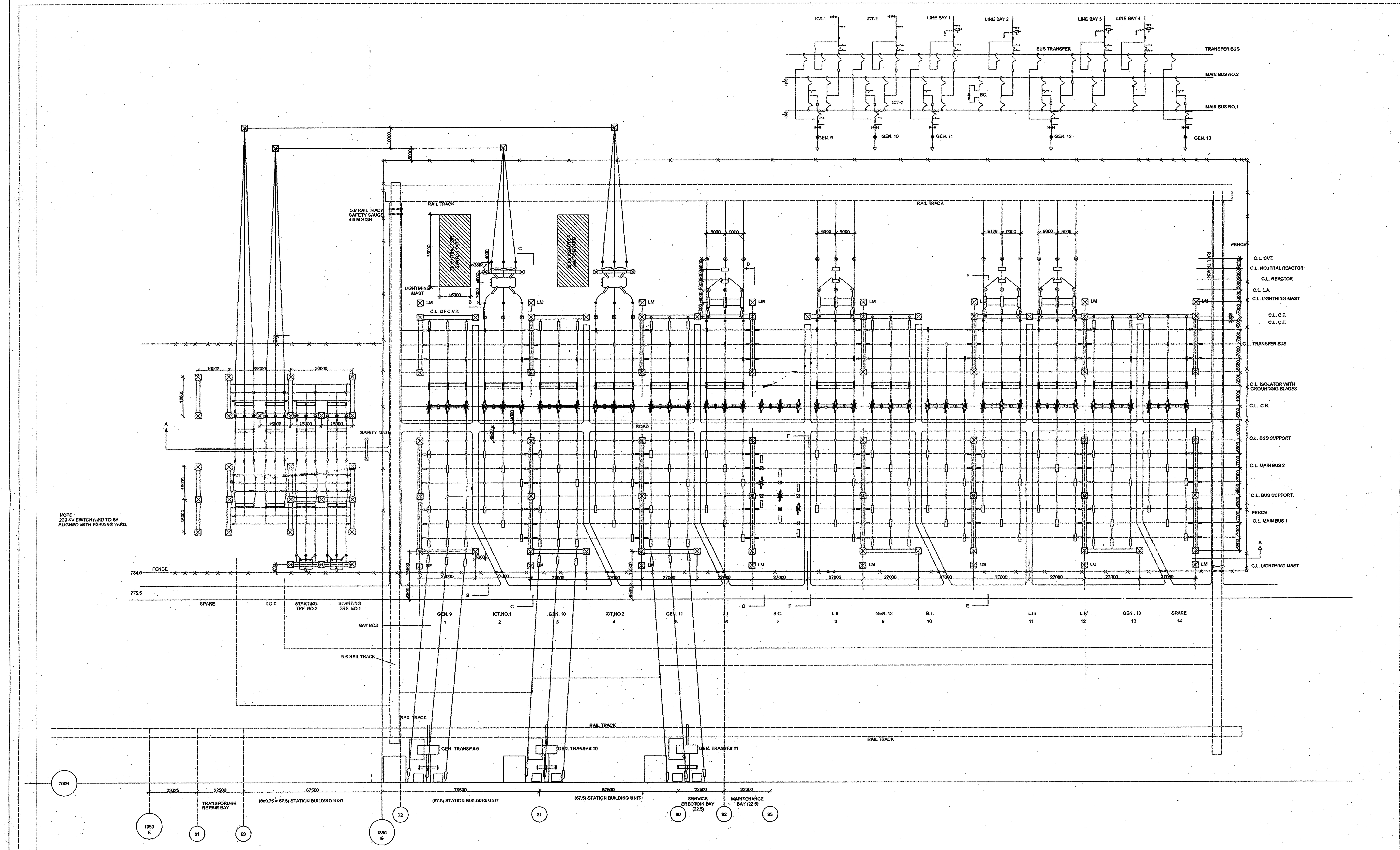


FIGURE- 7 (a)

FOR 220 KV SWITCHYARD

NOTE :

1. DESIGN VOLTAGE LEVEL
   OPERATING VOLTAGE 220 K.V. NOMINAL :245 K.V. MAXIMUM
   BASIC IMPULSE LEVEL 1050 K.V. FOR SWITCHYARD.
2. THE FOLLOWING MINIMUM CLEARANCES ARE PROVIDED
   (a) BETWEEN PHASES : 2.388 M
   (b) " " AND GROUND 2.082 M
   (c) MINIMUM LEVEL OF BOTTOM OF ANY INSULATOR 2.5 M
3. CONDUCTOR DETAILS MAIN BUSES 1 AND 2
   'TARANTULA' ALL ALUMINIUM CONDUCTOR

   TRANSFER BUS AND TAPS
   DEER: 0.4 SQ INCH COPPER EQUIVALENT ACSR
   AL/ STEEL/DIA :30 /7/ 4.27 MM
   OVERALL DIAMETER 29.89 MM
4. LIGHTNING MAST
   32 METRES HIGH STRUCTURE WITH
   3 METRES LIGHTINING ROD
5. INSULATORS
   16 DISCS OF STANDARD 146 X 254 MM
   INSULATORS EM STRENGTH 11370 KG
6. TENSIONS
   LINE ENTRY 1000 KG/ CONDUCTOR
   MAIN BUS : 800 "
7. BUS POST INSULATOR
   STACK OF 6 INSULATORS OF 33 KV CLASS
   ULTIMATE CANTILEVER STRENGTH. 340 KG

FOR 400 KV SWITCHYARD

1. DESIGN VOLTAGE LEVEL
   OPERATING VOLTAGE 400 KV NOMINAL :420 KV MAXIMUM
   BASIC IMPULSE LEVEL 1550 KV FOR SWITCHYARD.
2. THE FOLLOWING MINIMUM CLEARANCES ARE PROVIDED
   (a) BETWEEN PHASES ; 4.0 M
   (b) " " AND GROUND 3.5 M
   (c) MINIMUM LEVEL OF BOTTOM OF ANY INSULATOR 2.5 M
3. CONDUCTOR QETAILS (1S 398)
   (a) EQUIVALENT COPPER AREA = 325 SQ.MM (NOMINAL)
   (b) ALUMINIUM 54 STRANDS OF 3.53 MM DIA
   (c) STEEL 7 STRANDS OF 3.53 MM DIA
   (d) OVERALL DIAMETER 31.77 MM
   FOR MAIN BUSES AND TRANSFER BUS QUADRUPLE
   MOOSE BUNDLE
4. BAY BUS CONDUCTOR
   ALUMINIUM OF GRADE 91E CONFORMING TO THE
   REQUIREMENTS OF IS 5082/1969
   O.D : 114.3 MM , I.D. : 101.6 MM, AREA 2050 MM.
   WT : 5.5 KG/ M.
   E : MODULUS OF ELASTICITY 6.7X 10 ^{5} KG/ CM ^{2}
   X: COEFFICIENT OF LINEAR EXPANSION 2.3710 / DEG C
5. LIGHTNING MAST
   42 M HIGH STRUCTURE WITH 8 M LIGHTINING ROD
6. INSULATORS
   25 DISCS OF STANDARD 145 X 255 MM INSULATORS
   EM STRENGTH : 11370 KG
7. TENSIONS
   LINE ENTRY : 2000 KG / SUB- CONDUCTOR
   MAIN BUS : 1000 " " "
   EARTHWRE : 800 " CONDUCTOR
8. BUS POST INSULATOR
   TOTAL HEIGHT : 3.65 M
   ULTIMATE CANTILEVER STRENGTH 620 KG
   " TORSIONAL " 600 KG M

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
DOUBLE MAIN AND TRANSFER BUS TYPE 420 KV BIL 1550 KVp		
	SHEET 1 OF 1	SCALE: NTS

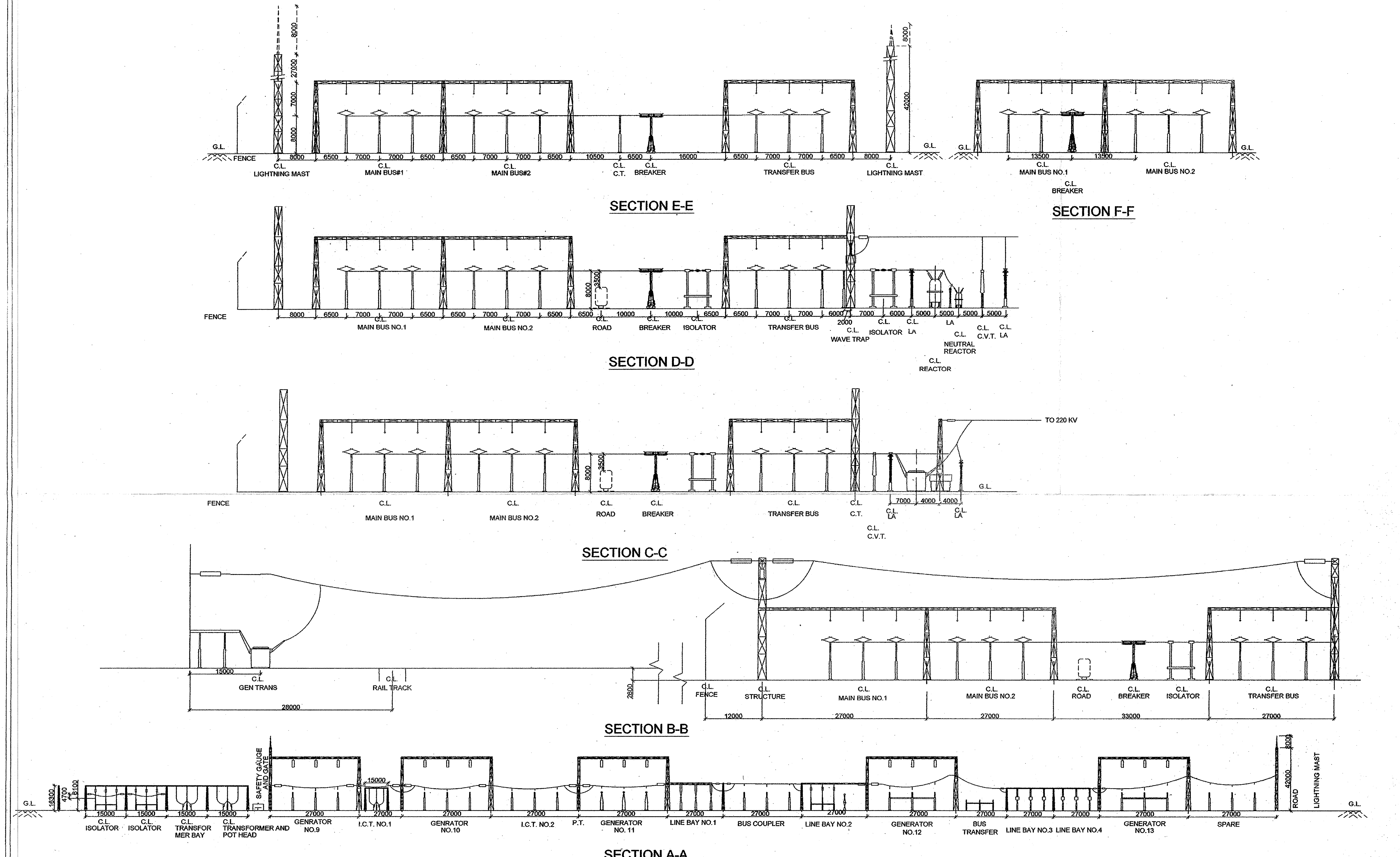
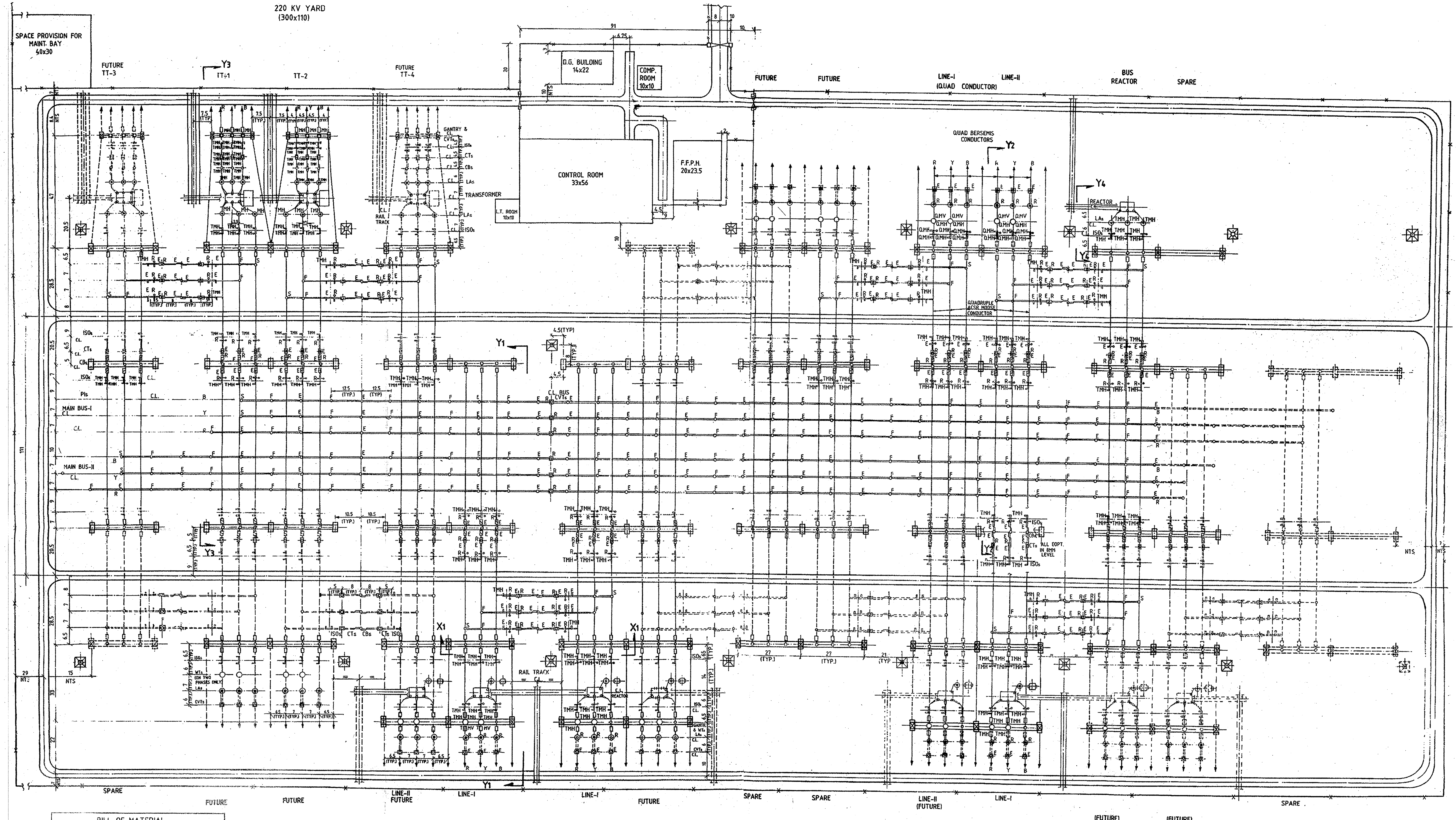


FIGURE- 7 (b)

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
DOUBLE MAIN AND TRANSFER BUS TYPE 420 KV BIL 1550 KVp	
SHEET 1 OF 1	SCALE: NTS



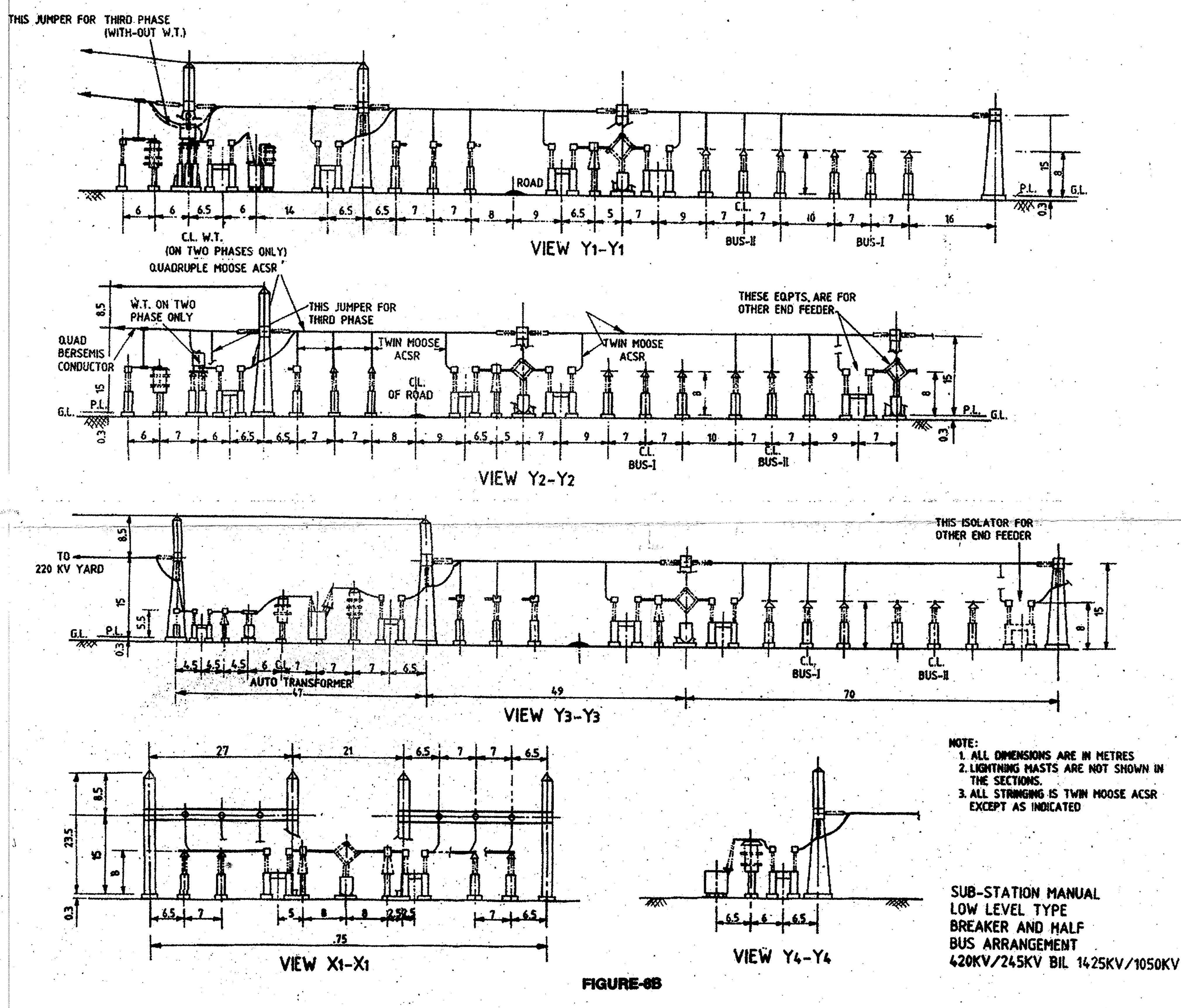
BILL OF MATERIAL					
SL.NO.	EQUIPMENTS	RATING	Q.TY.	TRML TYPE	CONNR. Q.TY.
1	CB 420KV 245KV	2000A 1600A	13 2	E THM	78 12
2	ISO 420KV (HCB) 245KV	2000A 1600A	38 2	R E TMH	
3	ISO 420KV	3150A	2	QMH	12
4	CT 420KV 245KV	2000A 1600A	42 6	R E TMH	42 42 12
5	CVT 420KV 245KV	8800PF	3 6	E TMH	3 6
6	CVT---420KV	4400PF	15	E R	9 6
7	LA--198KV	198KV	6	TMH	6
8	LA--372KV(ZnO)		21	R	21
9	BPI-- 420KV FOR 4"IPS.AL TUBE		242	F E S	122 104 16
10	WT-- 420KV CLASS	3000A 2000A 2000A	4 2 2	 TMH TMV	

NOTES:

1. WAVE TRAPS MAY HAVE TO BE INSTALLED ON ANY TWO OF THE THREE PHASES IN THE LINE,
2. ALL DIMENSIONS ARE IN METRES

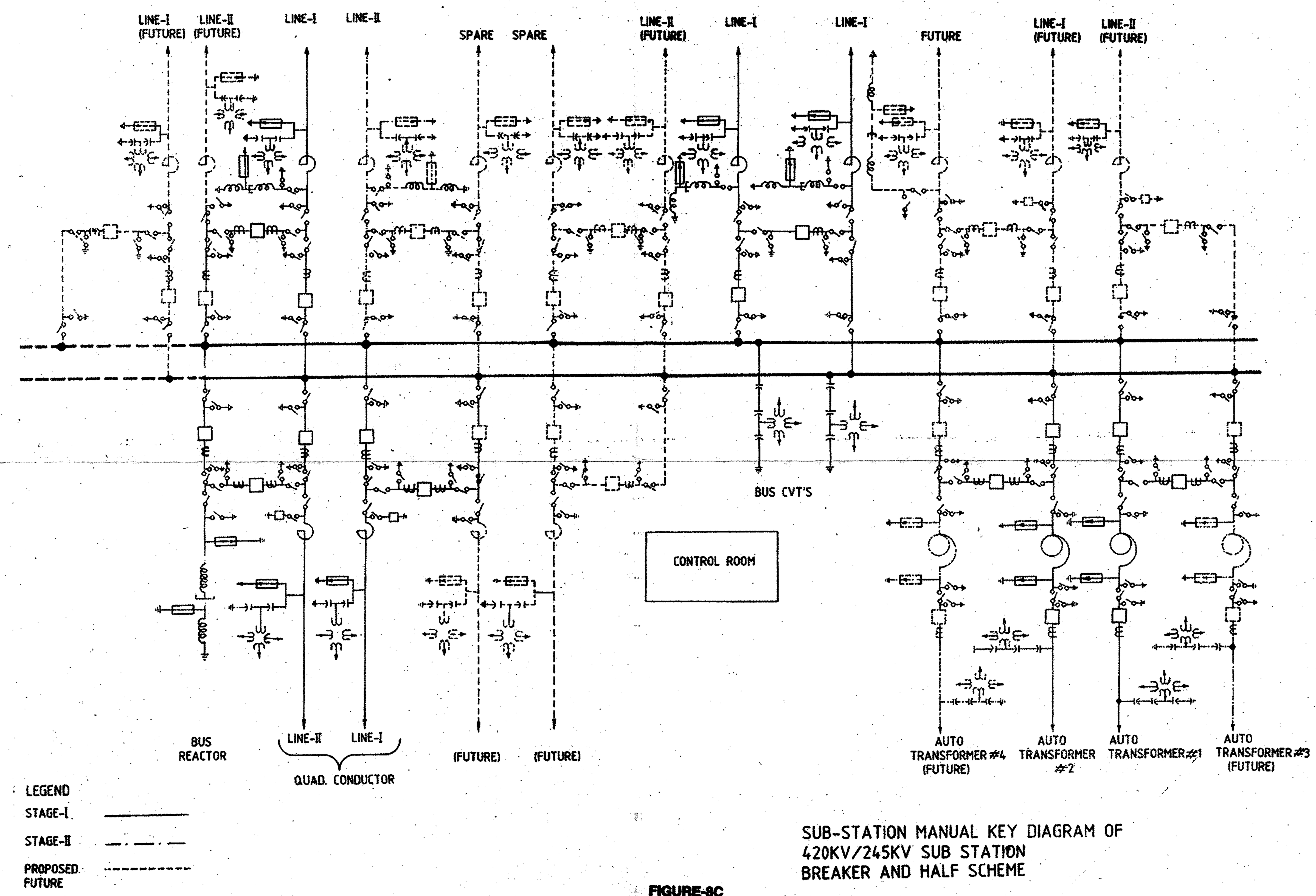
SUB-STATION MANUAL
LOW LEVEL TYPE
BREAKER AND HALF BUS ARRANGEMENT
420KV/245KV BIL 1425KV/1050KV

FIGURE-8A



SUB-STATION MANUAL
LOW LEVEL TYPE
BREAKER AND HALF
BUS ARRANGEMENT
420KV/245KV BIL 1425KV/1050KV

FIGURE-8B



SUB-STATION MANUAL KEY DIAGRAM OF
420KV/245KV SUB STATION
BREAKER AND HALF SCHEME

FIGURE-8C

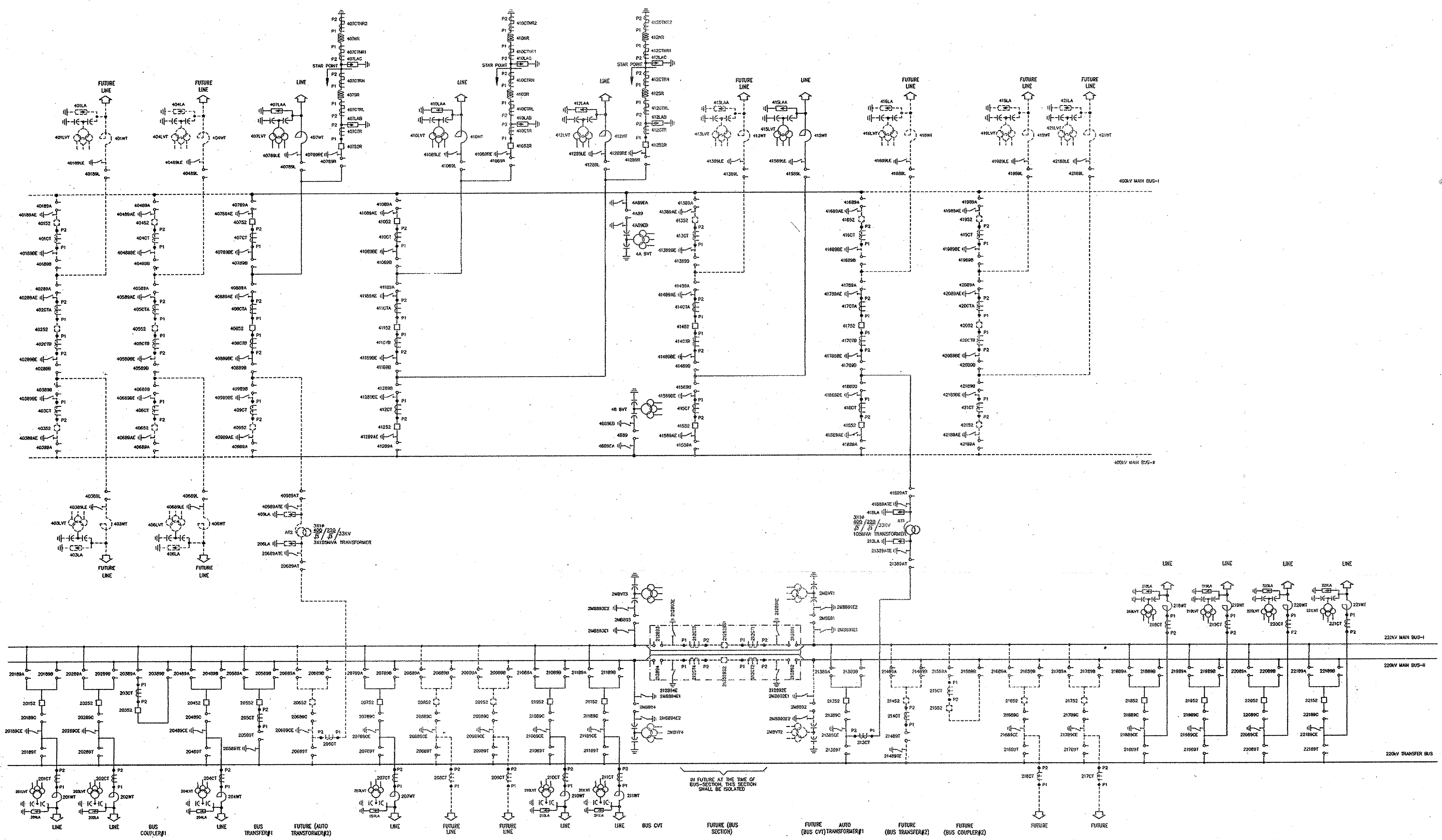
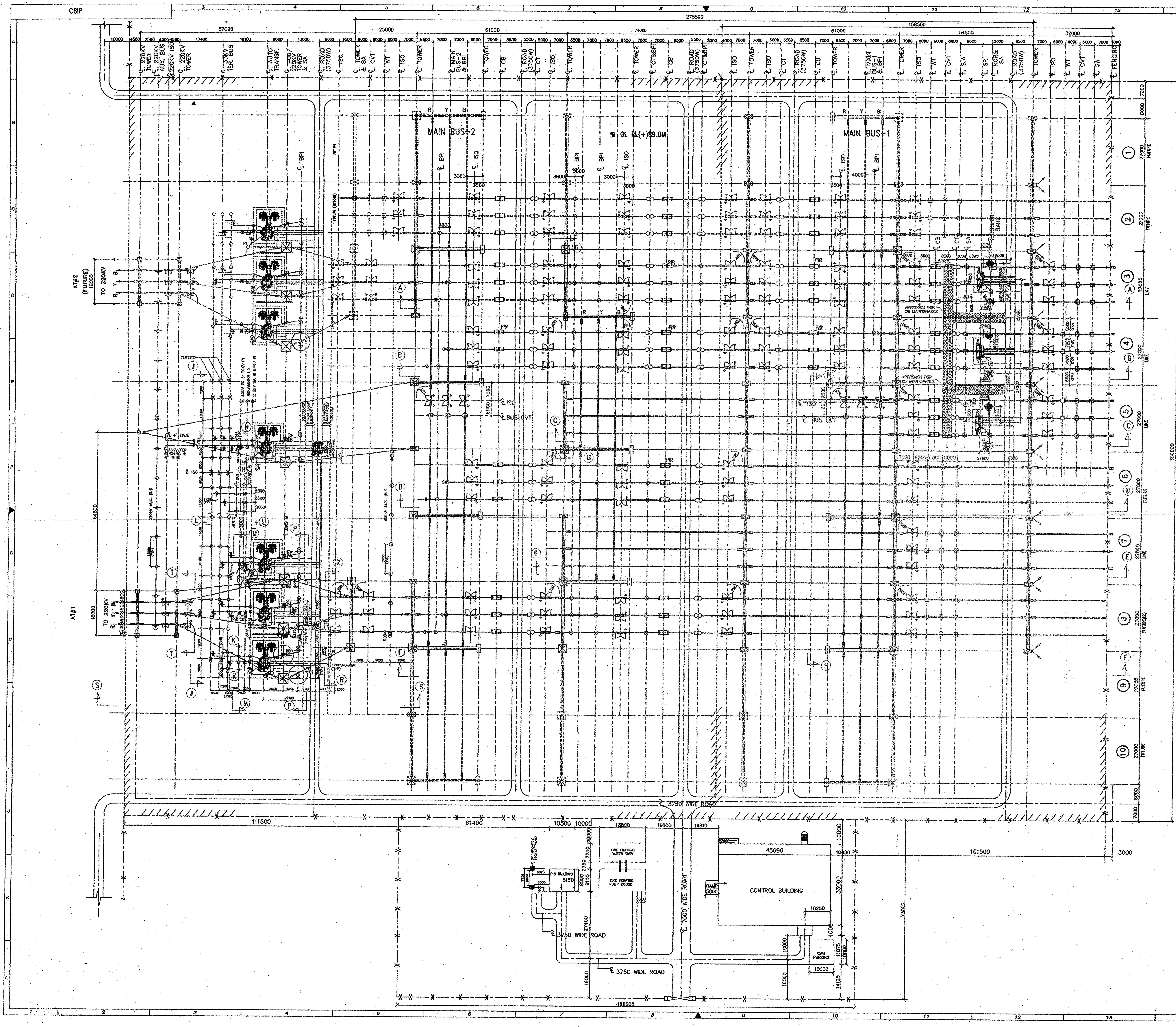


FIGURE 8 D (SHEET 1 OF 6)

MANUAL ON SUBSTATIONS (LAYOUT &DESIGN)
SLD FOR BREAKER AND HALF SCHEME.
400/220KV SUBSTATION
SINGLE LINE DIAGRAM - 400/220 KV SYSTEM



NOTES

1.... ALL DIMENSIONS ARE IN MILLIMETRE UNLESS OTHERWISE SPECIFIED.

2.... THE PARAMETERS FOR WHICH THE SYSTEM IS DEPENDENT FOR ARE :-

a) SYSTEM VOLTAGE(RMS) –	420KV	245KV	72.5KV
b) LIGHTNING IMPULSE WITHSTAND VOLTAGE(KVP) –	1425	1050	–
c) SWITCHING IMPULSE WITHSTAND VOLTAGE(KVP) –	1050	–	–
d) POWER FREQUENCY WITHSTAND VOLTAGE(RMS) –	630KV	460KV	140KV
e) MAX. FAULT LEVEL – FOR 1 SEC.	40KA	40KA	25KA

3.... MINIMUM CLEARANCE :-

a) PHASE TO PHASE – (IN MM)	4000	2400	630
b) PHASE TO EARTH – (IN MM)	3500	2100	630
c) SECTIONAL CLEARANCE – (IN MM)	6500	5000	3500
d) GROUND CLEARANCE – MM(MINIMUM)	8000	5500	4000

4.... ———— – PRESENT SCOPE
- - - - - – FUTURE SCOPE

5.... THIS DRAWING SHALL BE READ WITH ELECTRICAL LAYOUT 400KV SUBSTATION SECTIONS. FOR DETAILED LAYOUT OF AUTO-TRANSFORMER AND IT'S SECTIONS J–J TO T–T

6.... 400KV MAIN BUS – QUAD MOOSE AND AUXILIARY BUS – TWIN MOOSE ACSR COND.
EQUIPMENT INTERCONNECTION : 4" AL. TUBE (OD– 114.2mm, ID– 97.18mm)
EARTH WIRE – 10.98mm G.S WIRE.
ALL 400KV JACK BUS/ DROPPERS: ACSR TWIN MOOSE, 450mm SUBCONDUCTOR SPACING.

FIGURE 8 D (SHEET 2 OF 6)

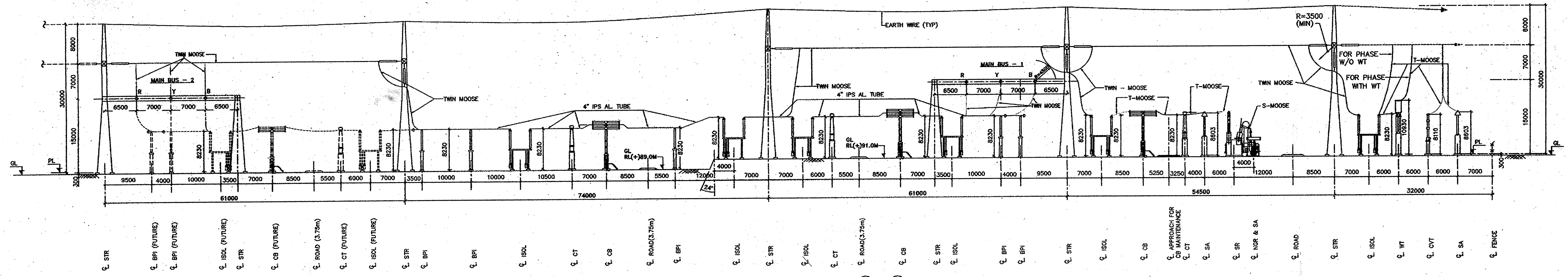
MANUAL ON SUBSTATIONS
(LAYOUT & DESIGN

BREAKER AND HALF SCHEME, WITH SINGLE PHASE AUTOTRANSFORMER (AUXILIARY BUS ARRANGEMENT)

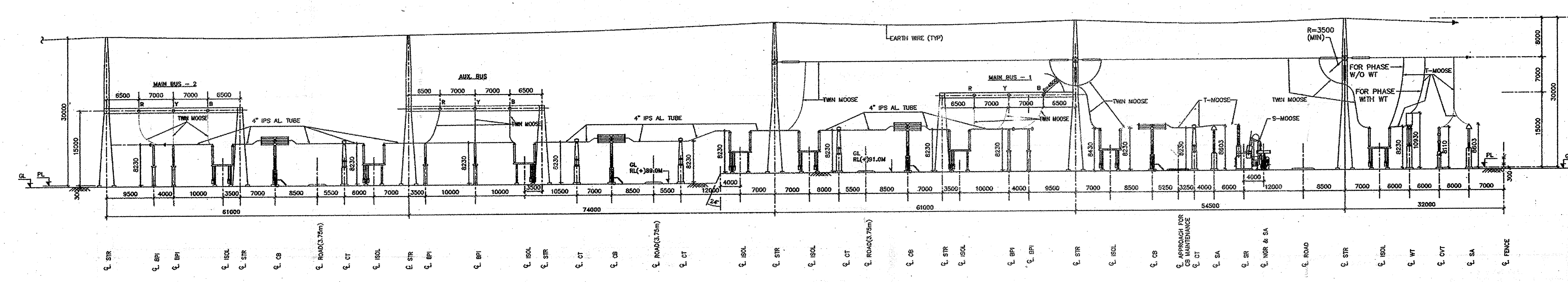
420 kV, BIL 1425 kVp

ELECTRICAL LAYOUT
400KV SUBSTATION – PLAN

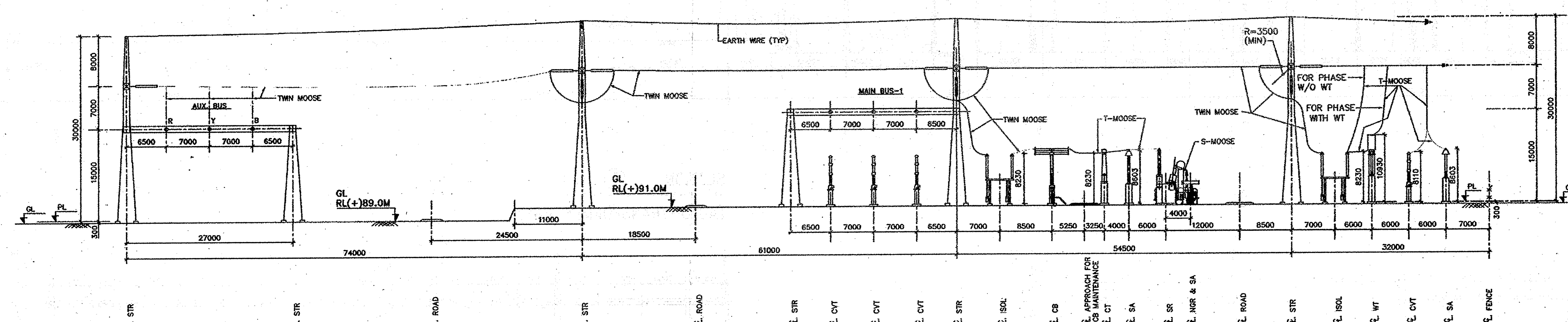
SCALE NTS



SECTION : (A)-(A)



SECTION : (B)-(B)



SECTION : (C)-(C)

NOTES

1... ALL DIMENSIONS ARE IN MILLIMETRE UNLESS OTHERWISE SPECIFIED.
2... GL : GROUND LEVEL, PL: PLINTH LEVEL
3... UNLESS OTHERWISE SPECIFIED ALL EQUIPMENT CONNECTIONS ARE WITH 4" EH IPS ALUMINIUM TUBE.

FIGURE 8D (SHEET 3 OF 6)

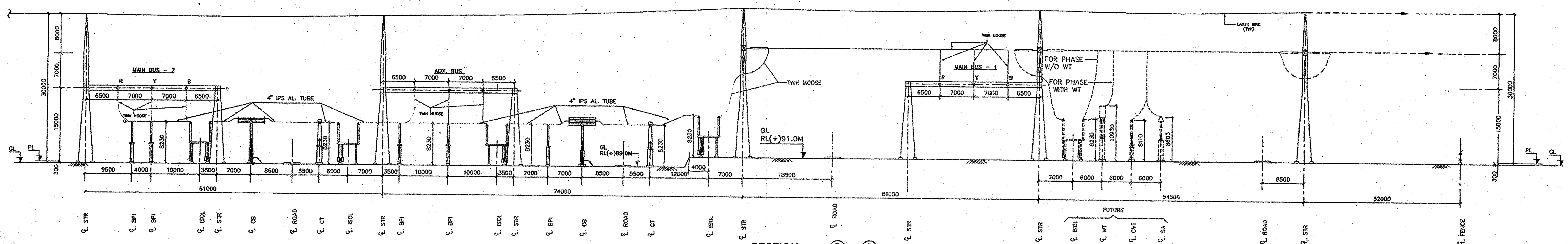
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)

BREAKER AND HALF SCHEME, WITH SINGLE PHASE AUTOTRANSFORMER (AUXILIARY BUS ARRANGEMENT)

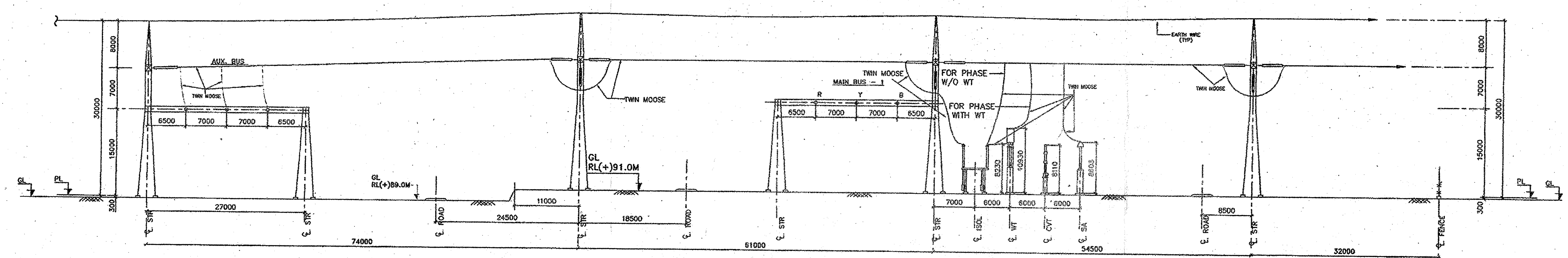
420 kV, BIL 1425kVp

ELECTRICAL LAYOUT
400KV SUBSTATION - SECTIONS

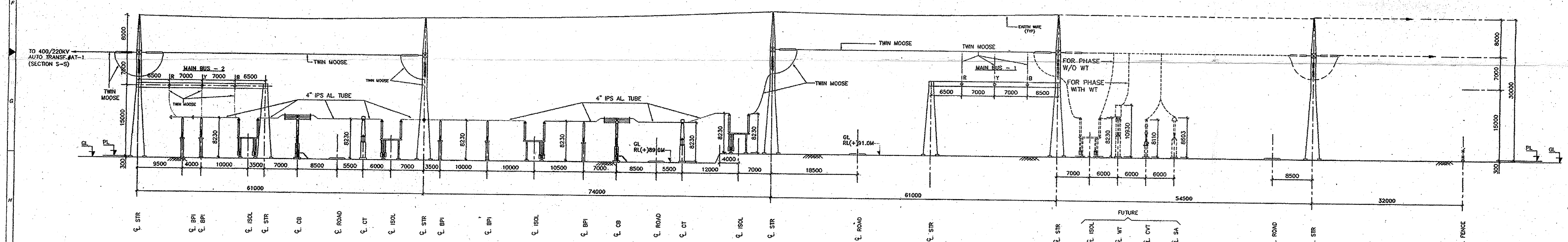
SCALE NTS



SECTION : (D)-(D)

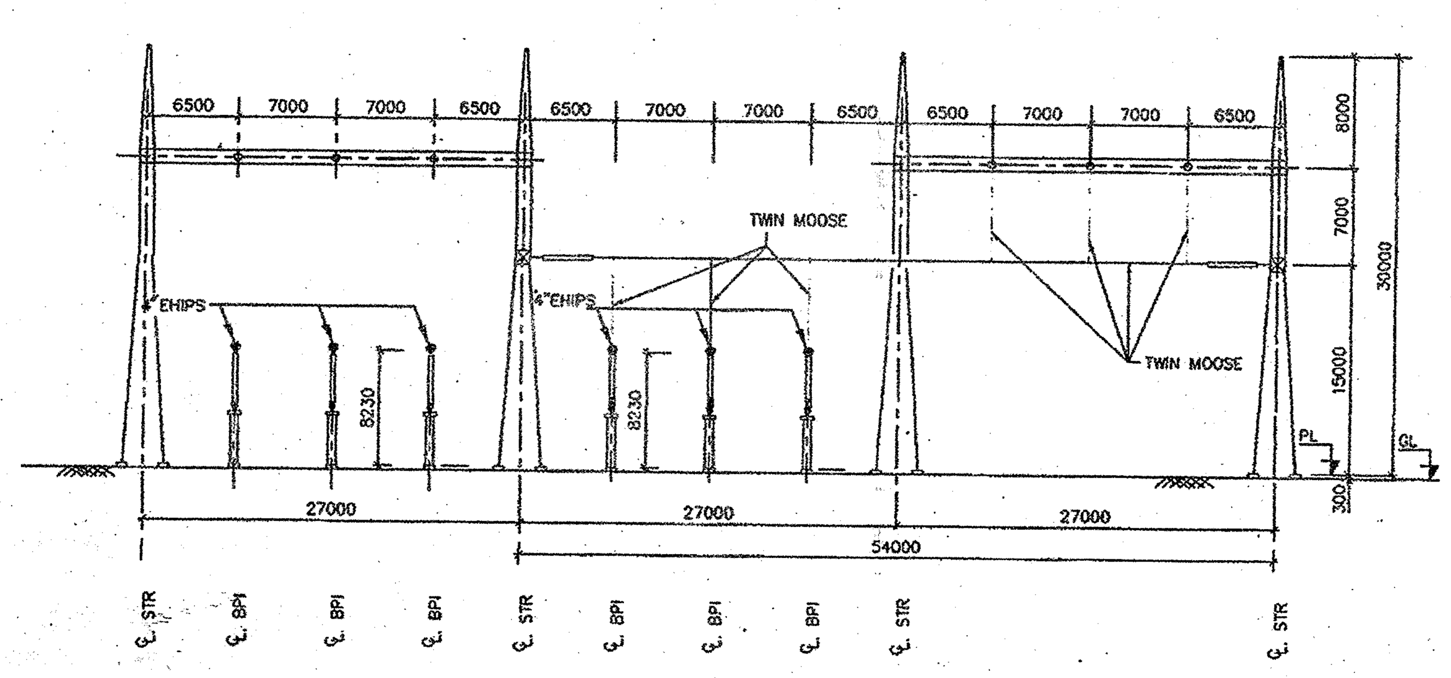


SECTION : (E)-(E)

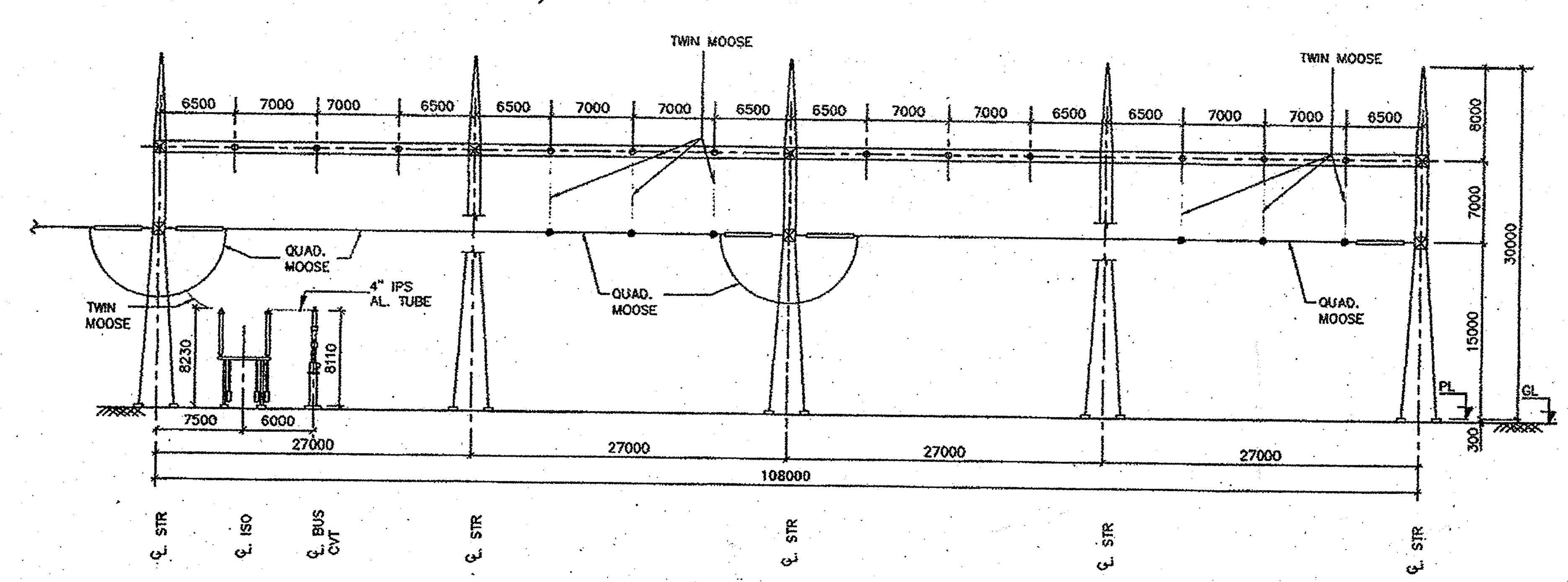


SECTION : (F)-(F)

(AUTO-TRANSFORMER BAY)



SECTION : (G)-(G)



SECTION : (H)-(H)

NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRE UNLESS OTHERWISE SPECIFIED.
2. UNLESS OTHERWISE SPECIFIED ALL EQUIPMENT CONNECTIONS ARE WITH 4"EHIPS ALUMINIUM TUBE.
3. GL - GROUND LEVEL, PL - PLINTH LEVEL

FIGURE 8D(SHEET 4 OF 6)

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)
BREKER & HALF SCHEME WITH SINGLE PHASE AUTOTRANSFORMER (AUXILIARY BUS ARRANGEMENT)
420 kV, BIL 1425 kVp
ELECTRICAL LAYOUT 400KV SUBSTATION-SECTIONS
SCALE NTS

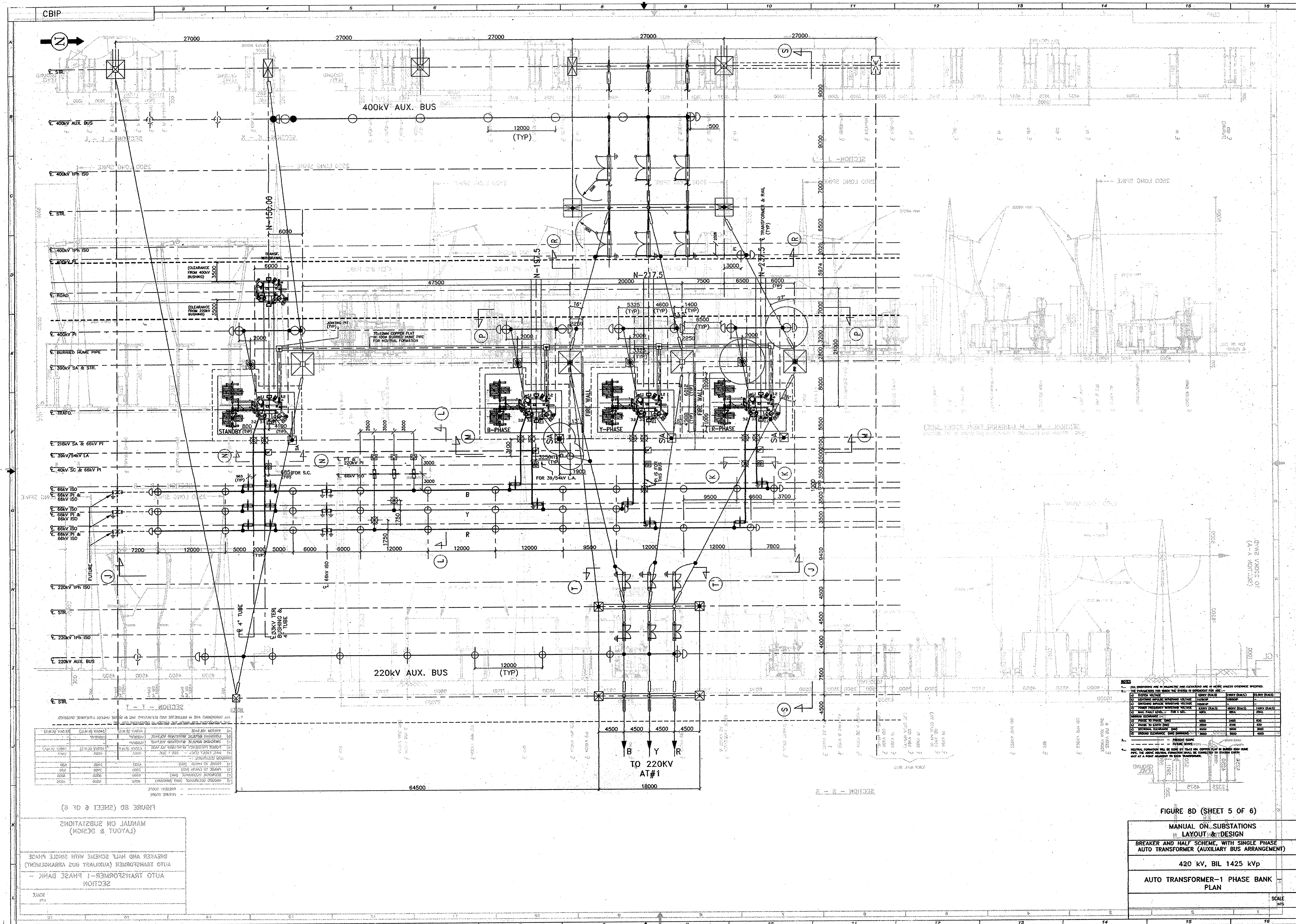


FIGURE 8D (SHEET 5 OF 6)

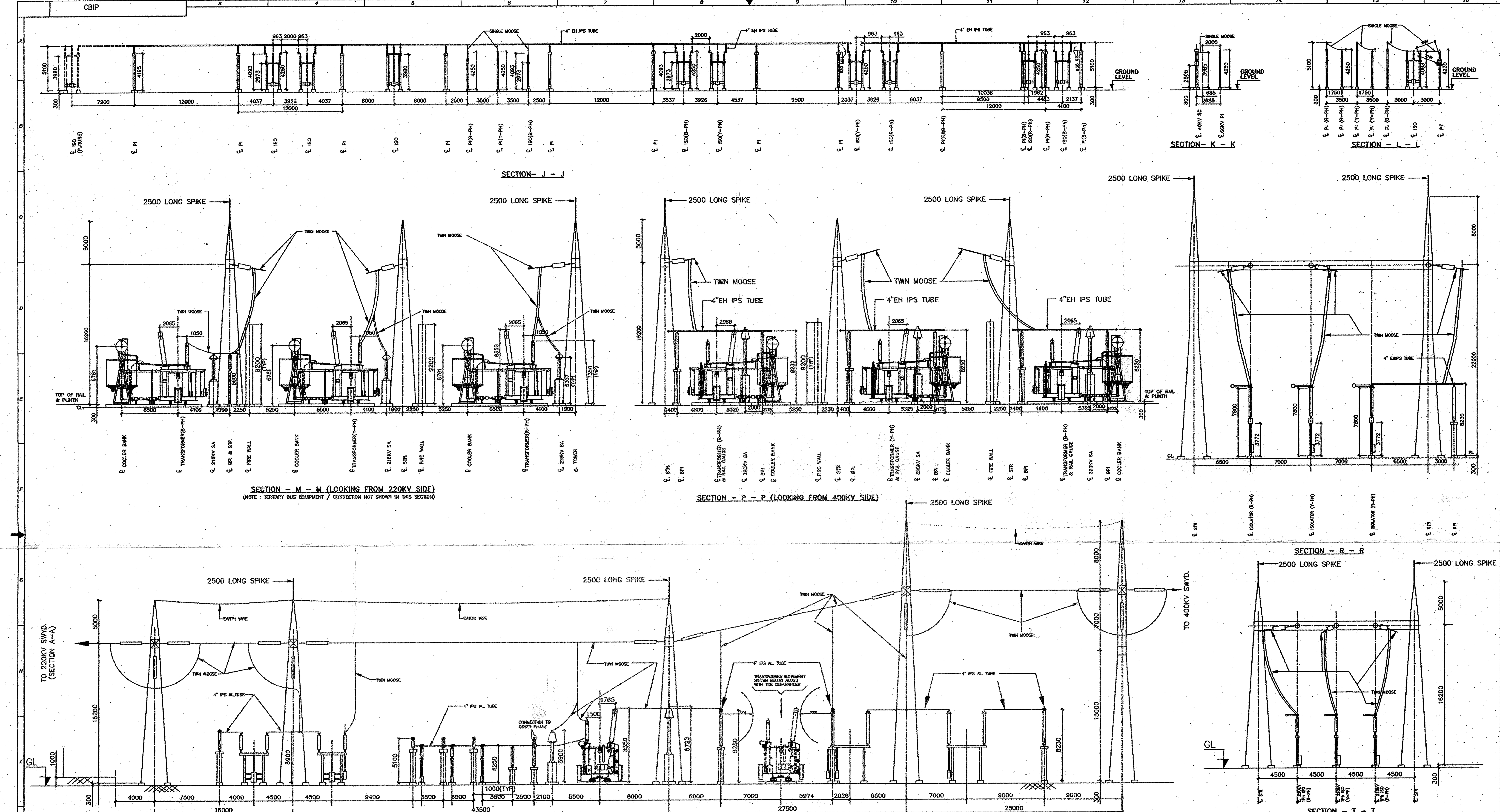
MANUAL ON SUBSTATIONS
LAYOUT & DESIGN

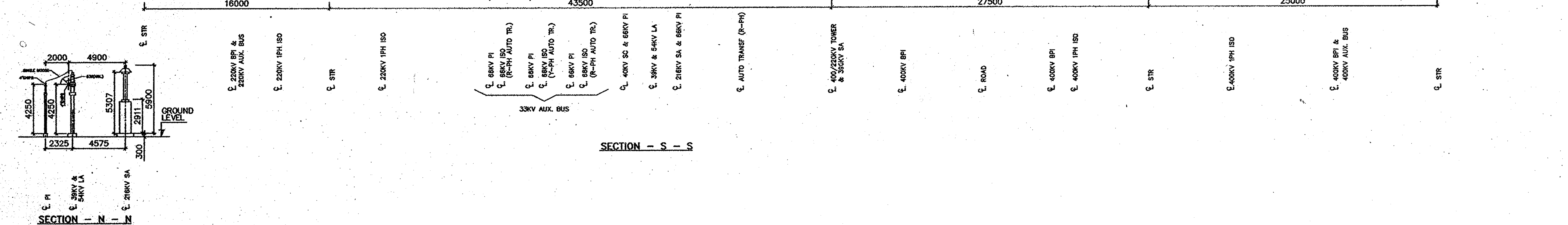
BREAKER AND HALF SCHEME, WITH SINGLE PHASE AUTO TRANSFORMER (AUXILIARY BUS ARRANGEMENT)

420 kV, BIL 1425 kVp

AUTO TRANSFORMER–1 PHASE BANK – PLAN

SCALE NTS





NOTES

1.... ALL DIMENSIONS ARE IN MILLIMETRE AND ELEVATIONS ARE IN METRE UNLESS OTHERWISE SPECIFIED.

2.... THE PARAMETERS FOR WHICH THE SYSTEM IS DEPENDENT FOR ARE :-

a) SYSTEM VOLTAGE	420KV (R.M.S)	245KV (R.M.S.)	72.5KV (R.M.S)
b) LIGHTNING IMPULSE WITHSTAND VOLTAGE	1425KVP	1050KVP	–
c) SWITCHING IMPULSE WITHSTAND VOLTAGE	1050KVP	–	–
d) POWER FREQUENCY WITHSTAND VOLTAGE	630KV (R.M.S)	460KV (R.M.S)	140KV (R.M.S)
e) MAX. FAULT LEVEL – FOR 1 SEC.	40KA	40KA	25KA
MINIMUM CLEARANCE :–			
a) PHASE TO PHASE (MM)	4000	2400	630
b) PHASE TO EARTH (MM)	3500	2100	630
c) SECTIONAL CLEARANCE (MM)	6500	5000	3000
d) GROUND CLEARANCE (MM) (MINIMUM)	8000	5500	4000

3.... ———— – PRESENT SCOPE
- - - - - – FUTURE SCOPE

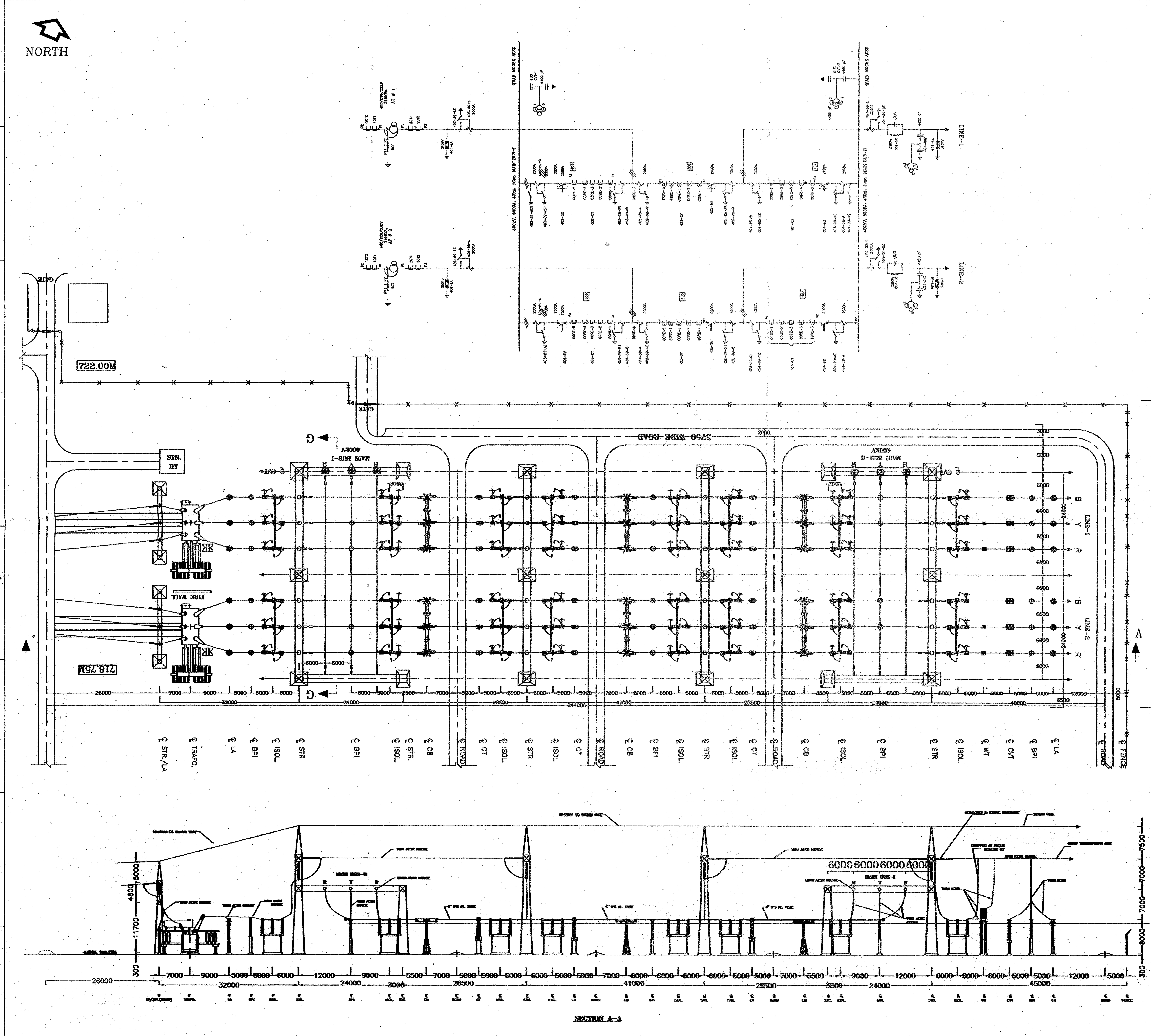
FIGURE 8D (SHEET 6 OF 6)

MANUAL ON SUBSTATIONS
(LAYOUT & DESIGN)

BREAKER AND HALF SCHEME WITH SINGLE PHASE AUTO TRANSFORMER (AUXILIARY BUS ARRANGEMENT)

AUTO TRANSFORMER–1 PHASE BANK – SECTION

SCALE NTS



NOTES:

1- ALL DIMENSIONS ARE IN MM. UNLESS OTHERWISE SPECIFIED

2- MINIMUM CLEARANCES:

a) BETWEEN PHASES	4000MM
b) BETWEEN PHASE TO EARTH	3500MM
c) SECTIONAL CLEARENCE	6500MM
d) VERTICAL DISTANCE BETWEEN LOWEST PART OF THE INSULATOR AND PLINTH LEVEL	2550MM

3- THE PARAMETERS FOR WHICH THE SYSTEM IS DESIGNED ARE:

a) SYSTEM VOLTAGE 420kV (RMS)	400KV
b) LIGHTNING IMPULSE WITHSTAND VOLTAGE : (DRY & WET)	±1550kVP
c) SWITCHING IMPULSE WITHSTAND VOLTAGE : (DRY & WET)	±1050kVP
d) POWER FREQUENCY WITHSTAND VOLTAGE : (DRY & WET)	630kV(rms)
e) MINIMUM CREEPAGE DISTANCE :	25MM/kV(10500mm)
f) MAXIMUM FAULT LEVEL :	40kA/1 Sec.

4- LINE TRAP POSITIONS SHOWN IN THE LAYOUT ARE INDICATIVE ONLY. FINAL LOCATION WILL BE DECIDED BASED ON PLCC REQUIREMENT.

5- PLINTH HEIGHT OF FOUNDATION WILL BE +300MM FROM THE FINISHED GROUND LEVEL. GRAVEL TOP LEVEL WILL BE +100MM FROM THE F.G.L.

6- CONNECTION TYPES

400KV SWITCHYARD	LEVEL FROM PLINTH	CONDUCTOR TYPE
a) MAIN BUS I &II	+15000MM	QUAD ACSR MOOSE
b) TRANSFER BUS	--	--
c) JACK BUS	+22000MM	TWIN ACSR MOOSE
d) EQUIP. TO EQUIP.	+8000MM	4" IPS. AL. TUBE

7- STATIC CONDUCTOR TENSION (AT 0 DEG. C WITHOUT WIND) :

a) MAIN BUS I &II	4000 KG/PHASE
c) JACK BUS	4000 KG/PHASE

8- TOWER BASE DETAILS:

a) LONGITUDINAL FACE	4500 MM - 4700 MM (B/B)
b) TRANSVERSE FACE	3500 MM - 4700 MM (B/B)

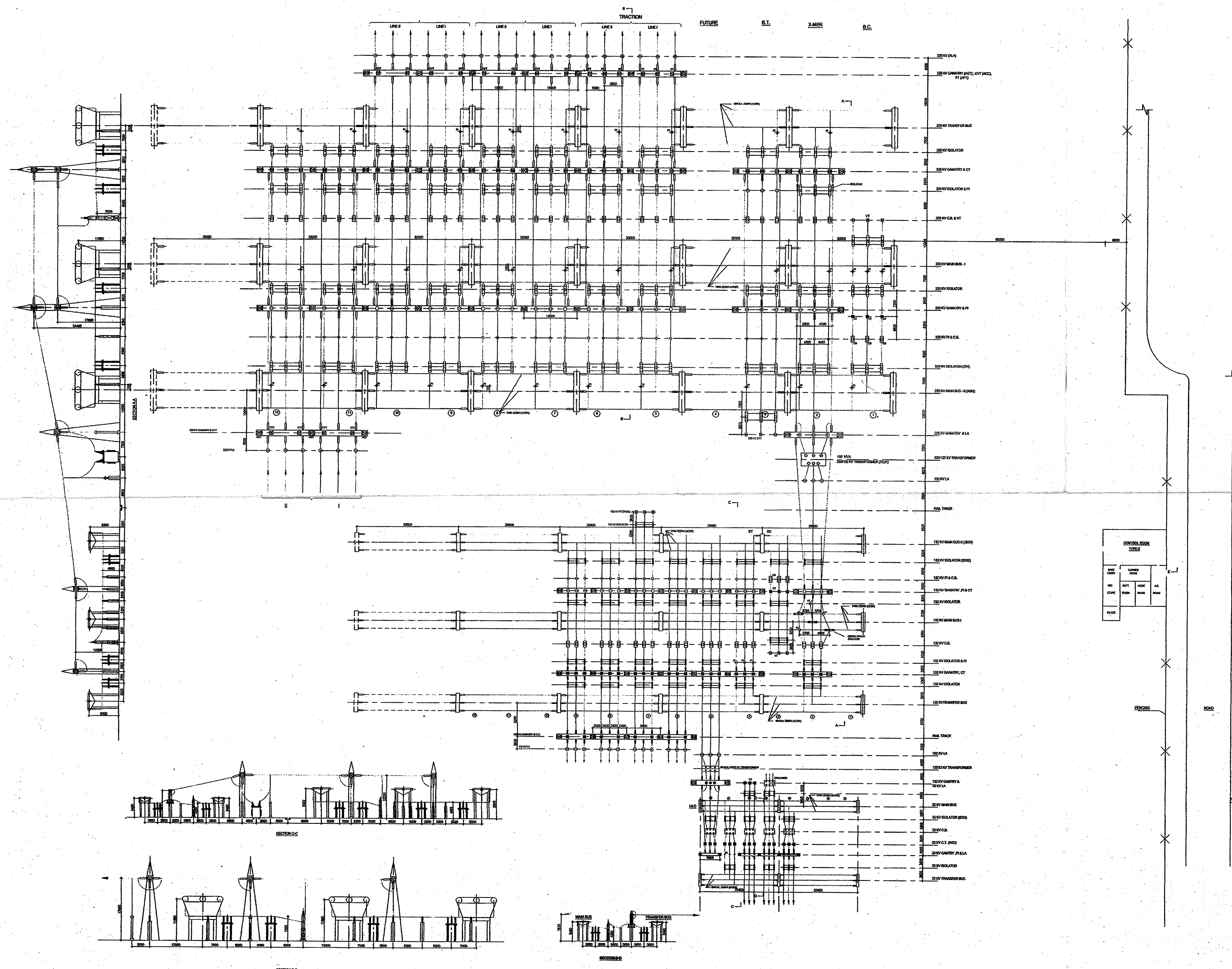
9- GIRDER/BEAM DIMENSION: 2000 MM (B/B) x 1500 MM (B/B)

Figure- 8 (e)

LAYOUT DRAWING - 400 KV /I-TYPE/24M BAY WIDTH (ONE AND HALF BREAKER SCHEME)

BIL- LI 1425KVp; SI 1050KVp

MANUAL ON SUB STATION LAYOUT & DESIGN



NOTE:-

1. FINISHED 220 KV YARD LEVEL 104.5
2. FINISHED 132 KV AND CONTROL ROOM LEVEL 103.5
3. FINISHED 33 KV YARD LEVEL 102.0
4. BEFORE TAKING UP THE WORK AVAILABILITY OF ADEQUATE CLEARANCE MAY BE ENSURED ON THE BASIS OF ACTUAL SITE CONDITION.
5. MINIUM GROUND CLEARANCE TO BE MAINTAINED :-

220 KV	——	5.55 M
132 KV	——	4.60 M
33 KV	——	4.00 M

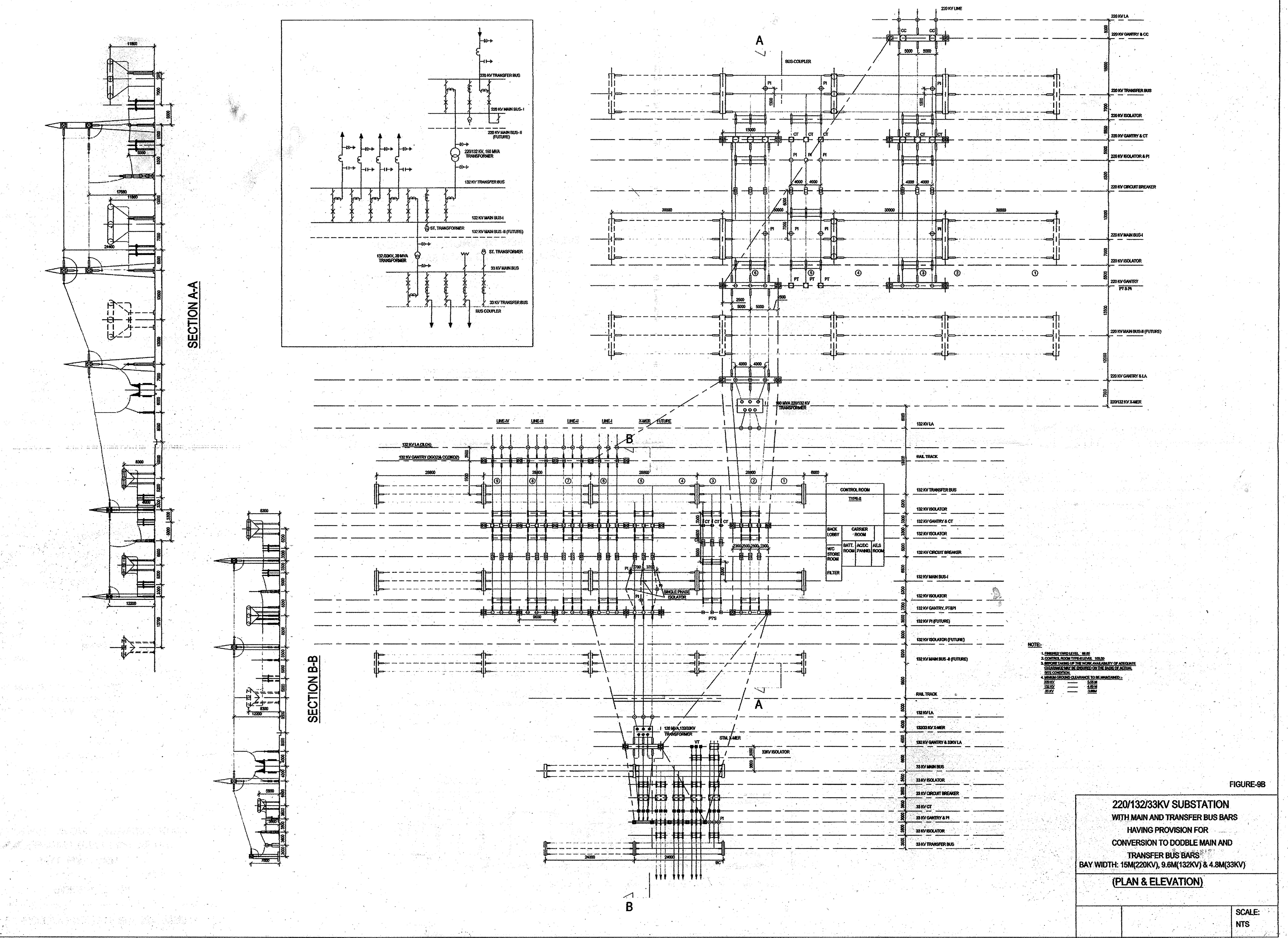
FIGURE-9A

220/132/33 KV SUB- STATION

WITH DOUBLE MAIN AND TRANSFER BUS BARS

(PLAN AND ELEVATION)

NTS

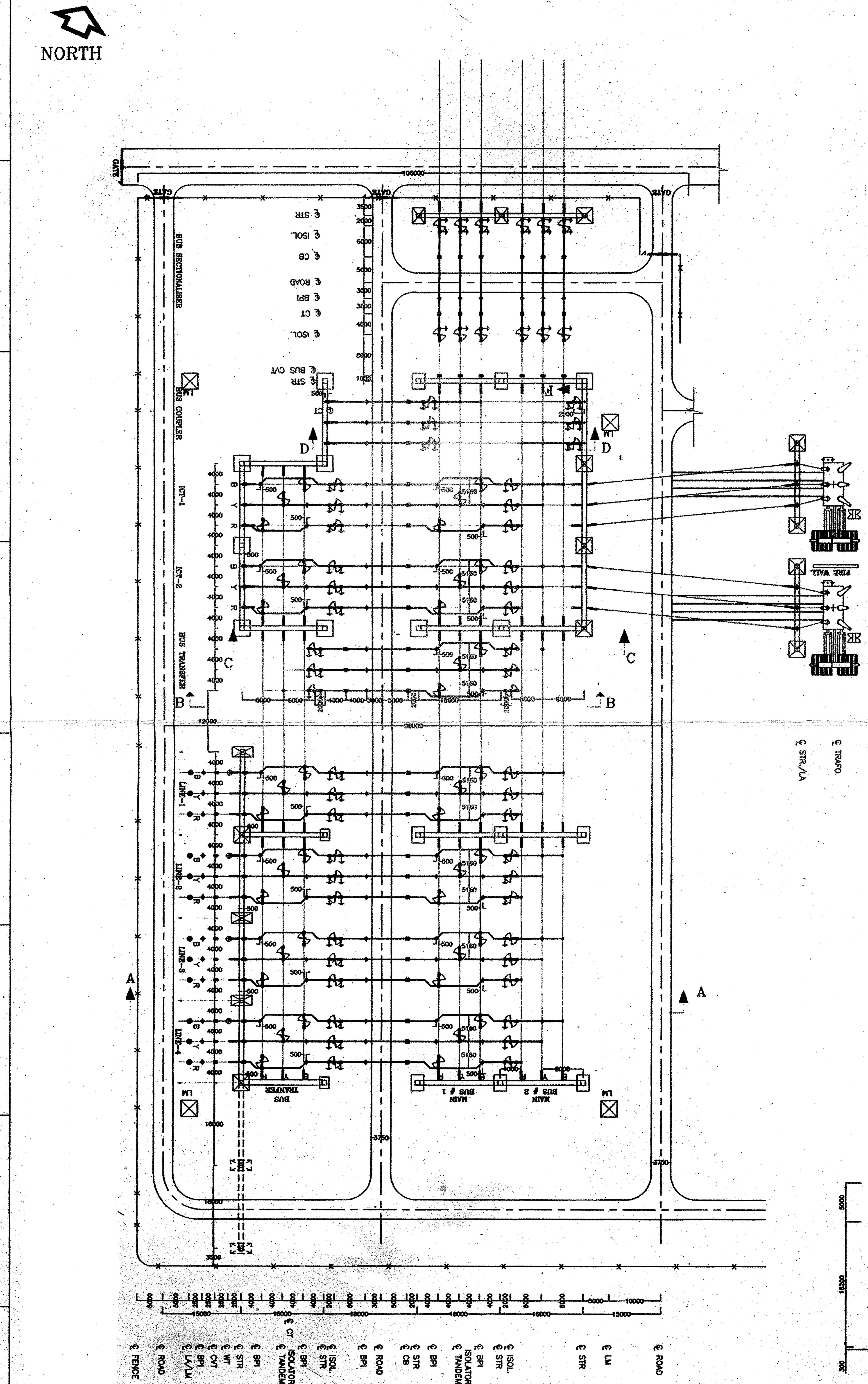


220/132/33KV SUBSTATION
WITH MAIN AND TRANSFER BUS BARS
HAVING PROVISION FOR
CONVERSION TO DODBLE MAIN AND
TRANSFER BUS BARS
BAY WIDTH: 15M(220KV), 9.6M(132KV) & 4.8M(33KV)

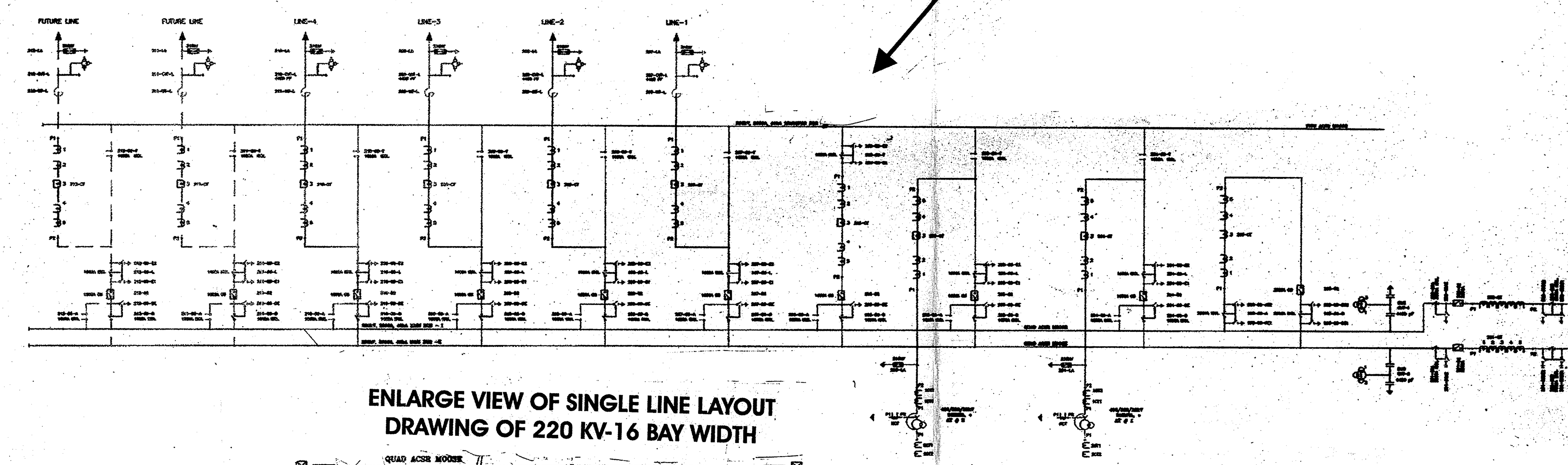
(PLAN & ELEVATION)

SCALE: NTS

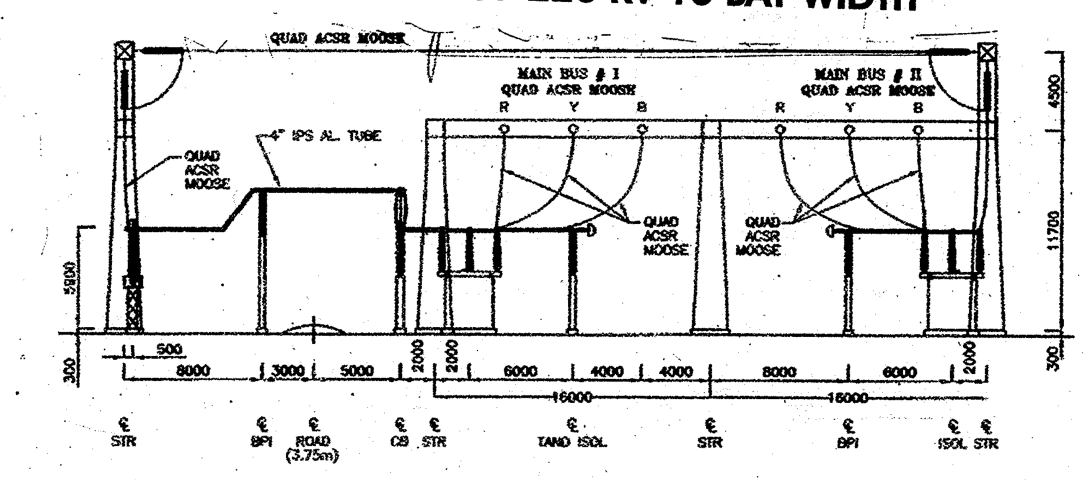
NORTH



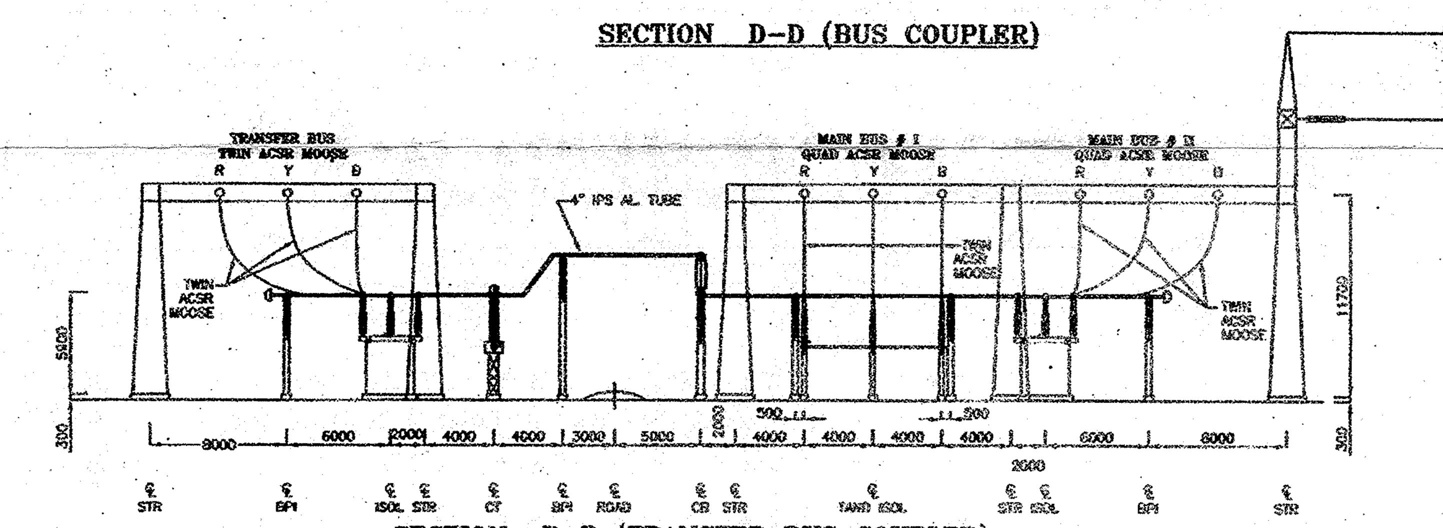
See Enlarge View as annexure 9C(a)



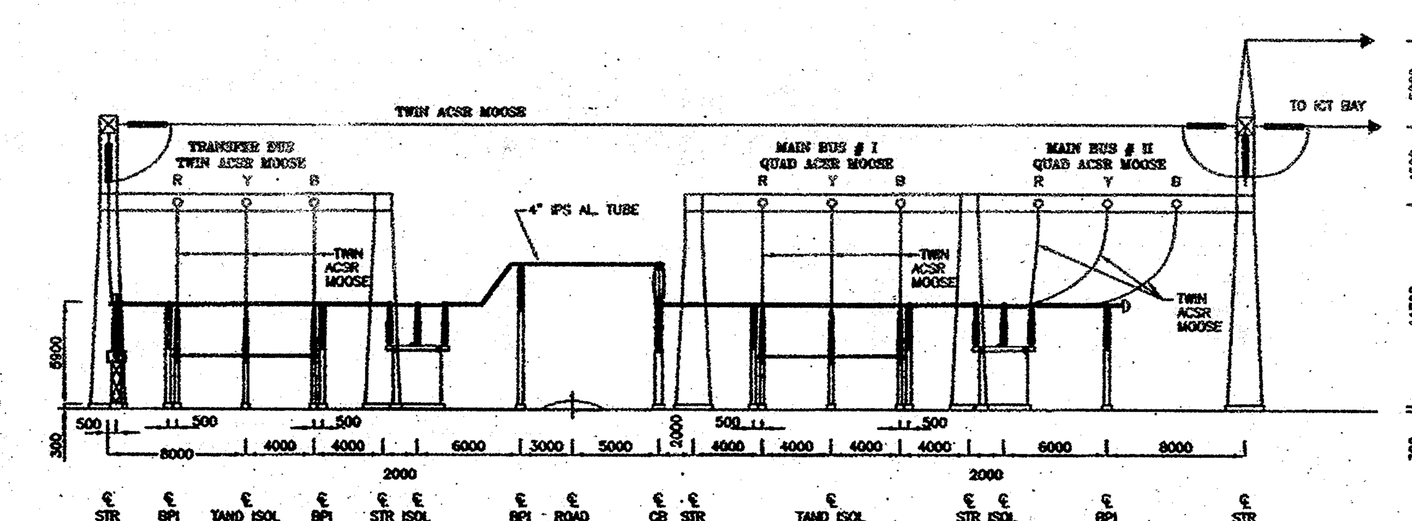
ENLARGE VIEW OF SINGLE LINE LAYOUT DRAWING OF 220 KV-16 BAY WIDTH



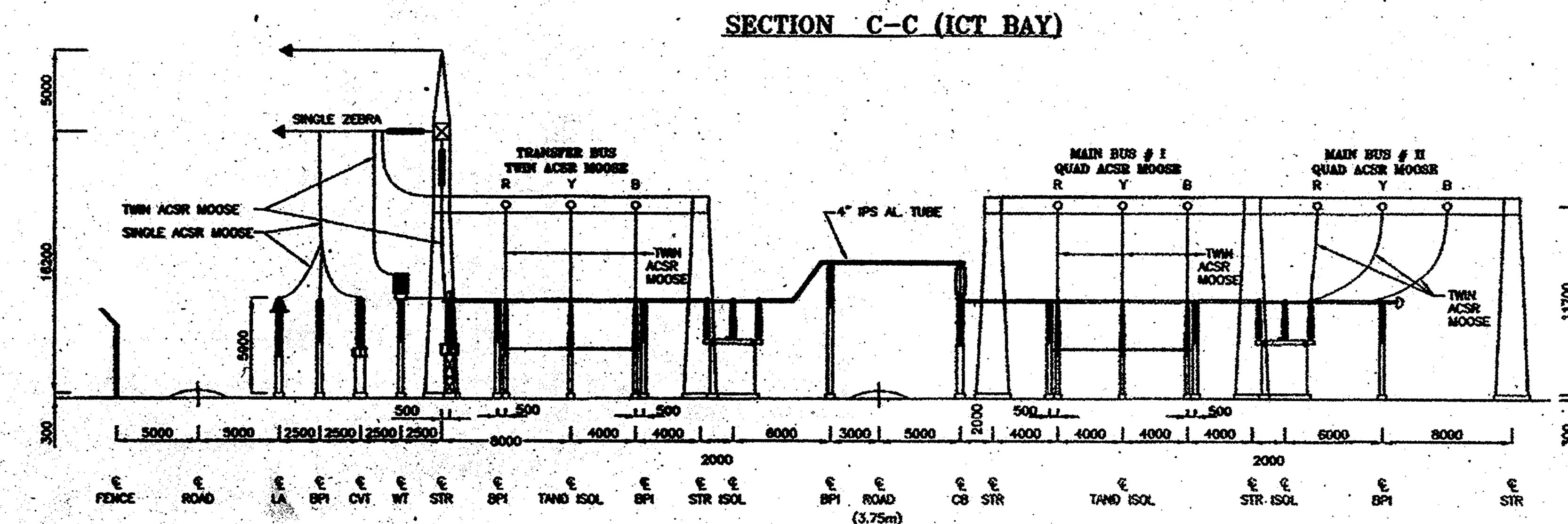
SECTION D–D (BUS COUPLER)



SECTION B–B (TRANSFER BUS COUPLER)



SECTION C–C (ICT BAY)



SECTION A–A (LINE BAY)

1– ALL DIMENSIONS ARE IN MM. UNLESS OTHERWISE SPECIFIED

2– MINIMUM CLEARANCE :

a) BETWEEN PHASES	2100MM
b) BETWEEN PHASE TO EARTH	2100MM
c) SECTONAL CLEARENCE	5000MM
d) VERTICAL DISTANCE BETWEEN LOWEST PART OF THE INSULATOR AND PLINTH LEVEL	2550MM

3– THE PARAMETERS FOR WHICH THE SYSTEM IS DESIGNED ARE:

a) SYSTEM VOLTAGE (RMS)	220KV
b) LIGHTNING IMPULSE WITHSTAND VOLTAGE :	±1050kVP
c) SWITCHING IMPULSE WITHSTAND VOLTAGE :	NA
d) POWER FREQUENCY WITHSTAND VOLTAGE :	460kV(rms)
e) MINIMUM CREEPAGE DISTANCE :	25MM/kV(6125mm)
f) MAXIMUM FAULT LEVEL :	40kA/1 Sec.

4– LINE TRAP POSITIONS SHOWN IN THE LAYOUT ARE INDICATIVE ONLY, FINAL LOCATION WILL BE DECIDED BASED ON PLCC REQUIREMENT.

5– PLINTH HEIGHT OF FOUNDATION WILL BE +300MM FROM THE FINISHED GROUND LEVEL. GRAVEL TOP LEVEL WILL BE +100MM FROM THE F.G.L.

6– CONNECTION TYPES — 220KV SWITCHYARD

	LEVEL FROM PLINTH	CONDUCTOR TYPE
a) MAIN BUS I &II	+11700MM	QUAD ACSR MOOSE
b) TRANSFER BUS	+11700MM	TWIN ACSR MOOSE
c) JACK BUS	+16200MM	TWIN ACSR MOOSE
d) EQUIP. TO EQUIP.	+5900MM	4" IPS. AL. TUBE
e) DROPPERS	––	TWIN ACSR MOOSE

7– STATIC CONDUCTOR TENSION (AT O DEG. C):

a) MAIN BUS I &II	1000 KG/CONDUCTOR (48M SPAN)
b) TRANSFER BUS	1000 kG/CONDUCTOR (48M SPAN)
c) JACK BUS	2000 KG/CONDUCTOR (66M SPAN)

8– TOWER BASE DETAILS:

a) LONGITUDINAL FACE	3500 MM (B/B)
b) TRANSVERSE FACE	2500 MM (B/B)

9– GIRDER DIMENSION: 1500 MM (B/B) x 1200 MM (B/B)

Figure- 9(c)

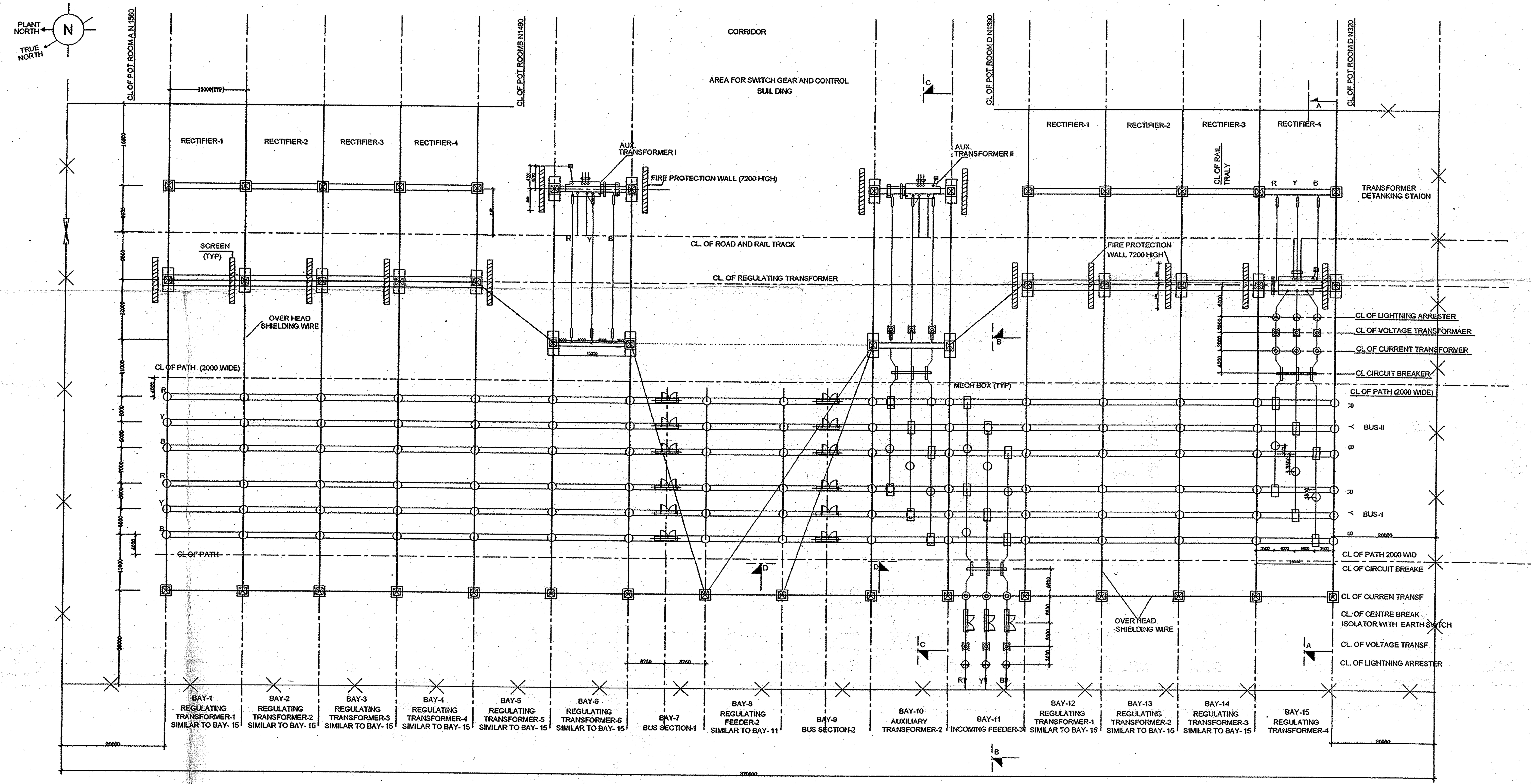
LAYOUT DRAWING - 220 KV /16M BAY WIDTH (DOUBLE MAIN AND TRANSFER SCHEME) LOW LEVEL TYPE

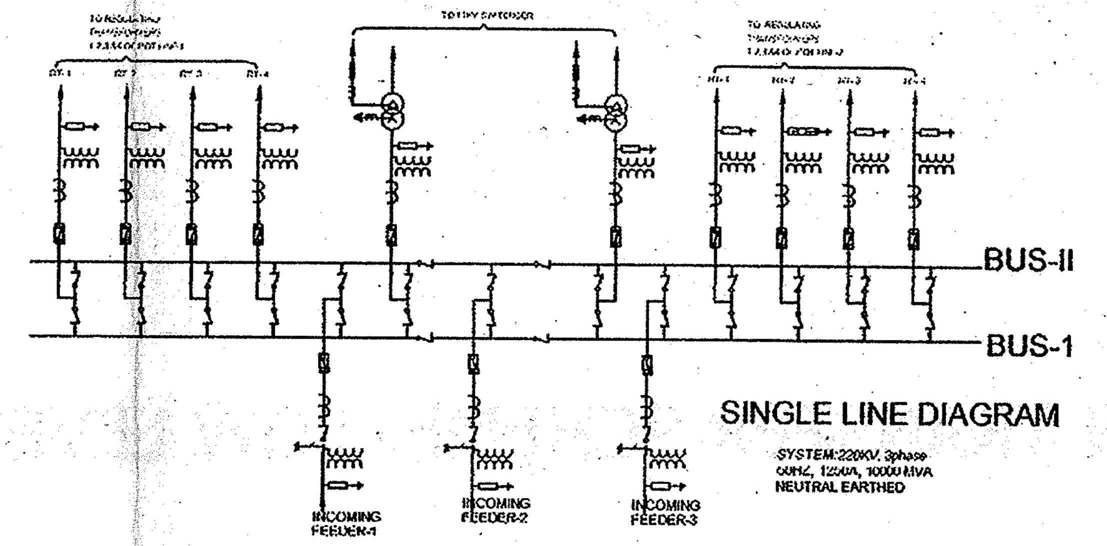
BIL- LI 1050KVp

MANUAL ON SUB STATION LAYOUT & DESIGN

ELABORATE VIEW OF SINGLE LINE DIAGRAM OF 220 KV /16M BAY WIDTH (DOUBLE MAIN TRANSFER SCHEME) LOW LEVEL TYPE

NOTE: THIS IS A PART OF FIGURE 9(c)





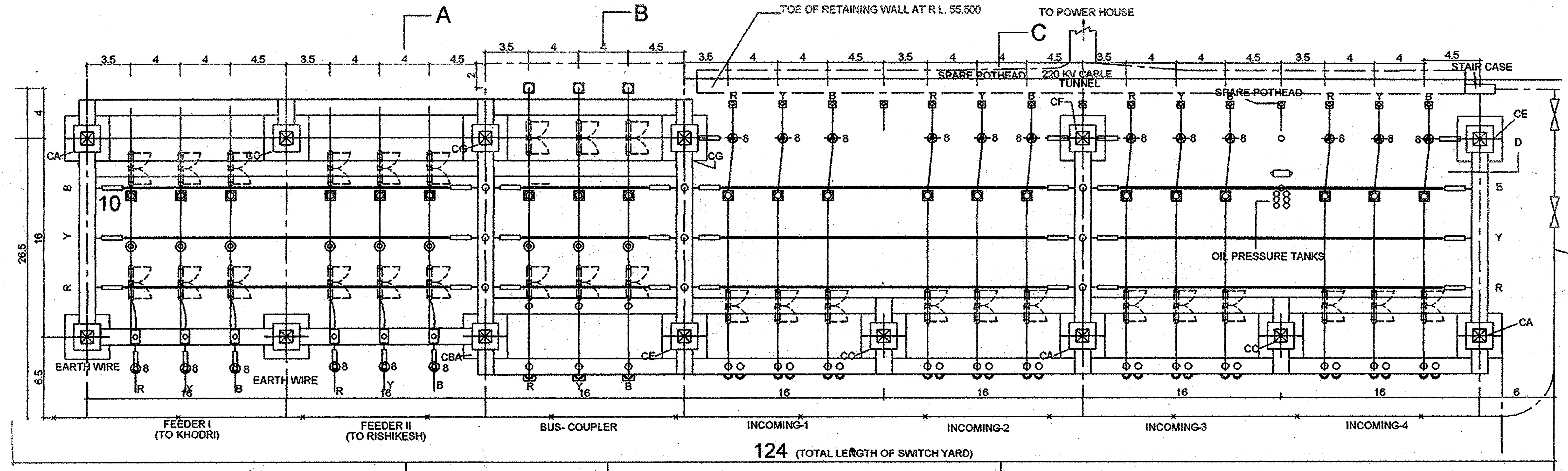
SINGLE LINE DIAGRAM

NOTE :-

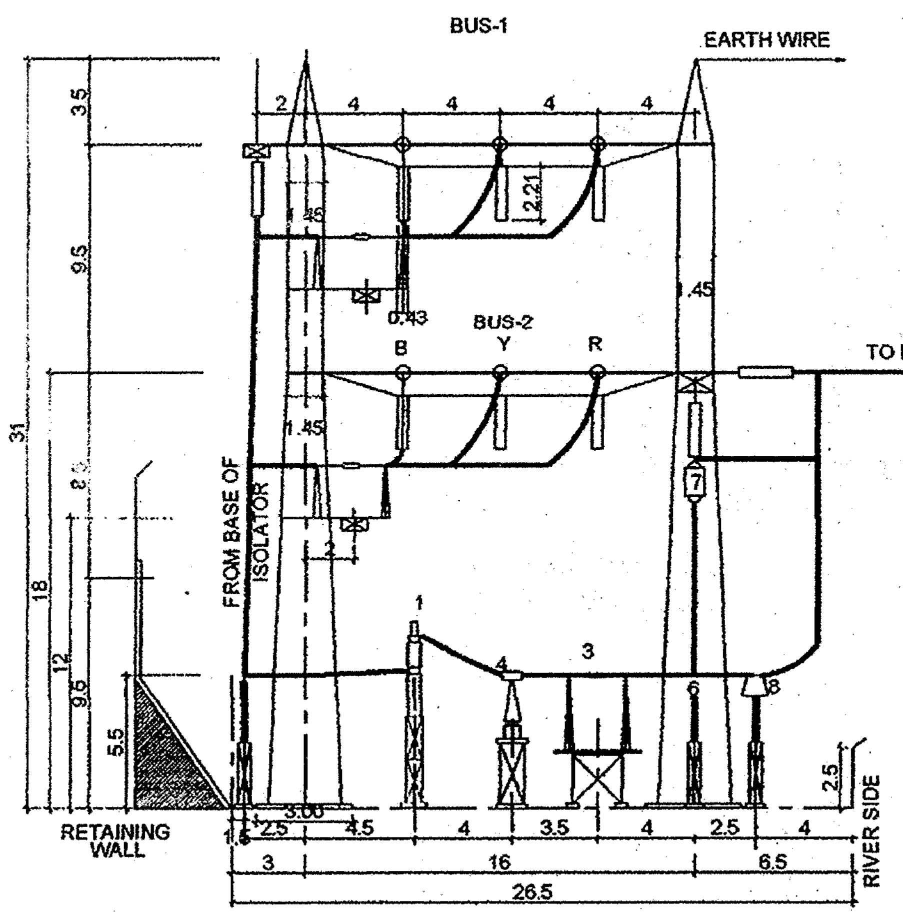
1. ALL DIMENSIONS ARE IN MM IF NOT INDICATED OTHERWISE
2. SECTIONAL FIGURES ARE GIVEN AT SHEET OF THIS DRAWING
3. INDICATE VERTICAL DOWN RUN OF EARTH WIRE ALONG THE STRUCTURE
4. POST INSULATOR STRUCTURES SHALL HAVE PROVISION FOR FITTING SCREEN

FIGURE-10A

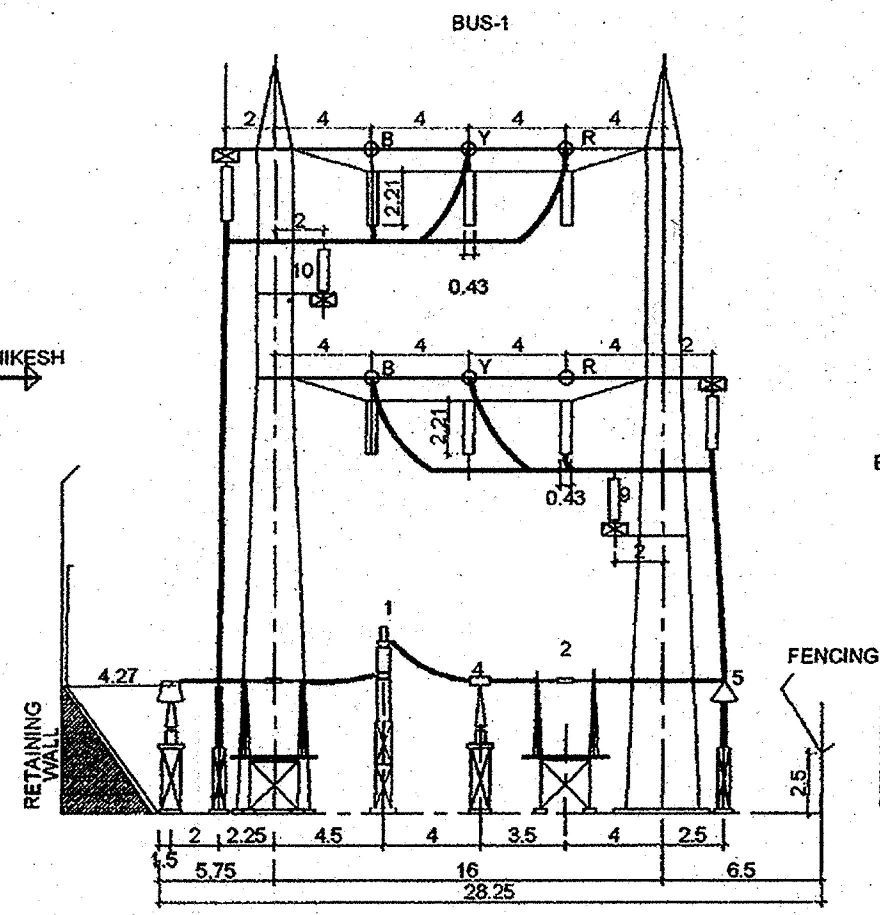
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
DOUBLE BUS ARRANGEMENT LOW LEVEL TYPE 245KV, BIL 1050KVp	
SHEET 1 OF 2	SCALE: NTS



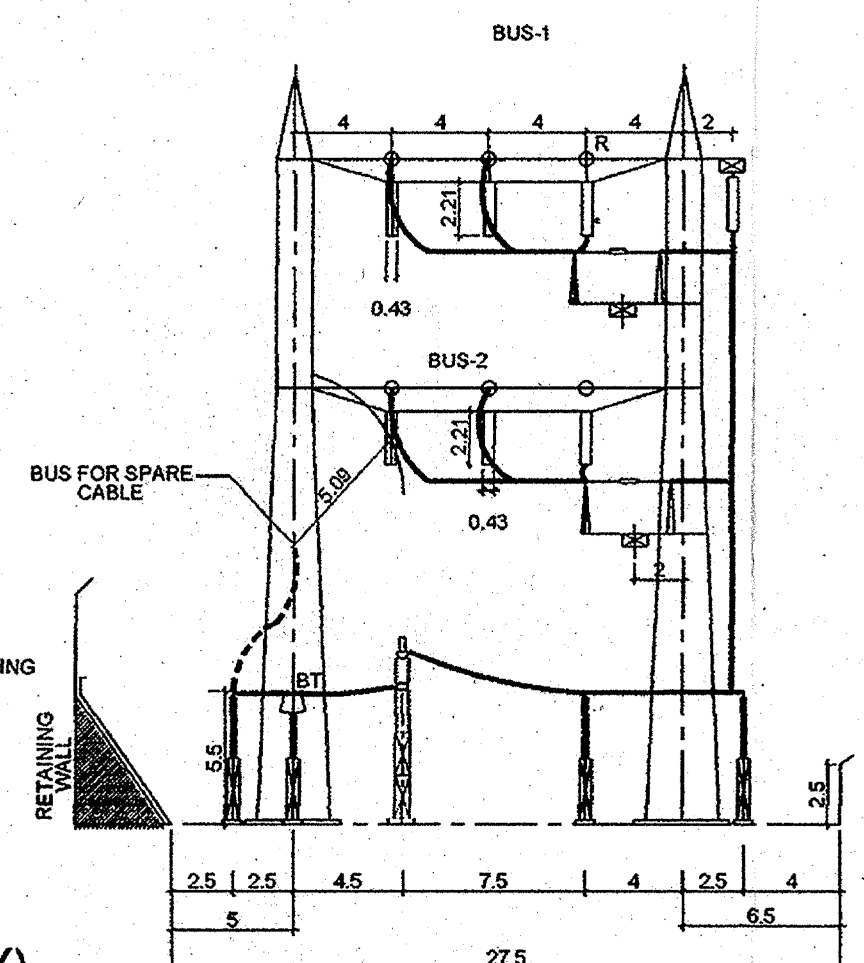
PLAN



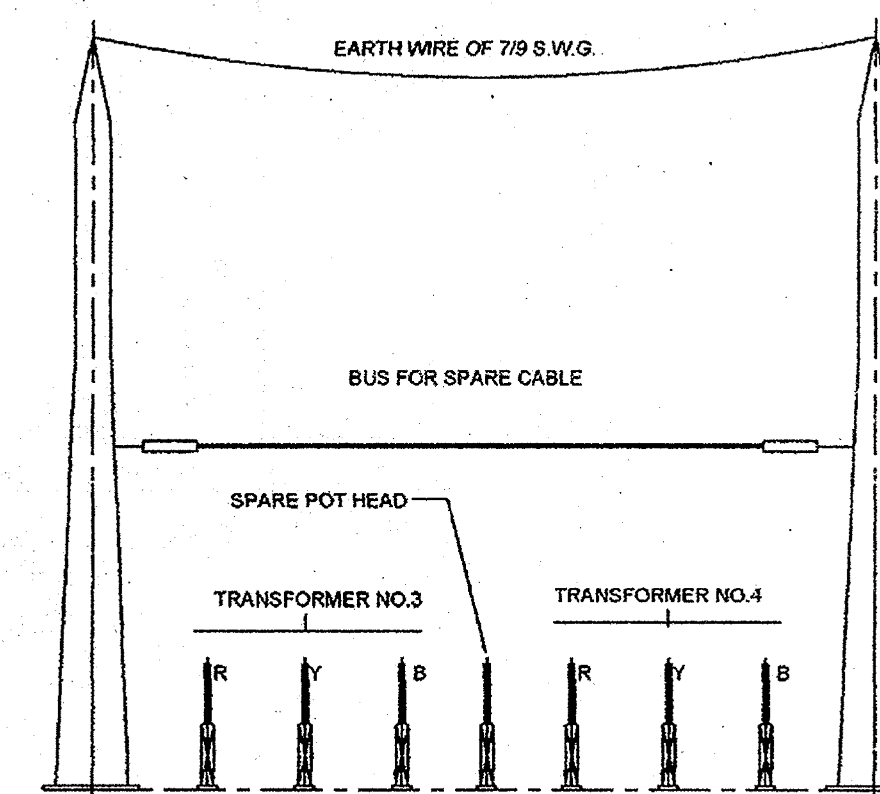
SECTION A-A (FEEDER BAY)



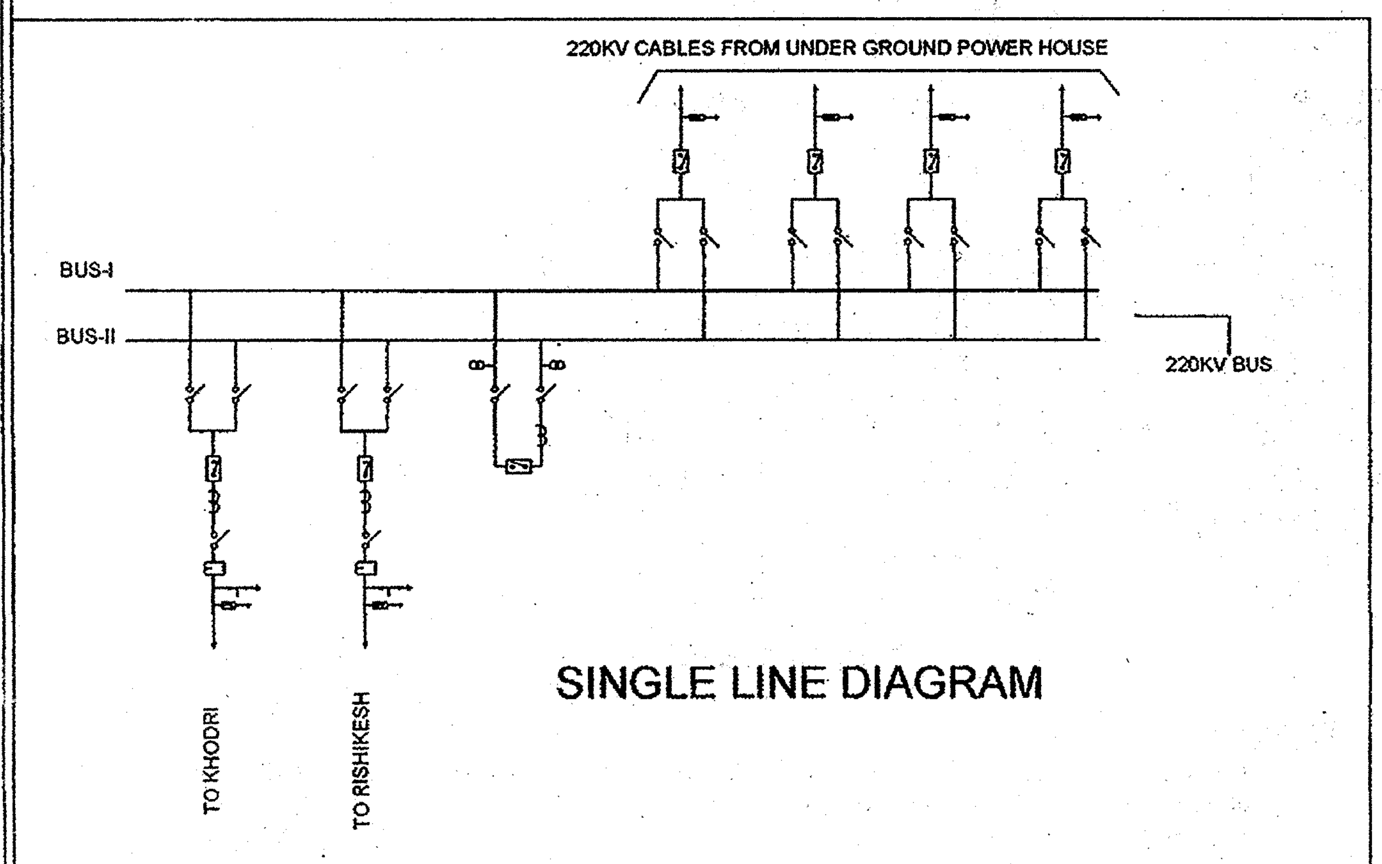
SECTION B-B (BUS COUPLER BAY)



SECTION C-C (INCOMING BAY)



SECTION D-D
(LIGHTNING ARRESTER NOT SHOWN)



SINGLE LINE DIAGRAM

CLEARANCES	
1. SAFETY CLEARANCE	
SECTION CLEARANCE	GROUND CLEARANCE
4.94 M	2.44M
2. MINIMUM CLEARANCES ADOPTED FOR 1050 (KV) (CREST) IMPULSE WITHSTAND VOLTAGE	
PHASE TO PHASE	PHASE TO EARTH
2.338 M	2.087 M

1 CB
2 ISO
3 ISO WITH E/S
4 CT
5 PT
6 COUPLING CAPACITOR
7 WAVE TRAP
8 LA
9 PI
10 INVERTED PI

NOTE:

1. REFERENCE GROUND LEVEL 554.85
2. THE MAIN BUSES ARE OF ALL ALLUMINUM 0.75 SQ. INCH COPPER EQUIVALENT, TARANTULA CONDUCTOR. ALL THE JUMPERS ARE OF ACSR 0.4 SQ. INCH DEER CONDUCTOR EXCEPT FOR BUS COUPLER BAY WHERE THESE WILL BE OF TARANTULA. BUS FOR SPARE CABLE SHALL BE OF DEER CONDUCTOR.

(ALL DIMENSIONS ARE IN METRES UNLESS MENTIONED OTHERWISE)

FIGURE-10B

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
DOUBLE BUS ARRANGEMENT (HIGH LEVEL TYPE) 245KV, BIL 1050 KVp	
SHEET 1 OF 1	SCALE: NTS

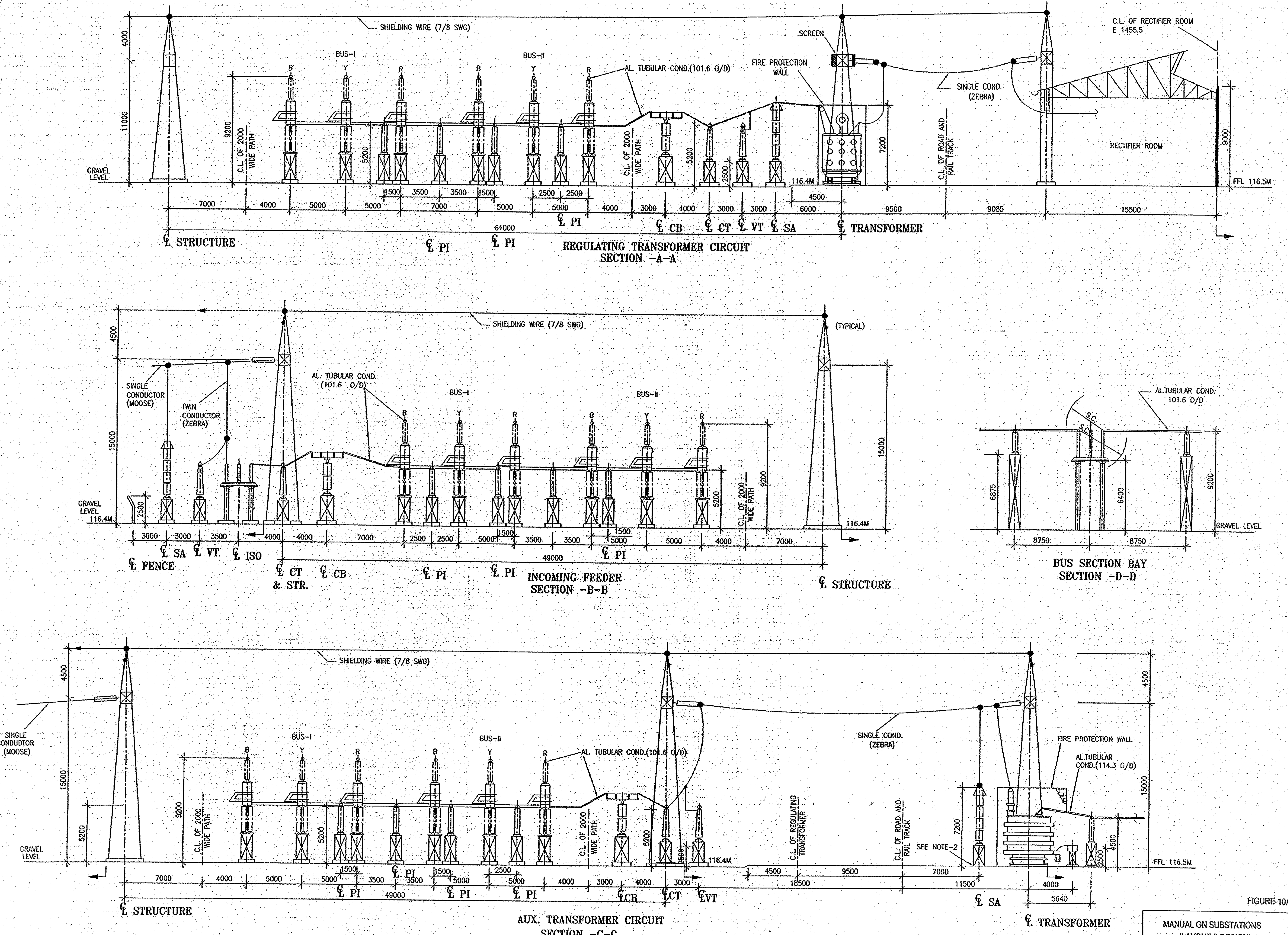
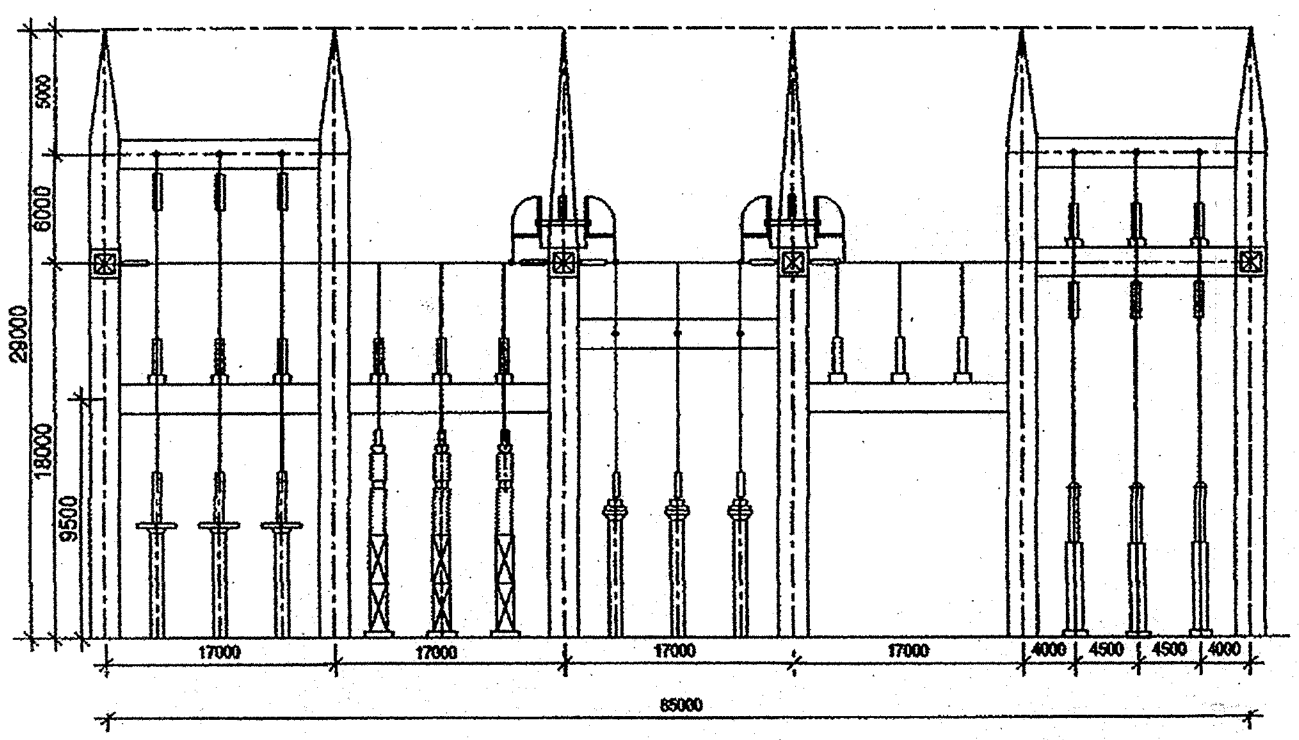


FIGURE-10A

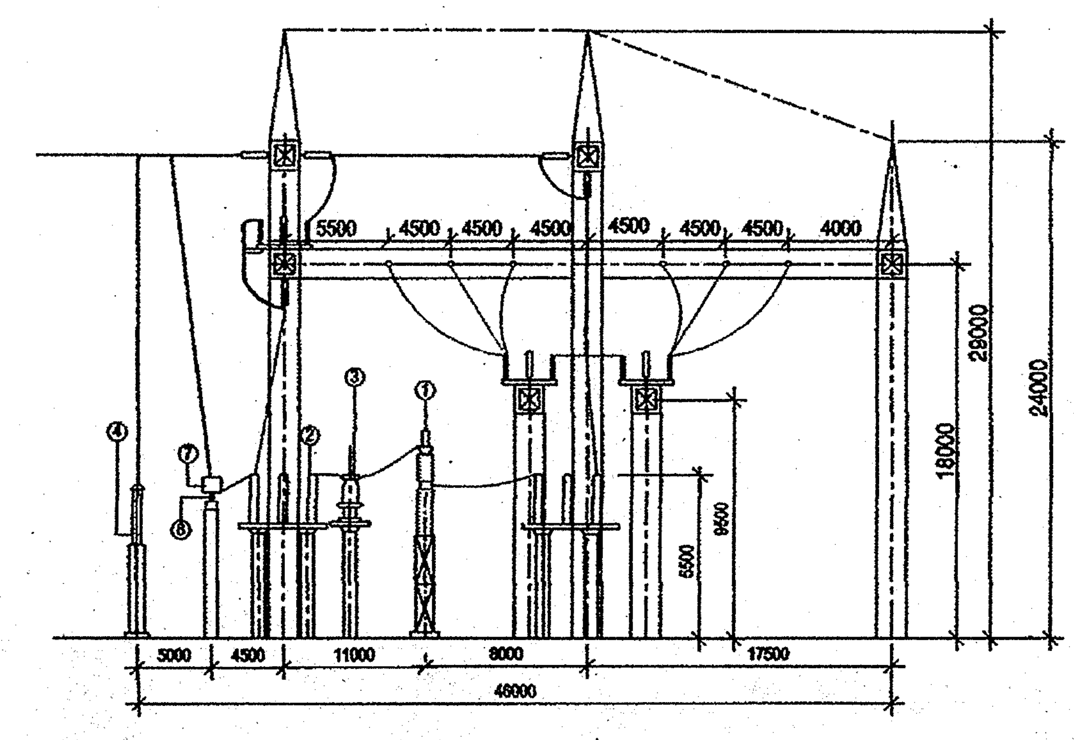
NOTES:-

1. SHIELD WIRE STRUCTURE CLAMP SHALL BE AT 1M INTERVAL
2. THE FOUNDATION OF LIGHTNING ARRASTERS SHALL BE MADE FLUSH WITH THE RAIL TRACK TO FACILITATE THE EASY REMOVAL OF THE AUX. TRANSFORMER
3. ALL DIMENSIONS ARE IN MM IF NOT INDICATED OTHERWISE

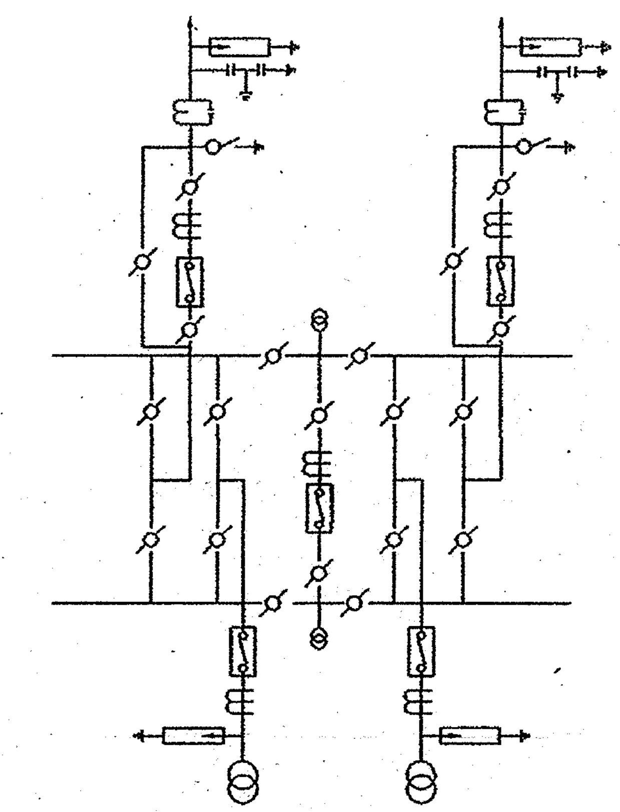
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
DOUBLE BUS ARRANGEMENT LOW LEVEL TYPE 245KV, BIL 1050KVp	
SHEET 2 OF 2	SCALE: NTS



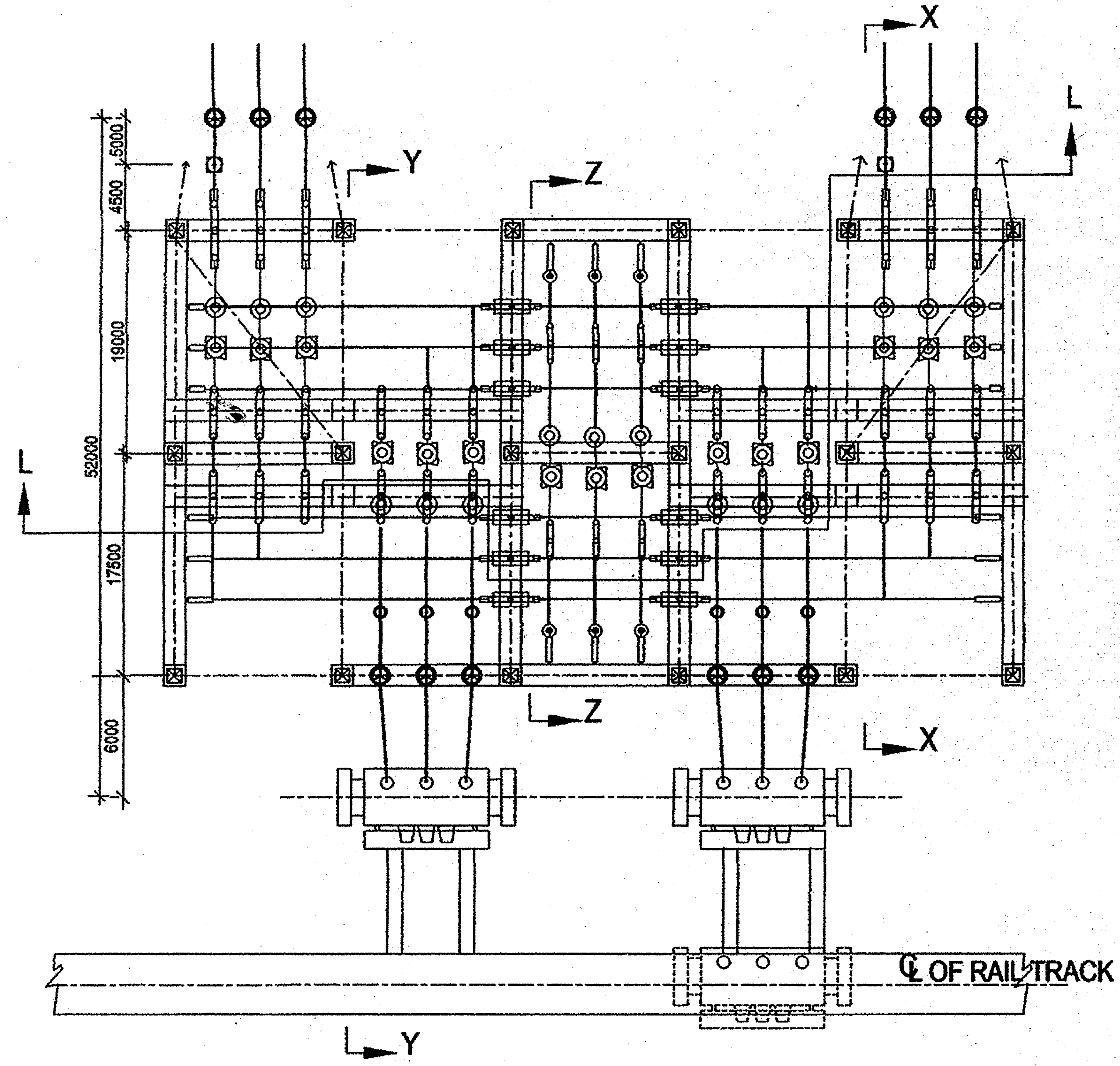
SECTION AT L-L



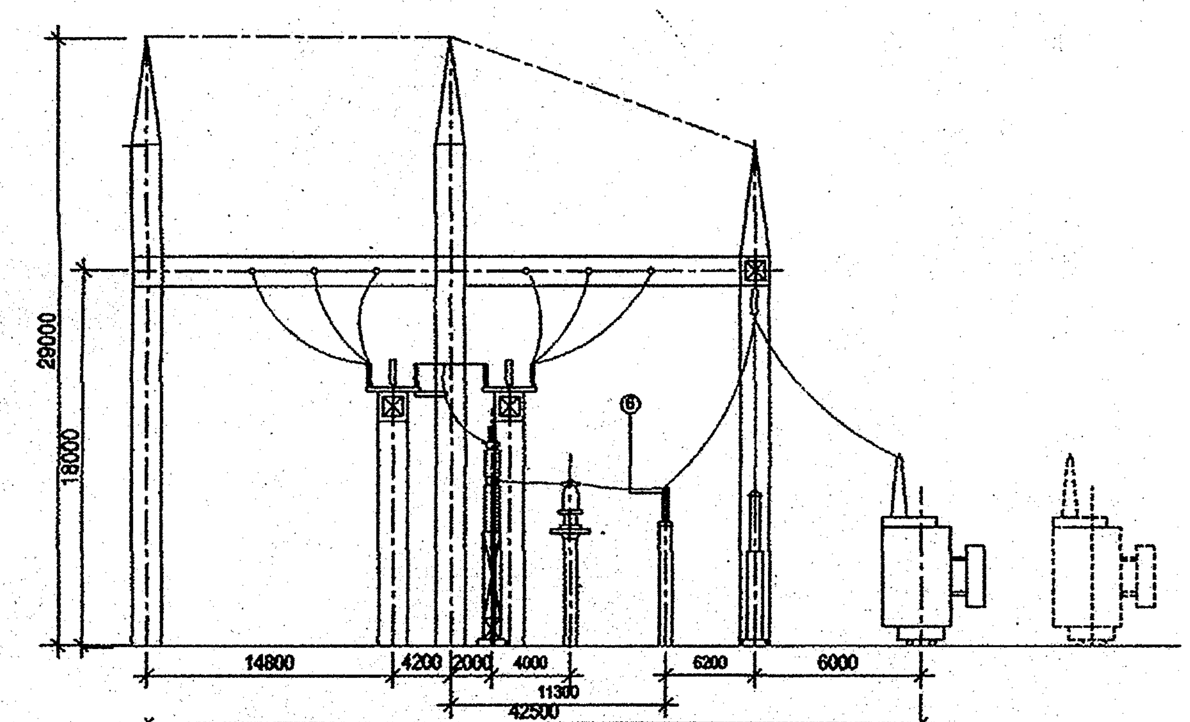
SECTION AT X-X (LINE BAY)



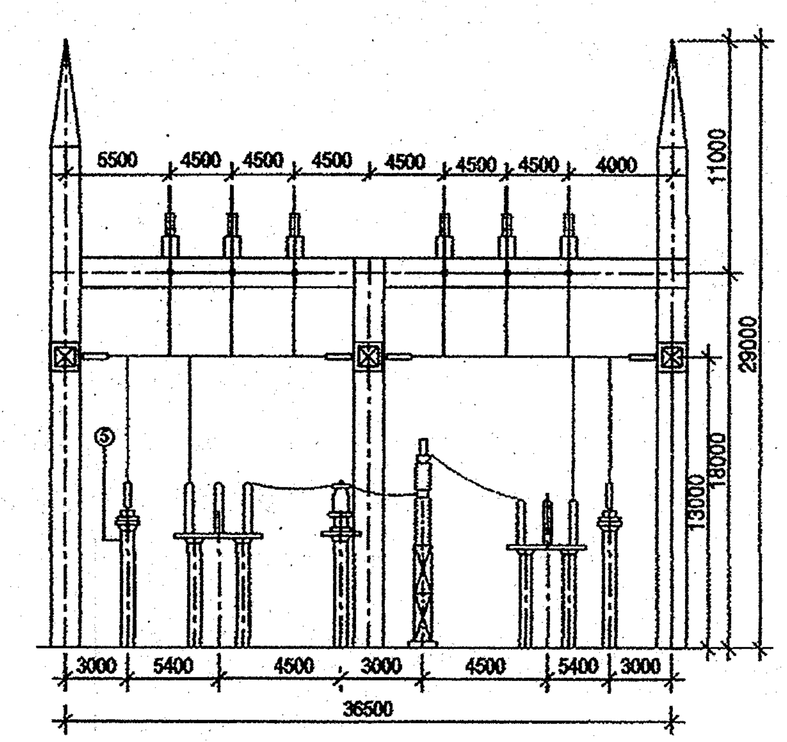
SINGLE LINE DIAGRAM



PLAN



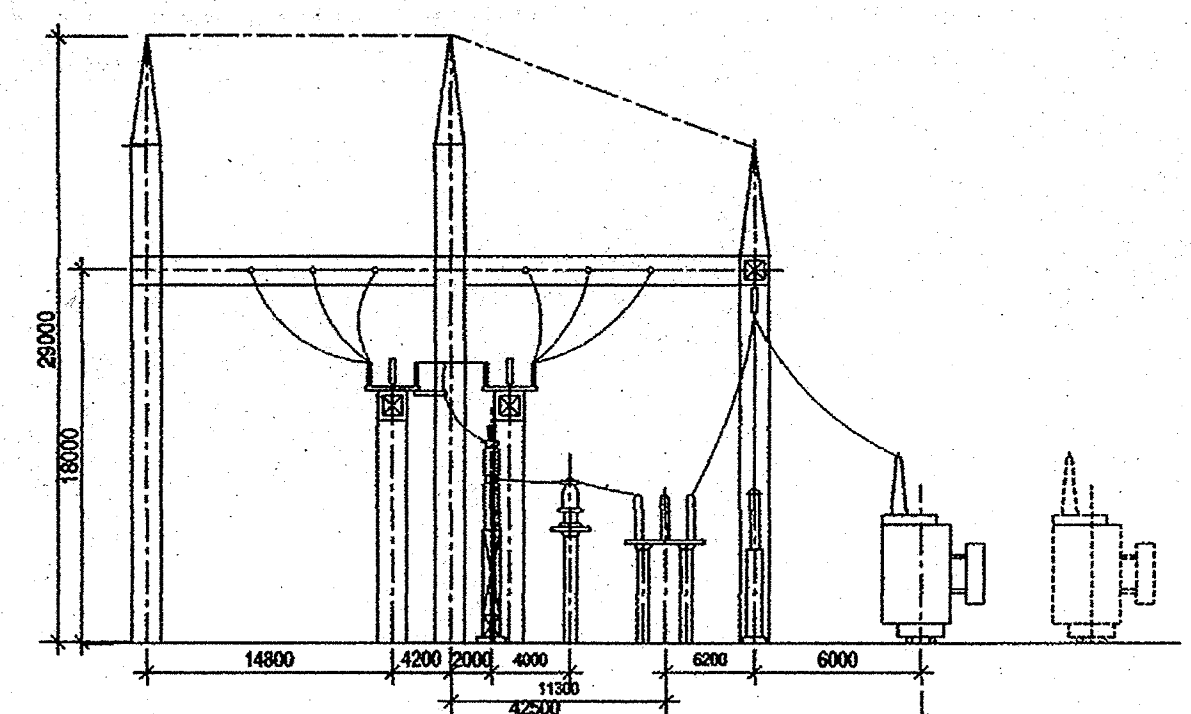
SECTION AT Y-Y(TRANSFORMER BAY)



SECTION AT Z-Z (BUS COUPLER BAY)

LEGEND

1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. LIGHTNING ARRESTER
5. POTENTIAL TRANSFORMER
6. POST INSULATOR
7. WAVETRAP
8. COUPLING CAPACITOR WITH POTENTIAL DEVICE



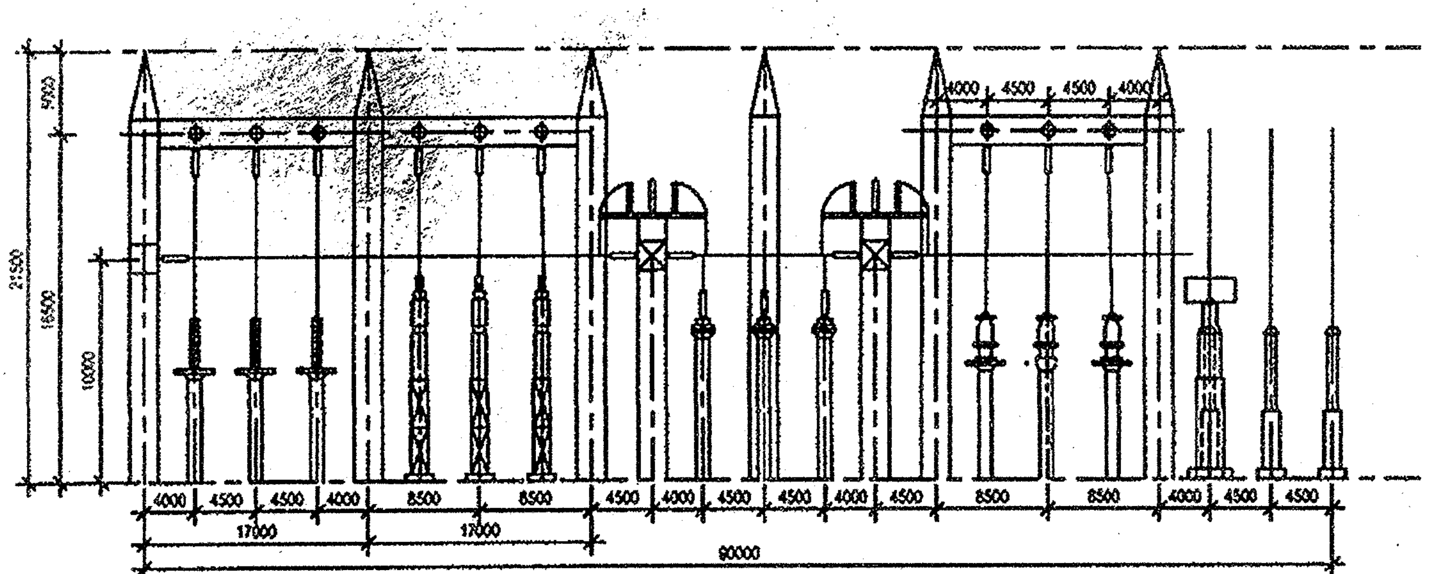
SECTION AT Y'-Y'(TRANSFORMER BAY)

NOTE

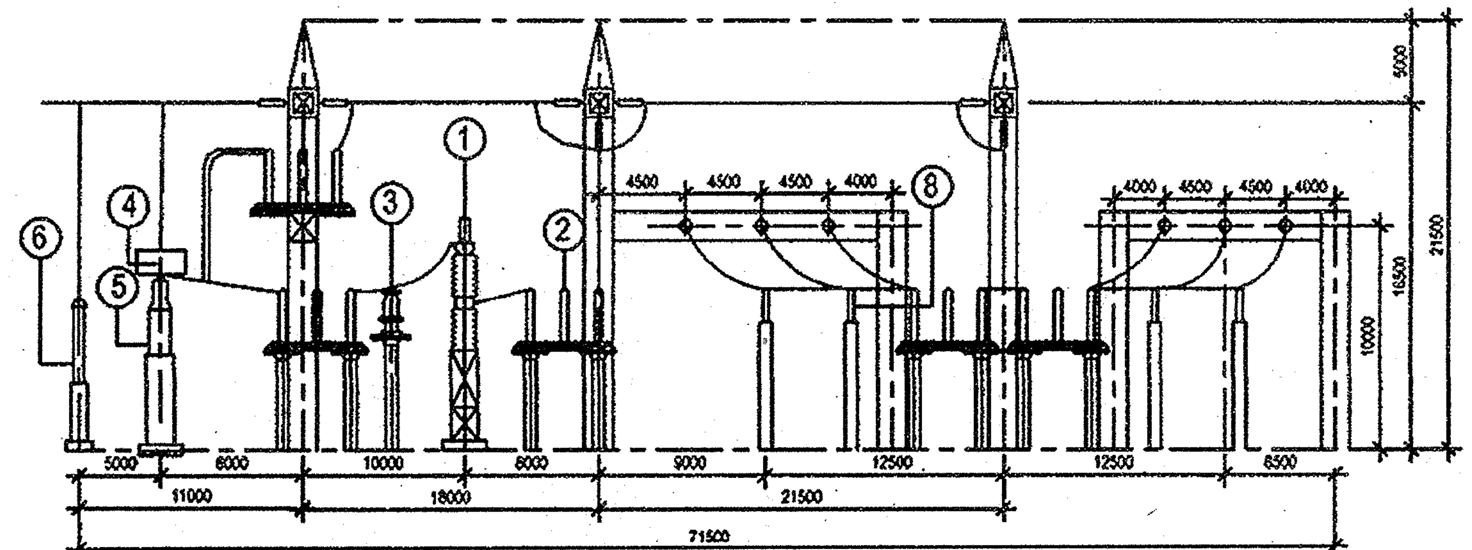
1. REPLACE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT.
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-10C

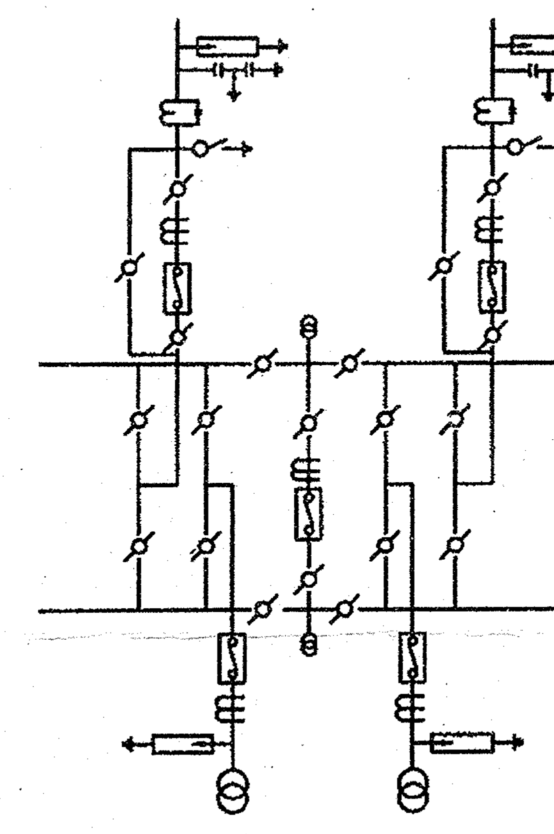
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
DOUBLE BUS ARRANGEMENT (HIGH LEVEL TYPE) 245KV, BIL 1050 KVp		
	SHEET 1 OF 1	SCALE: NTS



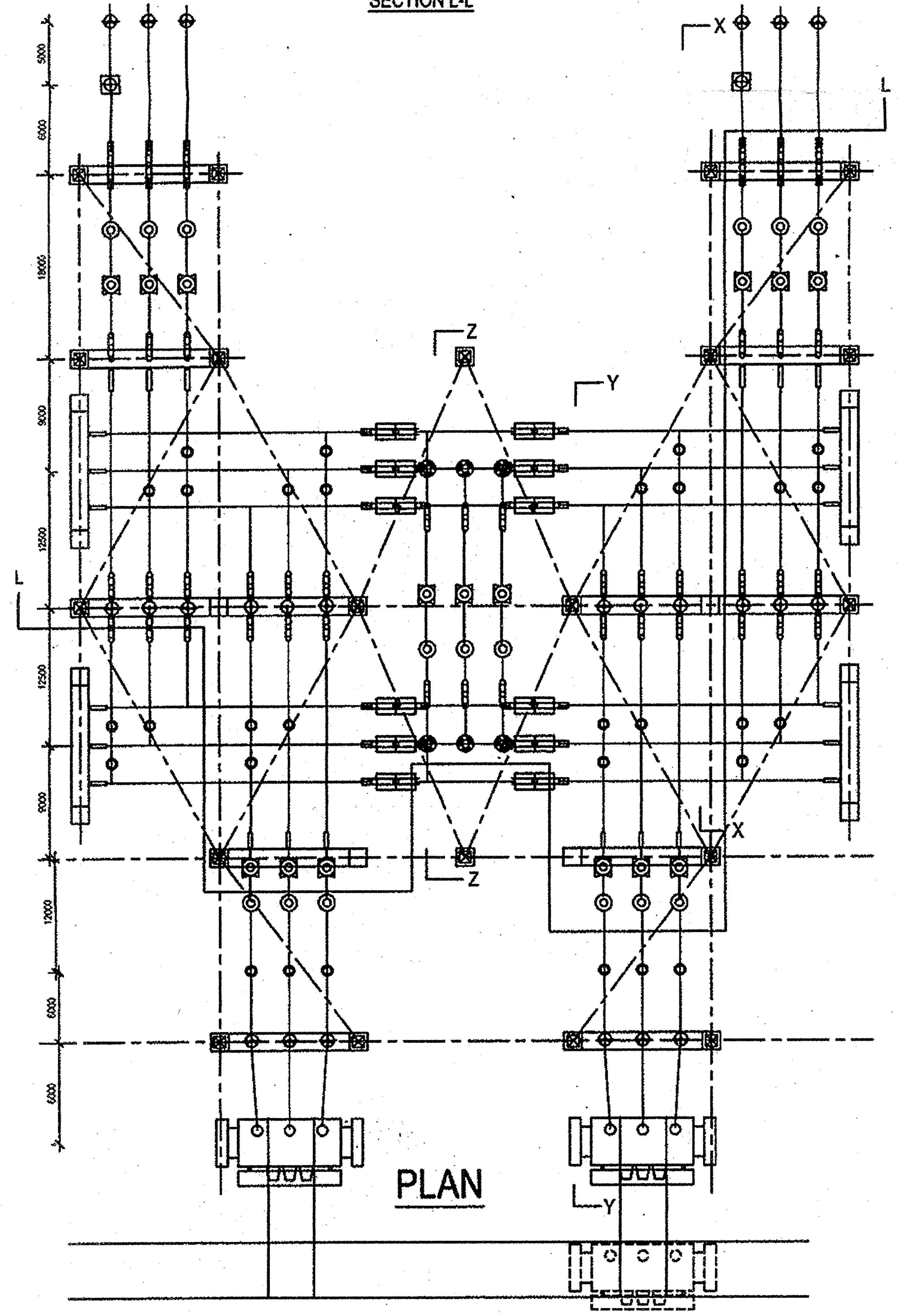
SECTION L-L



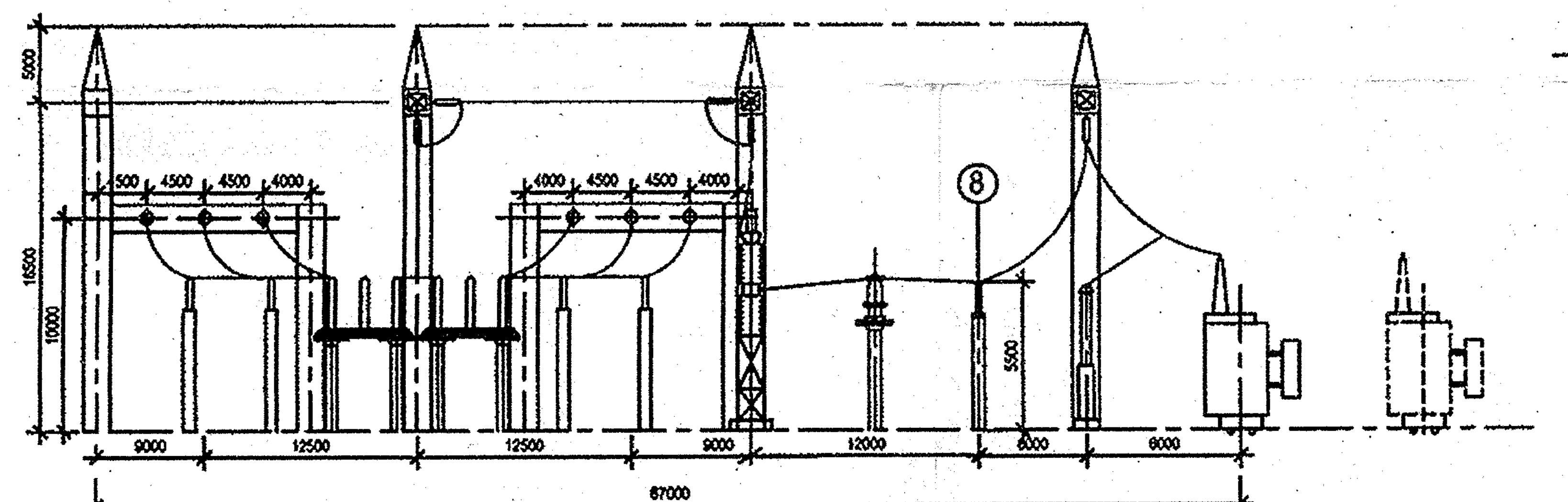
SECTION X-X (LINE BAY)



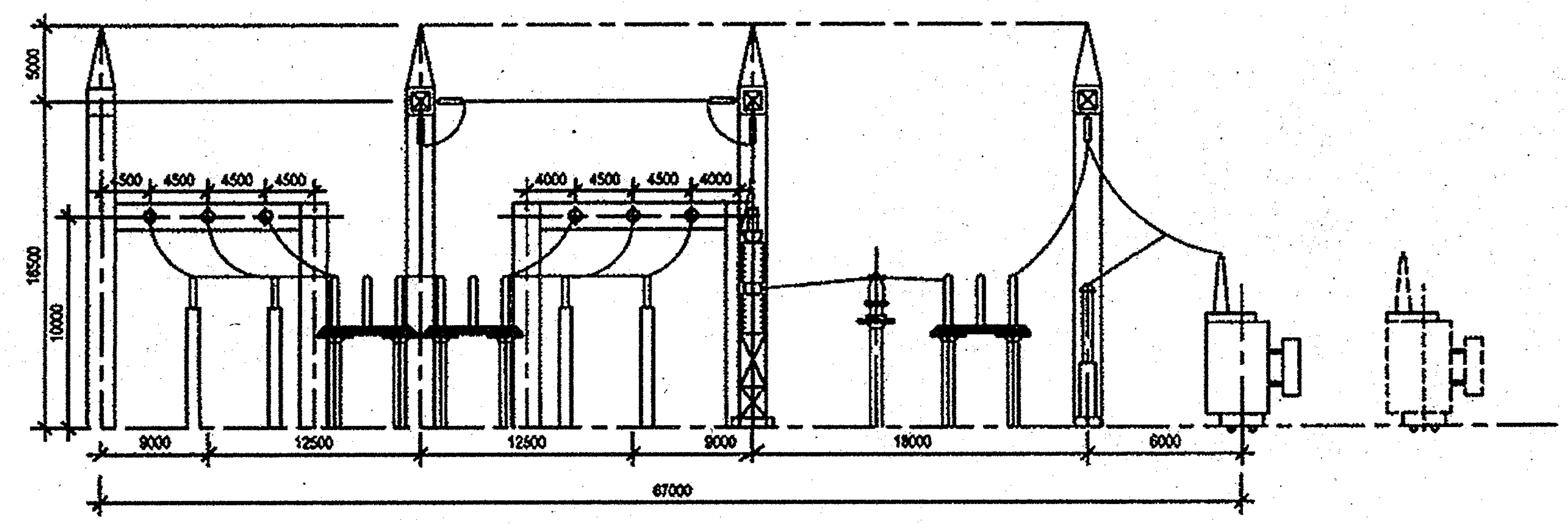
SINGLE LINE DIAGRAM



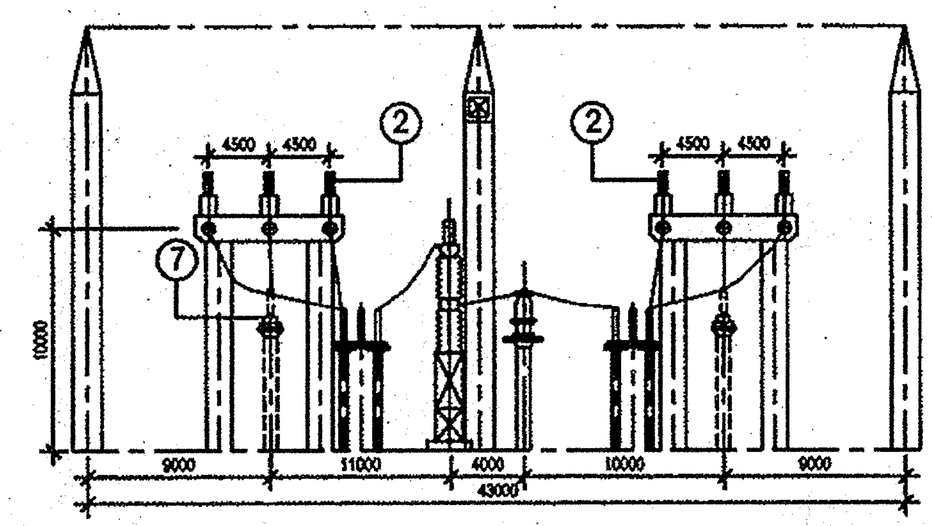
PLAN



SECTION Y-Y (TRANSFORMER BAY)



SECTION Y'-Y'(TRANFORMER BAY)



SECTION Z-Z (BUS COUPLER BAY)

LEGEND

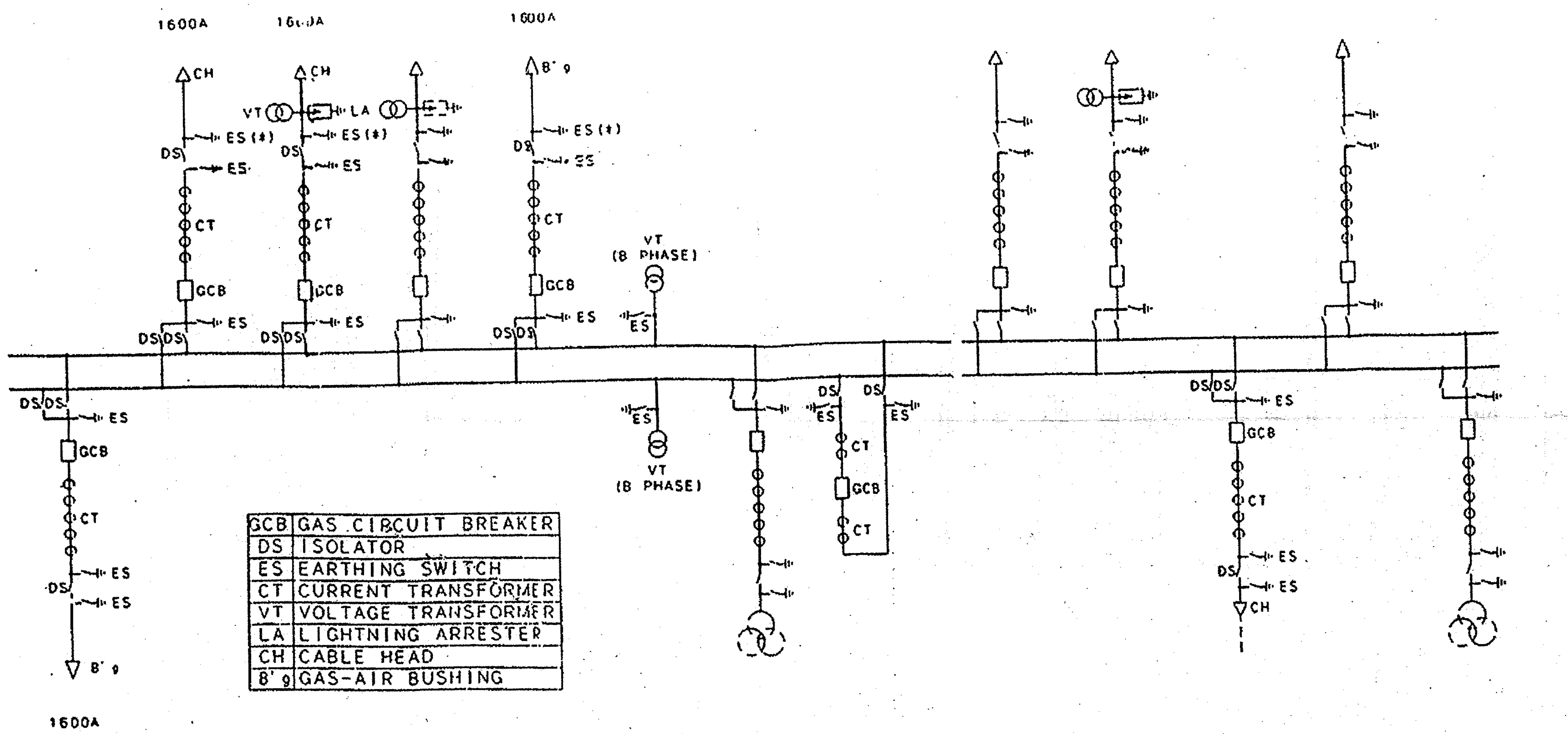
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. WAVE TRAP
5. COUPLING CAPACITOR WITH POTENTIAL TRANSFORMER
6. LIGHTNING ARRESTER
7. POTENTIAL TRANSFORMER
8. POST INSULATOR

NOTE

1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-11

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
DOUBLE BUS ARRANGEMENT (LOW LEVEL TYPE) 245 KV, BIL 1050 KVp	
SHEET 1 OF 1	SCALE: NTS



SINGLE LINE DIAGRAM

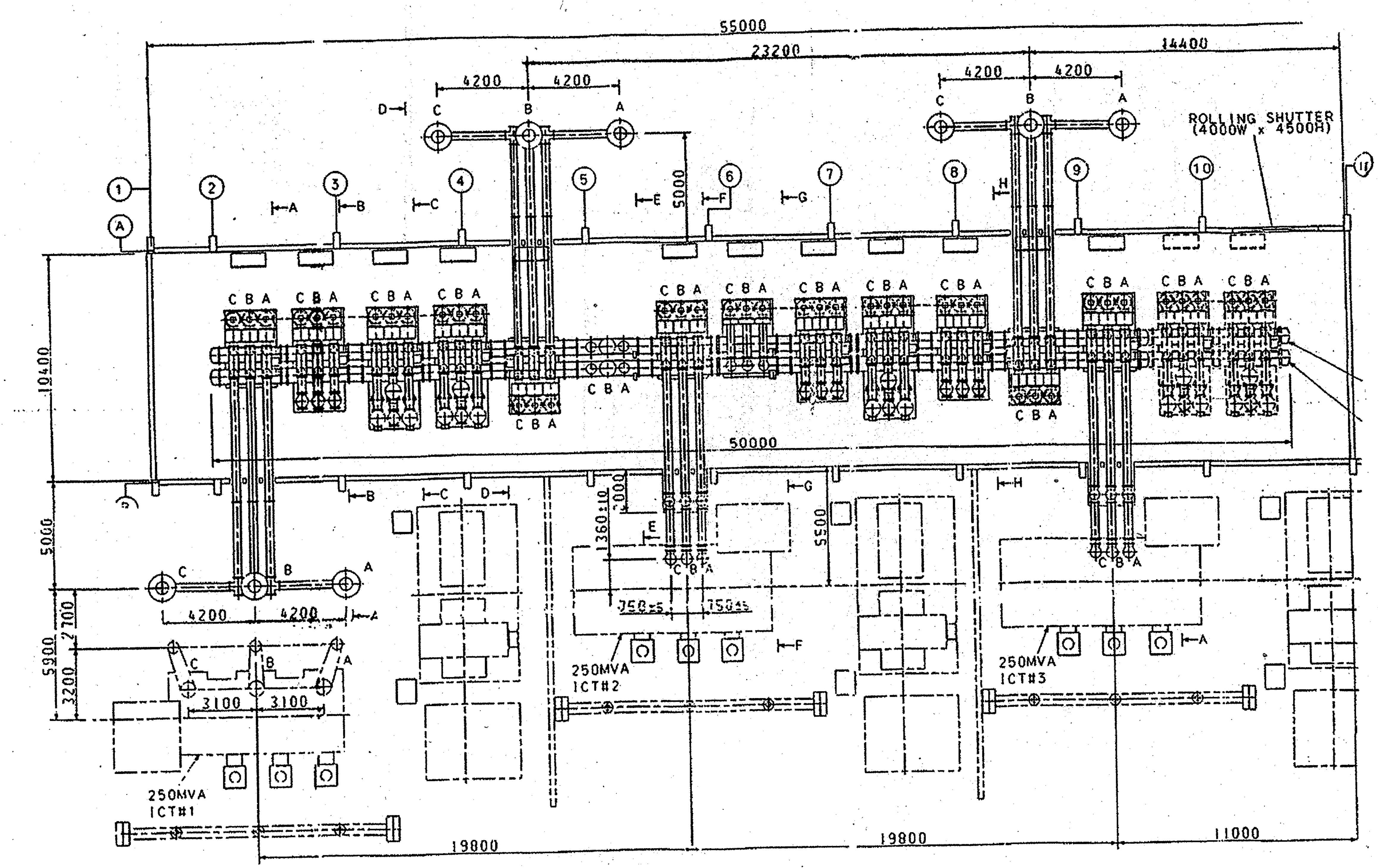
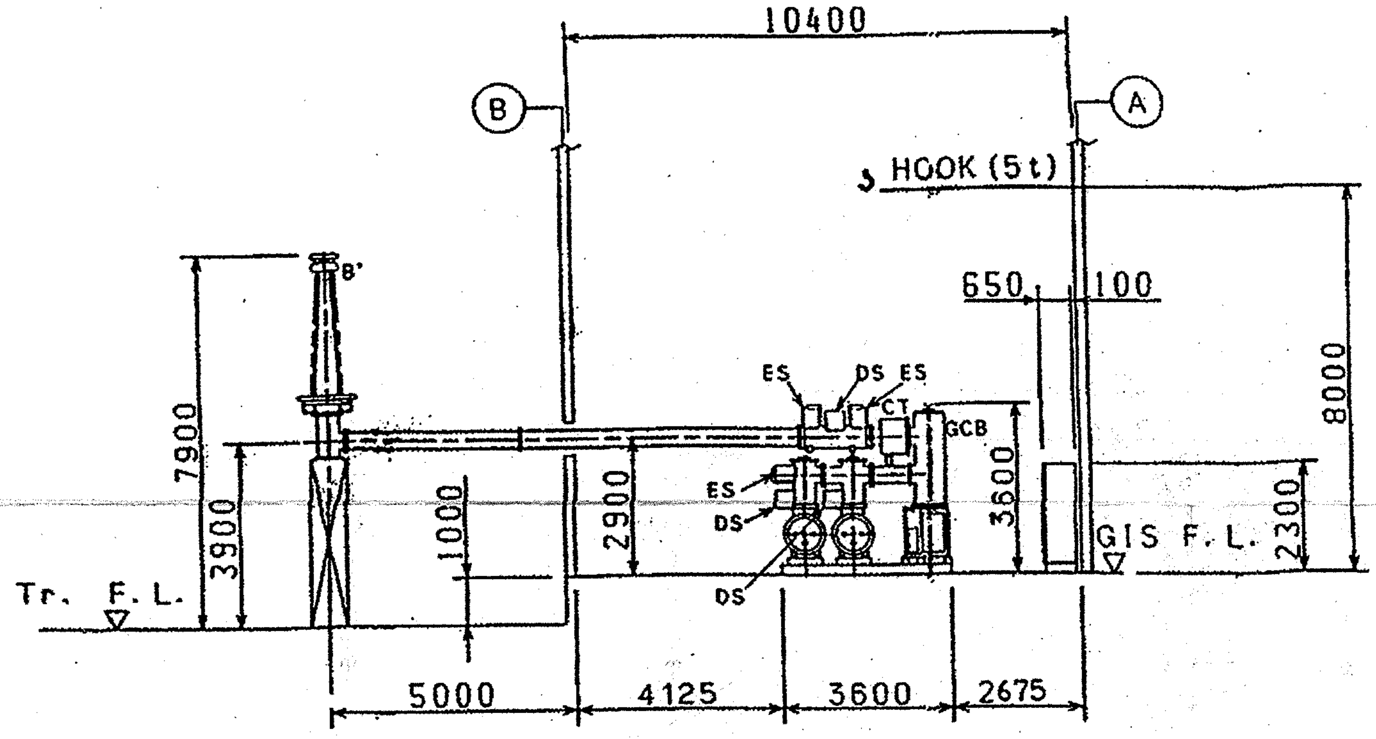
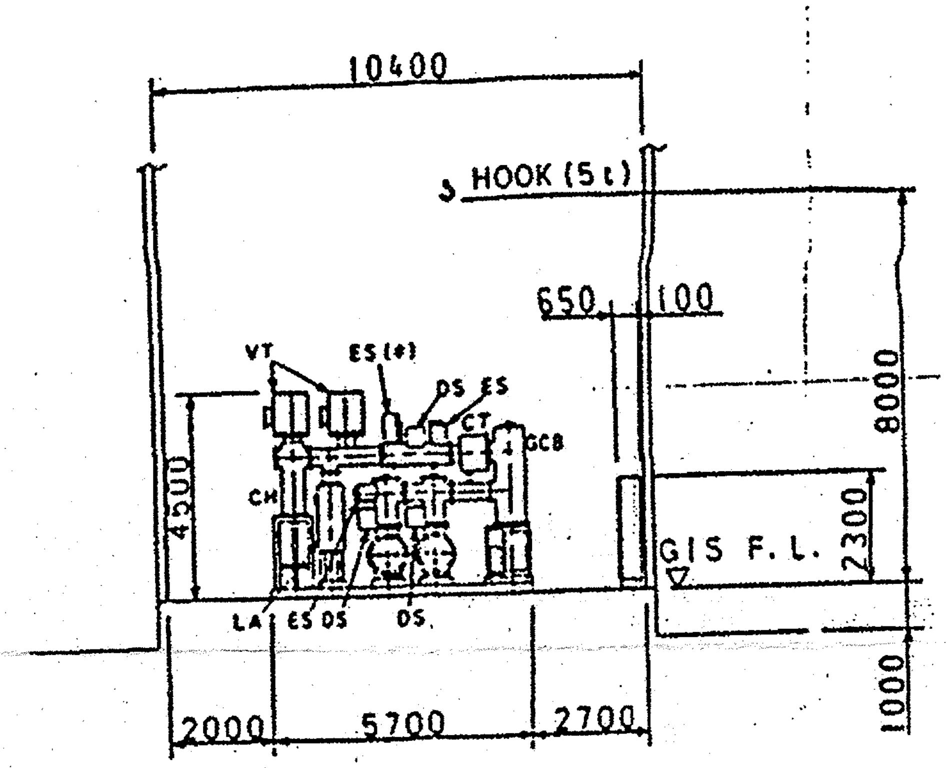


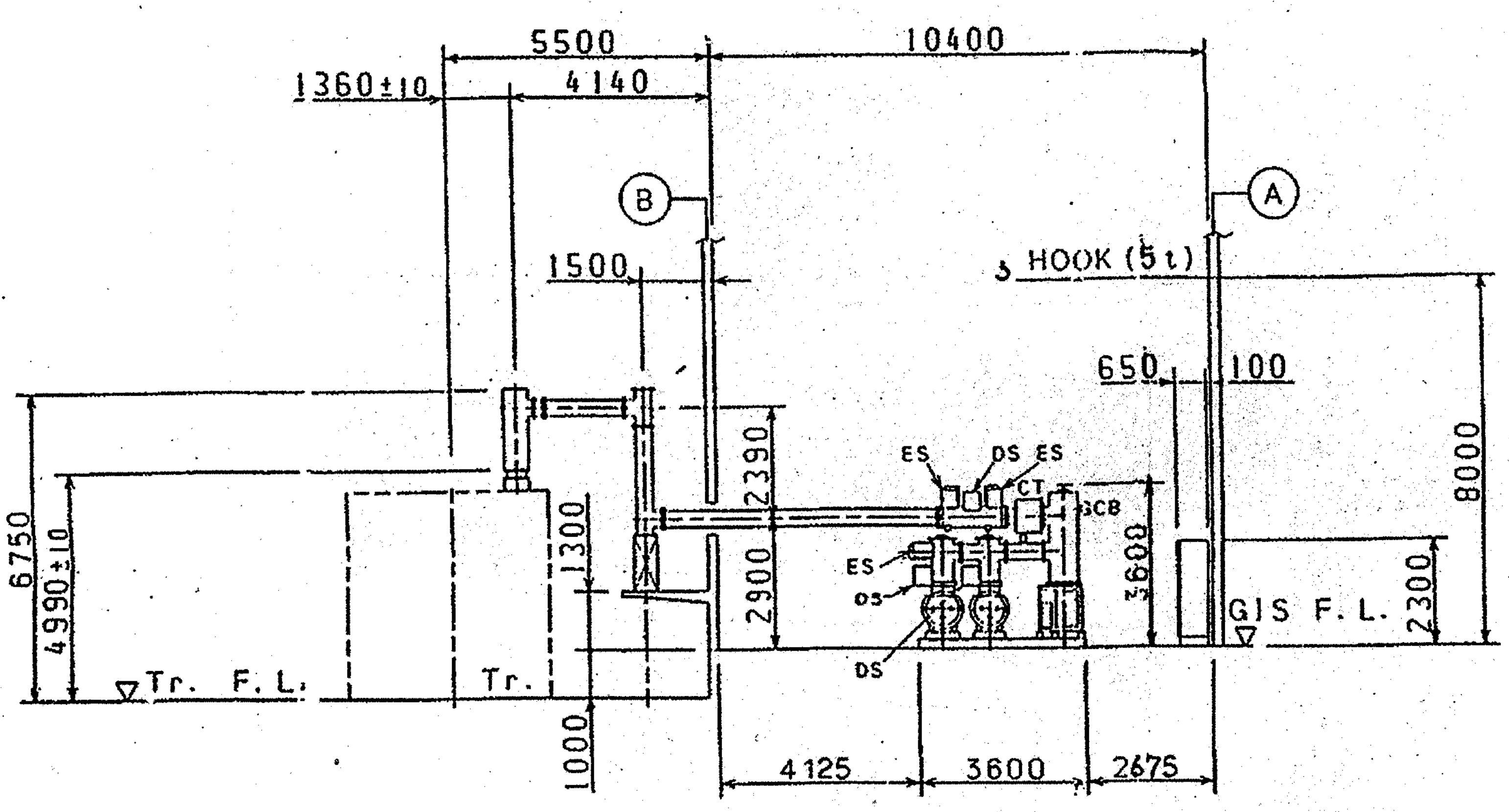
FIGURE-12A



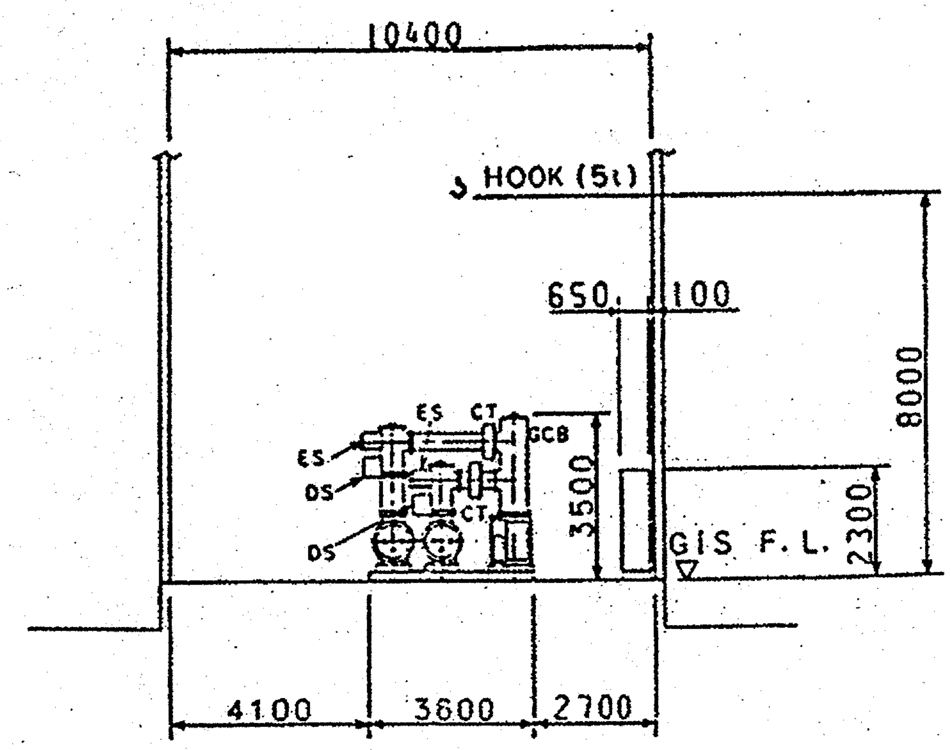
VIEW A-A



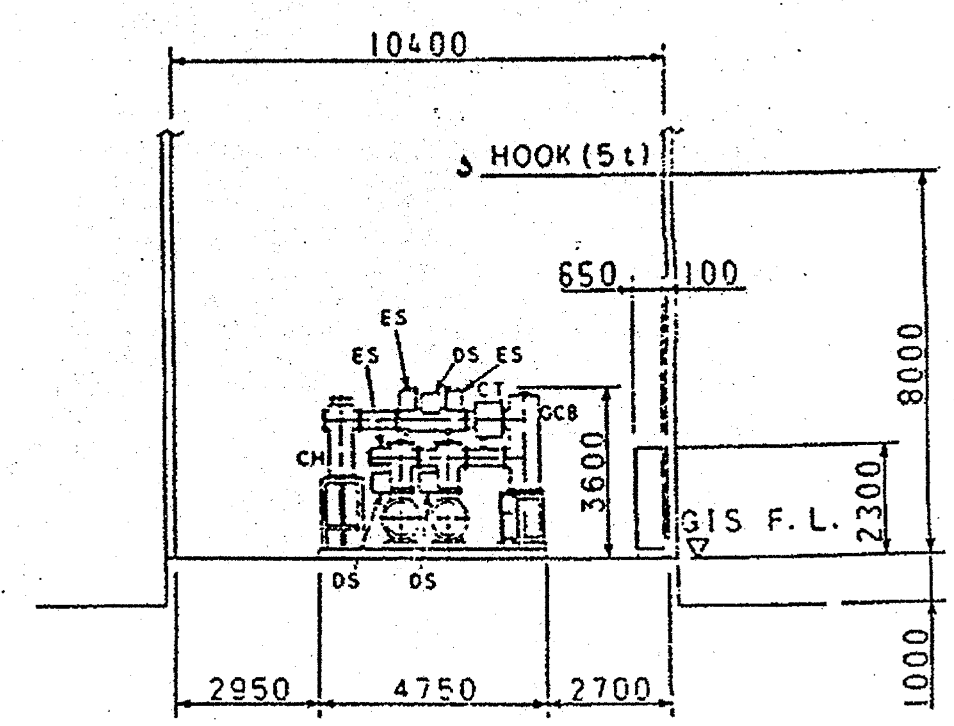
VIEW C-C



VIEW F-F

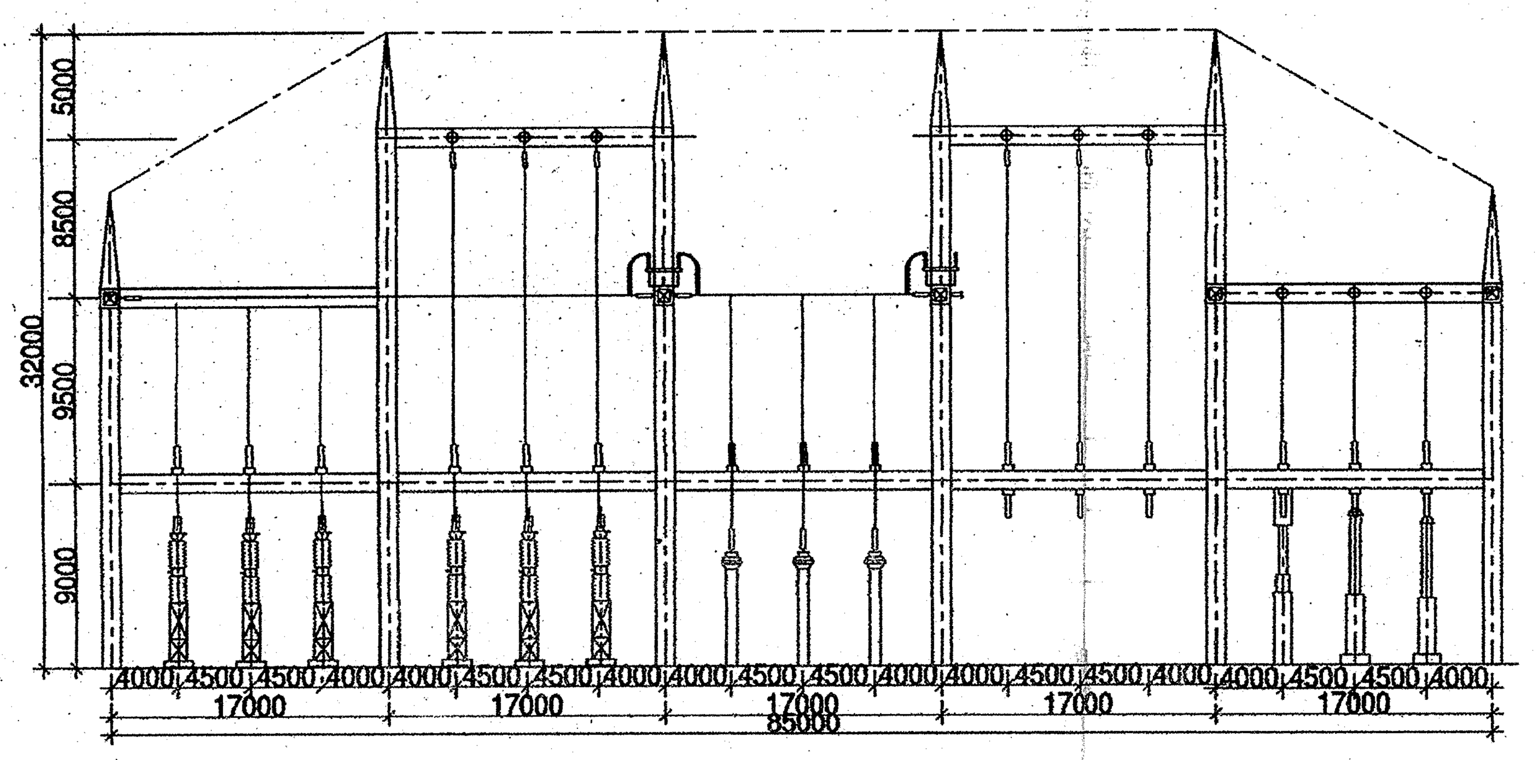


VIEW G-G

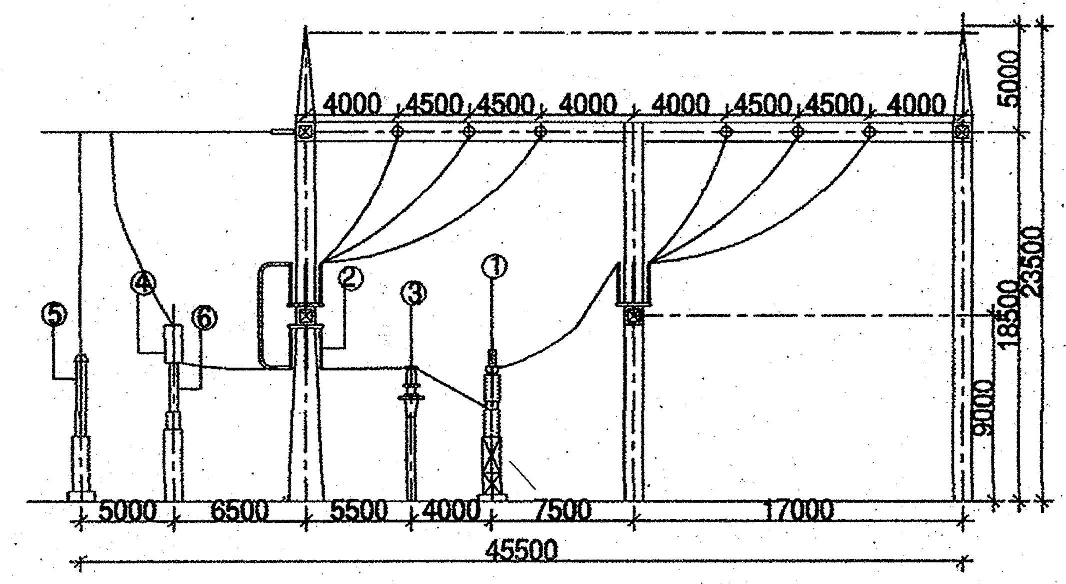


VIEW H-H

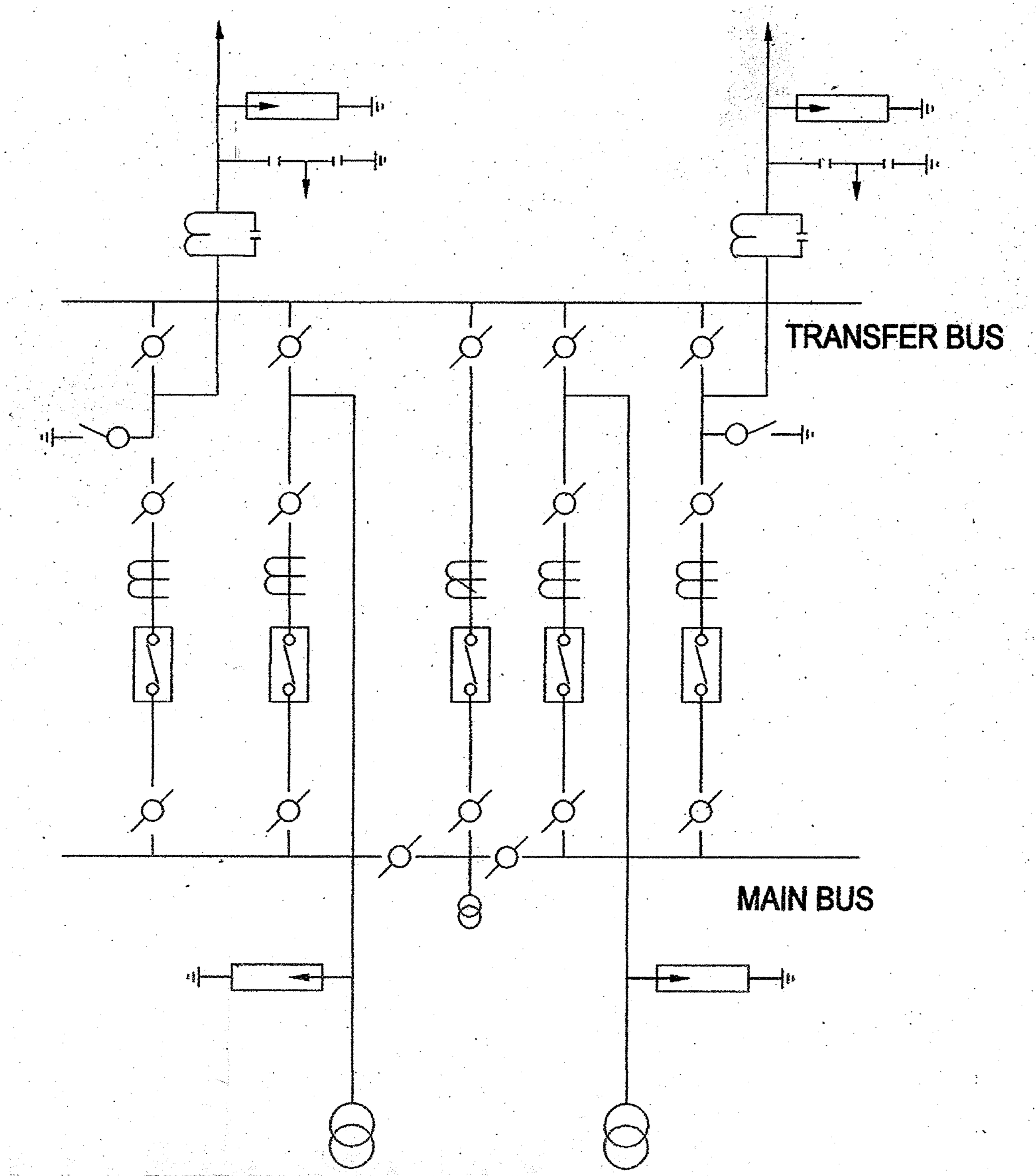
FIGURE-12B



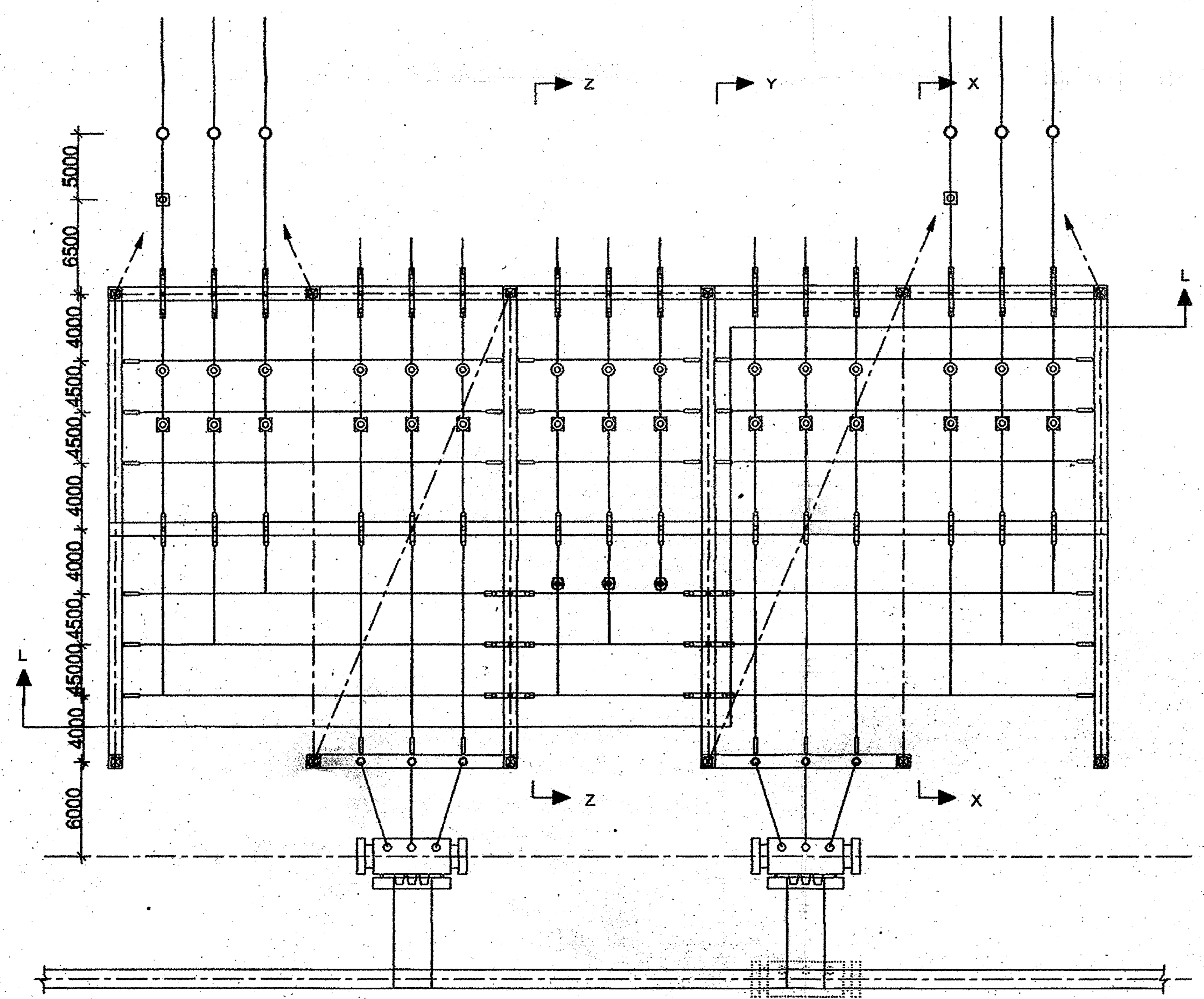
SECTION L-L



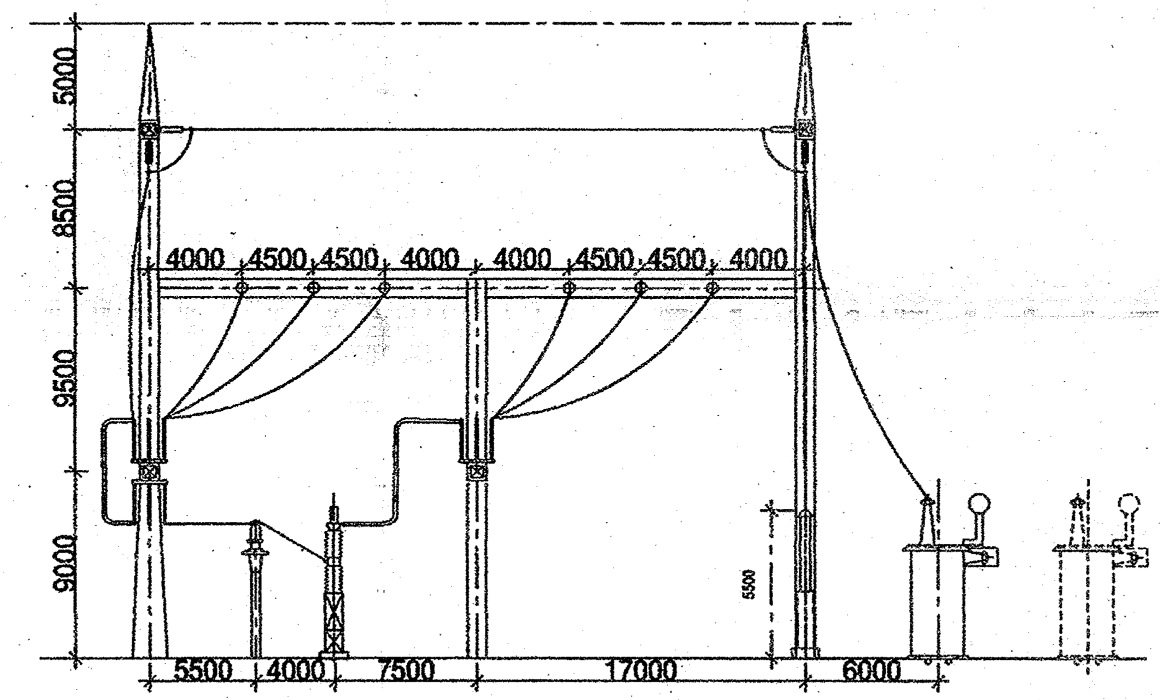
SECTION X-X (LINE BAY)



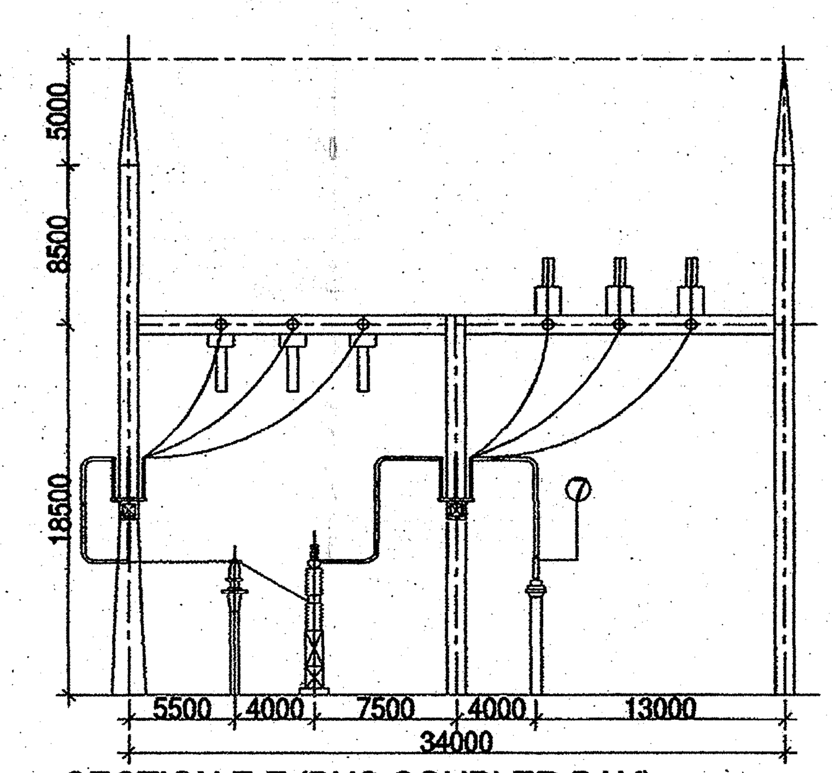
SINGLE LINE DIAGRAM



PLAN



SECTION Y-Y (TRANSFORMER BAY)



SECTION Z-Z (BUS COUPLER BAY)

LEGEND

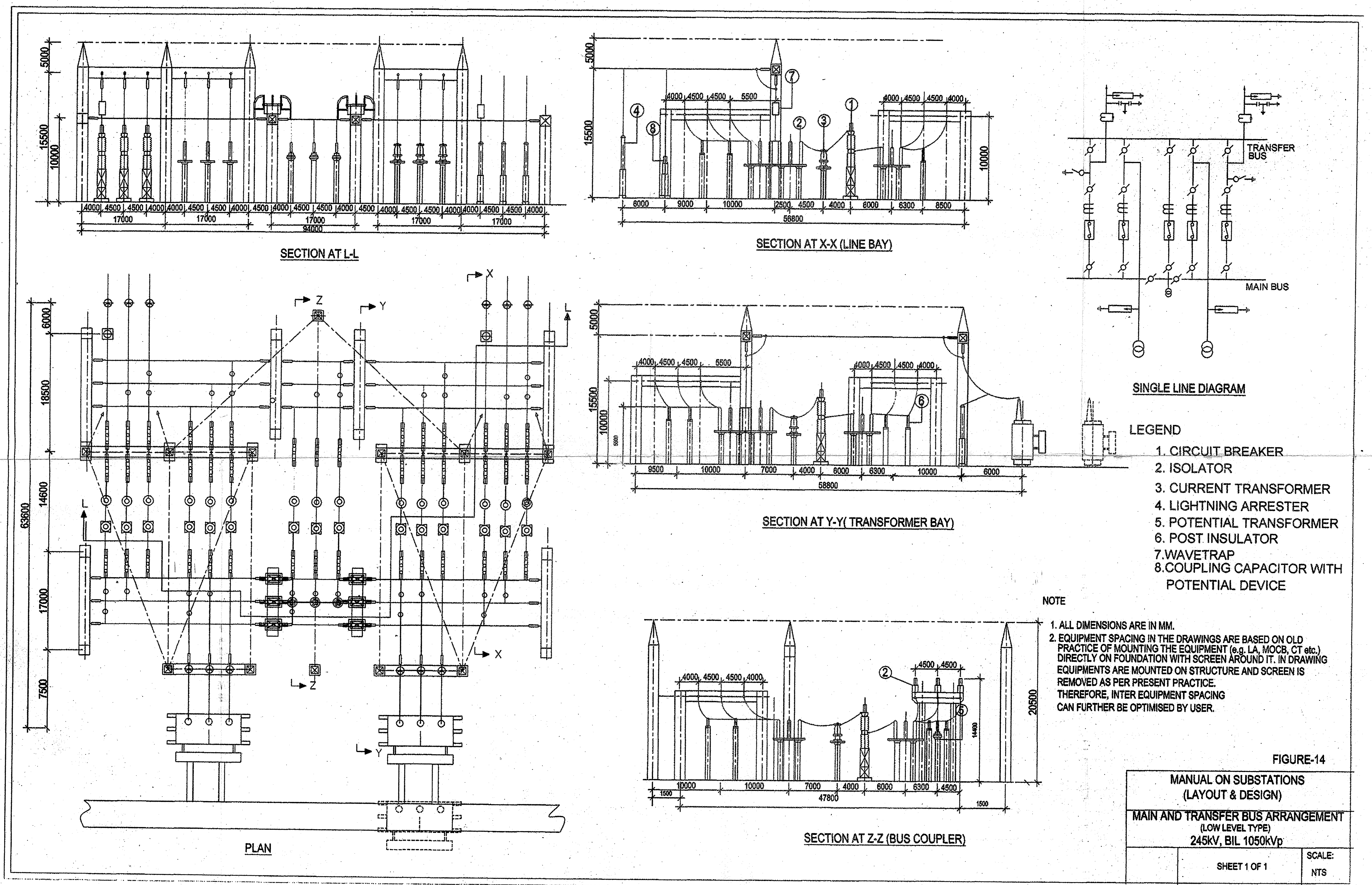
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. WAVE TRAP
5. LIGHTNING ARRESTER
6. COUPLING CAPACITOR WITH POTENTIAL DEVICE
7. POTENTIAL TRANSFORMER

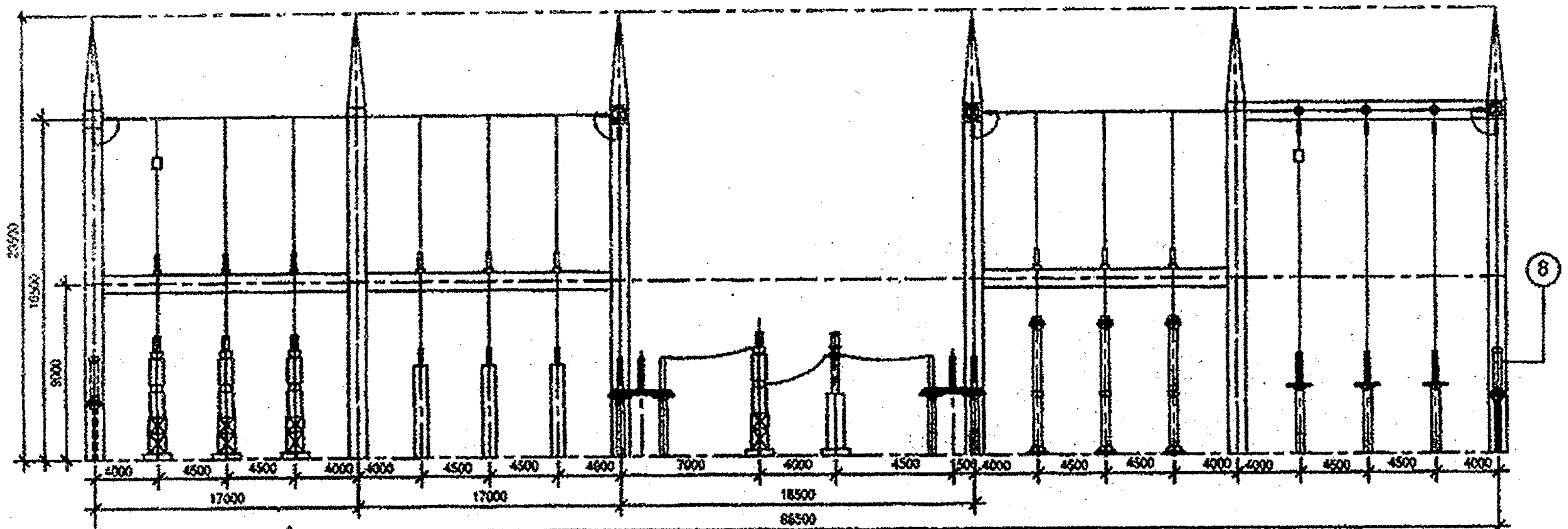
NOTE

1. ALL DIMENSIONS ARE IN MM.
2. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

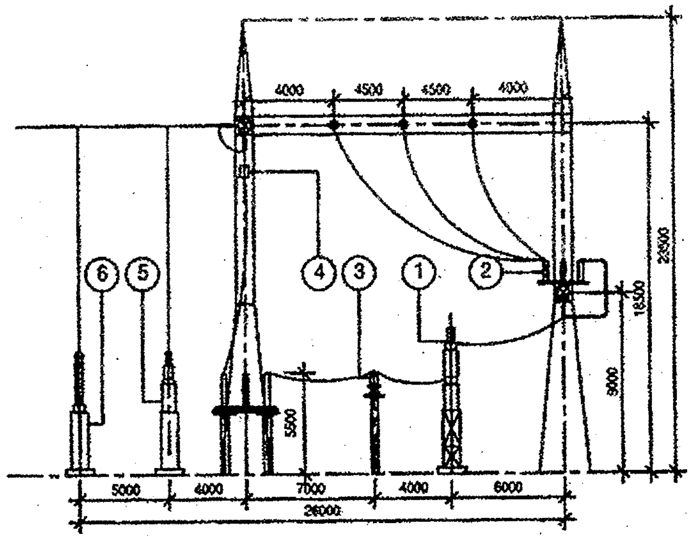
FIGURE-13

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
MAIN AND TRANSFER BUS ARRANGEMENT (HIGH LEVEL TYPE) 245 KV BIL 1050 KVp		
	SHEET 1 OF 1	SCALE: NTS

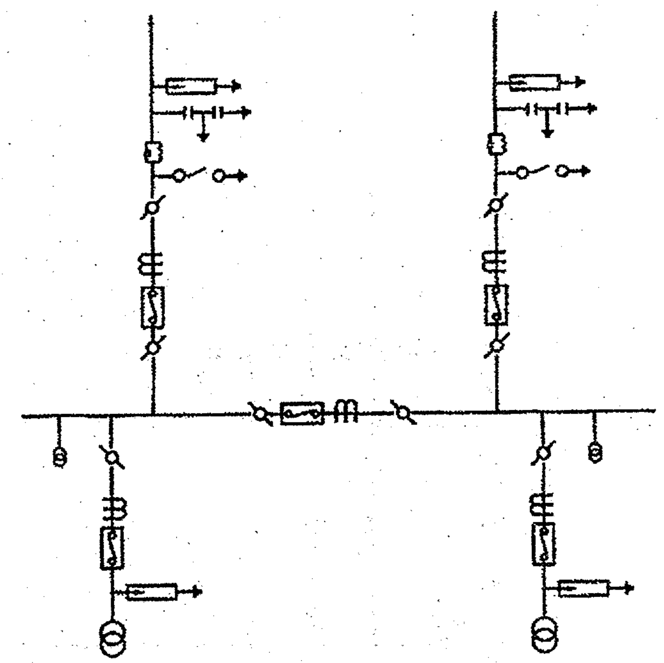

SECTION AT L-L
SECTION AT X-X (LINE BAY)
SINGLE LINE DIAGRAM
TRANSFER BUS
MAIN BUS
SECTION AT Y-Y(TRANSFORMER BAY)
PLAN
SECTION AT Z-Z (BUS COUPLER)
LEGEND
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. LIGHTNING ARRESTER
5. POTENTIAL TRANSFORMER
6. POST INSULATOR
7.WAVETRAP
8.COUPLING CAPACITOR WITH POTENTIAL DEVICE
NOTE
1. ALL DIMENSIONS ARE IN MM.
2. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.
FIGURE-14
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)
MAIN AND TRANSFER BUS ARRANGEMENT
(LOW LEVEL TYPE)
245kV, BIL 1050kVp
SHEET 1 OF 1
SCALE: NTS
94000
56800
58800
47800
63600
20500



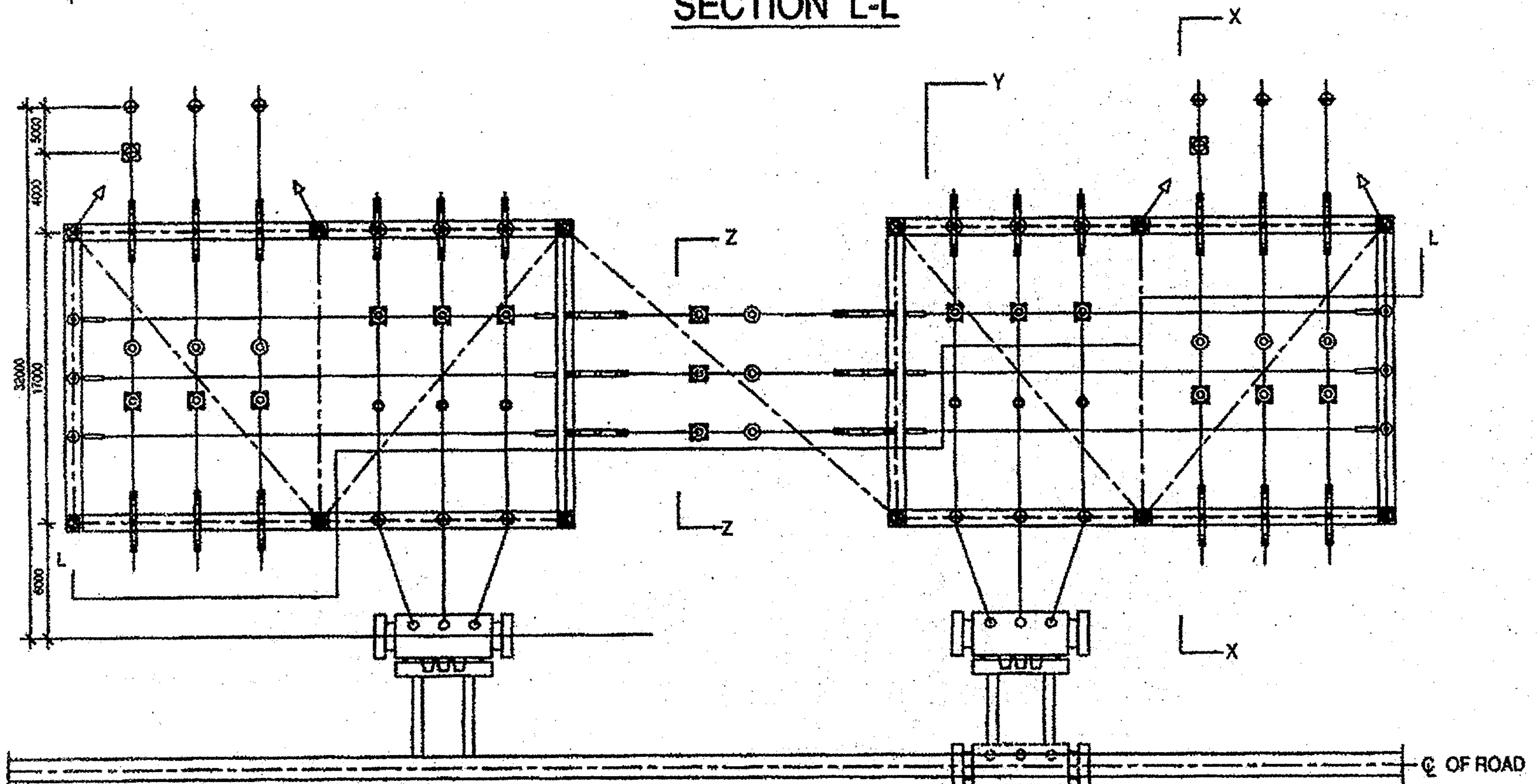
SECTION L-L



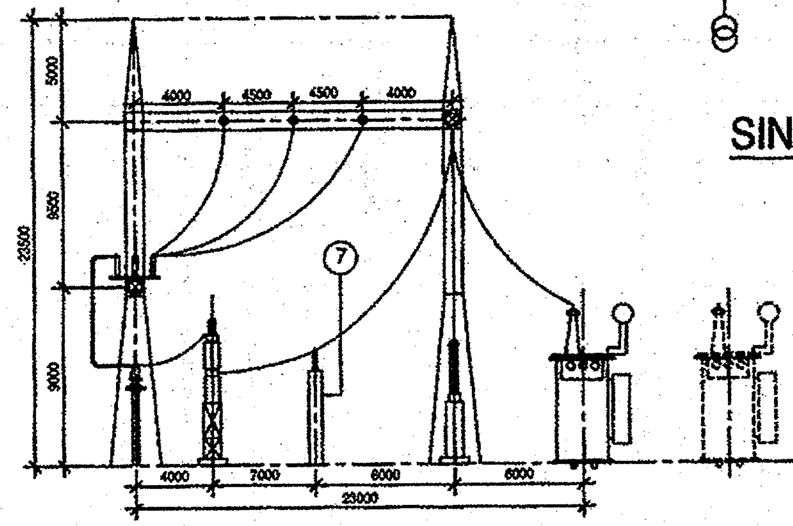
SECTION X-X (LINE BAY)



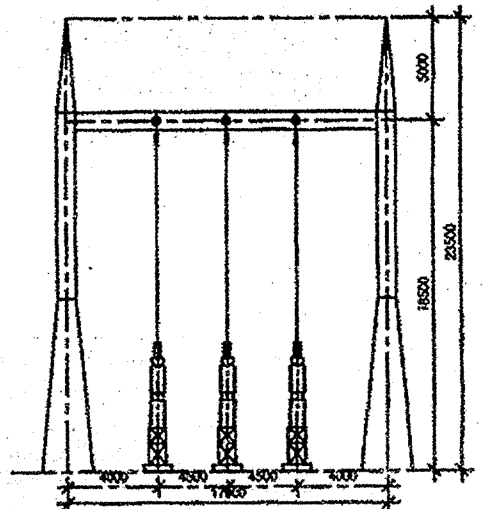
SINGAL LINE DIAGRAM



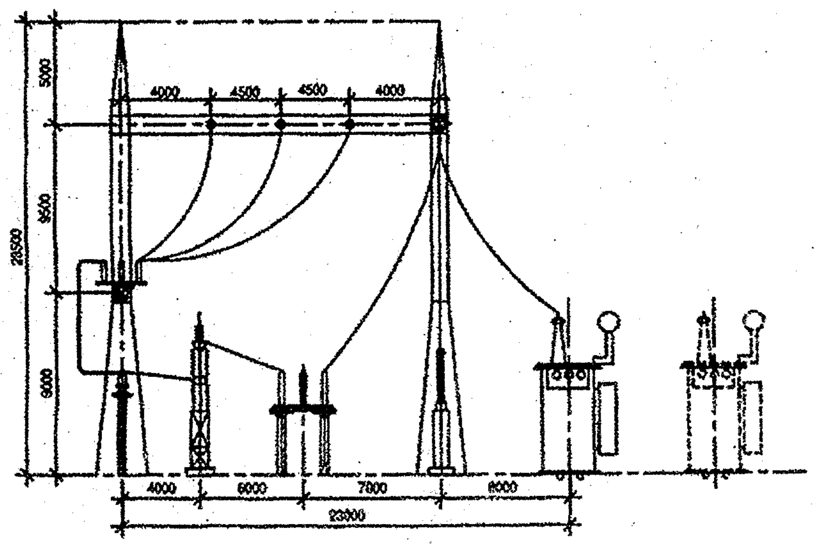
PLAN



SECTION Y-Y (TRANSFORMER BAY)



SECTION Z-Z



SECTION Y'-Y'(TRANSFORMER BAY)

LEGEND

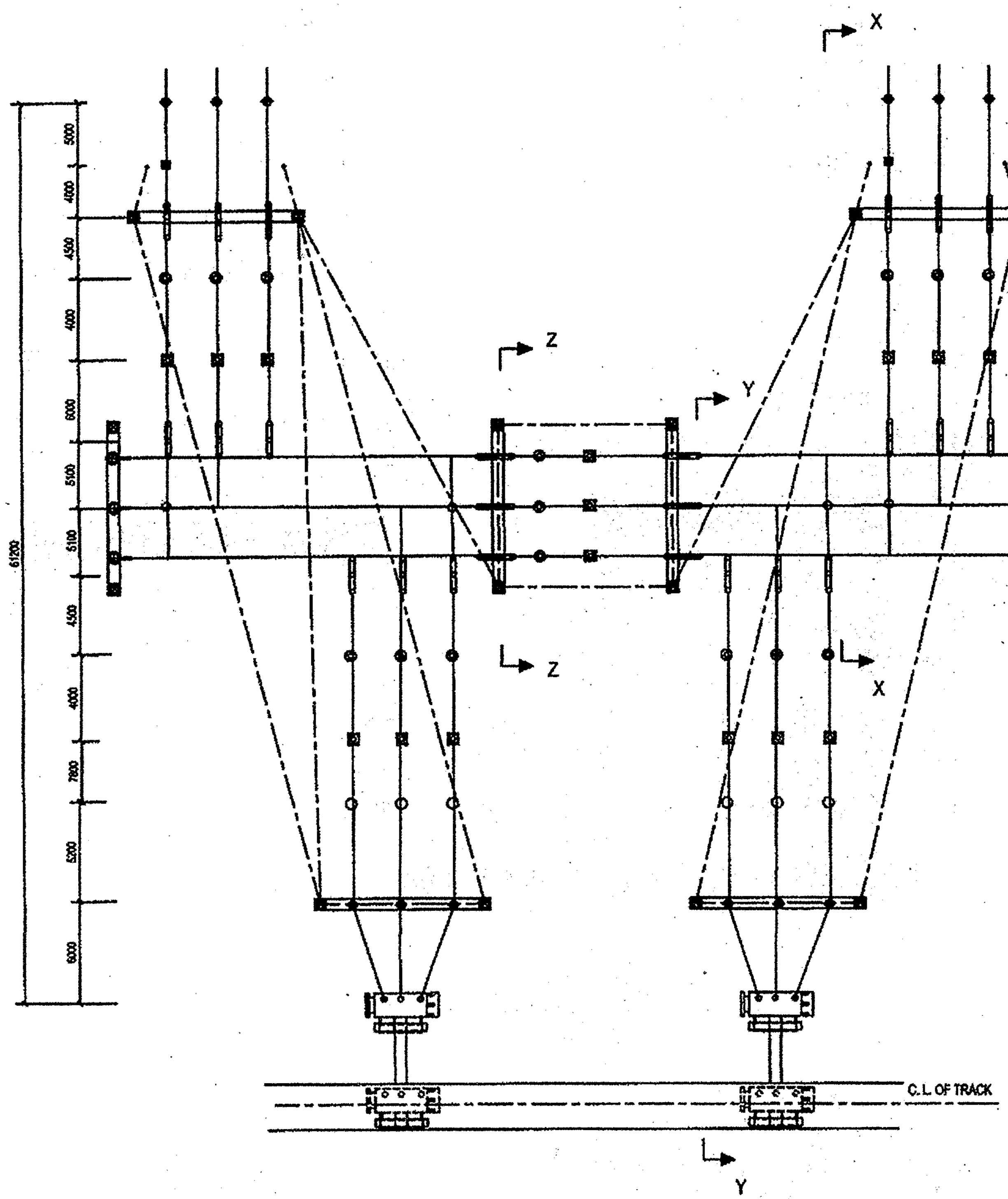
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. WAVE TRAP
5. COUPLING CAPACITOR WITH POTENTIAL DEVICE
6. LIGHTNING ARRESTER
7. POST INSULATOR
8. POTENTIAL TRANSFORMER

NOTE

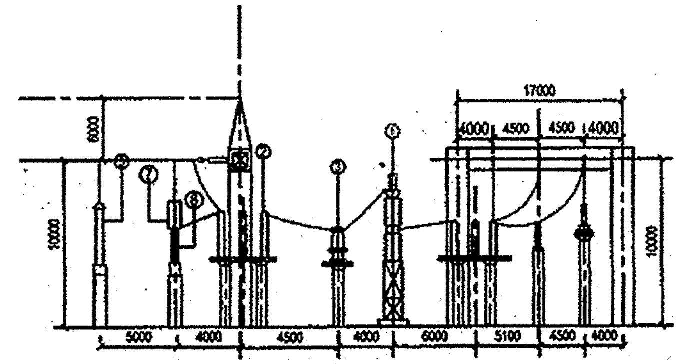
1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-15

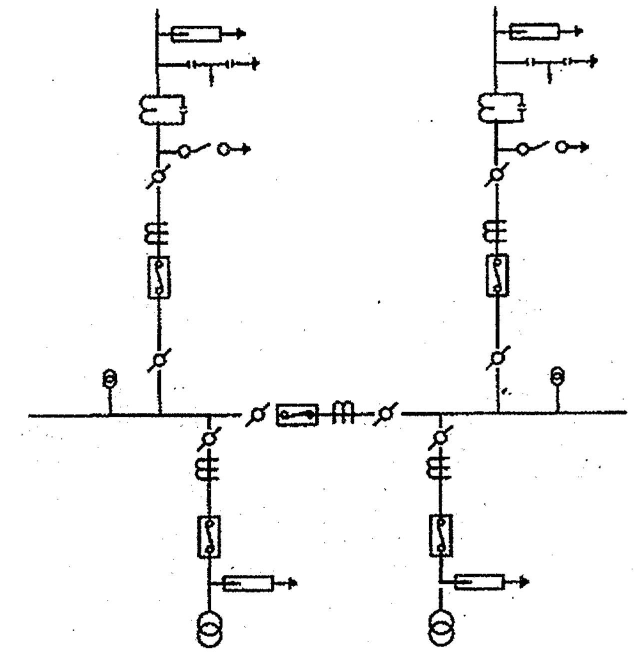
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
SINGLE BUS ARRANGMENT(HIGH LEVEL TYPE) 245 KV, BIL 1050 KVp		
	SHEET 1 OF 1	SCALE: NTS



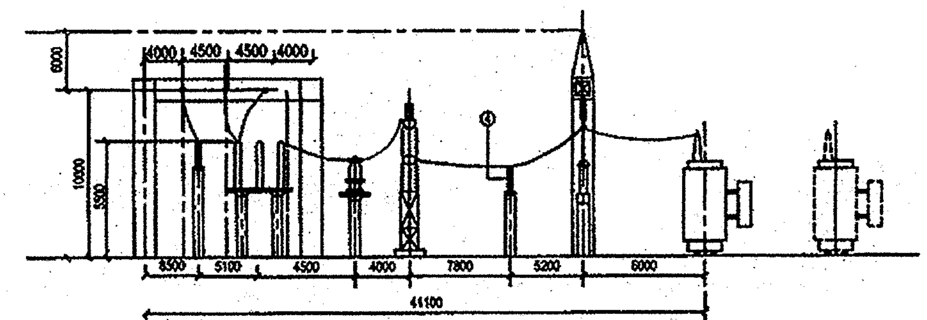
PLAN



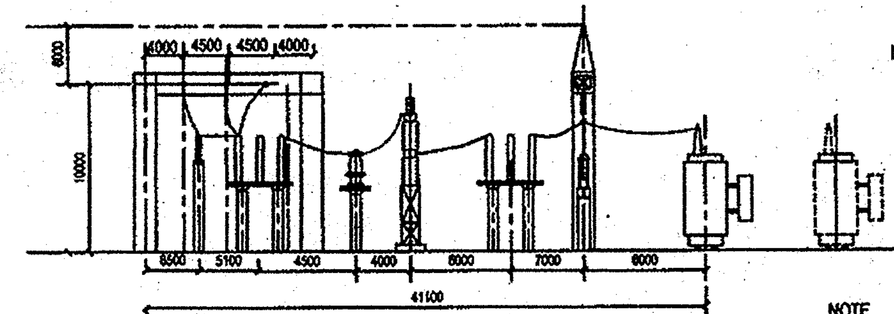
SECTION X-X (LINE BAY)



SINGLE LINE DIAGRAM



SECTION AT Y-Y (TRANSFORMER BAY)



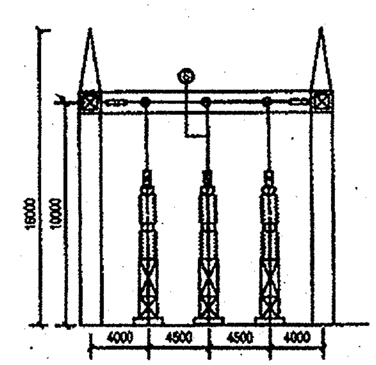
SECTION AT Y'-Y' (TRANSFORMER BAY)

LEGEND

1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. POST INSULATOR
5. LIGHTNING ARRESTER
6. POTENTIAL TRANSFORMER
7. WAVE TRAP
8. COUPLING CAPACITOR WITH POTENTIAL DEVICE

NOTE

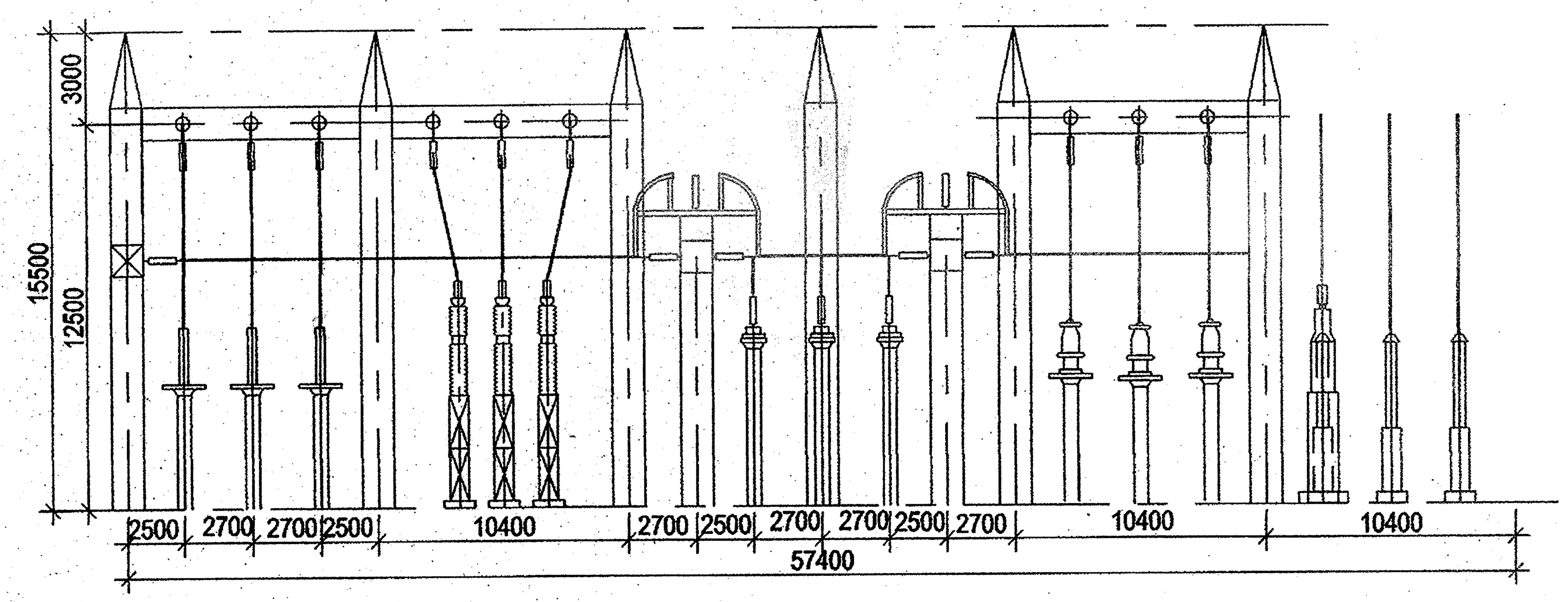
1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.



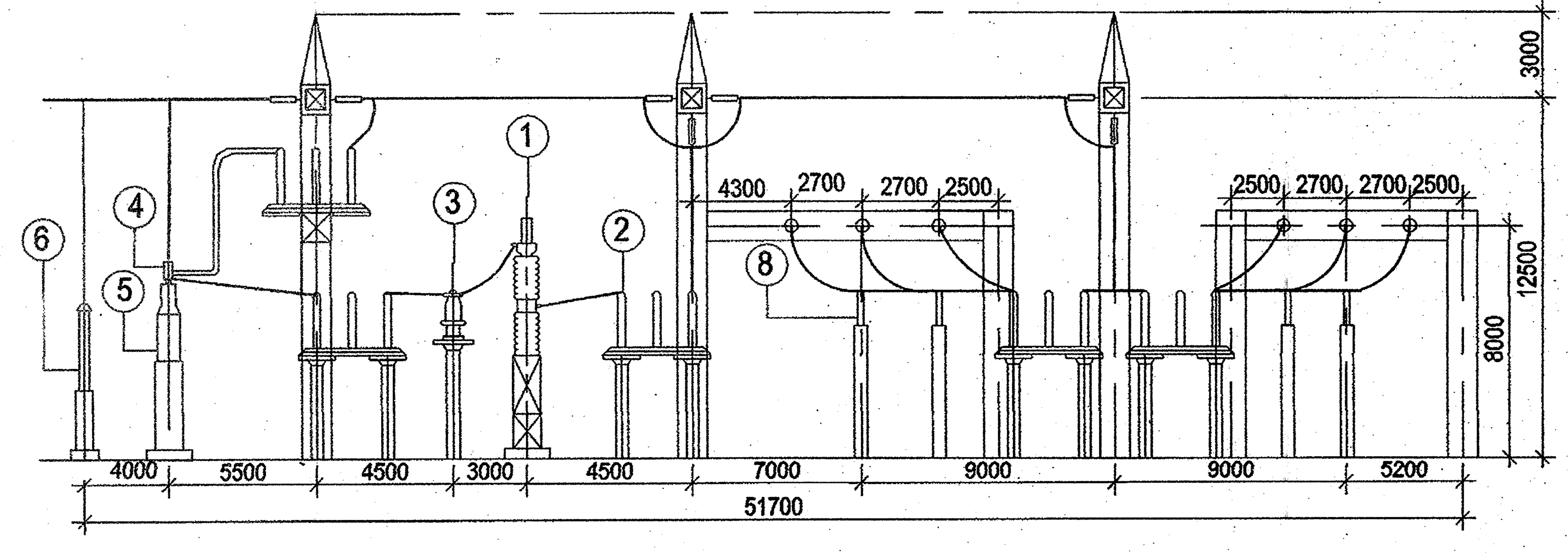
SECTION AT Z-Z

FIGURE-16

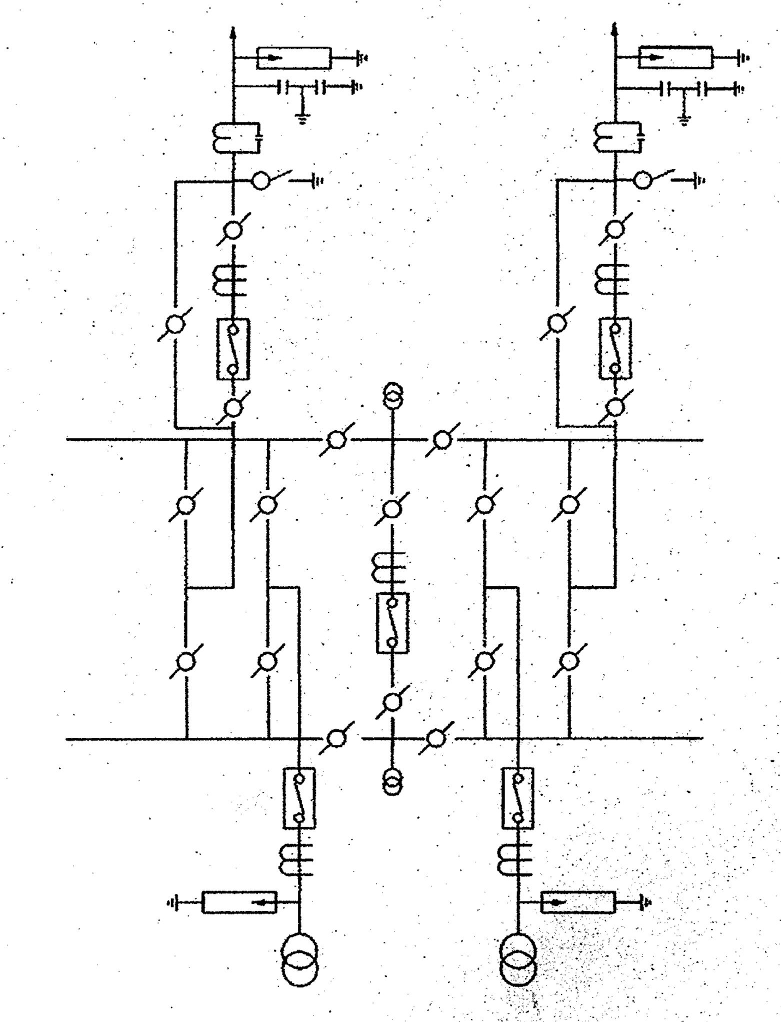
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
SINGLE BUS ARRANGMENT (LOW LEVEL TYPE) 245 KV, BIL 1050 KVp	
SHEET 1 OF 1	SCALE NTS



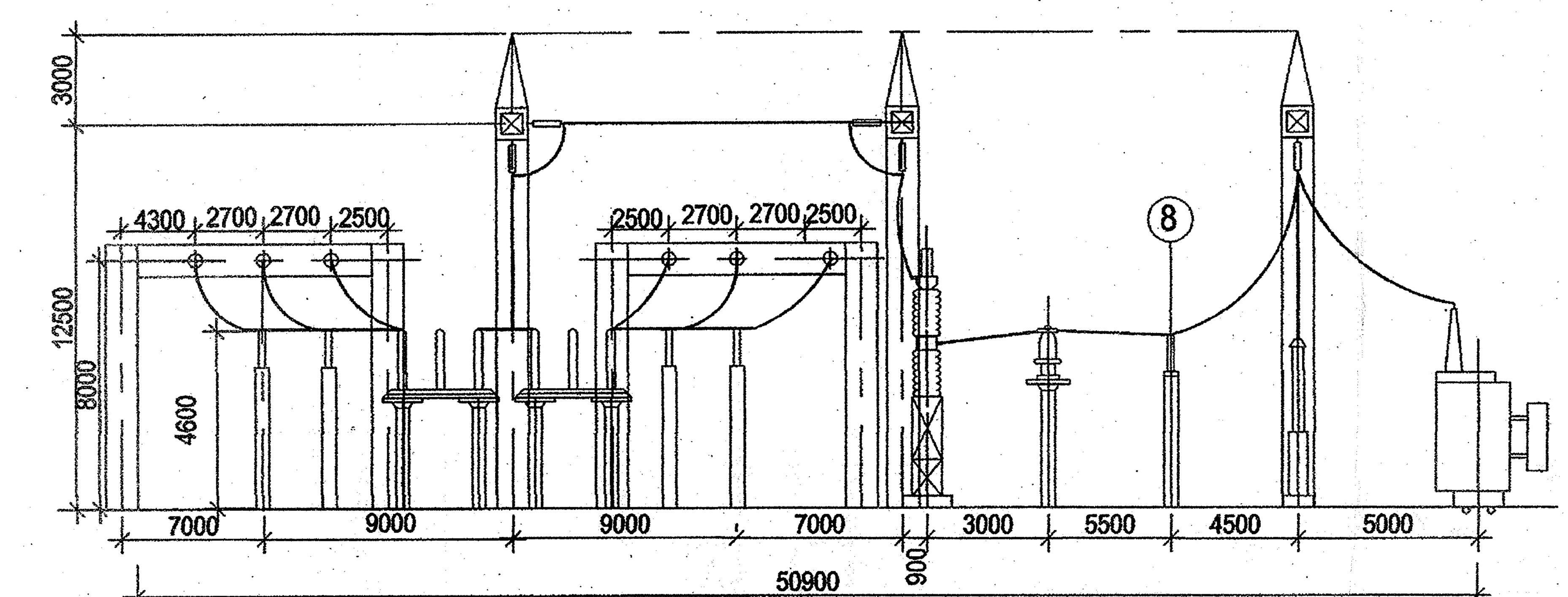
SECTION L-L



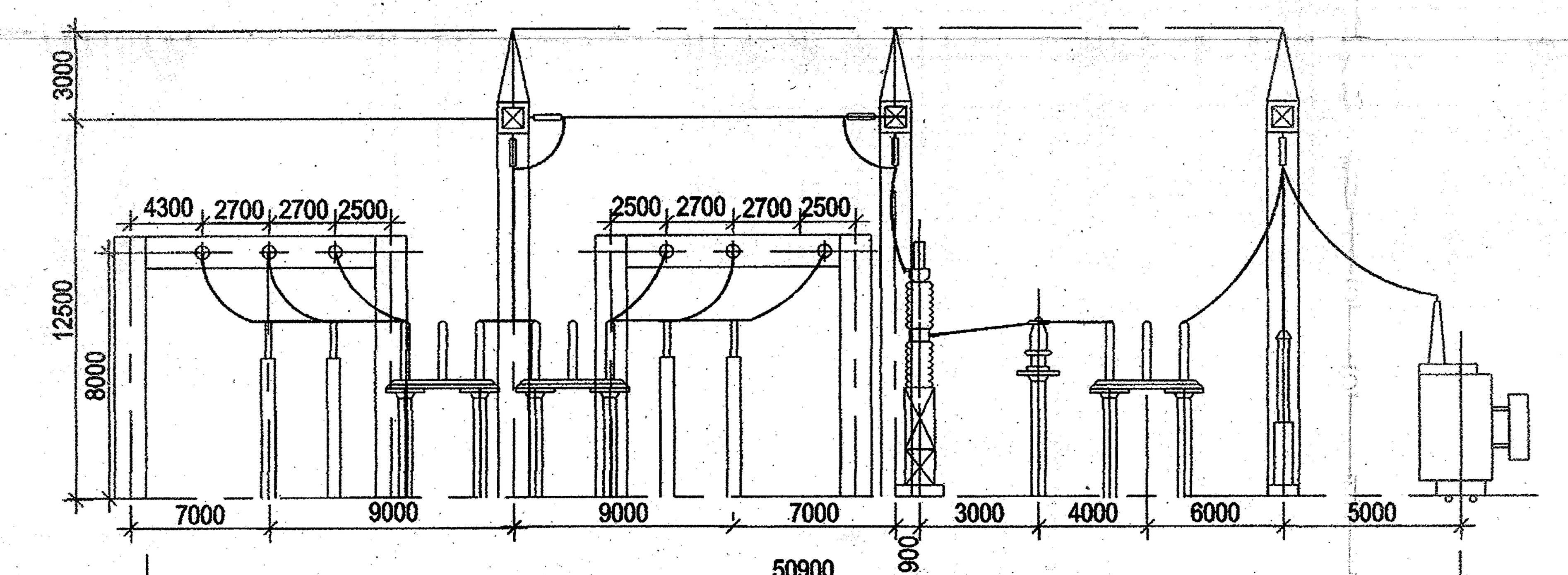
SECTION X-X (LINE BAY)



SINGLE LINE DIAGRAM



SECTION Y-Y (TRANSFORMER BAY)

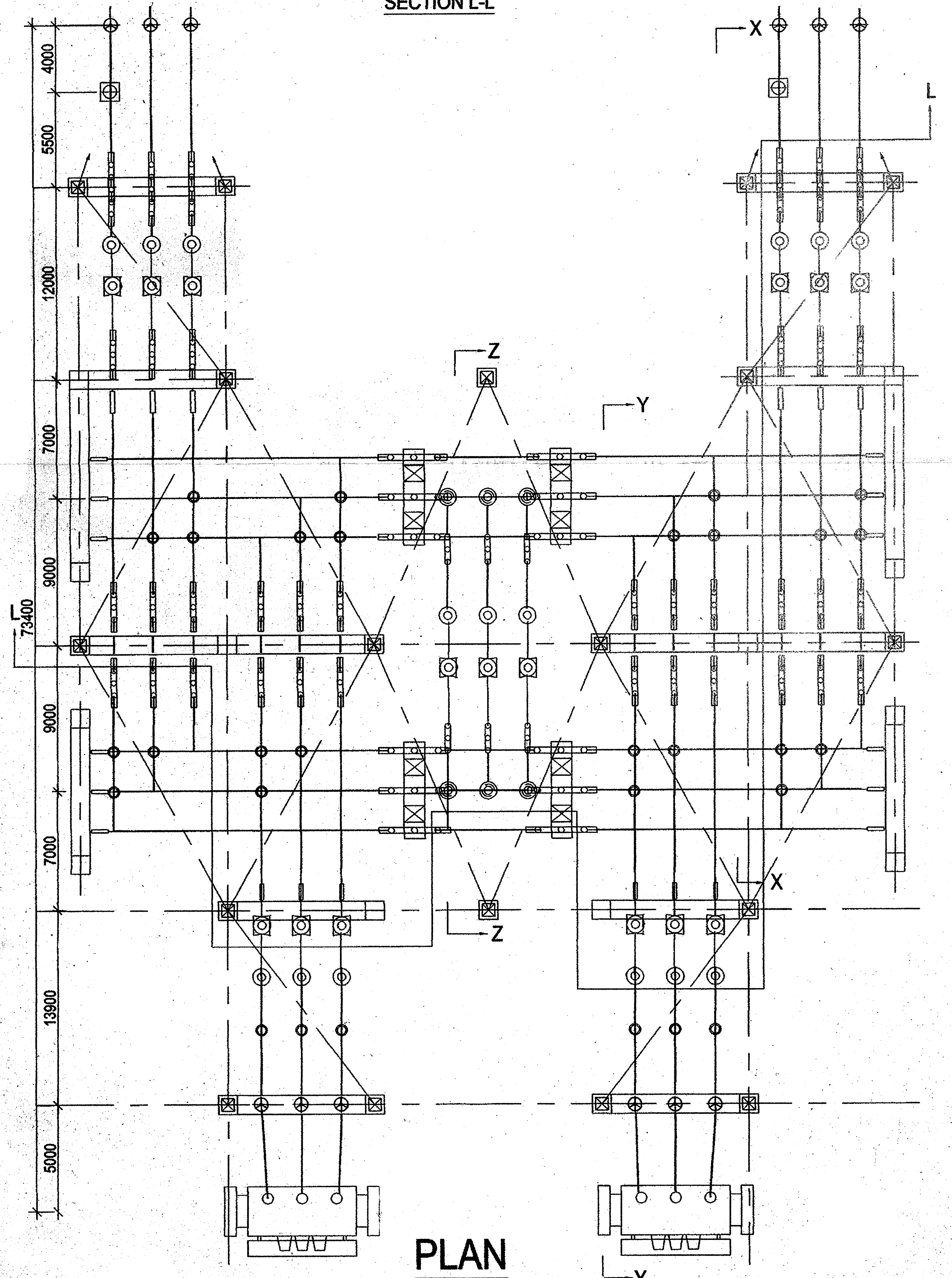


SECTION Y'-Y' (TRANSFORMER BAY)

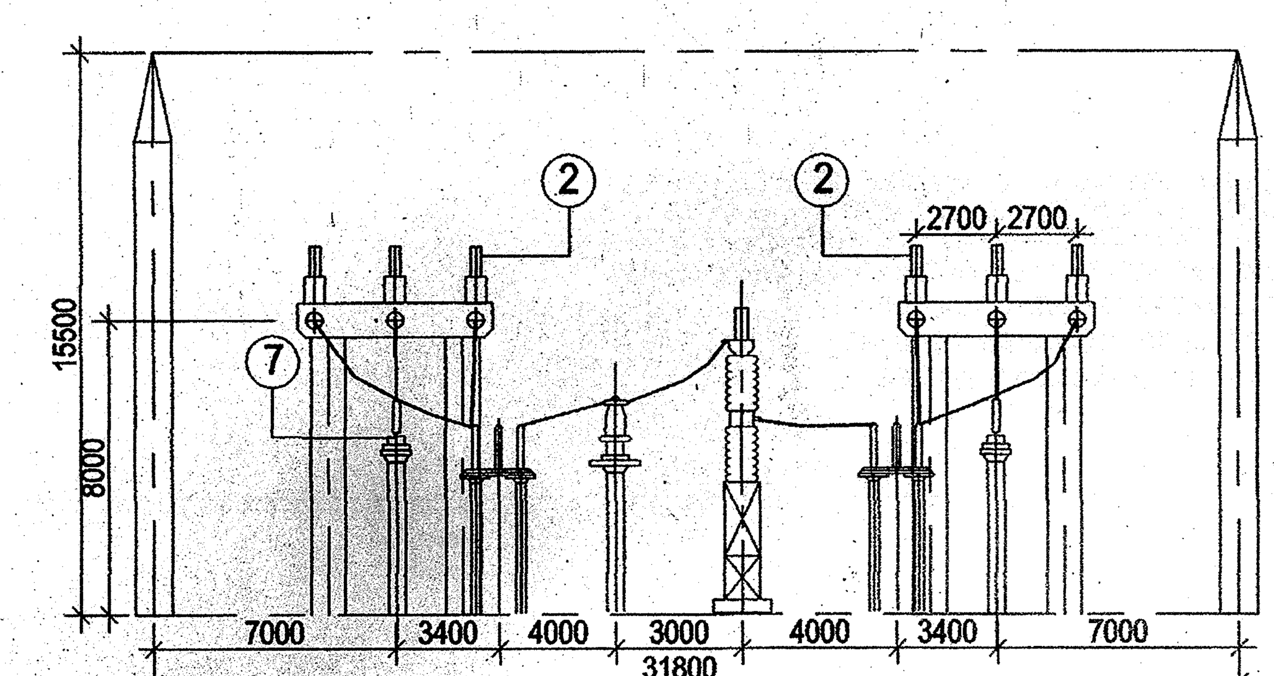
LEGEND:
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. WAVE TRAP
5. COUPLING CAPACITOR WITH POTENTIAL TRANSFORMER
6. LIGHTNING ARRESTER
7. POTENTIAL TRANSFORMER
8. POST INSULATOR

NOTE:

1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.



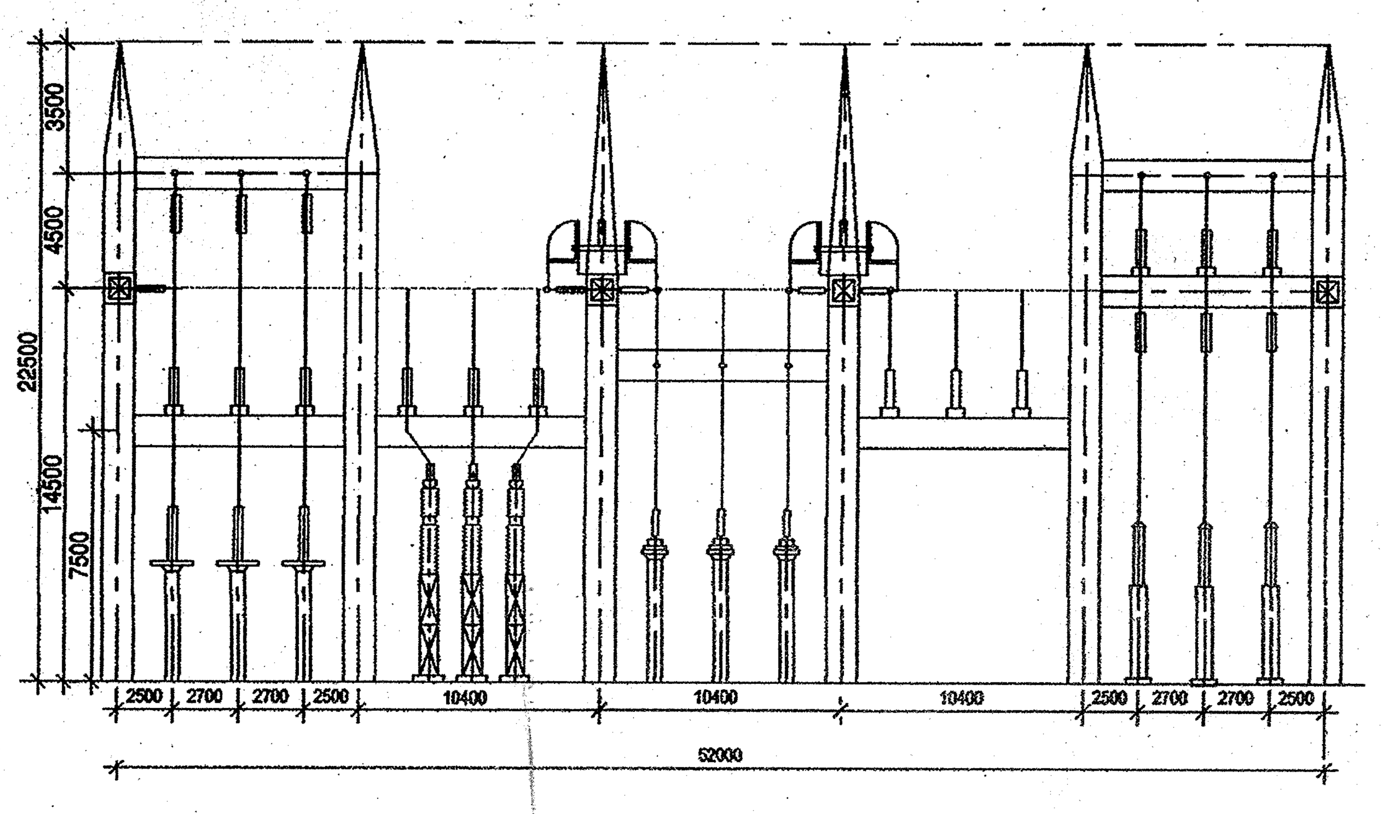
PLAN



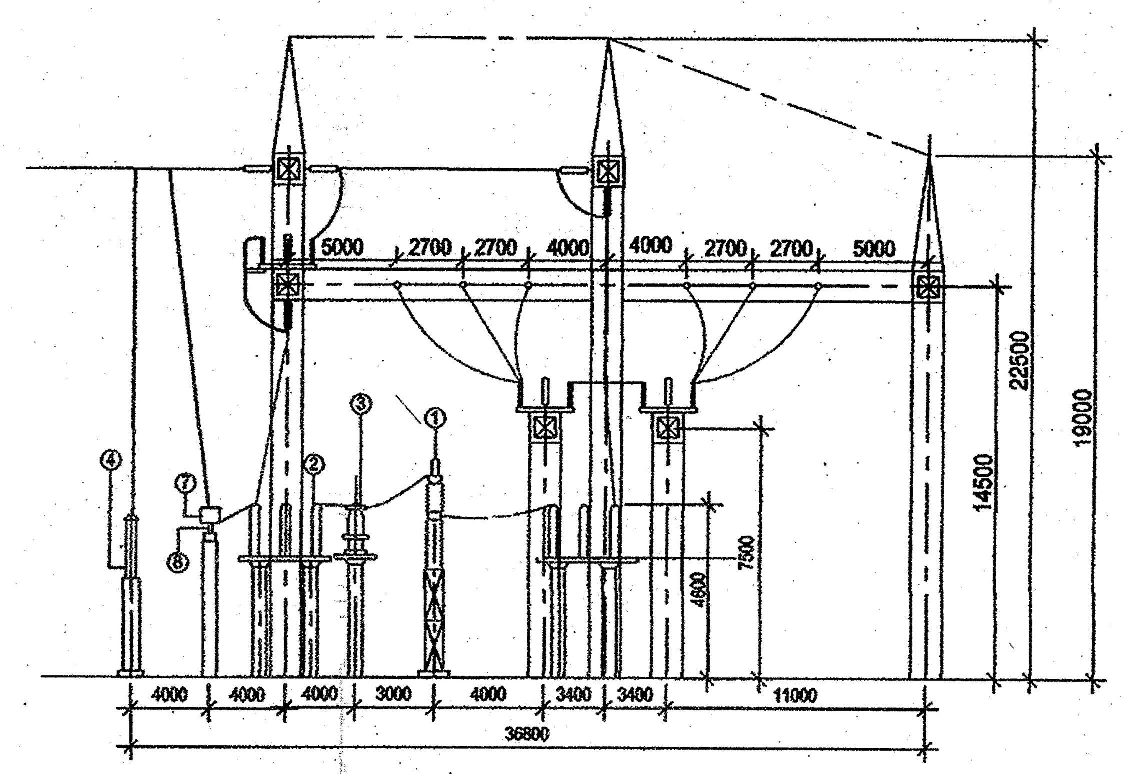
SECTION Z-Z (BUS COUPLER)

FIGURE-18

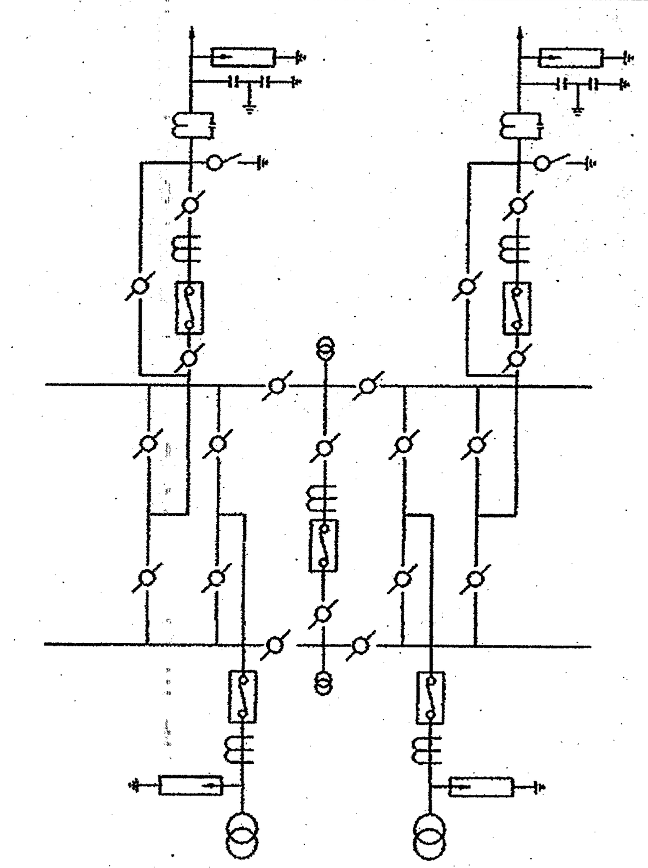
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
DOUBLE BUS ARRANGEMENT (LOW LEVEL TYPE) 145 KV ,BIL 650 KVp	
SHEET 1 OF 1	SCALE: NTS



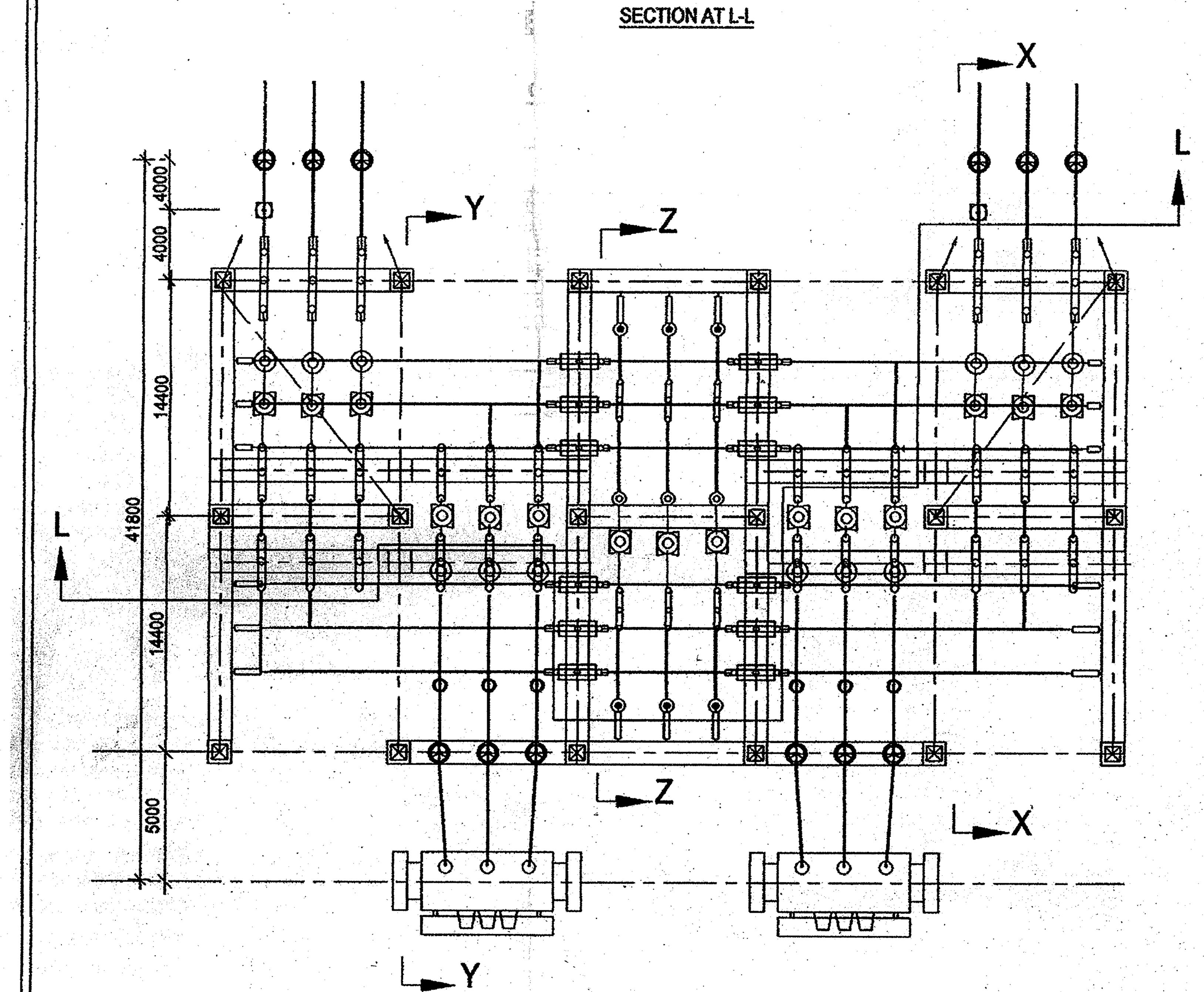
SECTION AT L-L



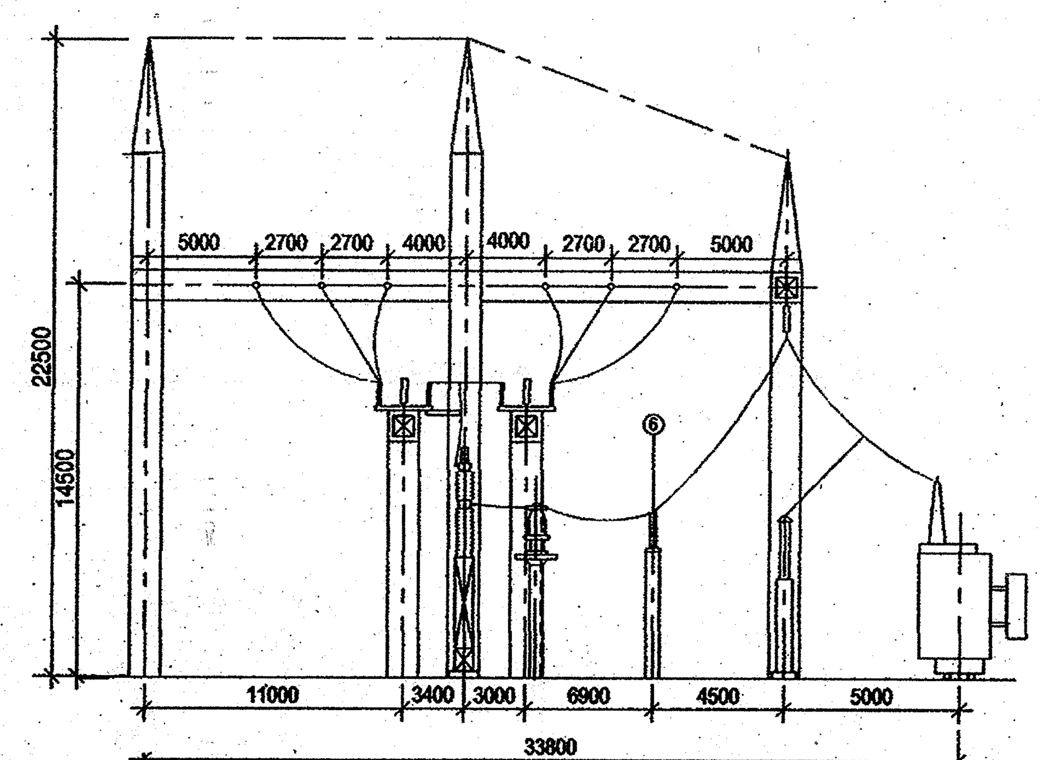
SECTION AT X-X (LINE BAY)



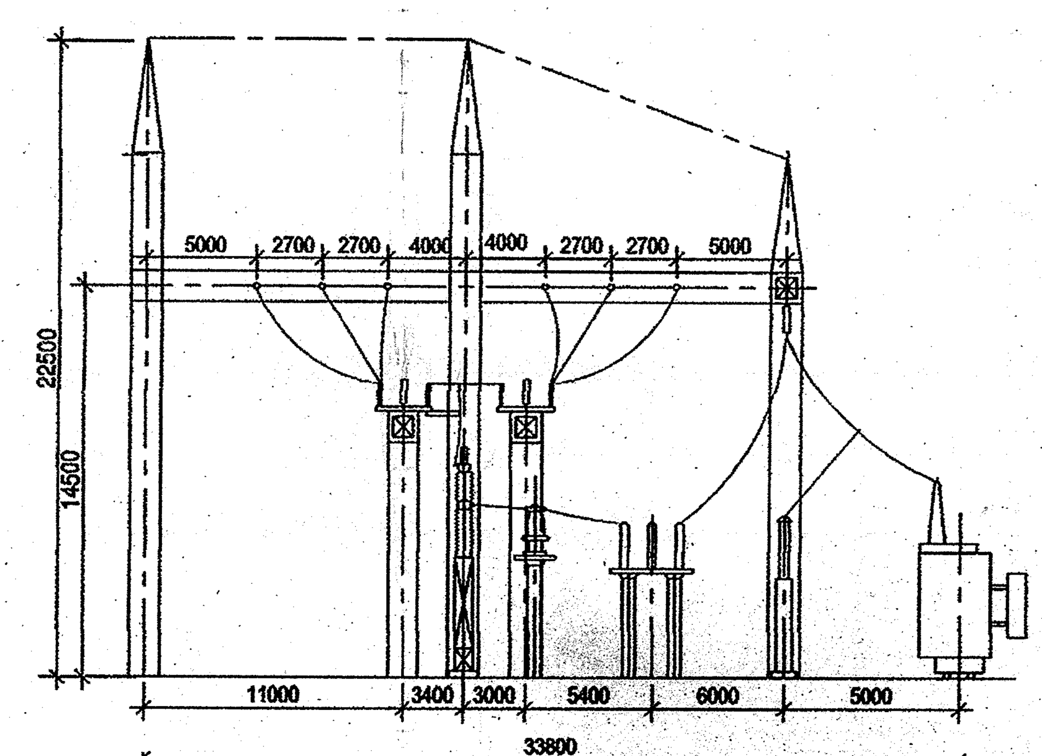
SINGLE LINE DIAGRAM



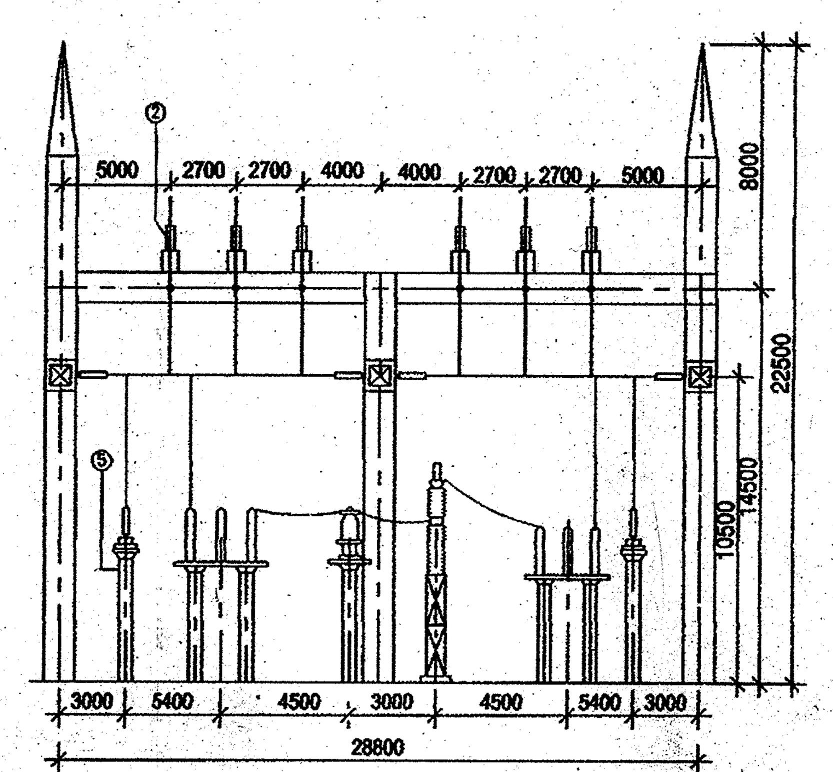
PLAN



SECTION AT Y-Y (TRANSFORMER BAY)



SECTION AT Y'-Y'(TRANSFORMER BAY)



SECTION AT Z-Z

LEGEND

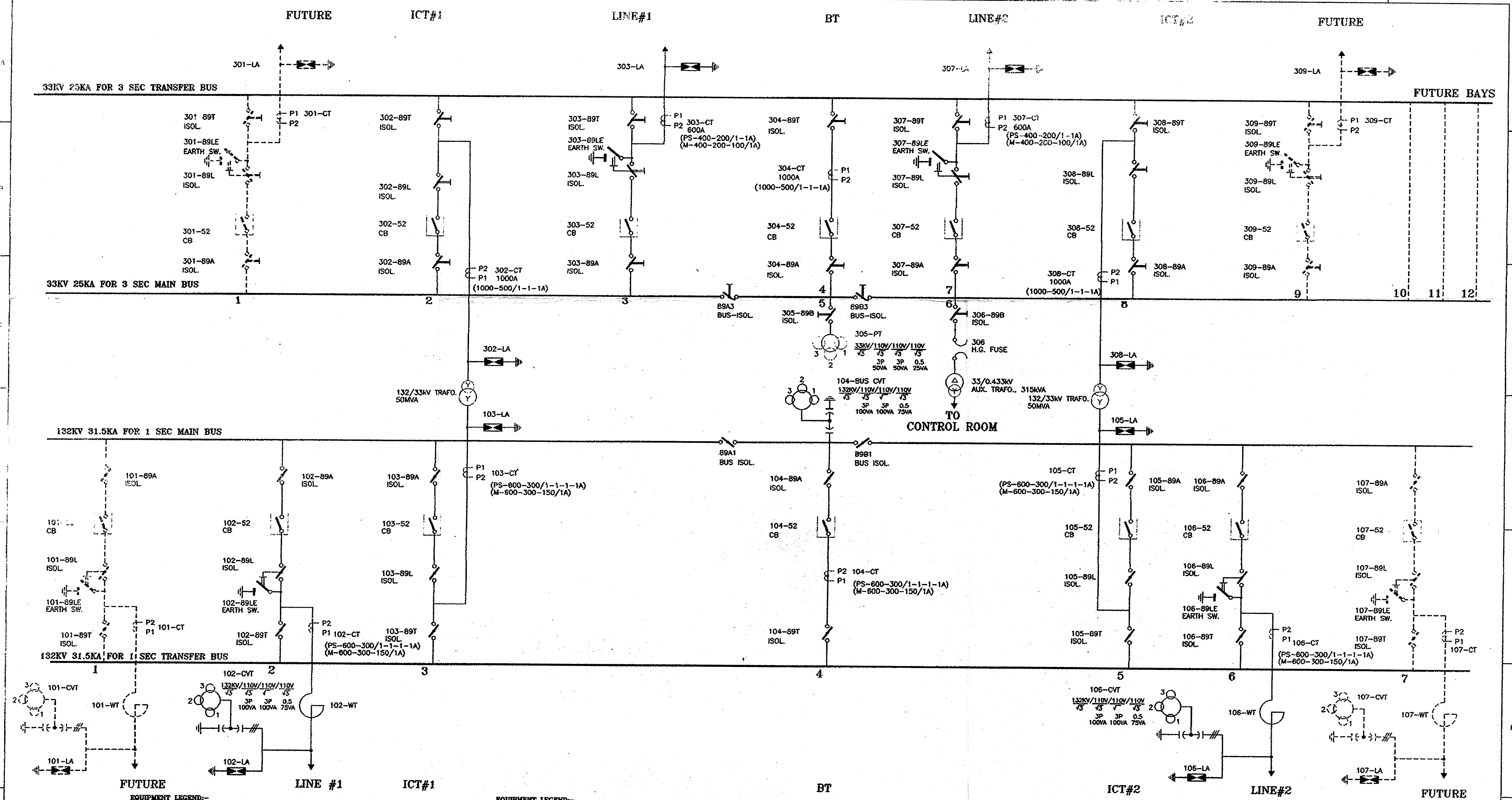
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. LIGHTNING ARRESTER
5. POTENTIAL TRANSFORMER
6. POST INSULATOR
7. WAVETRAP
8. COUPLING CAPACITOR WITH POTENTIAL DEVICE

NOTE

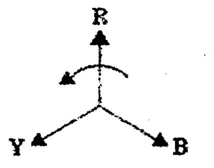
1. REPLACE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT.
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-17

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
DOUBLE BUS ARRANGEMENT (HIGH LEVEL TYPE) 145KV, BIL 650 KVp		
	SHEET 1 OF 1	SCALE: NTS



SYSTEM 132kV, 3 PHASE, 50Hz



PHASE ROTATION

EQUIPMENT LEGEND:-

SR.NO.	EQUIPMENT	DESCRIPTION	QTY.
1.		145KV, 1250A SF6 CIRCUIT BREAKER	05 NOS.
2.		CURRENT TRANSFORMER 145KV, 1-PH, 600A, 5CORE, 31.5KA FOR 1 SEC.	15 NOS.
3.		CAPACITIVE VOLTAGE TRANSFORMER 145KV, 1-PH, 4400pF	09 NOS.
4.		DOUBLE BREAK ISOLATOR WITH ONE EARTH SWITCH 145KV, 1250A, 31.5KA FOR 1SEC.	02 NOS.
5.		DOUBLE BREAK ISOLATOR WITHOUT EARTH SWITCH 145KV, 1250A, 31.5KA FOR 1SEC. (INCL. TANDEM ISOLATOR AND BEAM MOUNTED ISOLATOR)	14 NOS.
6.		SURGE ARRESTOR 120KV,1-PH,GAPLESS, 10KA DISCHARGE CLASS : III	12 NOS.
7.		WAVE TRAP 145KV, 1250A, 31.5KA FOR 1 SEC., 0.5mH	02 NOS.
8.		VACUUM CIRCUIT BREAKER 36KV, 1250A, 25KA FOR 3 SEC.	05 NOS.
9.		CURRENT TRAFORMER 36KV 1-PH, 3CORE, 25KA FOR 3 SEC.	15 NOS.

EQUIPMENT LEGEND:-

SR.NO.	EQUIPMENT	DESCRIPTION	QTY.
10.		POTENTIAL TRANSFORMER 36KV, 1-PH	03 NOS.
11.		DOUBLE BREAK ISOLATOR WITH ONE EARTH SWITCH 36KV, 1250A, 25KA FOR 3SEC., MANUALLY OPERATED	02 NOS.
12.		DOUBLE BREAK ISOLATOR WITHOUT EARTH SWITCH 36KV, 1250A, 25KA FOR 3SEC., MANUALLY OPERATED (INCL. TANDEM ISOLATOR AND BEAM MOUNTED ISOLATOR)	16 NOS.
13.		POWER TRANSFORMER 50MVA, 132/33kV, 3-PH, YNyn0, ONAN/ONAF	02 NOS.
14.		HORN GAP FUSE 33KV, 1-PH	03 NOS.
15.		SURGE ARRESTOR 30KV, 1-PH, GAPLESS, 10KA DISCHARGE CLASS : II	12 NOS.
16.		LT TRANSFORMER 315KVA, 33/0.433KV, Dyn1, ONAN	01 NOS.

——— PRESENT
------- FUTURE/SPARE

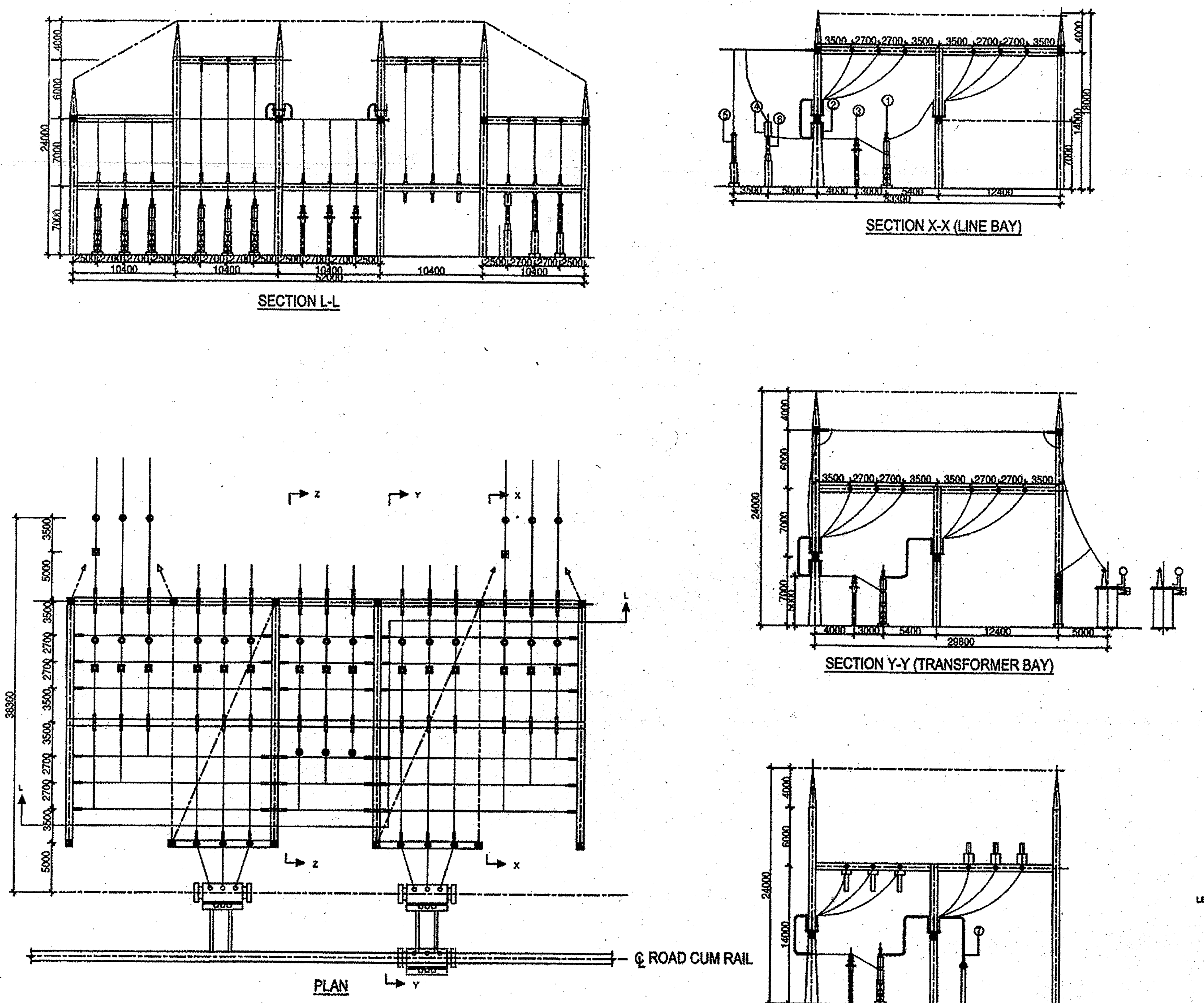
FIGURE 19 A (SHEET1 OF 4)

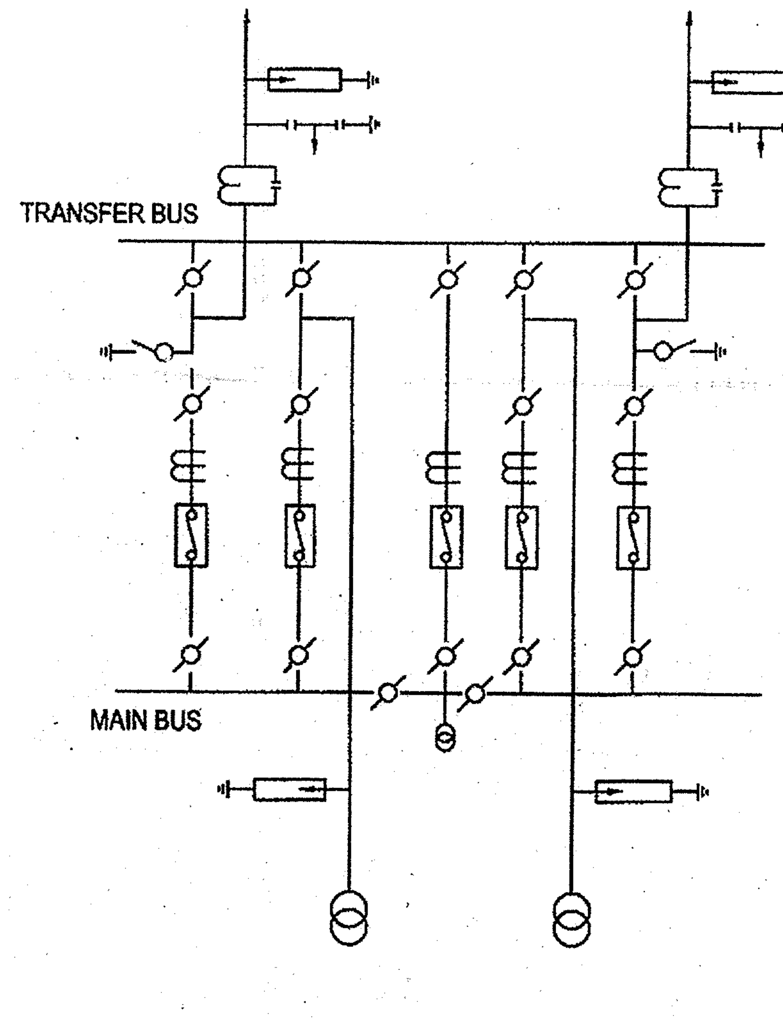
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)

132/33 KV SUBSTATION -MAIN & TRANSFER SCHEME WITH BUS SECTIONALISER

Scale: NTS

12





SINGLE LINE DIAGRAM

NOTE

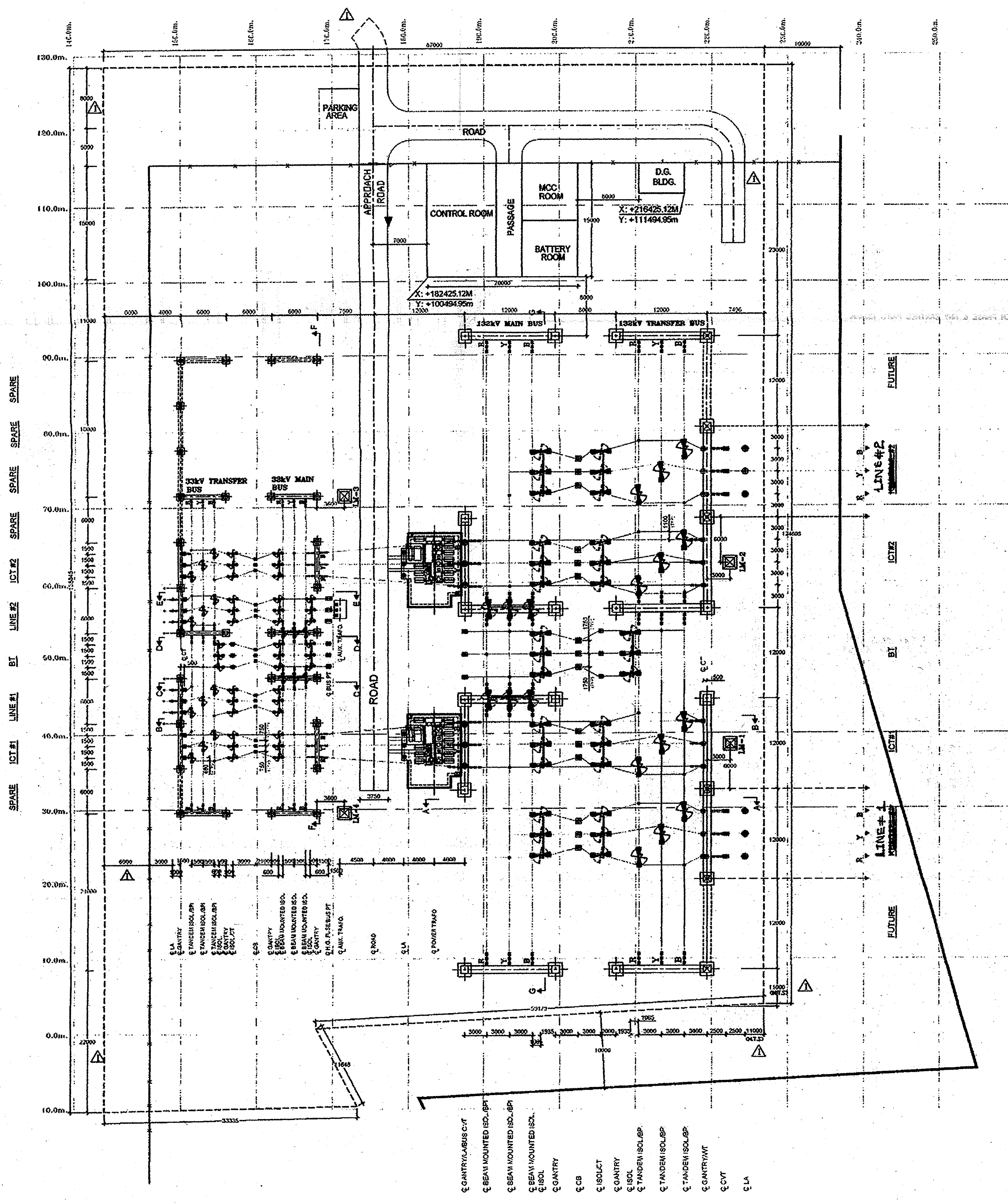
1. ALL DIMENSIONS ARE IN MM.
2. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

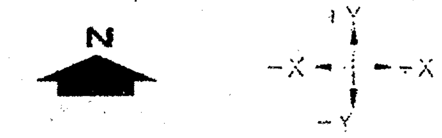
LEGEND

1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. WAVE TRAP
5. LIGHTNING ARRESTER
6. COUPLING CAPACITOR WITH POTENTIAL DEVICE
7. POTENTIAL TRANSFORMER

FIGURE-19

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
MAIN AND TRANSFER BUS ARRANGEMENT (HIGH LEVEL TYPE) 145 KV BIL 650 KVp		
	SHEET 1 OF 1	SCALE: NTS





LEGEND:-

N - DIRECTION NORTH

NOTES:-

1. ALL DIMENSIONS ARE IN mm. UNLESS SPECIFIED OTHERWISE
2. MINIMUM CLEARANCE
   a. FOR 132kV
      - BETWEEN PHASE: 1300mm
      - BETWEEN PHASE & ANY EARTHED PART: 1300mm.
      - SECTIONAL CLEARANCE: 4000mm.
      - GROUND CLEARANCE: 4600mm.
   b. FOR 33kV
      - BETWEEN PHASES: 320mm.
      - BETWEEN PHASE & EARTHED PART: 320mm.
      - SECTIONAL CLEARANCE: 3000mm.
      - GROUND CLEARANCE: 3700mm.
3. CONDUCTOR SIZE DETAILS
   a. FOR 132kV
      - MAIN BUS: ACSR TWIN MOOSE
      - TRANSFER BUS: ACSR SINGLE MOOSE
      - ALL OTHER BAY CONNECTION: ACSR SINGLE MOOSE
   b. FOR 33kV
      - MAIN BUS: ACSR TWIN BERSIMIS
      - TRANSFER BUS: ACSR SINGLE BERSIMIS
      - INCOMER FROM TRANSFORMER & INTER CONNECTION UP TO BUS } ACSR SINGLE BERSIMIS
      - ALL OTHER BAY CONNECTION: ACSR SINGLE BERSIMIS
4. SHIELD WIRE: 7/3.66mm GI WIRE
5. CONDUCTOR TENSION
   - MAIN BUS GANTRY & INCOMING LINE TERMINATION: 1000 Kg/Ph. FOR 132kV AND 500 Kg/Ph. FOR 33kV
   - SHIELD WIRE: 500 Kg/WIRE
6. PLINTH LEVEL FOR EQUIPT.: 300mm ABOVE GL.
7. SYSTEM PARAMETER

Nominal system voltage (kv)	132kV	33kV
Highest system voltage (kv)	145	36
Lightening impulse withstand Voltage (KVp)	650	170
Power frequency withstand Voltage (KVrms)	275	70
Max. fault level (KA)	31.5(1 SEC.)	25(3 SEC.)
Creepage	25 mm/kv	25 mm/kv

8. BAYS SHOWN IN DOTTED ARE FUTURE BAYS

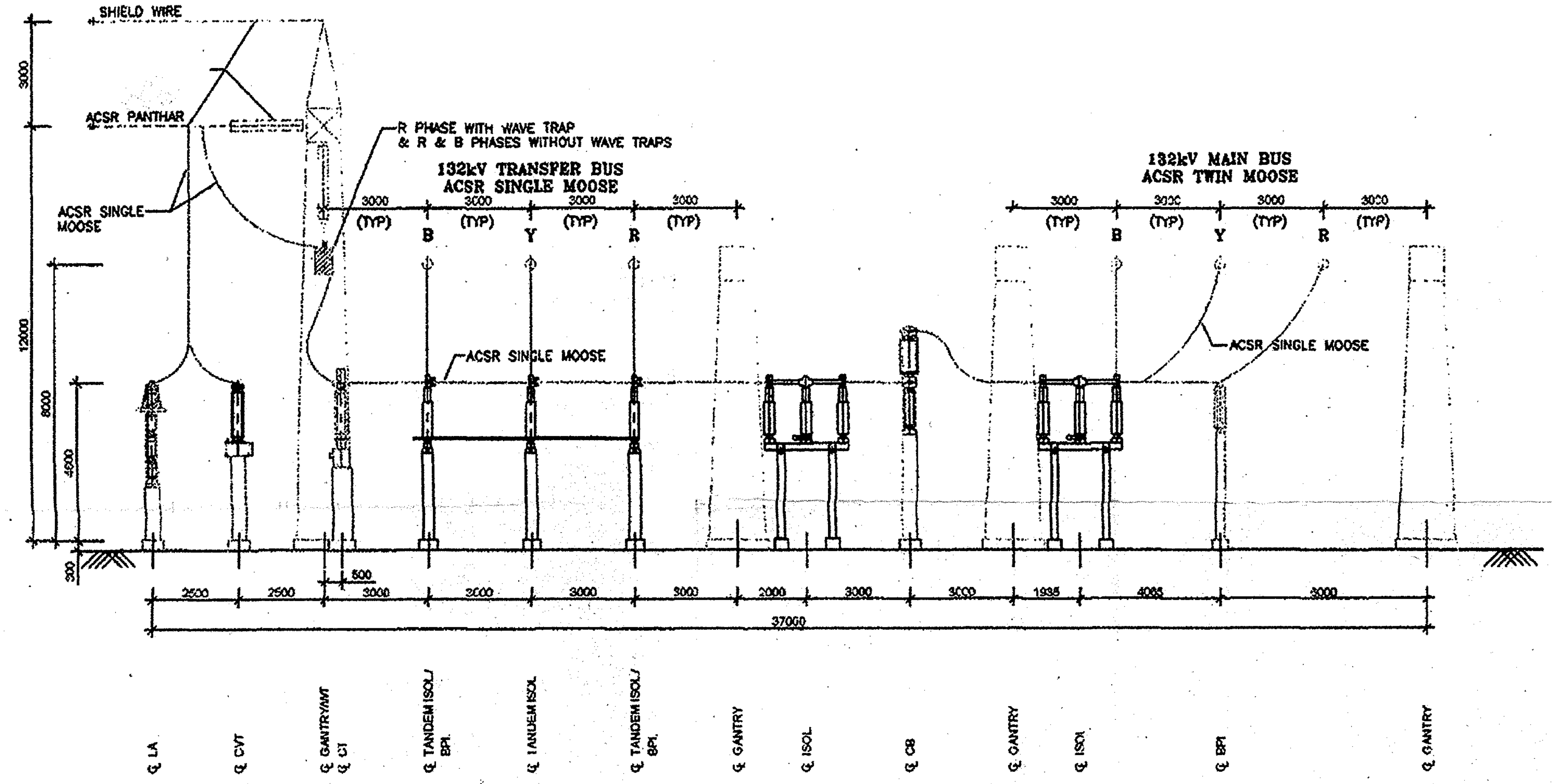
11. ——— PRESENT
    - - - - FUTURE

FIGURE 19 A (SHEET 2 OF 4)

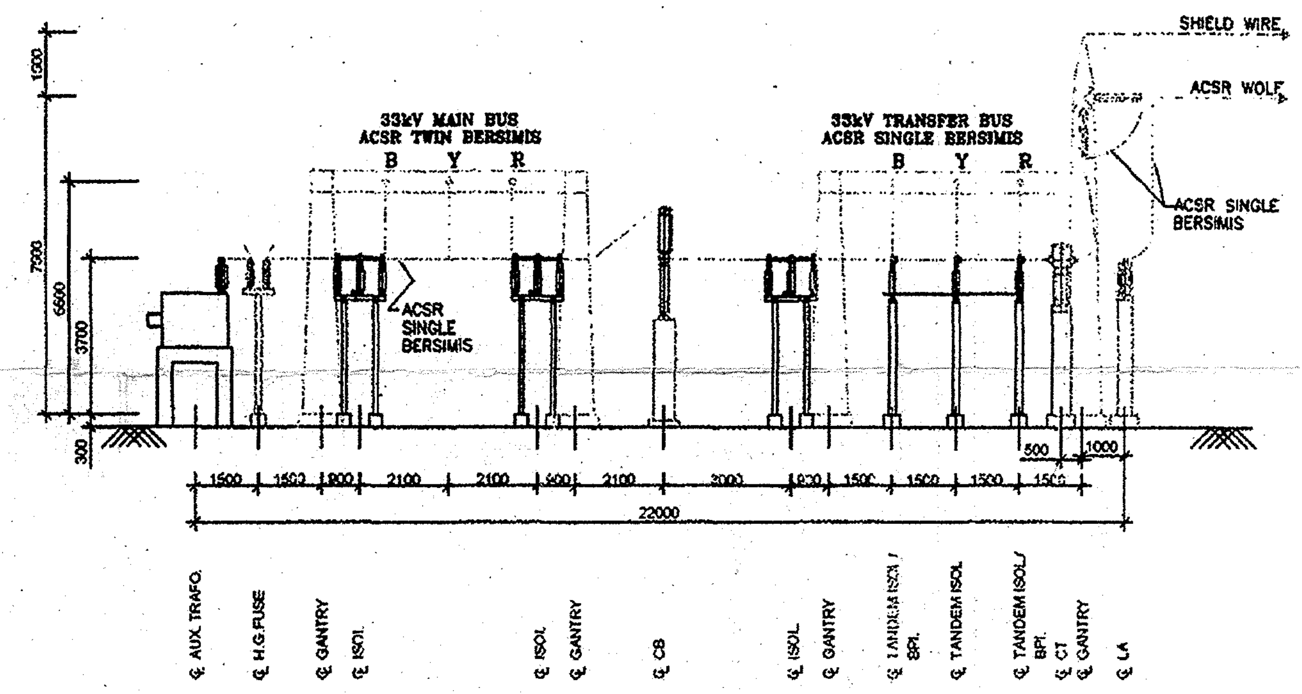
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)

132/33 KV SUBSTATION -MAIN & TRANSFER SCHEME WITH BUS SECTIONALISER

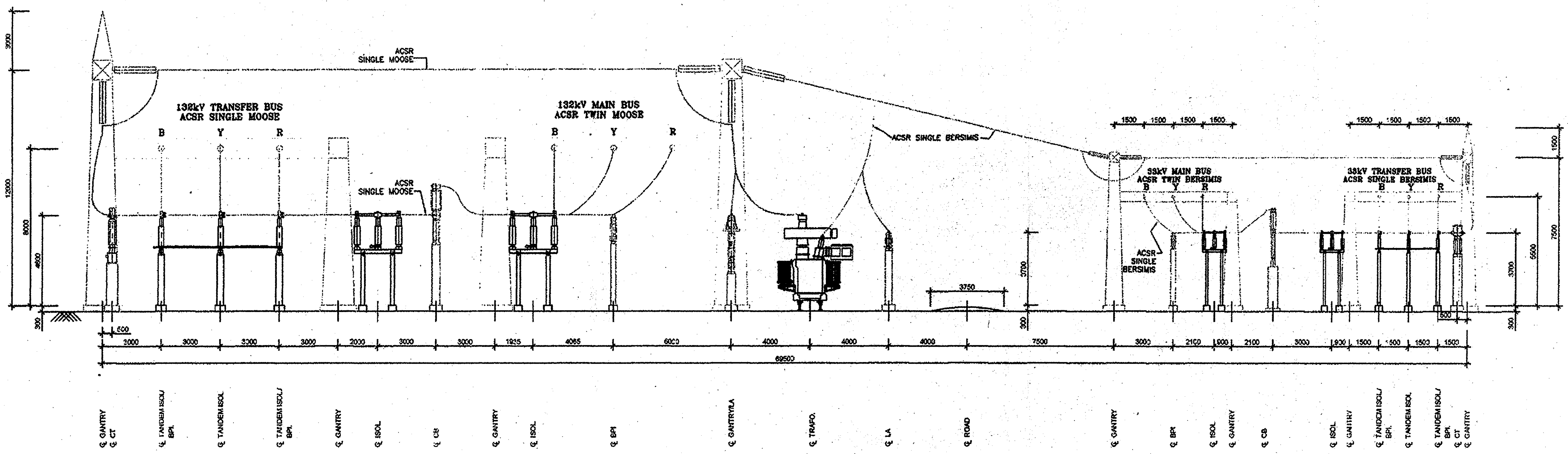
Scale: NTS



SECTION A-A
132KV LINE #2



SECTION E-E
33KV LINE #1



SECTION B-B
ICT #2

NOTES:-

1. ALL DIMENSIONS ARE IN mm UNLESS OTEHRWISE SPECIFIED.
2. EQUIPMENT BUS, MAIN BUS, TRANSFER BUS AND JACK BUS HEIGHT ARE FROM TOP OF PLINTH.

PLINTH LVL.

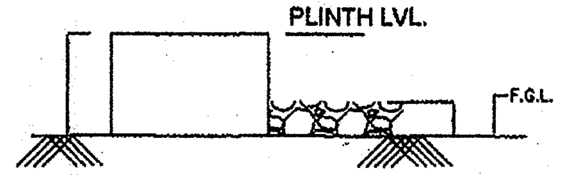
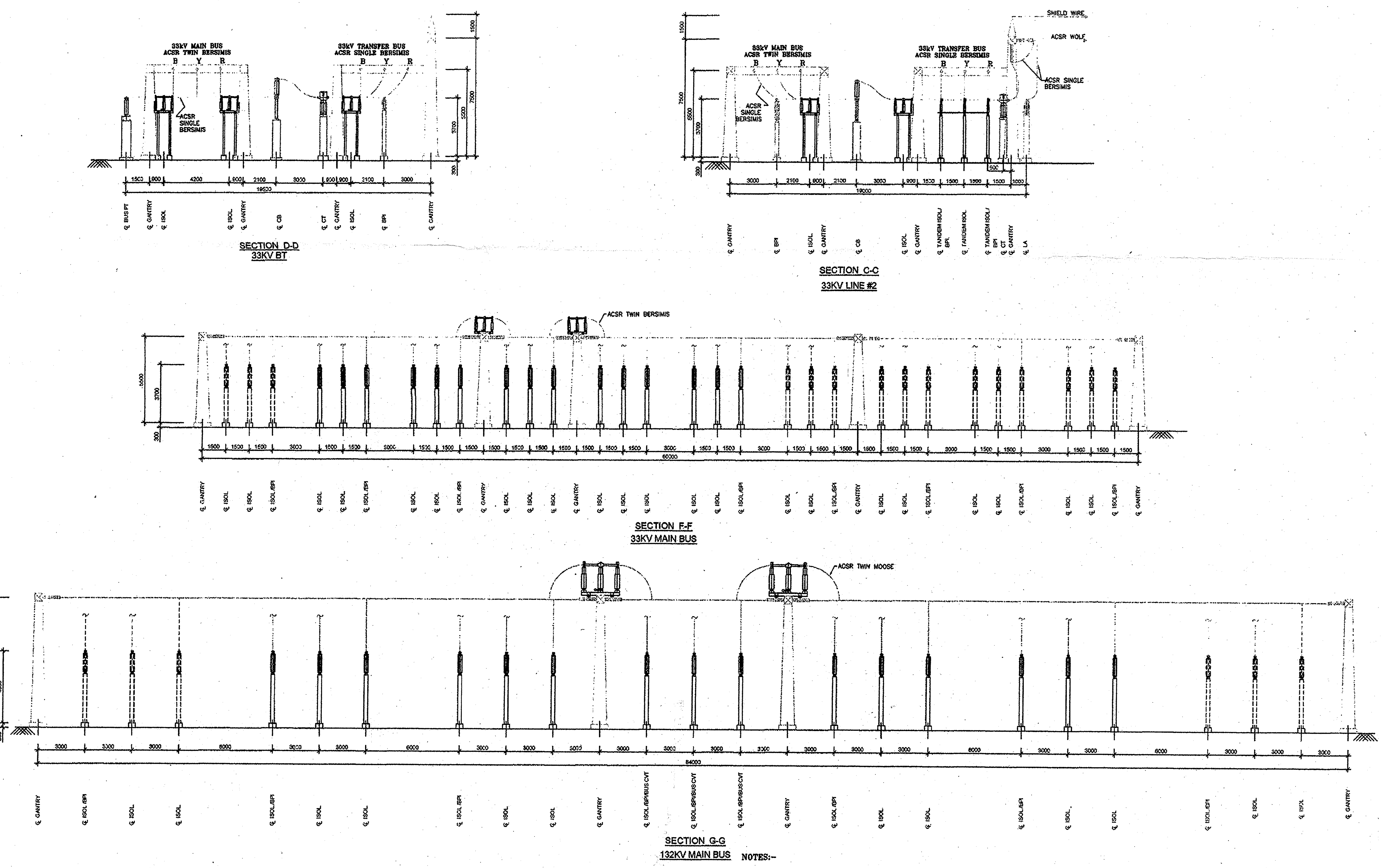


FIGURE 19 A (SHEET 3 OF 4)

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)

132/33 KV SUBSTATION -MAIN & TRANSFER SCHEME WITH BUS SECTIONALISER

Scale: NTS

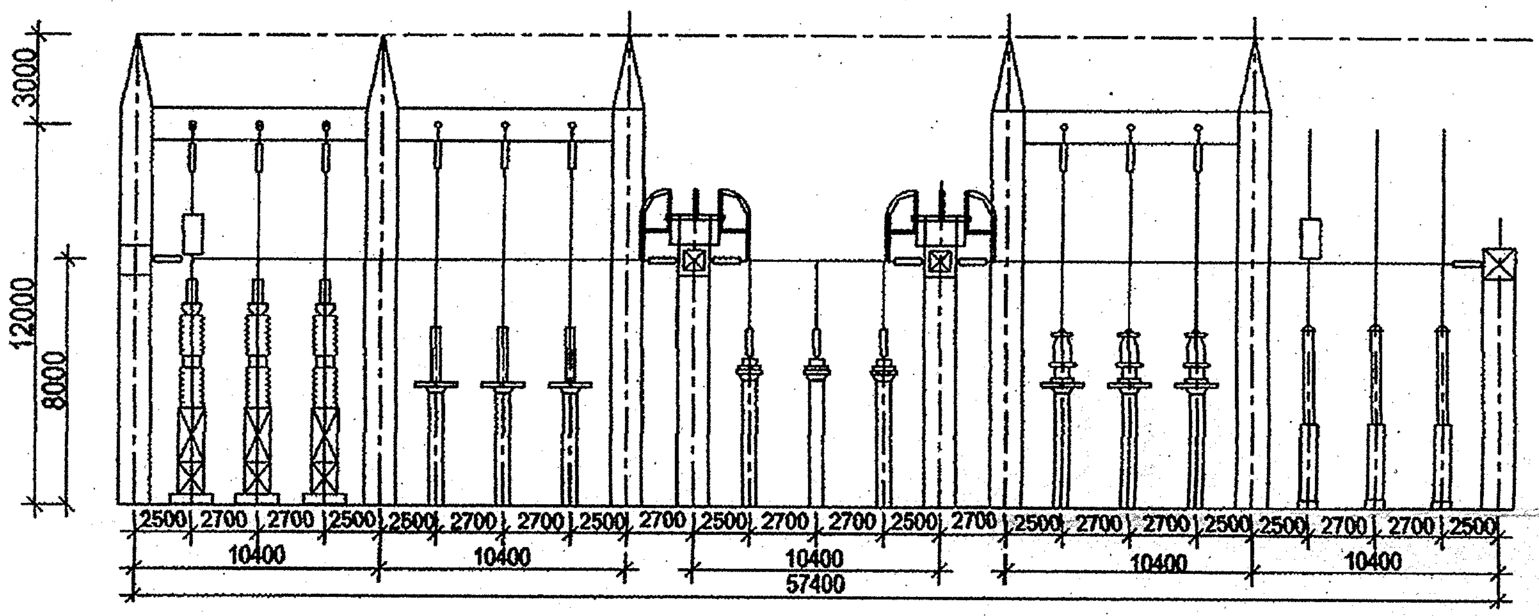


NOTES:-

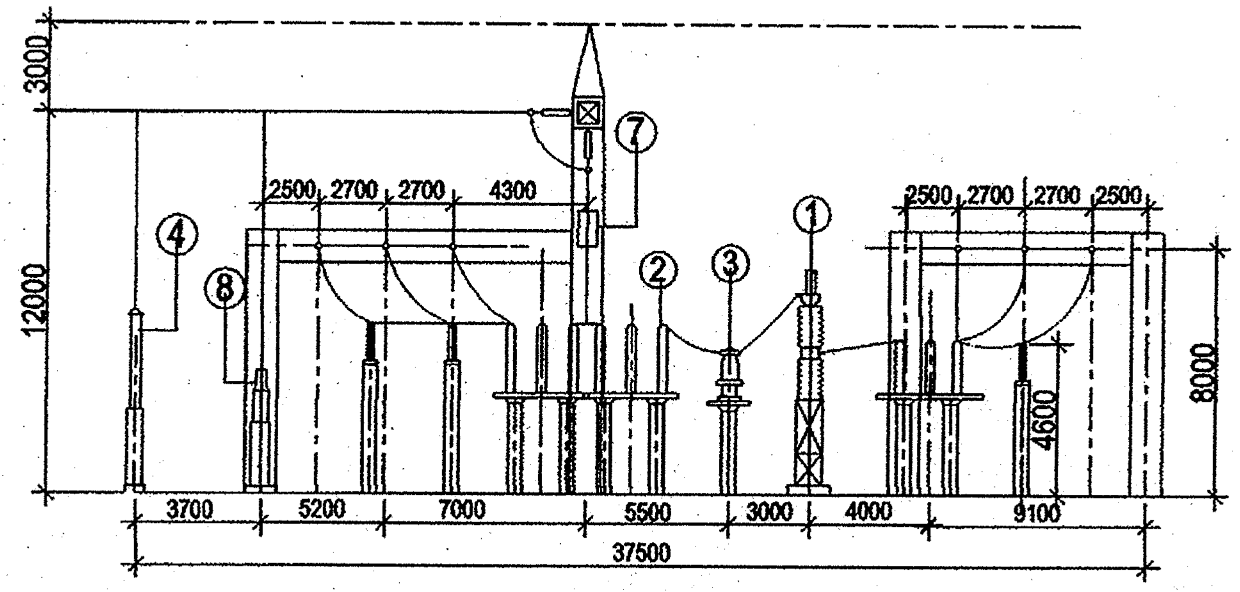
1. ALL DIMENSIONS ARE IN mm UNLESS OTEHRWISE SPECIFIED.
2. EQUIPMENT BUS, MAIN BUS, TRANSFER BUS AND JACK BUS HEIGHT ARE FROM TOP OF PLINTH.

——— PRESENT
- - - - FUTURE

FIGURE 19 A (SHEET 4 OF 4)	
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
132/33 KV SUBSTATION -MAIN & TRANSFER SCHEME WITH BUS SECTIONALISER	
	Scale
	NTS

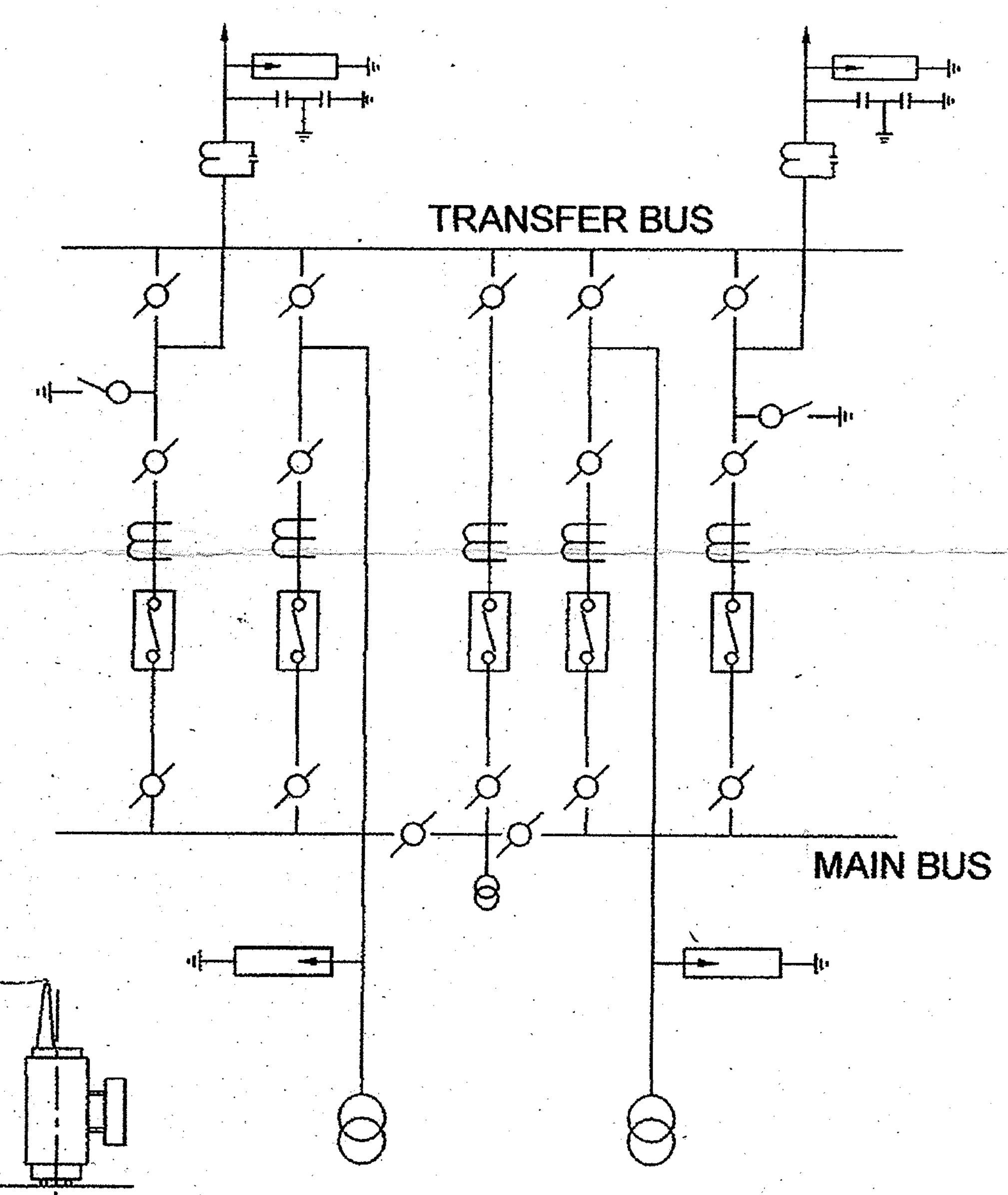


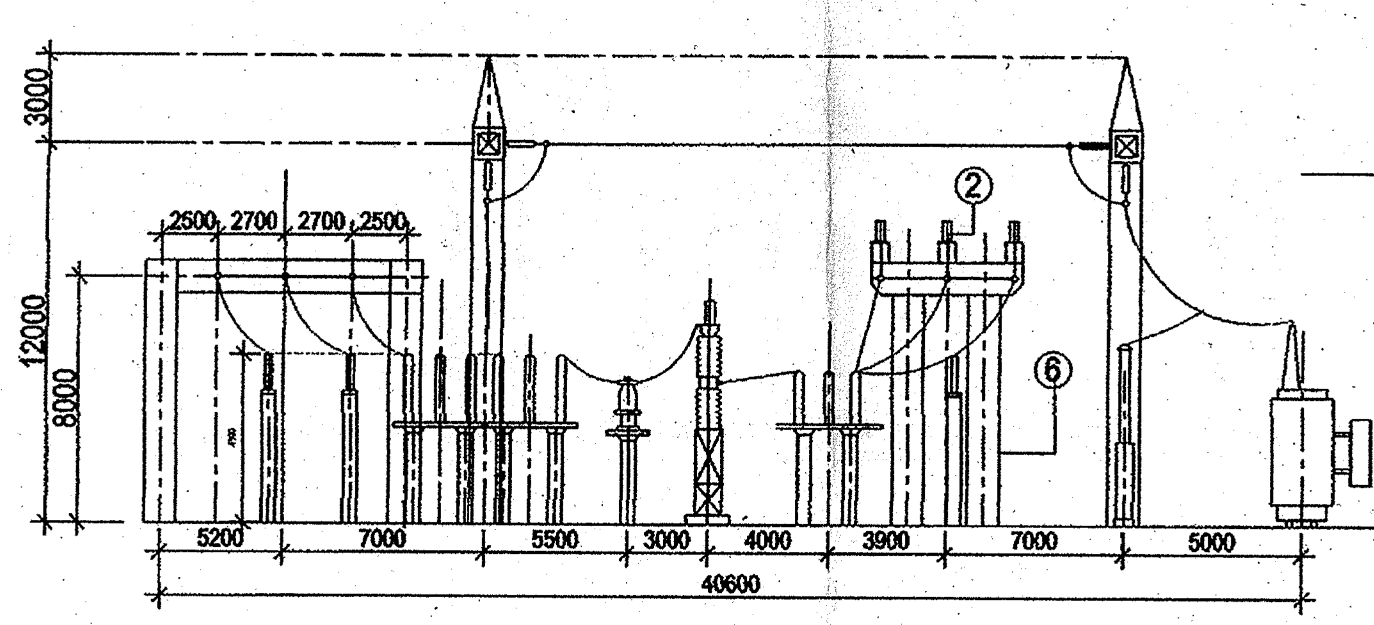
SECTION AT L-L



SECTION AT X-X (LINE BAY)

SINGLE LINE DIAGRAM

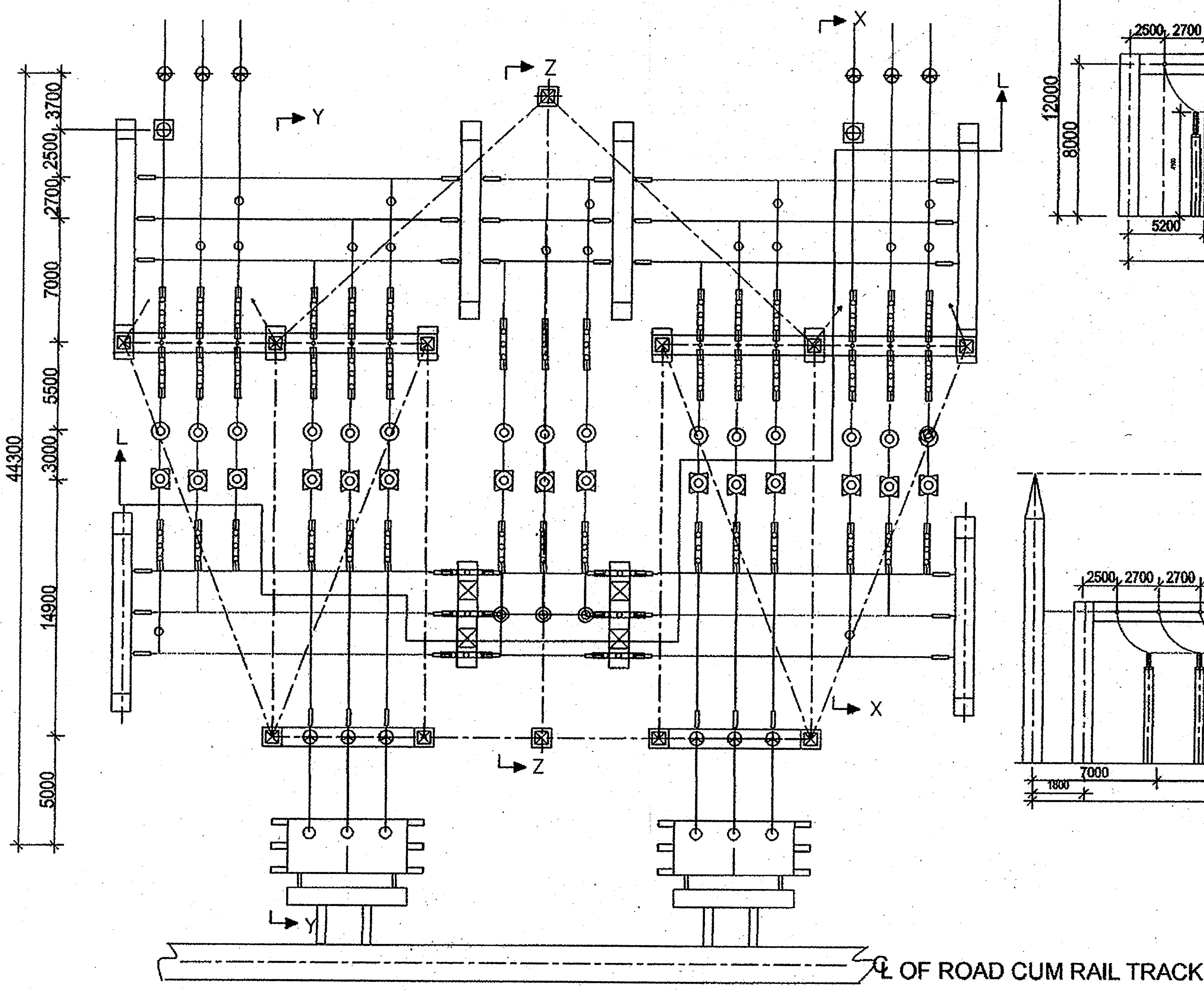




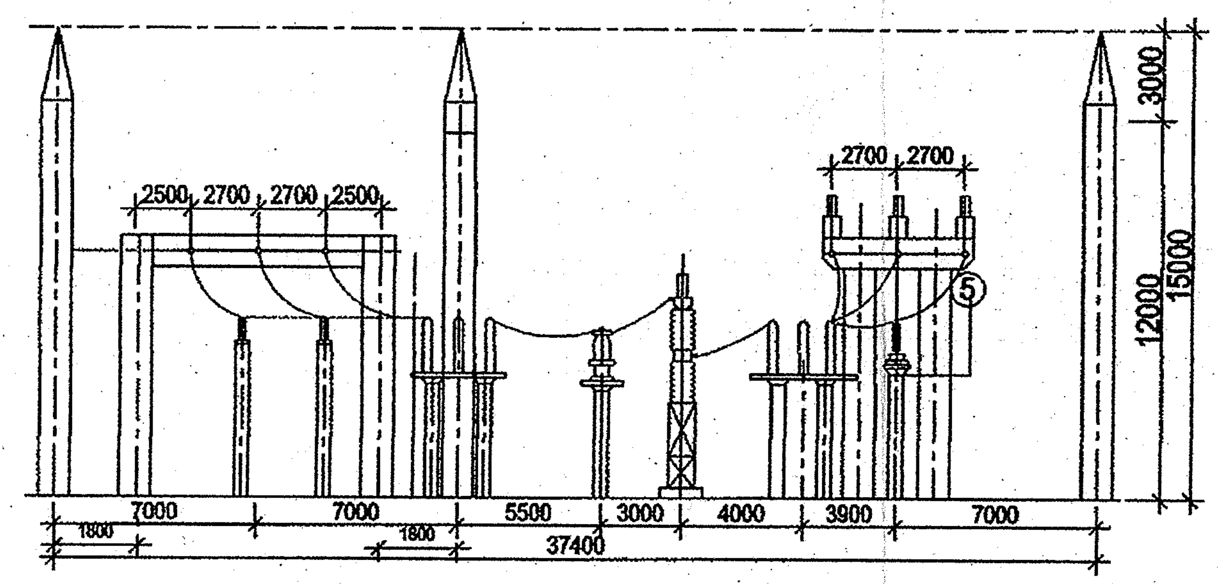
SECTION AT Y-Y (TRANSFORMER BAY)

LEGEND

1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. LIGHTNING ARRESTER
5. POTENTIAL TRANSFORMER
6. POST INSULATOR
7. WAVETRAP
8. COUPLING CAPACITOR WITH POTENTIAL DEVICE



PLAN



SECTION AT Z-Z (BUS COUPLER BAY)

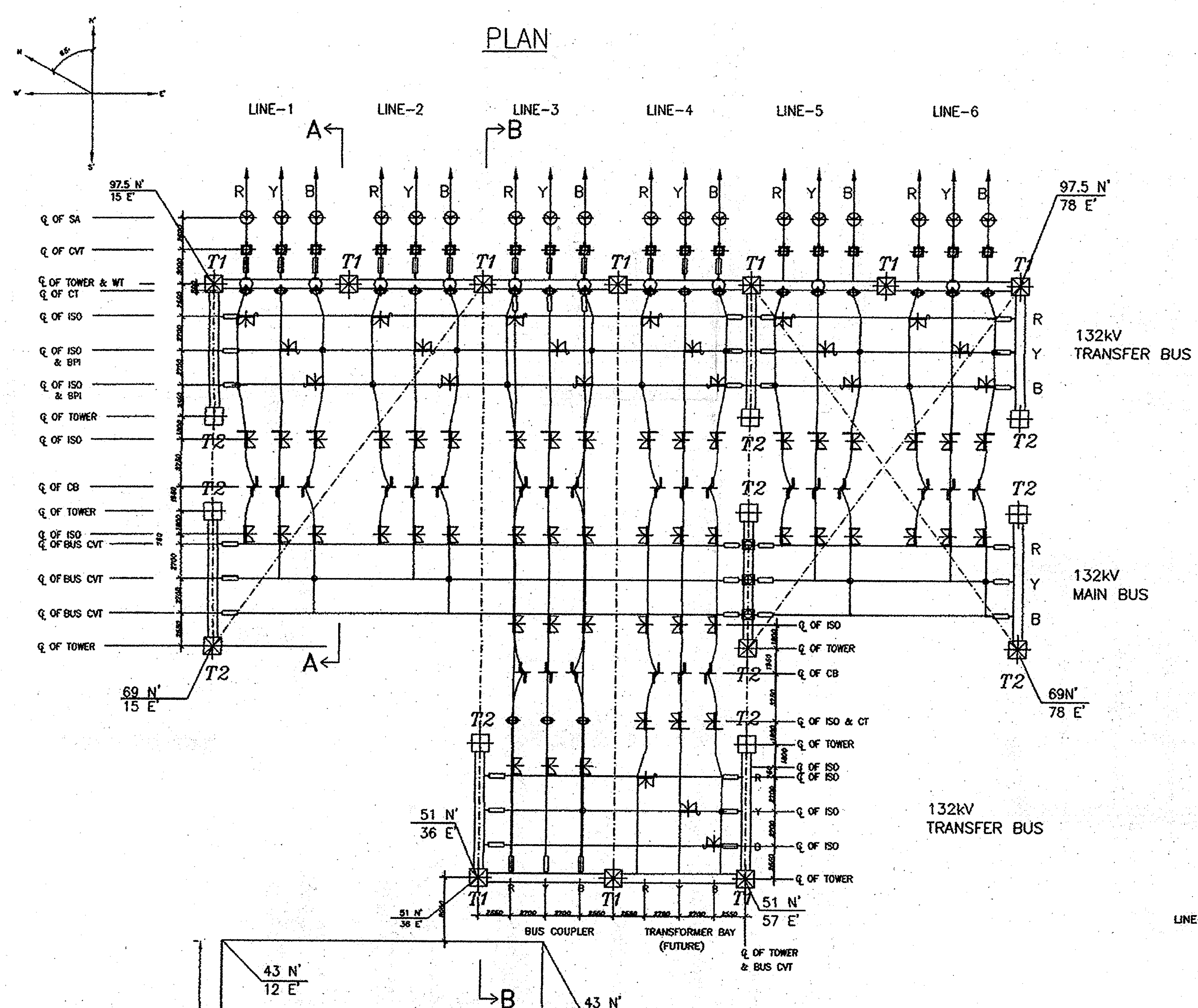
NOTE

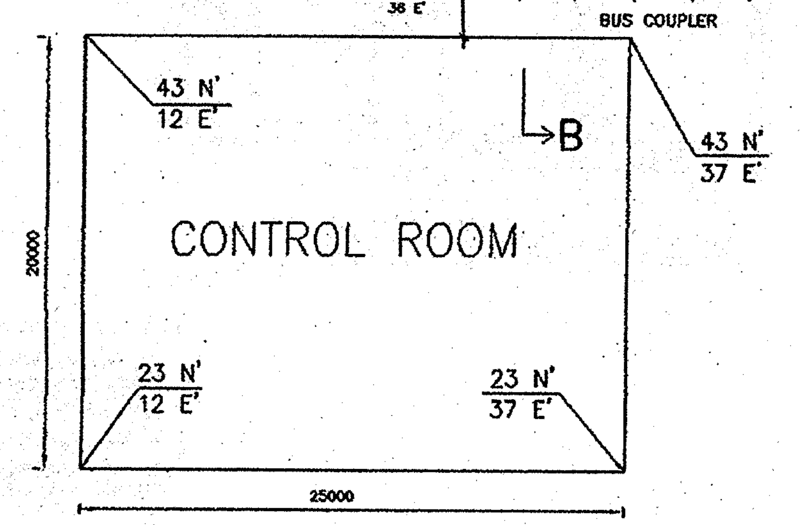
1. ALL DIMENSIONS ARE IN MM.
2. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-20

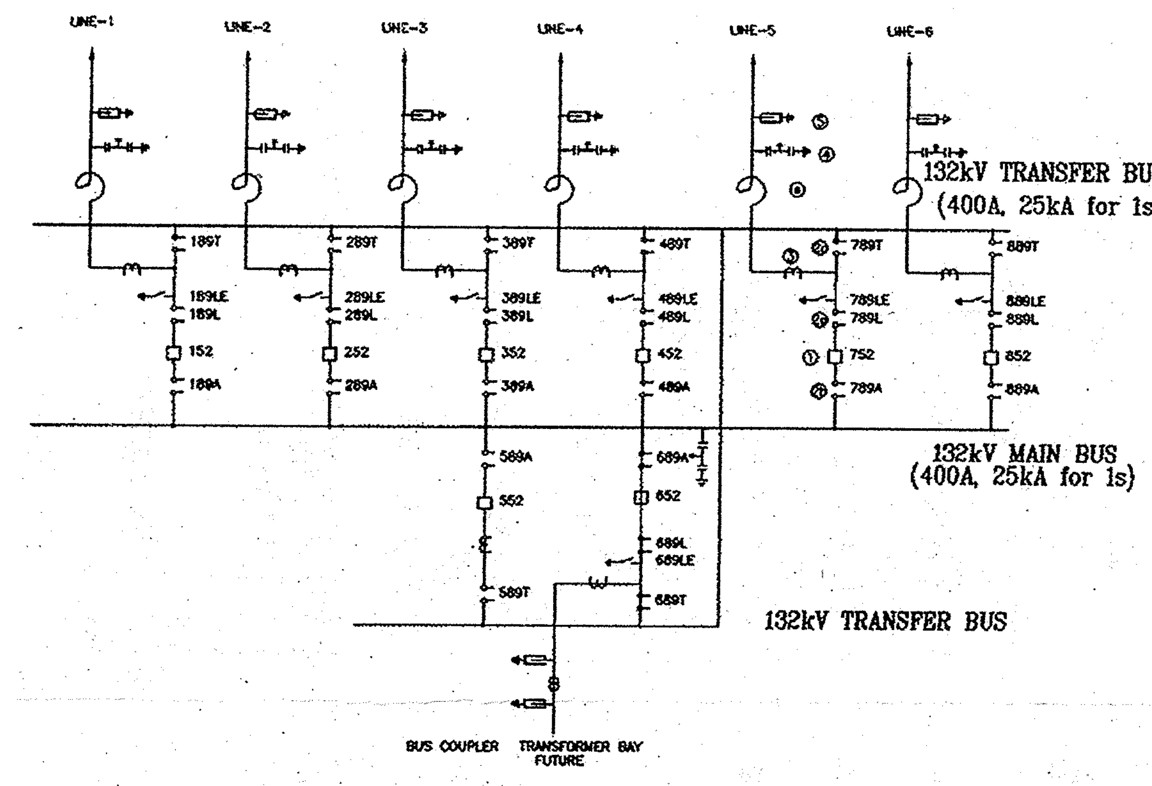
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
MAIN AND TRANSFER BUS ARRANGEMENT (LOW LEVEL TYPE) 145kV, BIL 650kVp		
	SHEET 1 OF 1	SCALE: NTS

PLAN

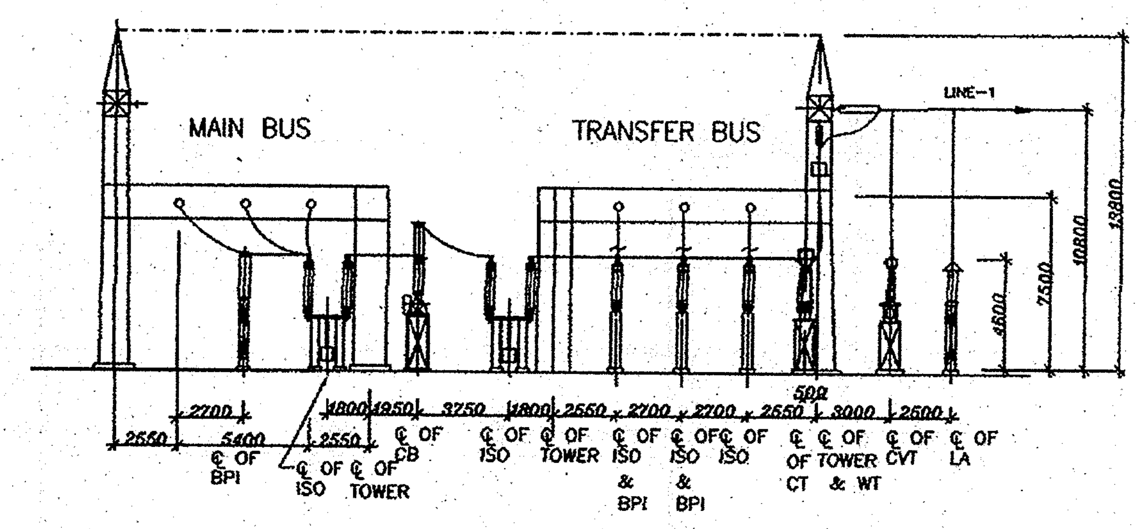




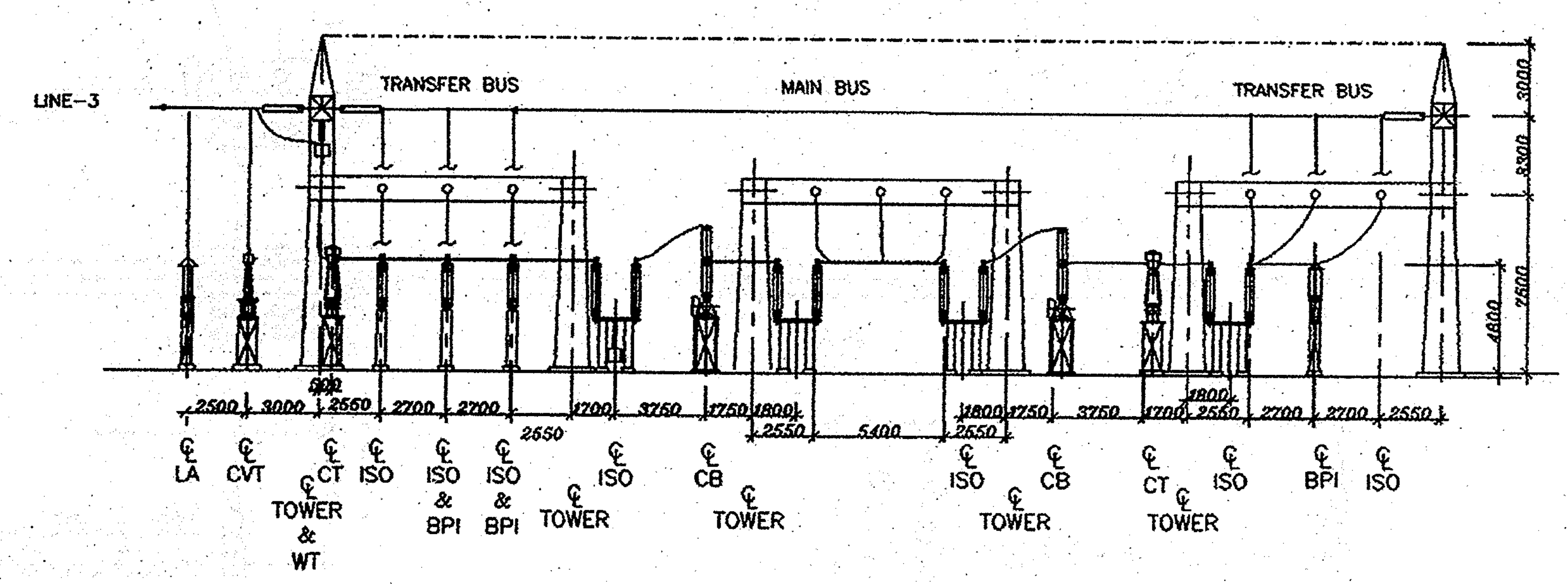
LEGEND	
	CIRCUIT BREAKER
	CURRENT TRANSFORMER
	CVT
	3 POLE HCB ISOLATOR
	SINGLE TENSION ASSEMBLY
	TANDEM ISOLATOR
	SURGE ARRESTER
	WAVE TRAP
	BPI



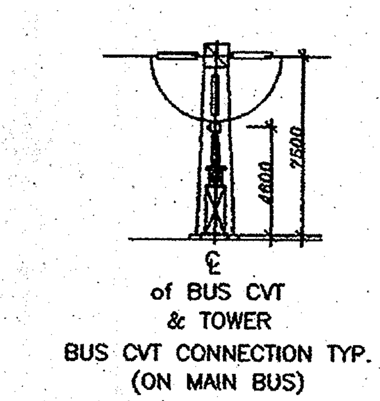
SINGLE LINE DIAGRAM



SECTION – AA (LINE BAY)



SECTION – BB



SECTION – CC

NOTES:

1. ALL DIMENSIONS ARE IN MM.
2. EQUIPMENT INTERCONNECTION AT 4.6 METRE.
3. MAIN BUS HEIGHT 7.5 METER.
4. ALL CONDUCTORS ARE ACSR PANTHER.
5. SHORT CIRCUIT CURRENT & DURATION : 25kA FOR 1 SEC.

* DESIGN VOLTAGE

a. HIGHEST SYSTEM VOLTAGE =145 kV rms
b. P.F. WITH STAND VOLTAGE =275 kV rms
c. LIGHTNING IMPULSE =650 kV peak

* CLEARANCE (mm)

a. PHASE TO EARTH (MIN.) =1300
b. PHASE TO PHASE (MIN.) =1300
c. SECTIONAL CLEARANCE =4000

* STATIC CONDUCTOR TENSION (AT 0 DEG. C):

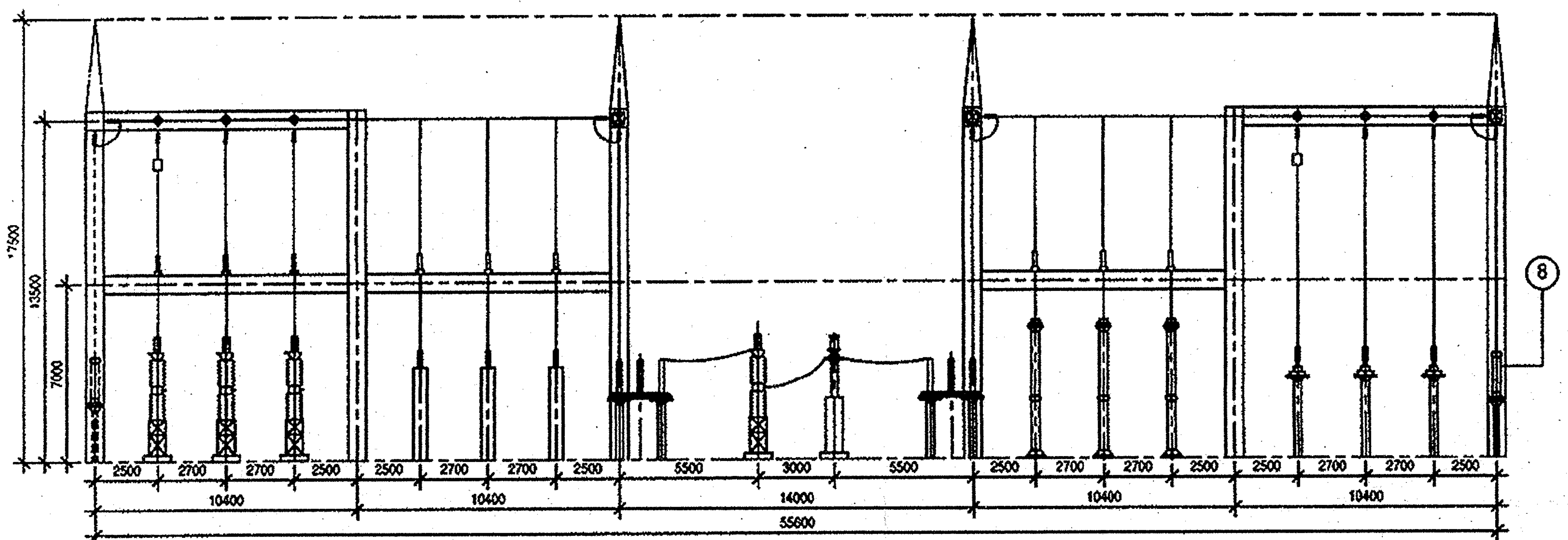
a. CONDUCTOR 1000 KG/CONDUCTOR
b. O/H EARTHWIRE 500 KG/WIRE

Figure-20a

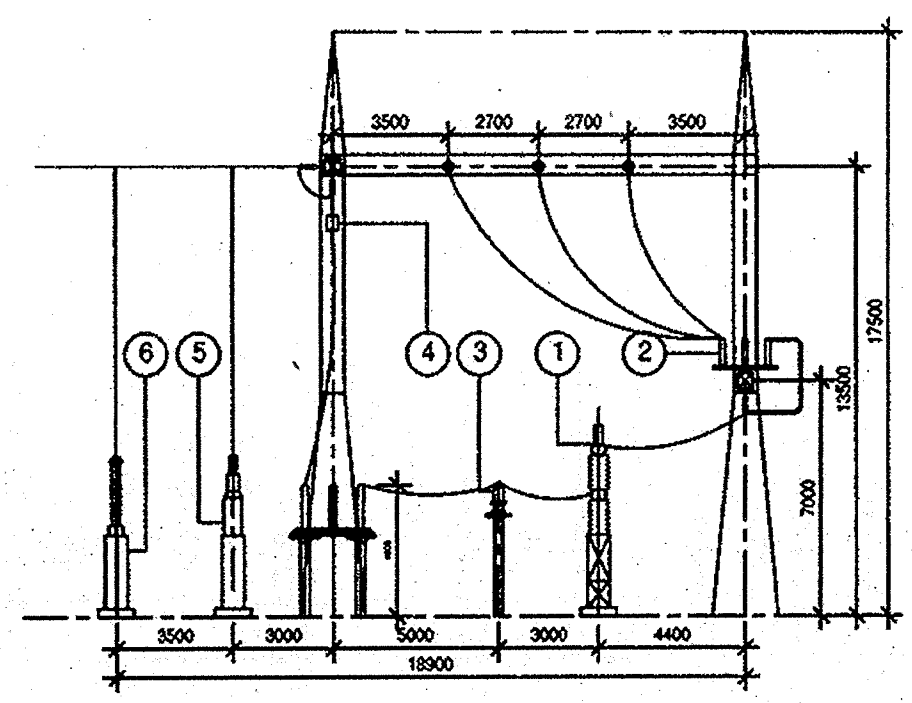
LAYOUT DRAWING - 145 KV /10.5M BAY WIDTH (MAIN AND TRANSFER SCHEME)

BIL- LI 650KVp

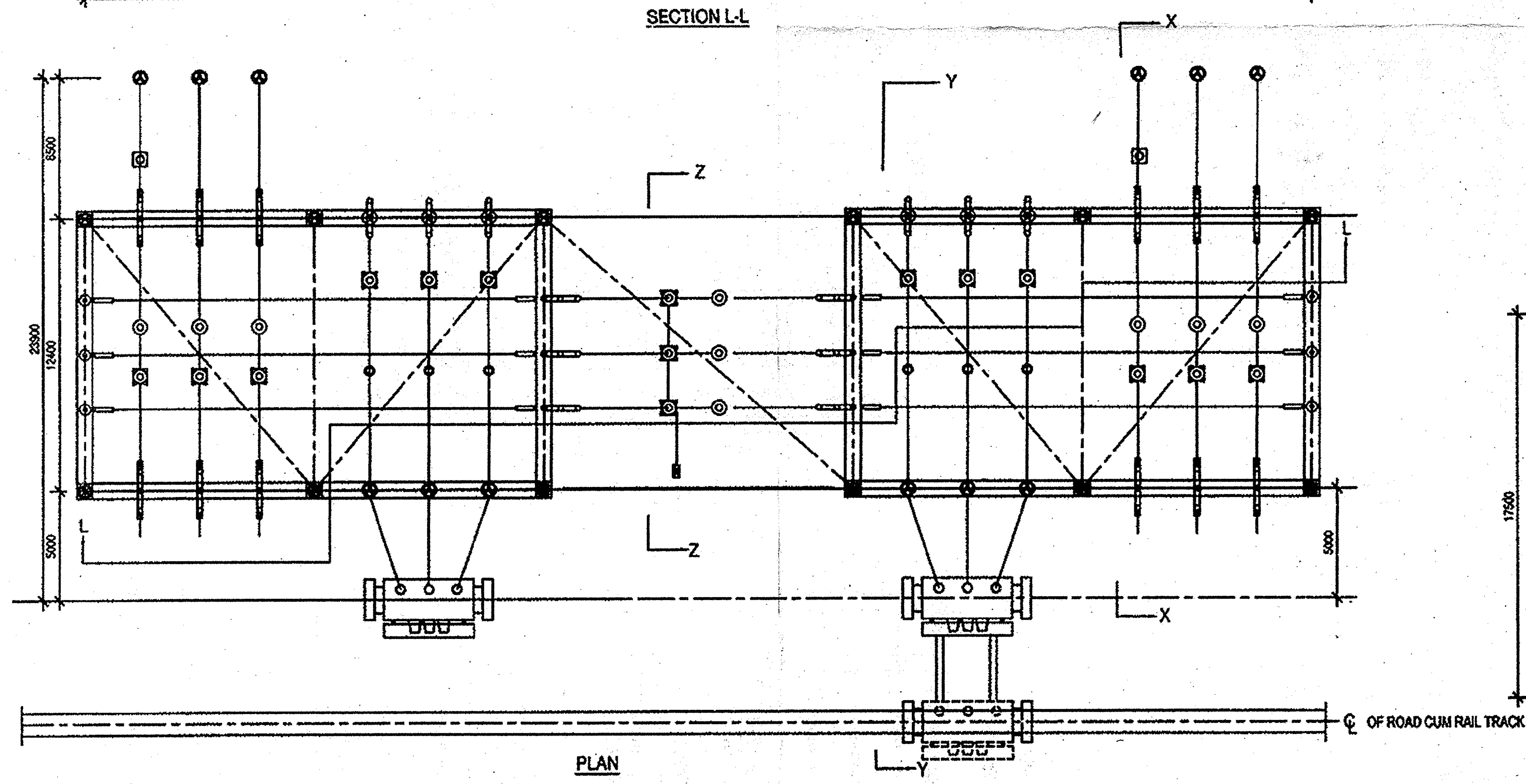
MANUAL ON SUB STATIONS LAYOUT & DESIGN



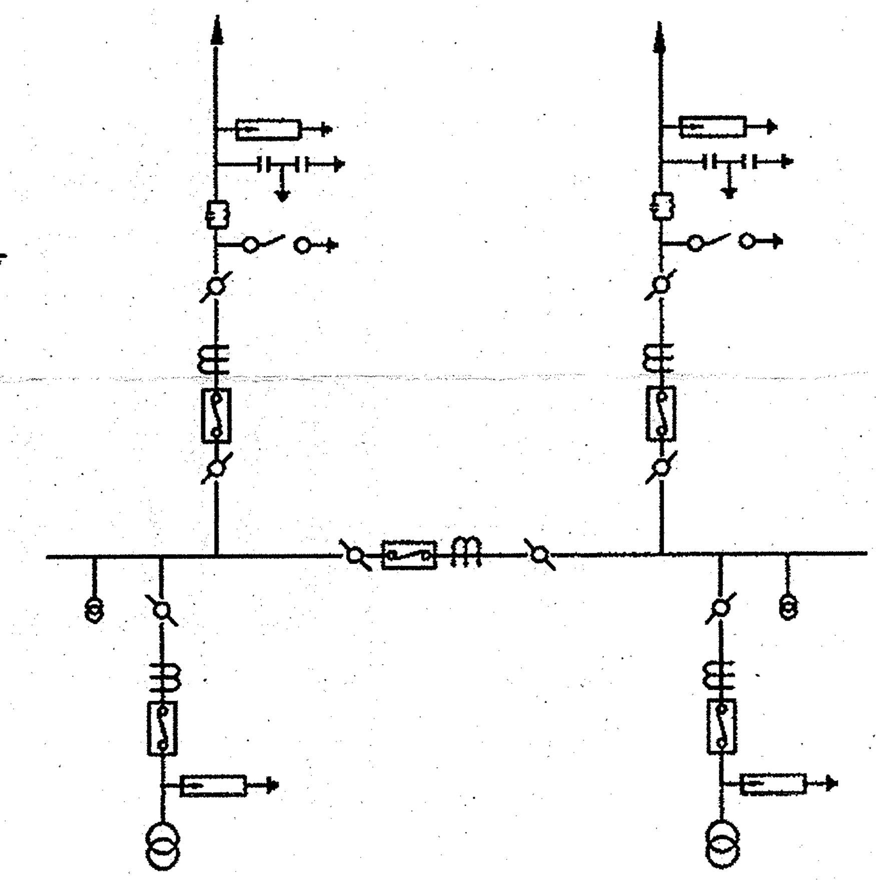
SECTION L-L



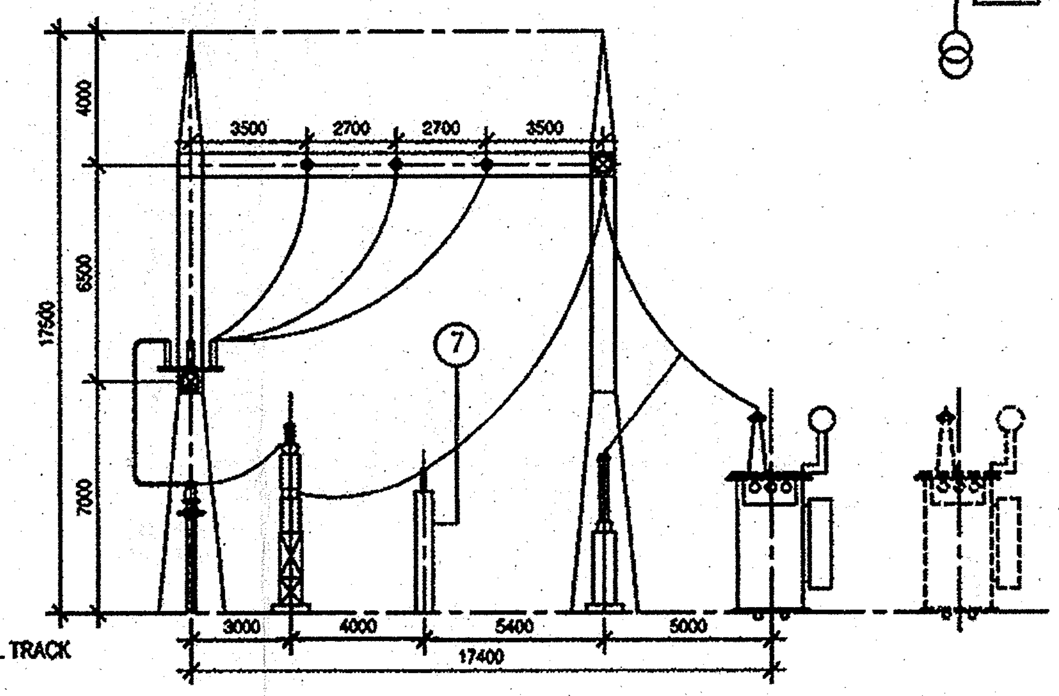
SECTION X-X (LINE BAY)



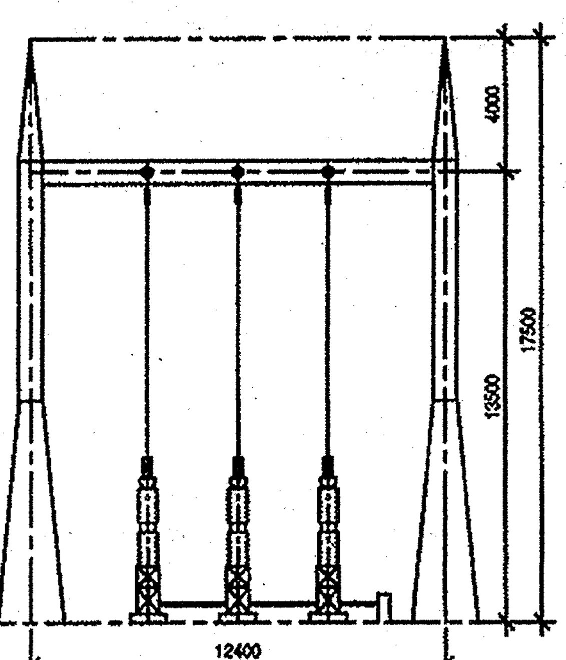
PLAN



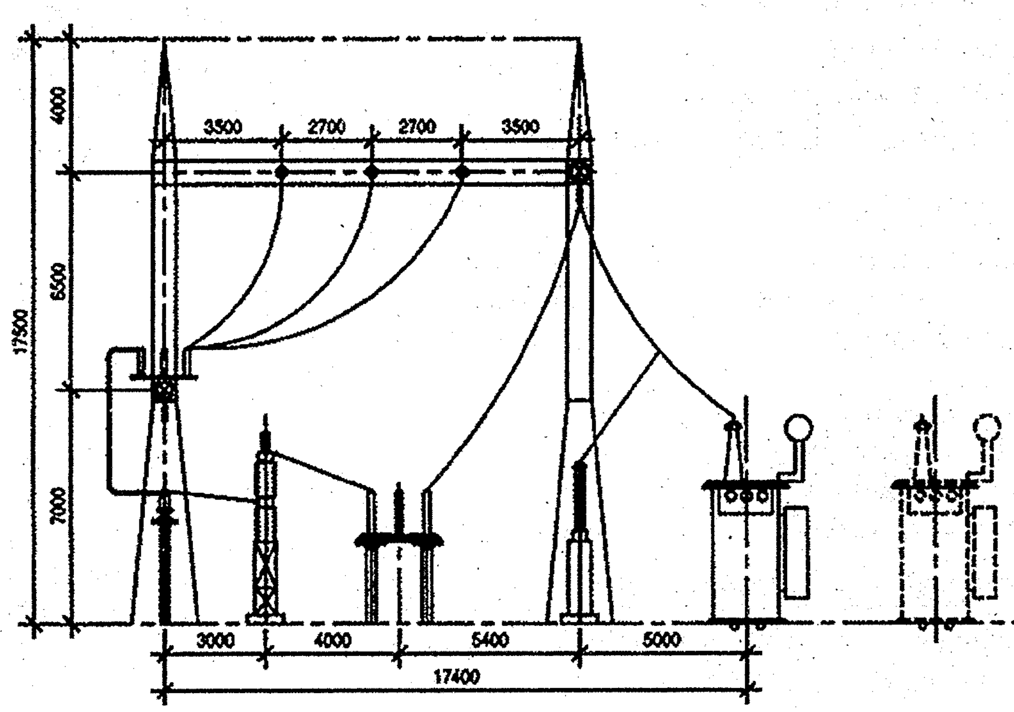
SINGAL LINE DIAGRAM



SECTION Y-Y (TRANSFORMER BAY)



SECTION Z-Z



SECTION Y'-Y' (TRANSFORMER BAY)

NOTE

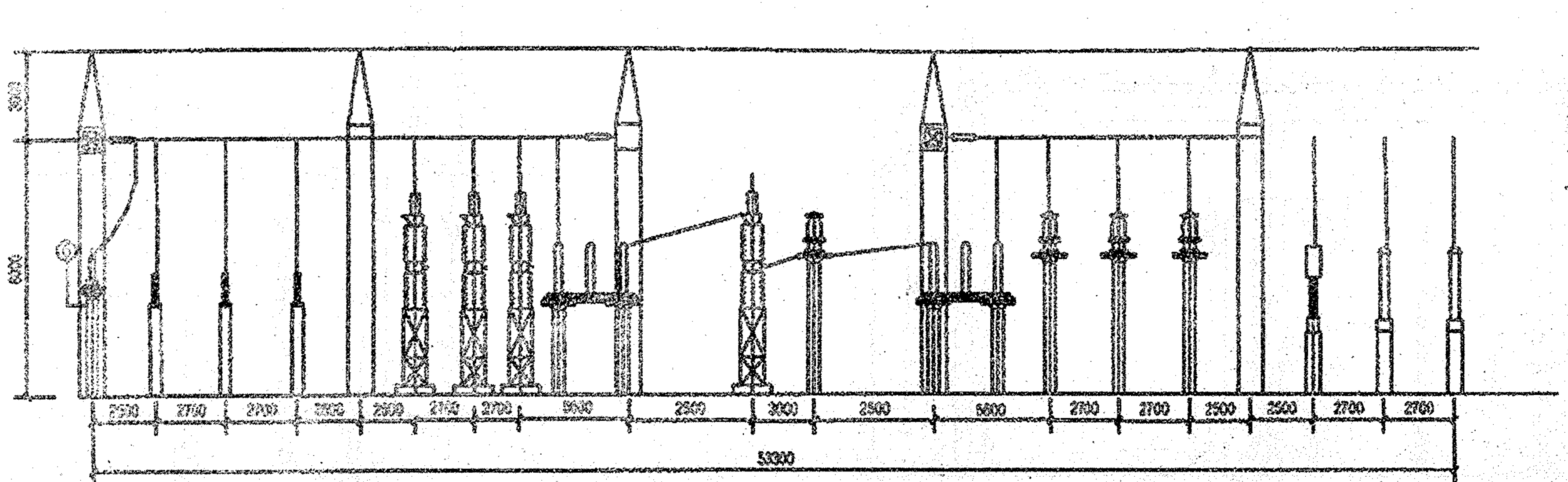
1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORNER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

LEGEND

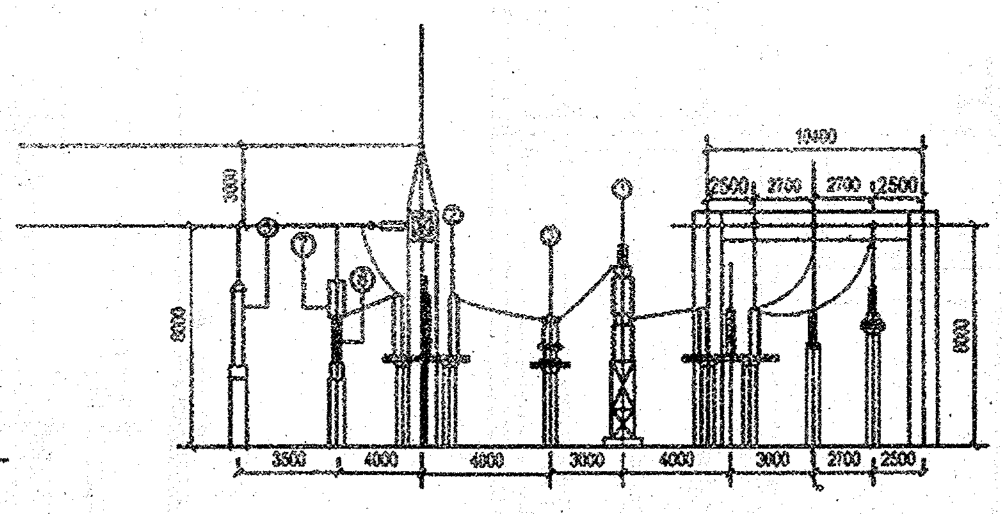
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. WAVE TRAP
5. COUPLING CAPACITOR WITH POTENTIAL DEVICE
6. LIGHTNING ARRESTER
7. POST INSULATOR
8. POTENTIAL TRANSFORMER

FIGURE-21

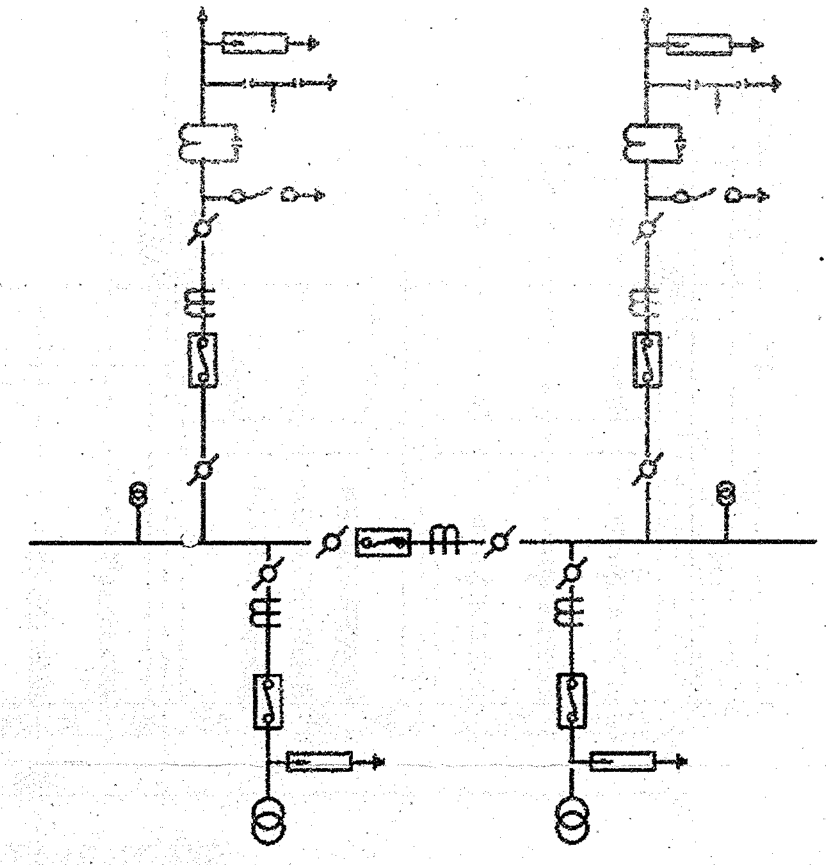
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
SINGLE BUS ARRANGMENT(HIGH LEVEL TYPE) 145 KV BIL 650 KVp	
SHEET 1 OF 1	SCALE: NTS



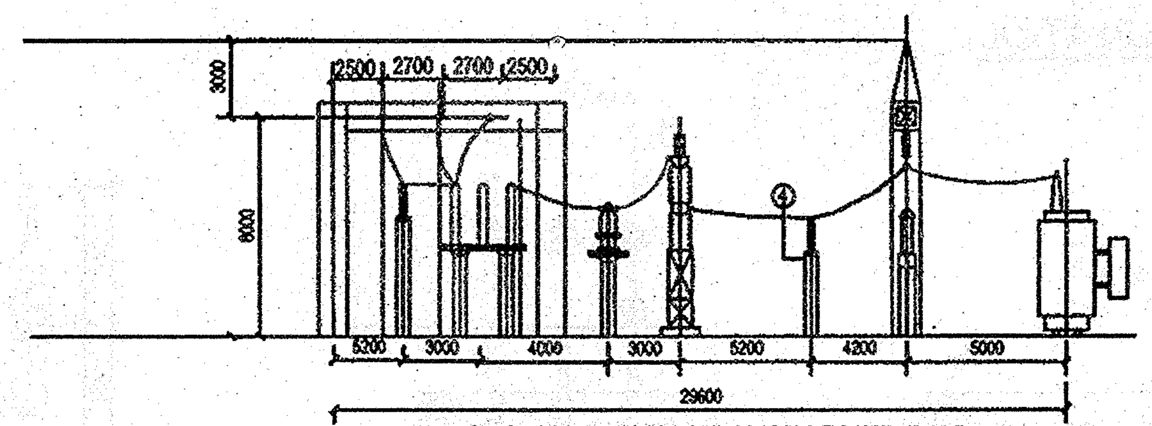
SECTION L-L



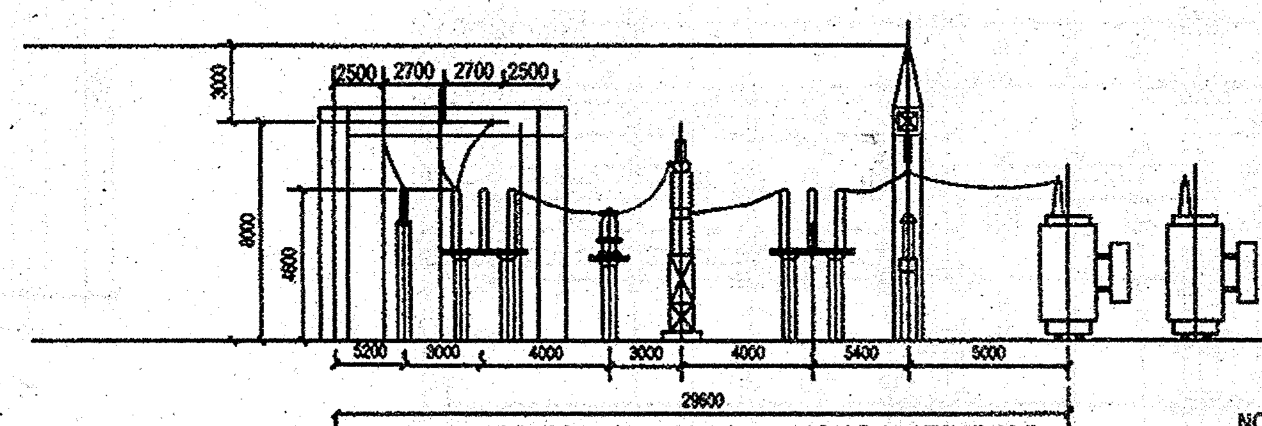
SECTION X-X (LINE BAY)



SINGAL LINE DIAGRAM



SECTION AT Y-Y (TRANSFORMER BAY)



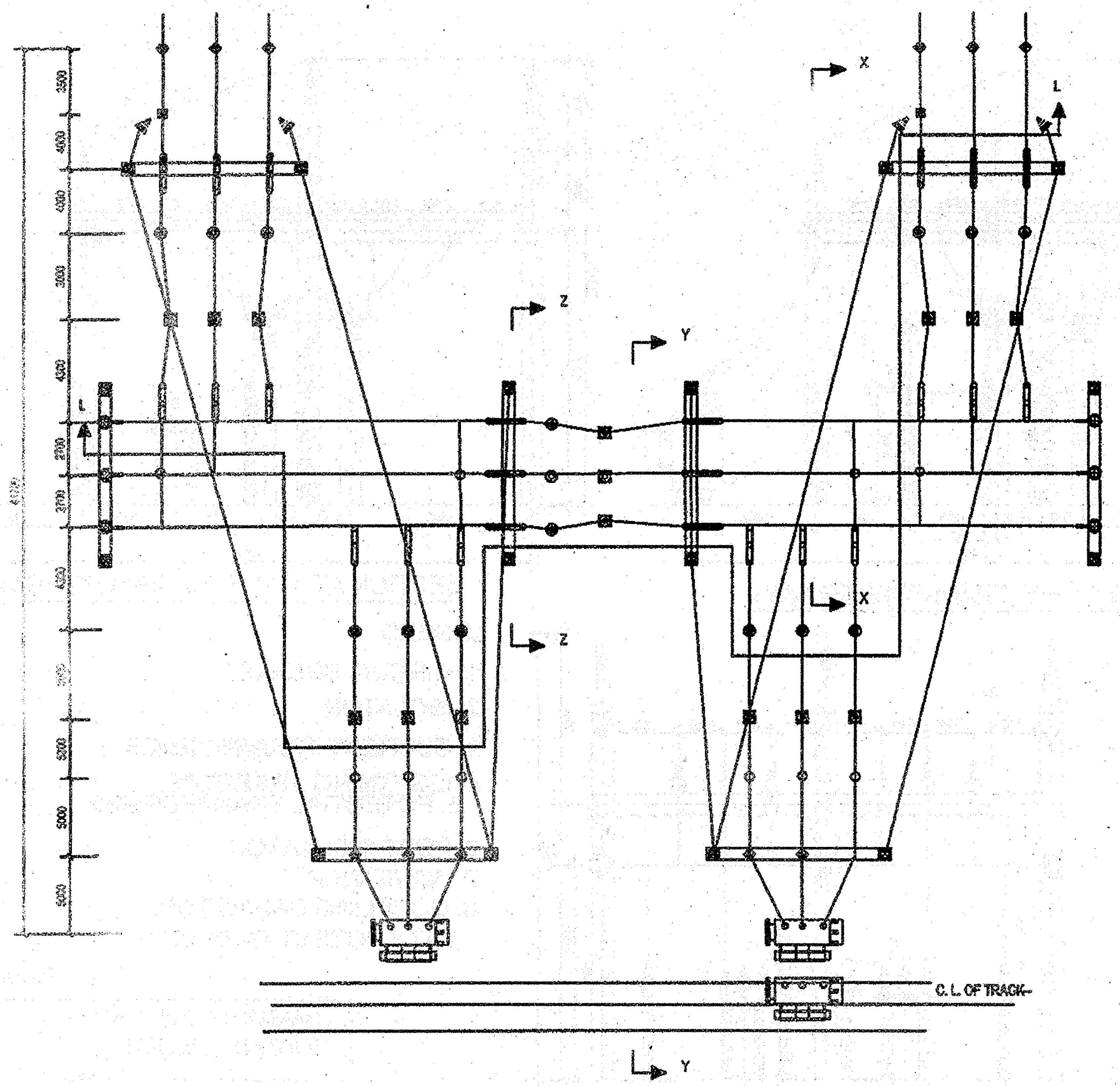
SECTION AT Y'-Y' (TRANSFORMER BAY)

LEGEND

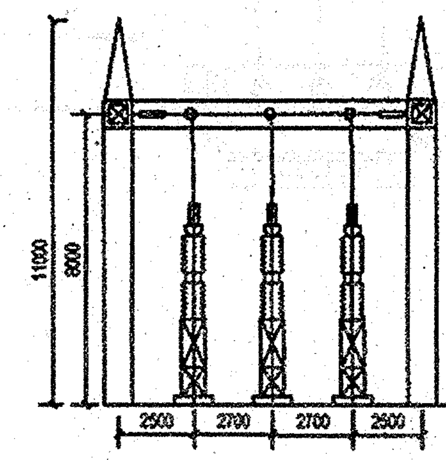
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. POST INSULATOR
5. LIGHTNING ARRESTER
6. POTENTIAL TRANSFORMER
7. WAVE TRAP
8. COUPLING CAPACITOR WITH POTENTIAL

NOTE

1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.



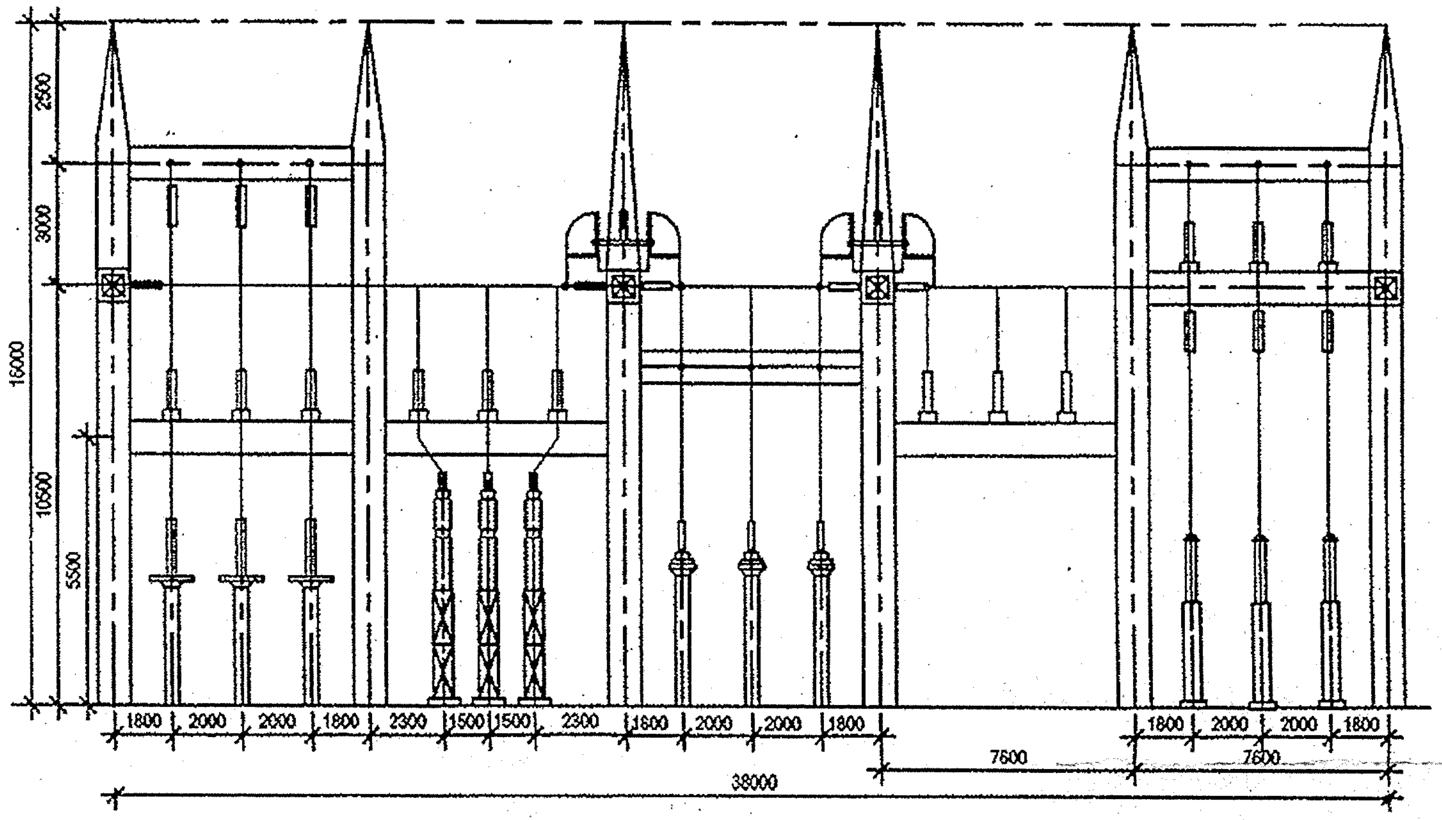
PLAN



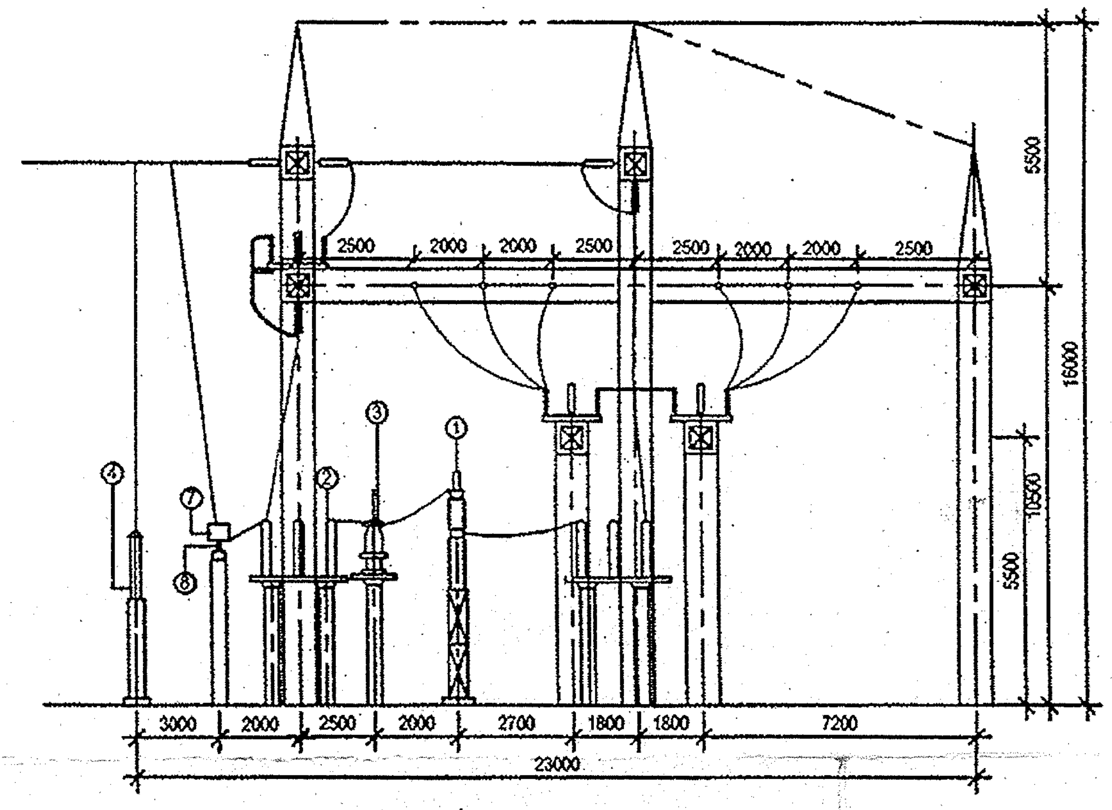
SECTION AT Z-Z

FIGURE-22

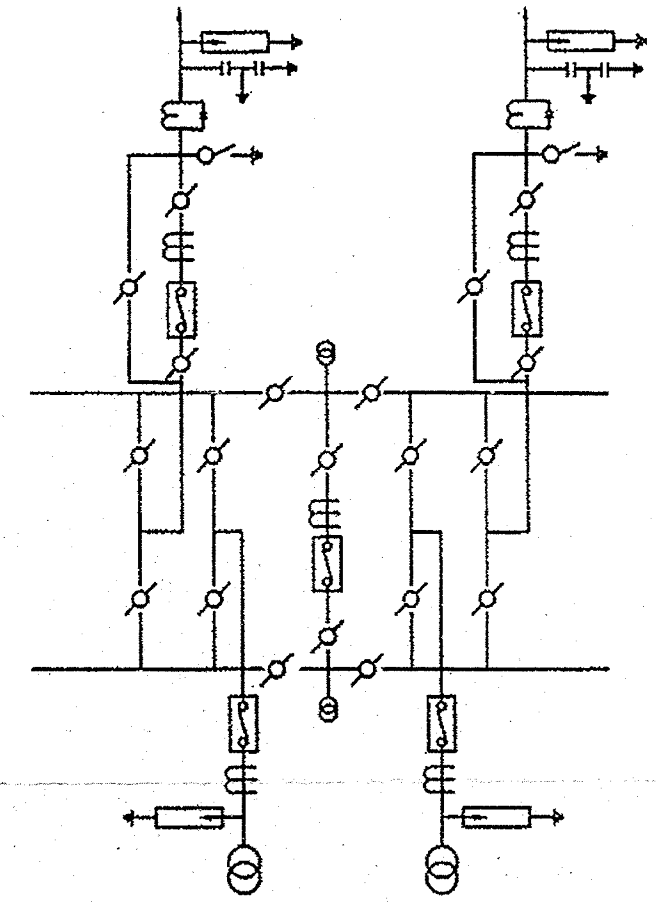
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
SINGLE BUS ARRANGMENT (LOW LEVEL TYPE) 145 KV, BIL 650 KVp	
SHEET 1 OF 1	SCALE: NTS



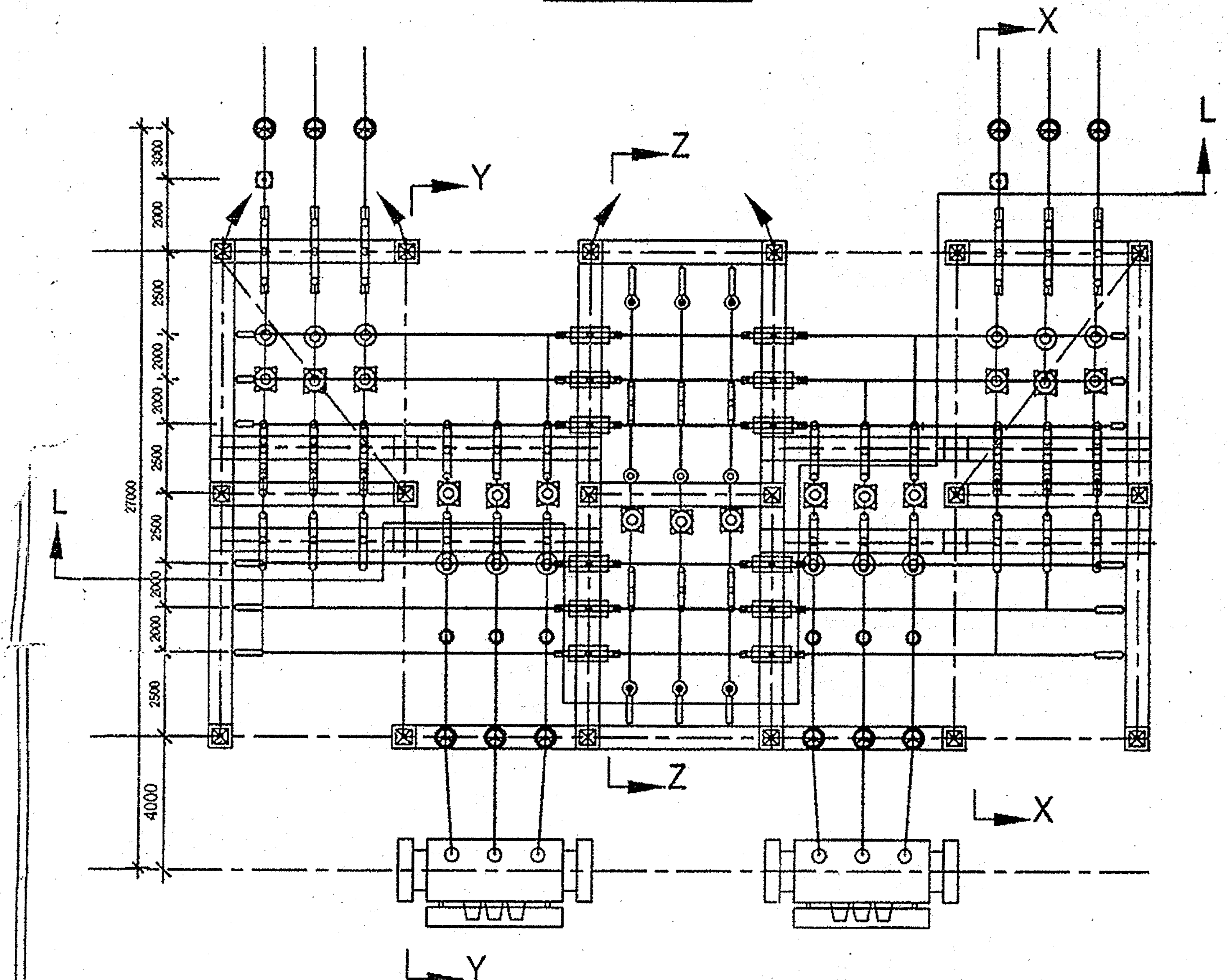
SECTION AT L-L



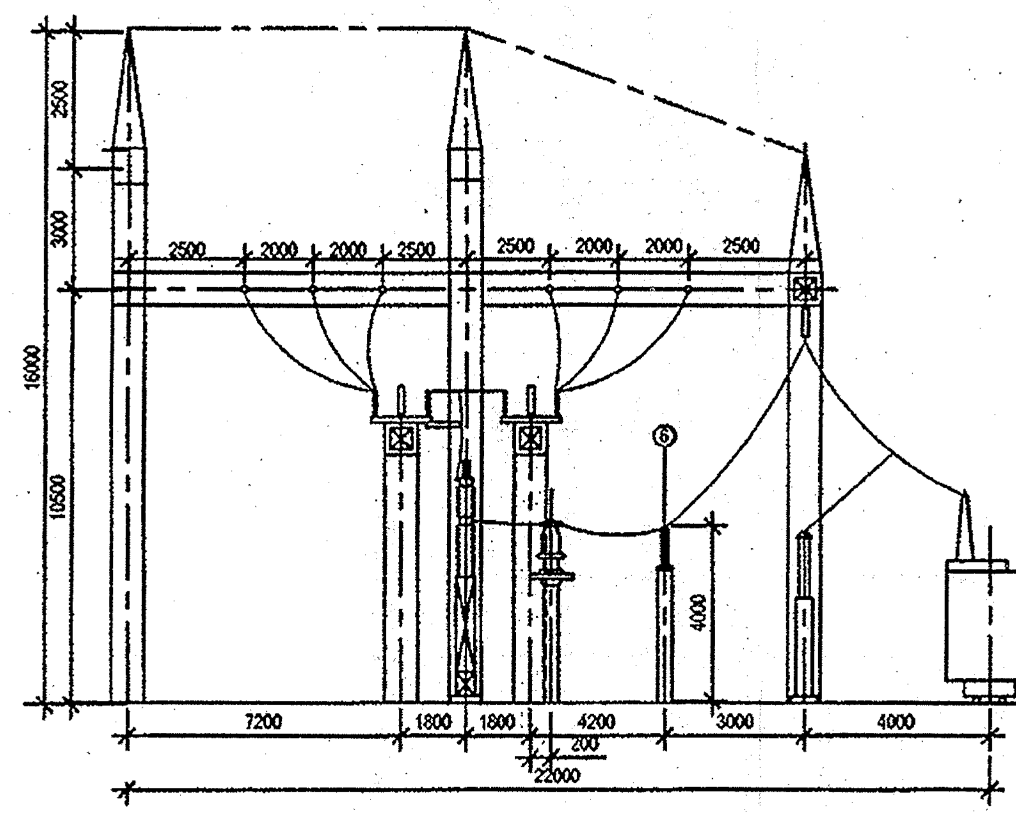
SECTION AT X-X (LINE BAY)



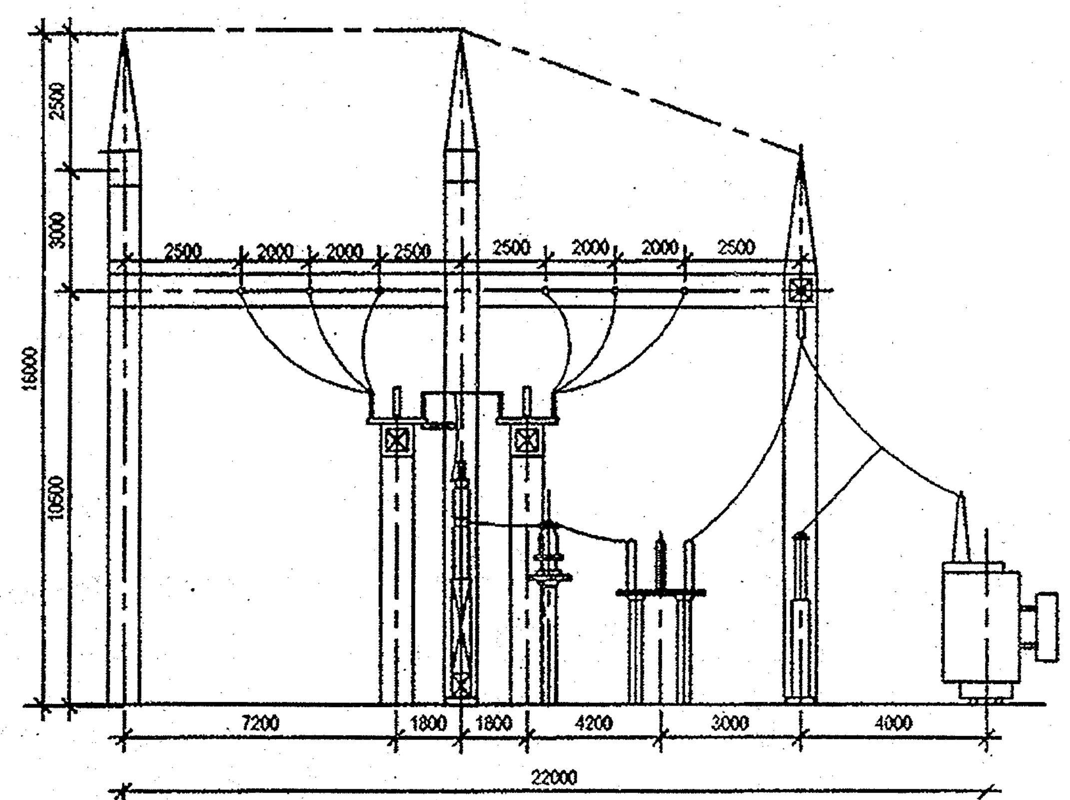
SINGLE LINE DIAGRAM



PLAN



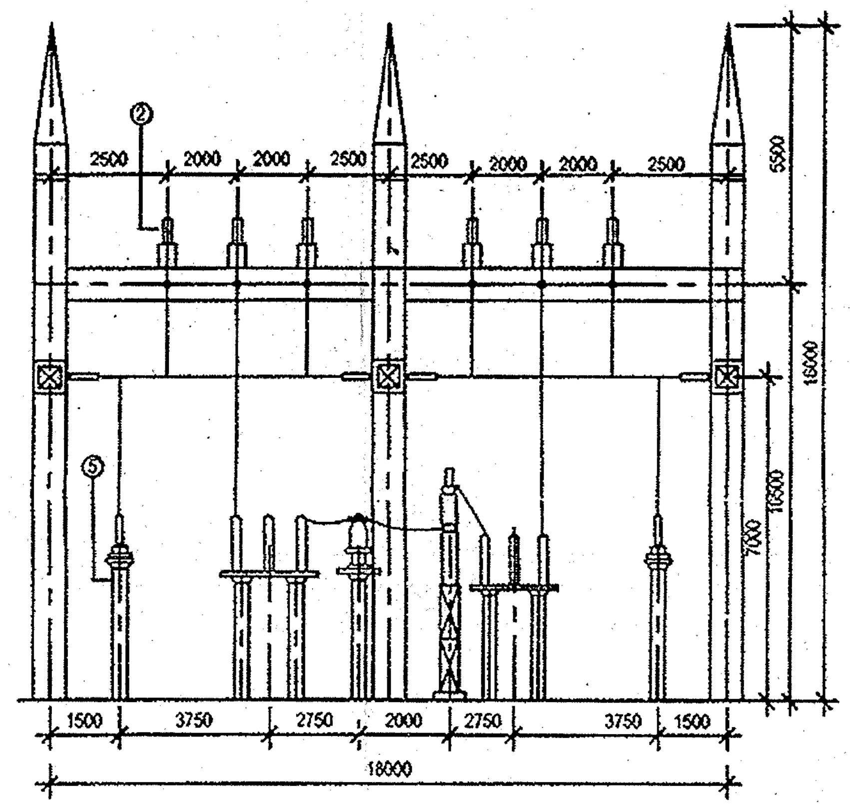
SECTION AT Y-Y (TRANSFORMER BAY)



SECTION AT Y'-Y' (TRANSFORMER BAY)

LEGEND

1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. LIGHTNING ARRESTER
5. POTENTIAL TRANSFORMER
6. POST INSULATOR
7. WAVETRAP
8. COUPLING CAPACITOR WITH POTENTIAL DEVICE



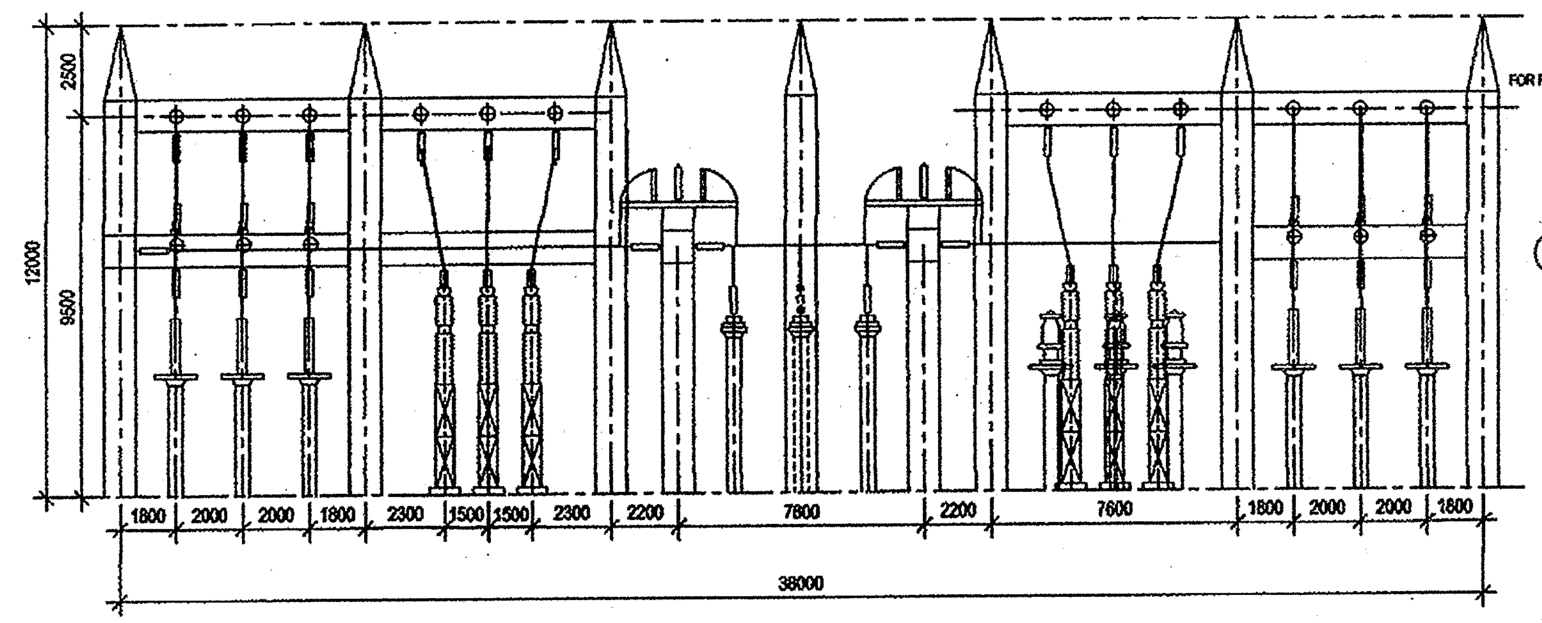
SECTION AT Z-Z (BUS COUPLER BAY)

NOTE

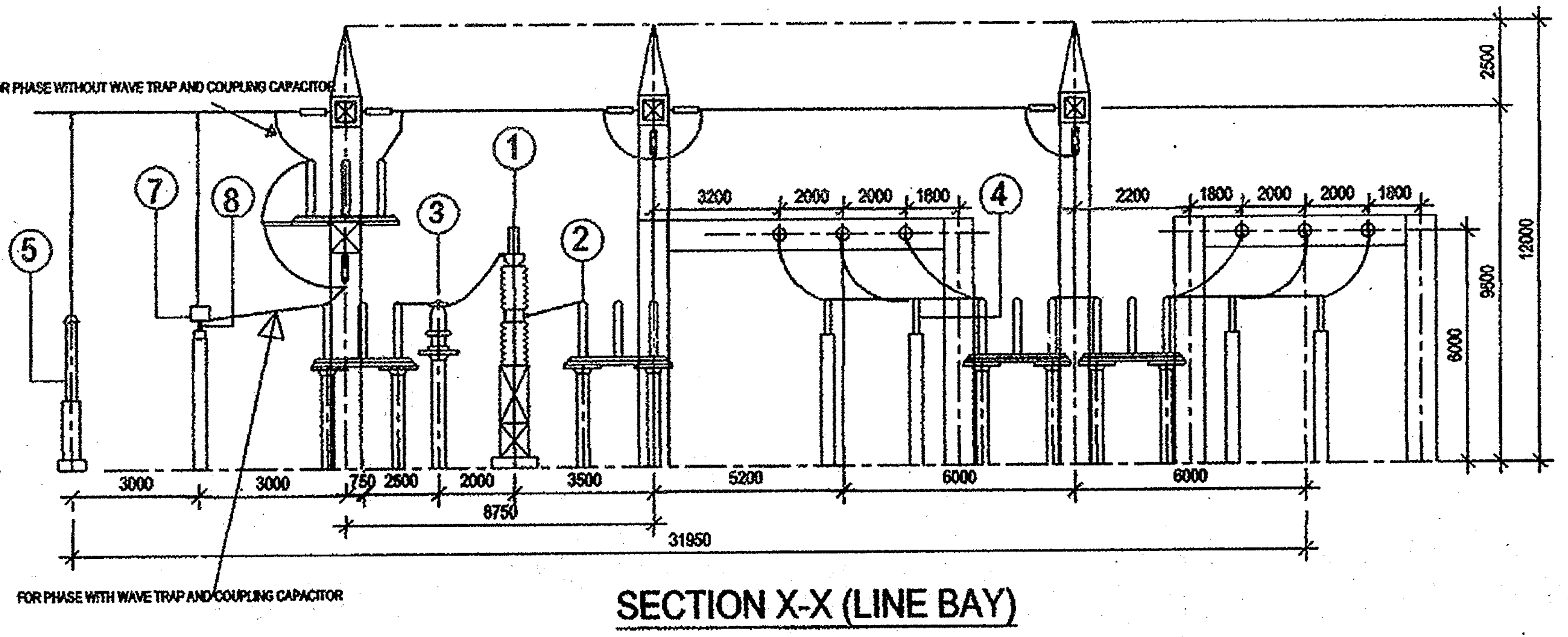
1. REPLACE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT.
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-23

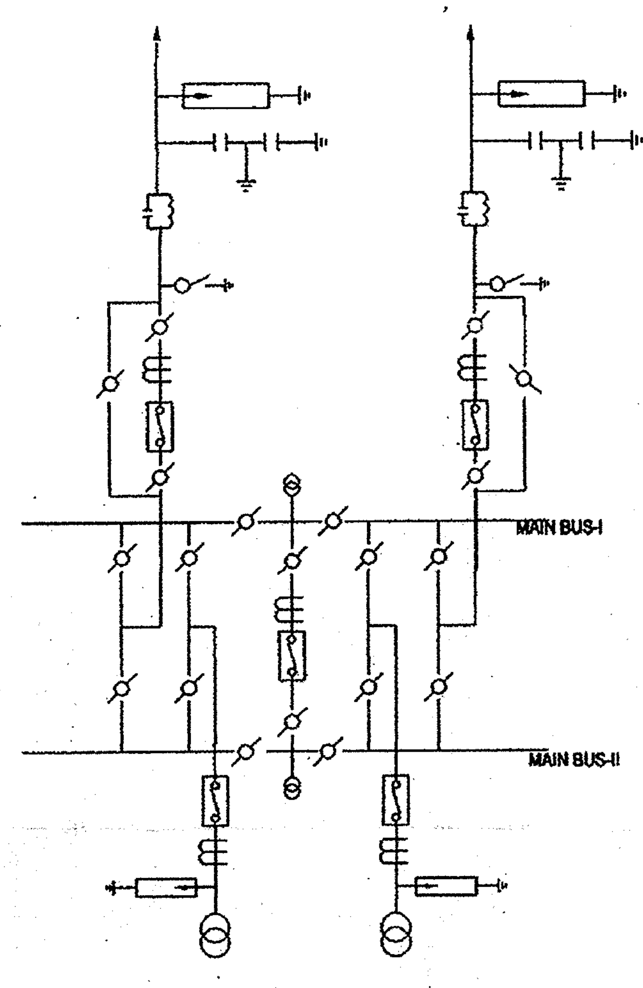
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
DOUBLE BUS ARRANGEMENT (HIGH LEVEL TYPE) 72.5KV, BIL 325 KVp	
SHEET 1 OF 1	SCALE: NTS



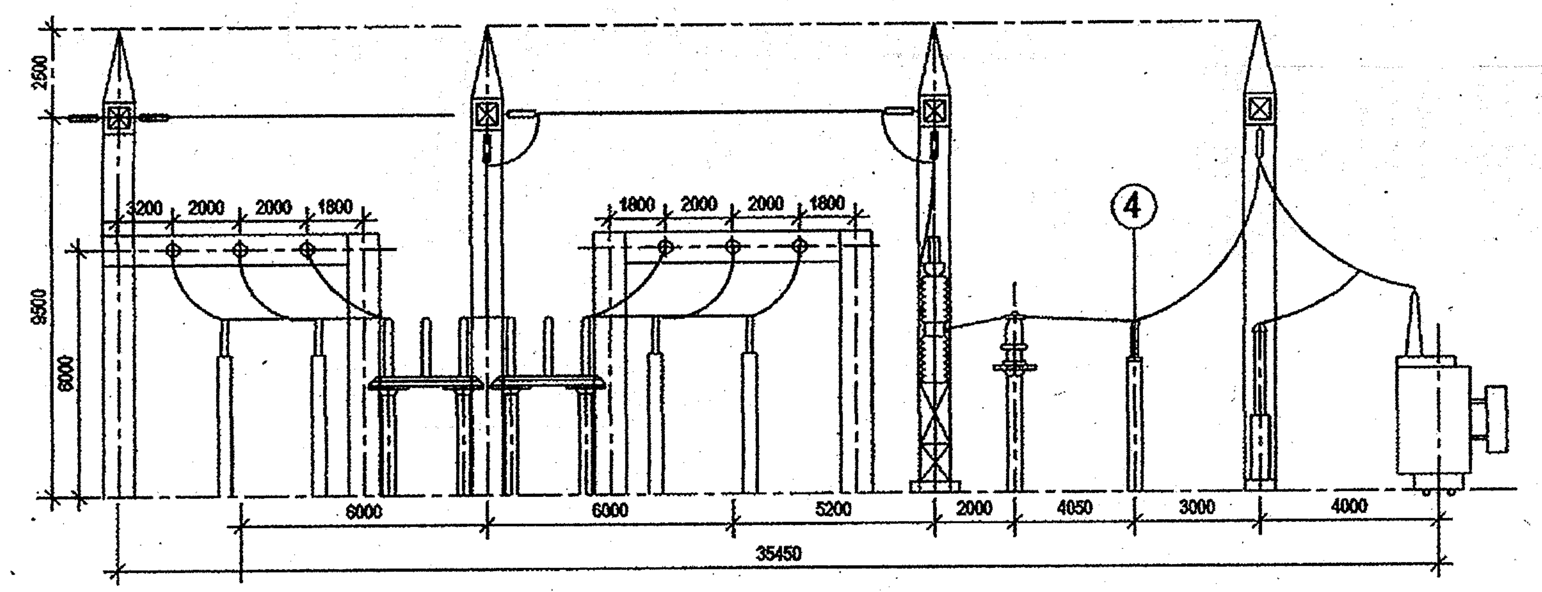
SECTION L-L



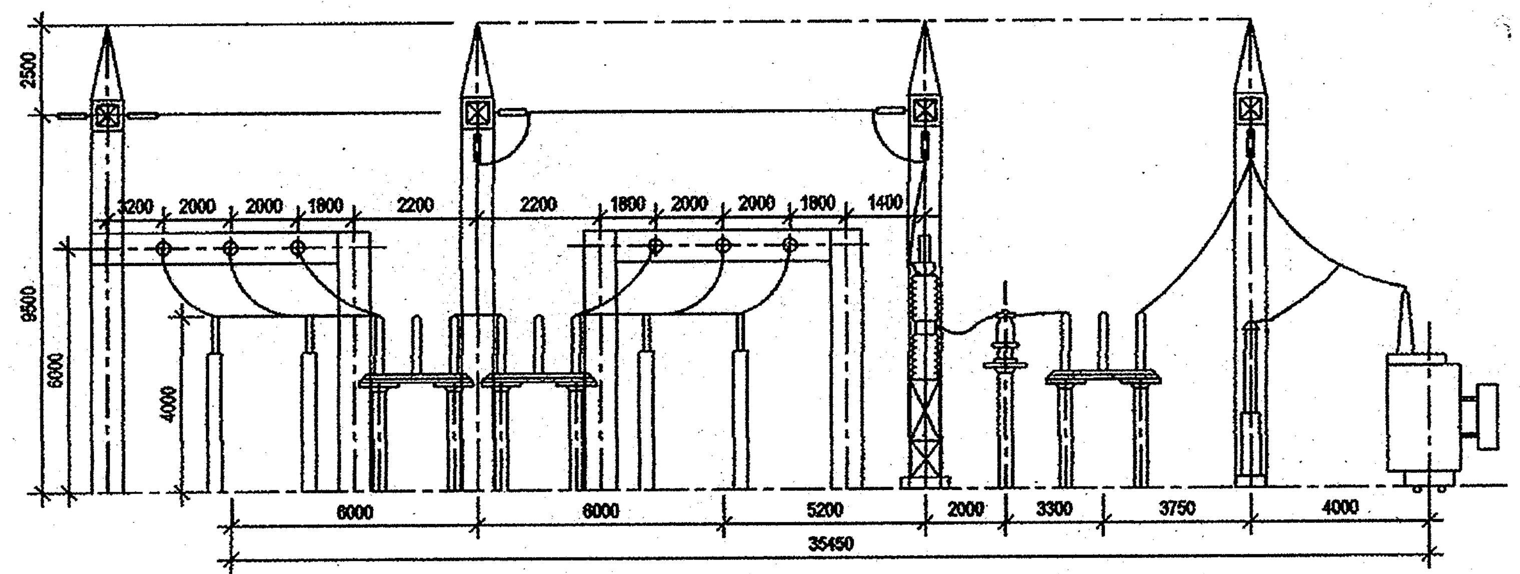
SECTION X-X (LINE BAY)



SINGLE LINE DIAGRAM



SECTION AT Y-Y (TRANSFORMER BAY)



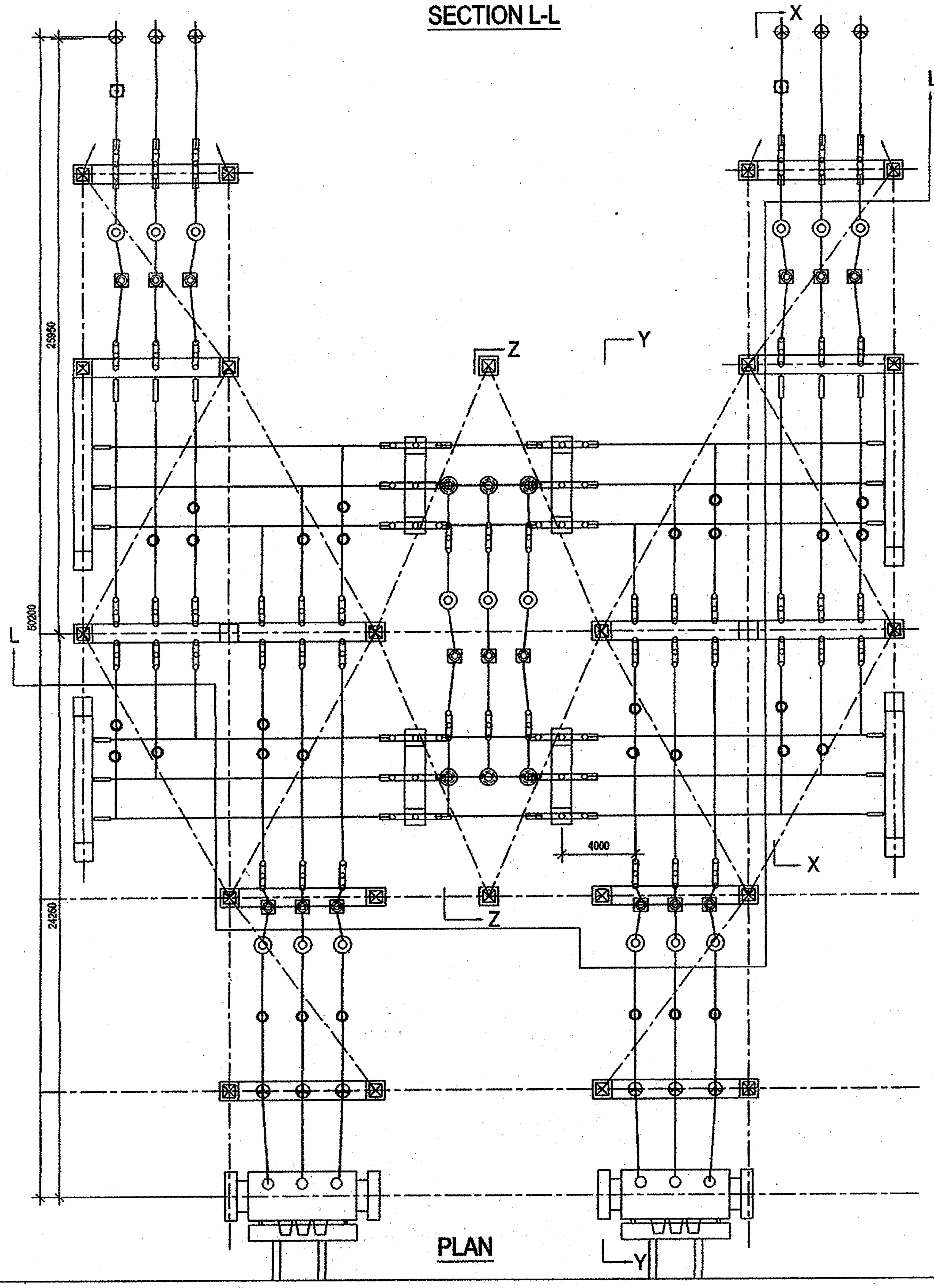
SECTION AT Y'-Y' (TRANSFORMER BAY)

LEGEND

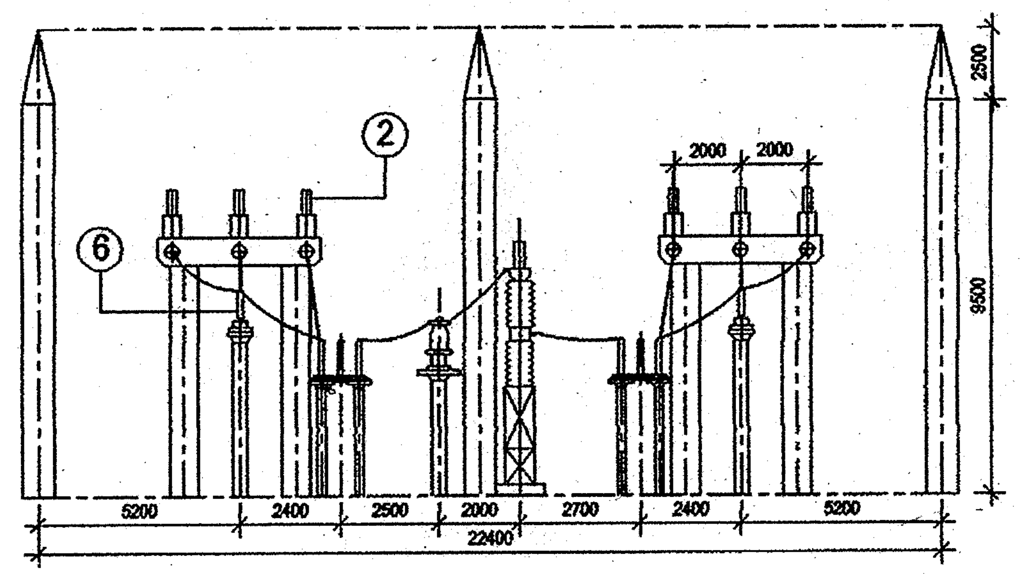
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. POST INSULATOR
5. LIGHTNING ARRESTER
6. POTENTIAL TRANSFORMER
7. WAVE TRAP
8. COUPLING CAPACITOR WITH POTENTIAL DEVICE

NOTE

1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.



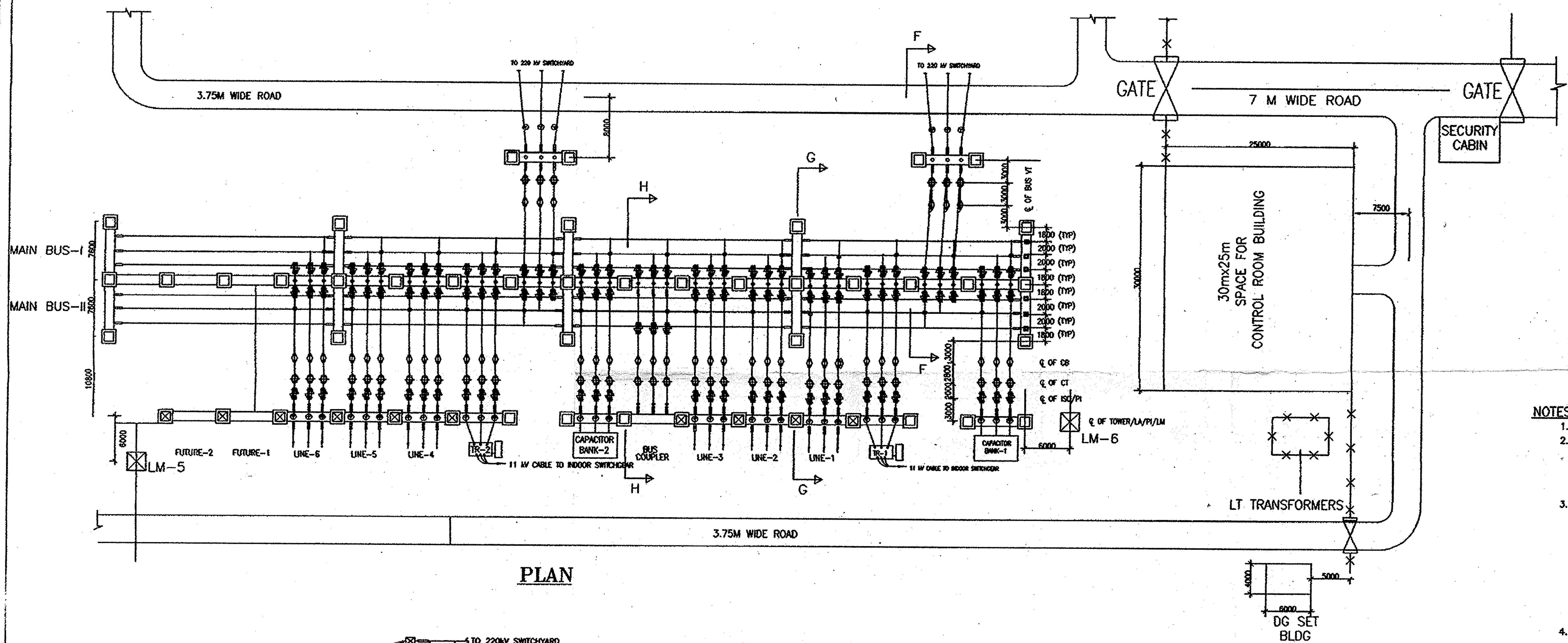
PLAN



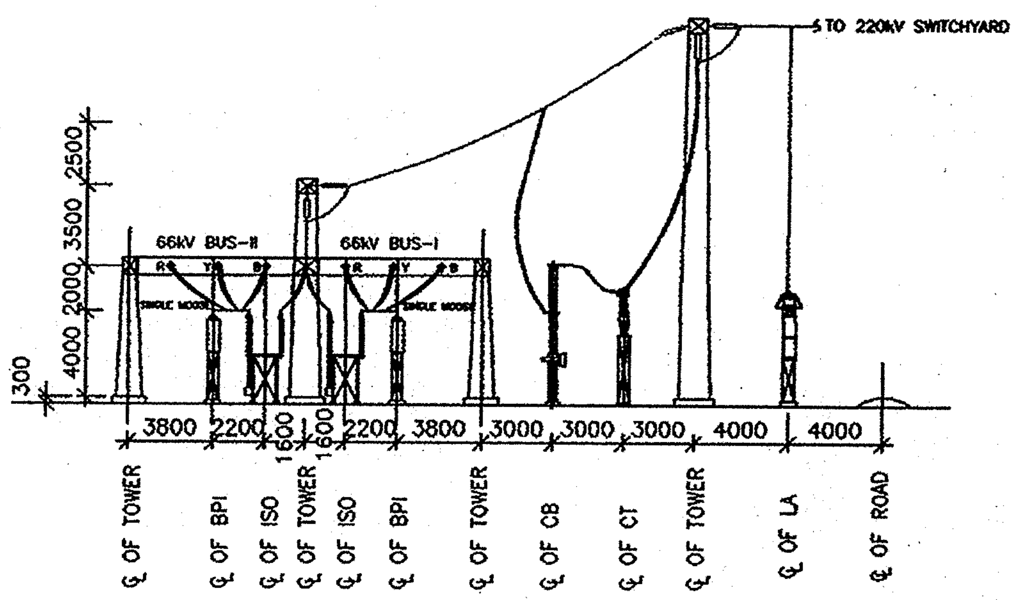
SECTION Z-Z (BUS COUPLER)

FIGURE-24

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
DOUBLE BUS ARRANGEMENT (LOW LEVEL TYPE) 72.5 KV , BIL 325 KVp		
	SHEET 1 OF 1	SCALE: NTS

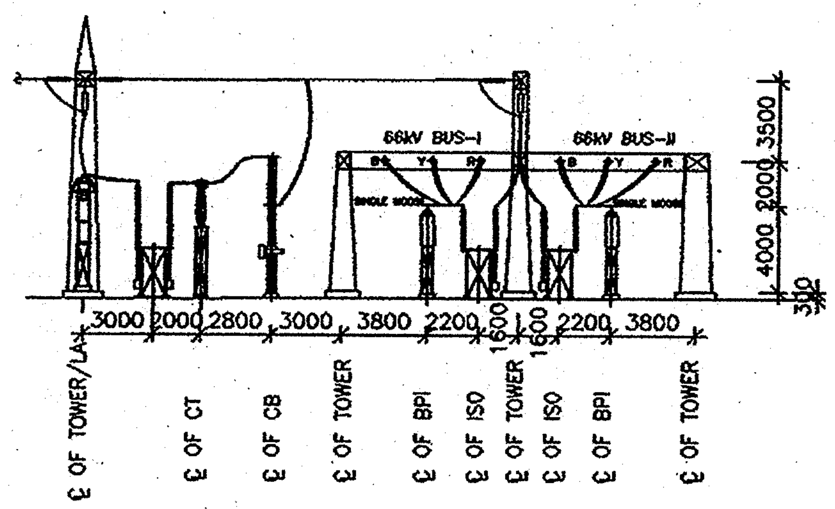


PLAN



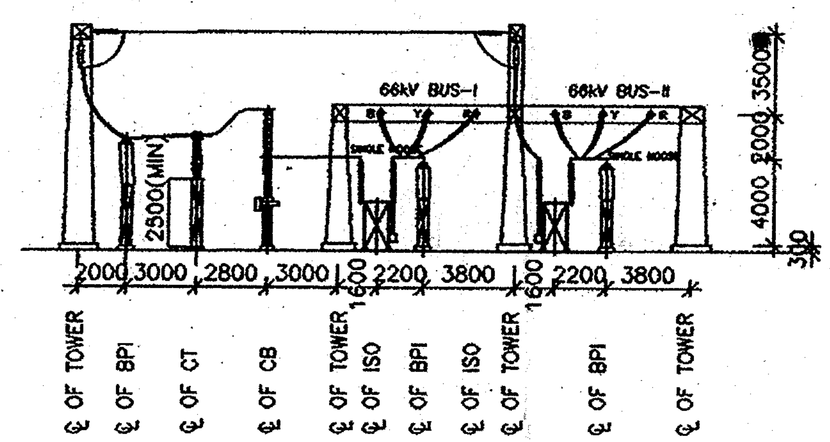
SECTION–FF

(66kV ICT BAY)



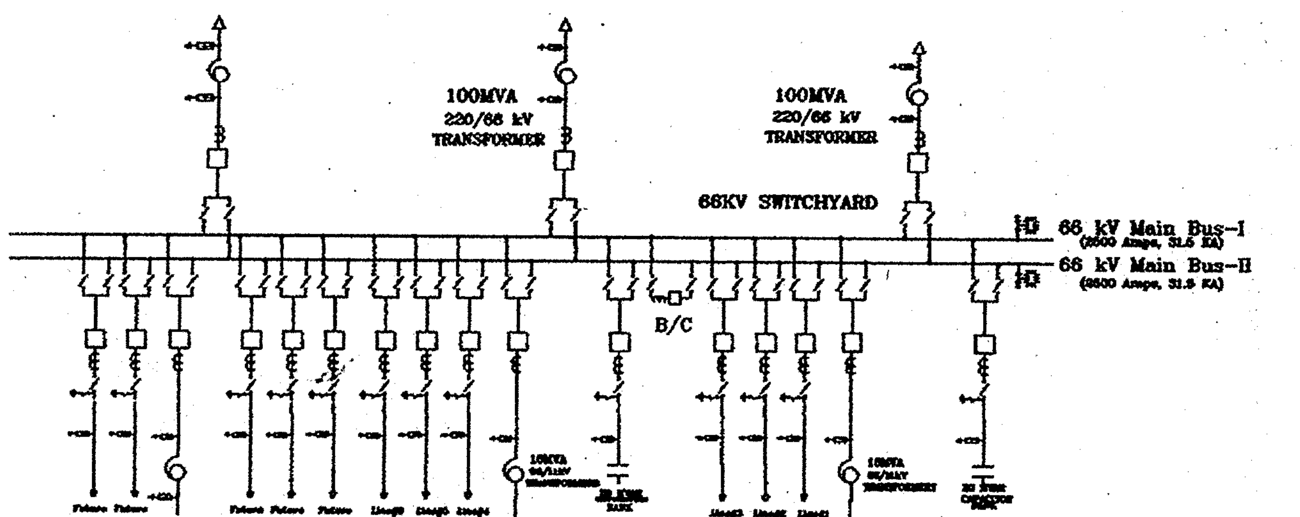
SECTION–GG

(66kV LINE BAY)

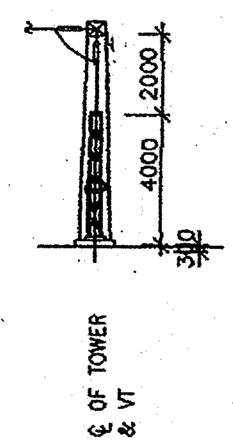


SECTION–HH

(66kV BUS COUPLER BAY)



SINGLE LINE DIAGRAM



SECTION–II

(66kV BUS VT)

LEGEND

	220 kV CIRCUIT BREAKER
	220 kV HCB ISOLATOR WITH 1 E/S
	220kV HCB ISOLATOR WITH 2 E/S
	220kV TANDEM ISOLATOR
	CURRENT TRANSFORMER
	CAPACITIVE VOLTAGE TRANSFORMER
	LIGHTNING ARRESTER
	WAVE TRAP
	BUS POST INSULATOR
	DOUBLE TENSION STRING
	66kV CB
	66 KB HDB ISOLATOR
	66 kV BUS VT

NOTES :

1. ALL DIMENSIONS ARE IN MM UNLESS OTHERWISE OTHEWISE SPECIFIED
2. THE FOLLOWING MINIMUM CLEARANCE SHALL BE MAINTAINTED:
   - PHASE TO PHASE : 630mm
   - PHASE TO PHASE : 630mm
   - SECTIONAL CELARANCE : 3000m
3. BUS LEVELS AND CONDUCTOR DETAILS:

	HEIGHT FROM PLINTH LEVEL	CONDUCTOR
BAY CONNECTION	4000mm	SINGLE MOOSE ACSR
MAIN BUS I & II	6000mm	QUAD. MOOSE ACSR
INTERCONNECTION (ICT BAY)		TWIN MOOSE ACSR
INTERCONNECTION (EXCEPT ICT BAY)		SINGLE MOOSE ACSR
JACK BUS	9500mm	TWIN MOOSE ACSR

4. CONDUCTOR TENSION
   - MAIN BUS: 500Kg/CONDUCTOR
   - LINE AND JACK BUS: 500 Kg/CONDUCTOR
5. PLINTH LEVEL : 300mm ABOVE F.G.L.
6. GRAVEL LEVEL : 100mm ABOVE F.G.L.
7. LINE TAKE-OFF STRINGS ARE NOT IN THE SCOPE OF S/S PACKAGE.

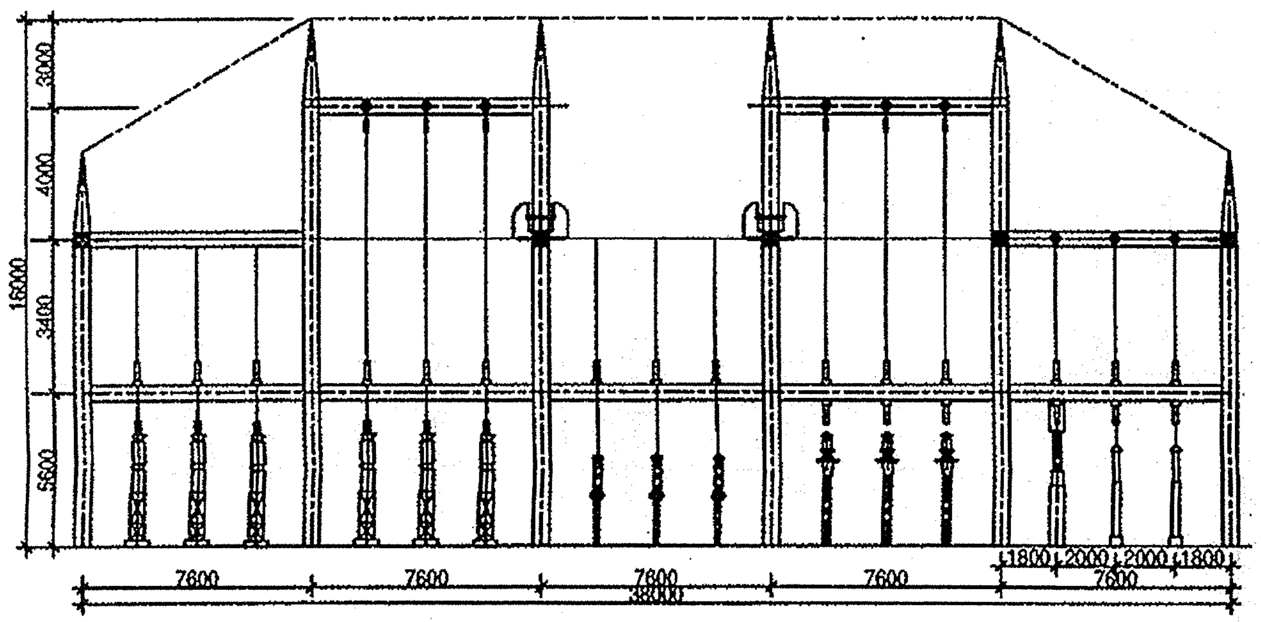
Figure-24(a)

LAYOUT DRAWING - 66 KV / 7.6 M BAY WIDTH (DOUBLE BUS SCHEME)

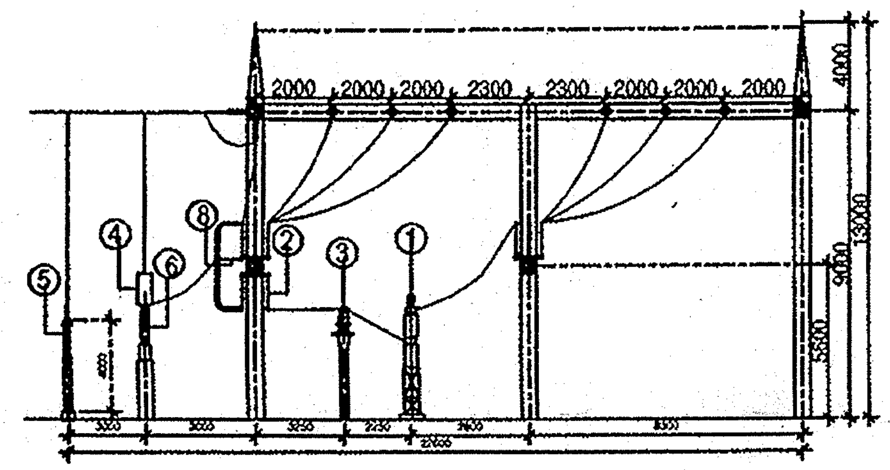
BIL- LI 325 KVp

MANUAL ON SUB STATION LAYOUT & DESIGN

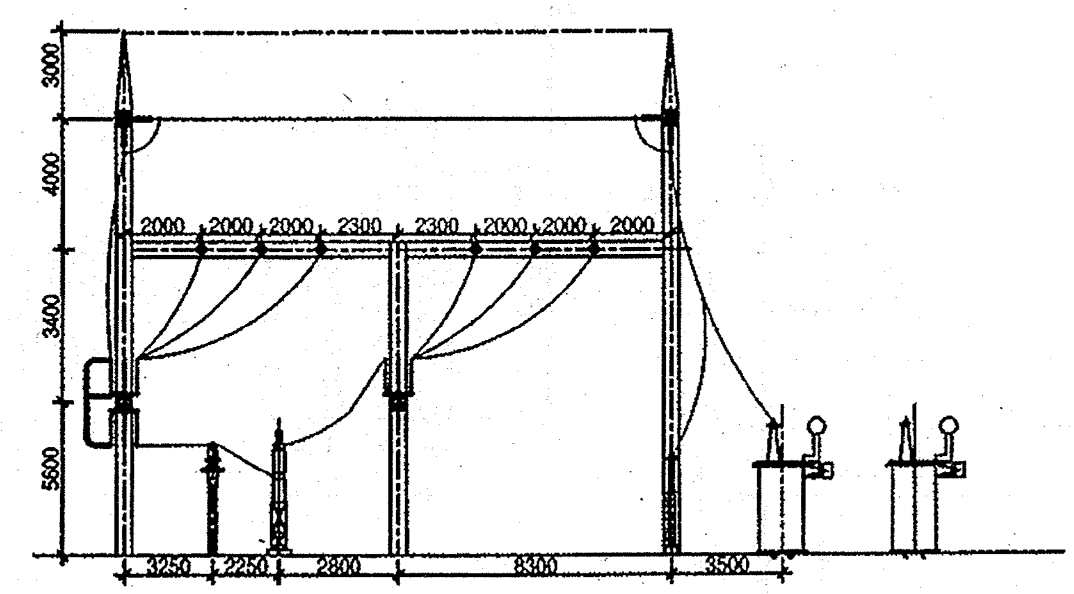
/DOC-3/C:\PGCIL\KKS\66KV-LAY



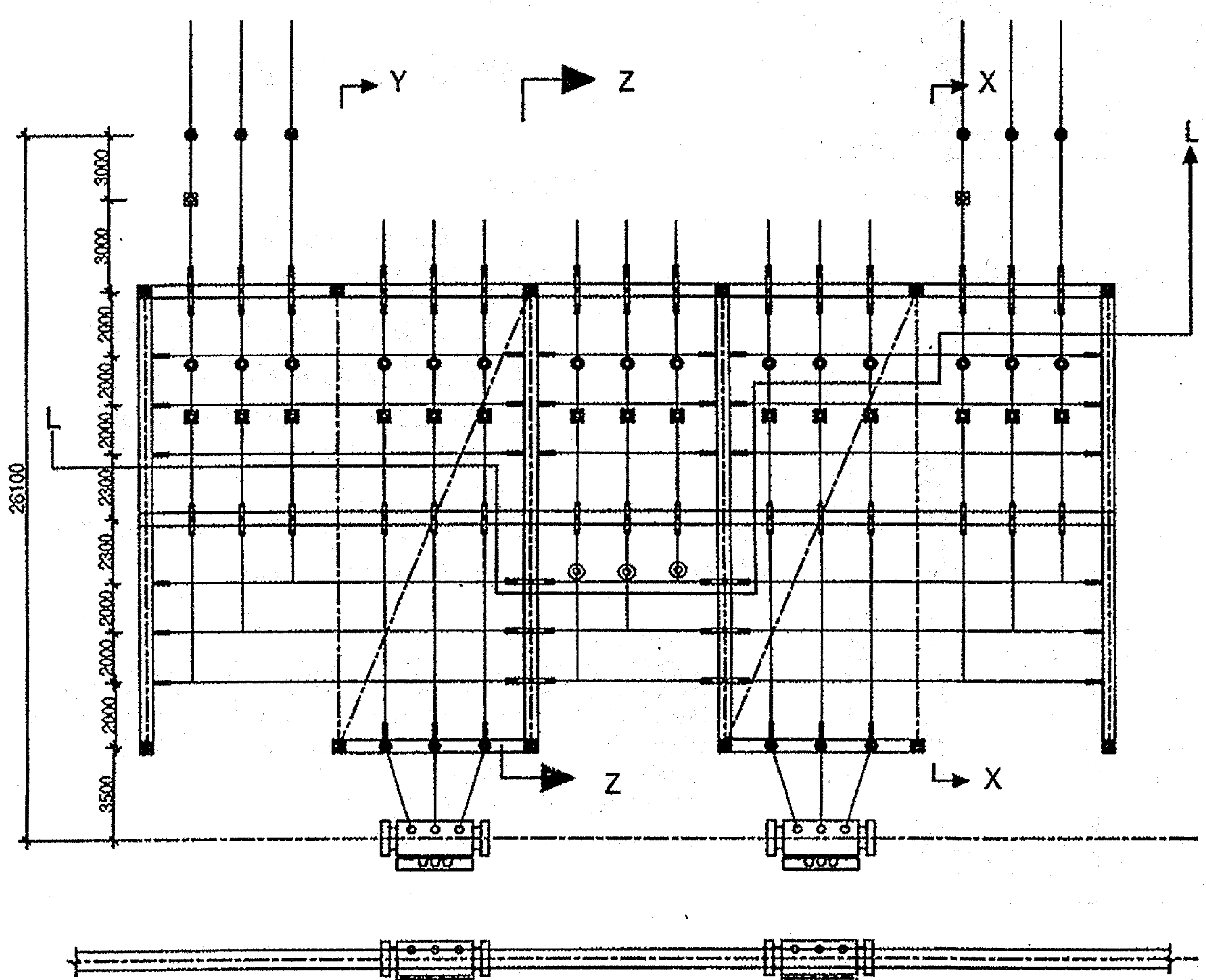
SECTION L-L



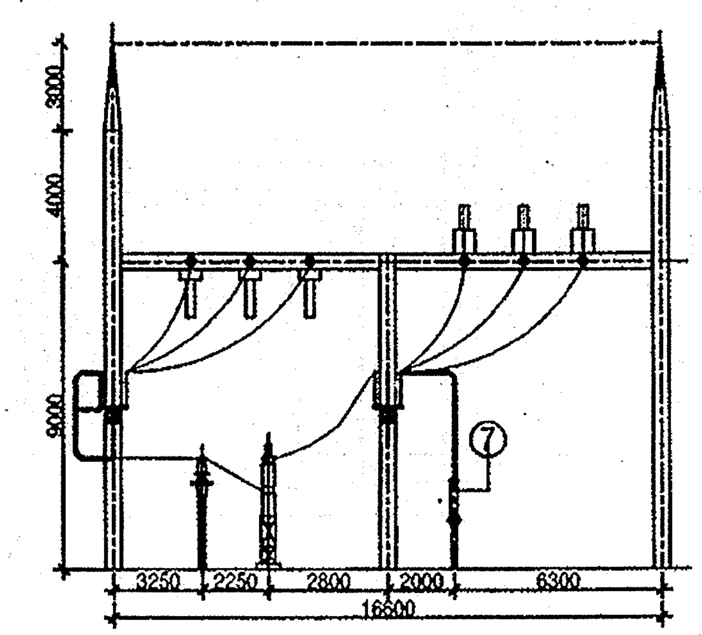
SECTION X-X (LINE BAY)



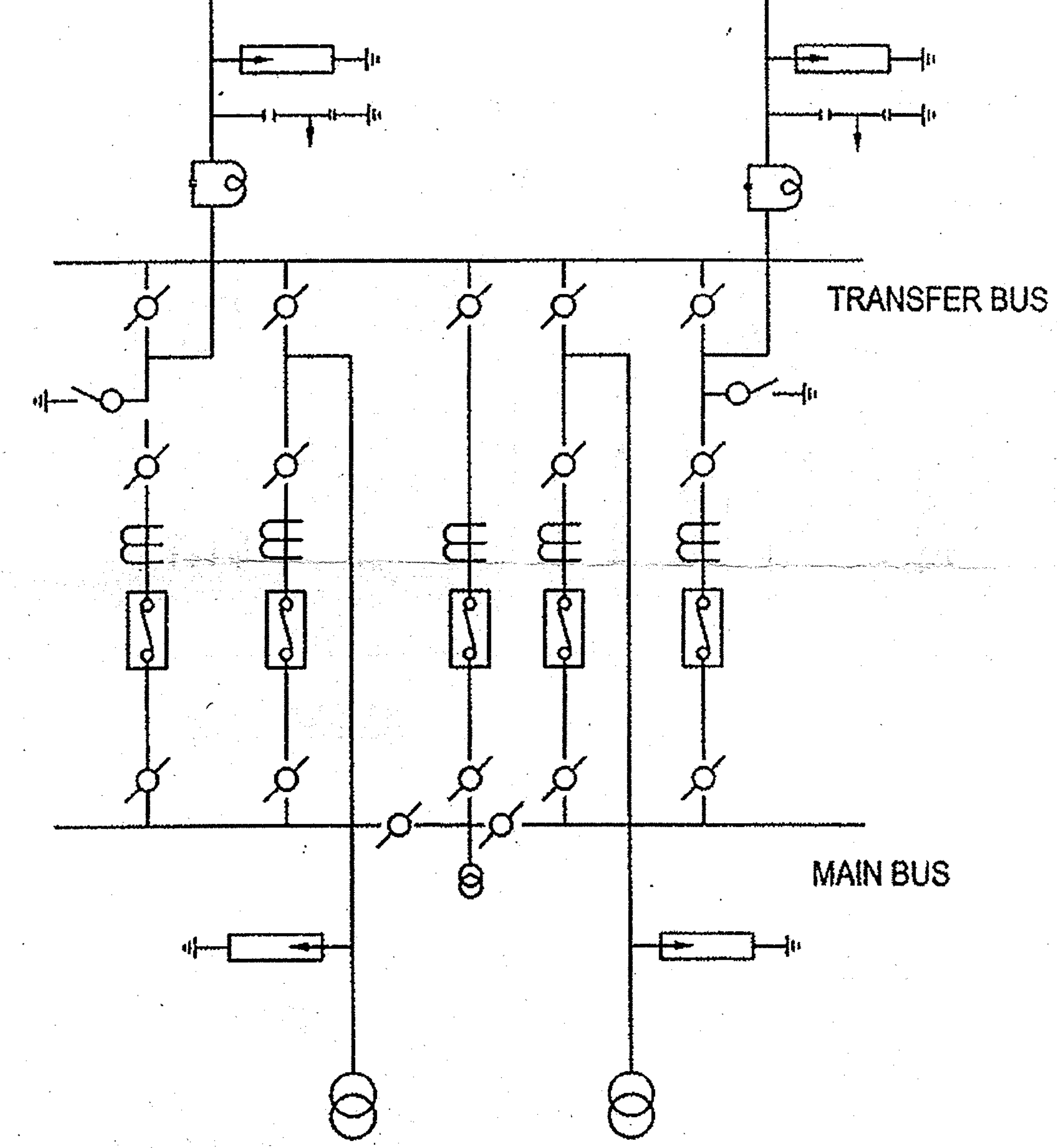
SECTION Y-Y(TRANSFORMER BAY)



PLAN



SECTION Z-Z(BUS COUPLER)



SINGLE LINE DIAGRAM

NOTE

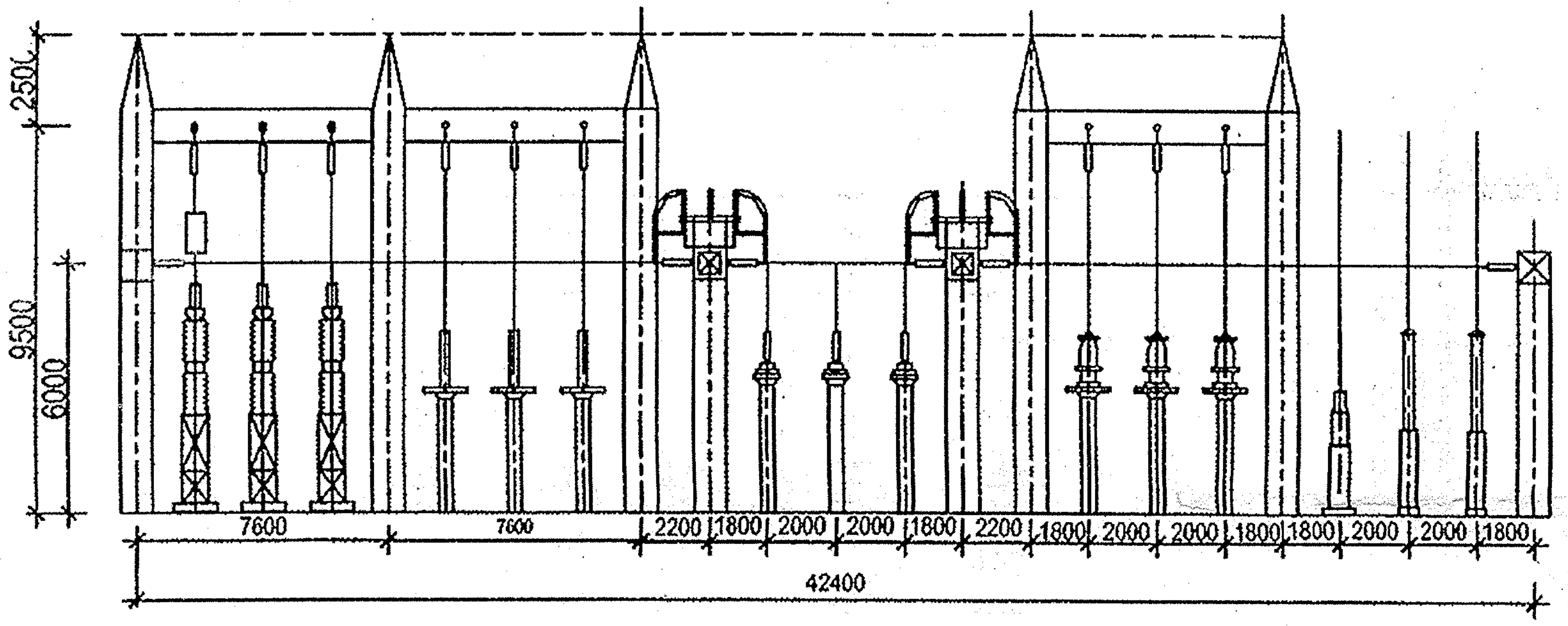
1. ALL DIMENSIONS ARE IN MM.
2. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

LEGEND

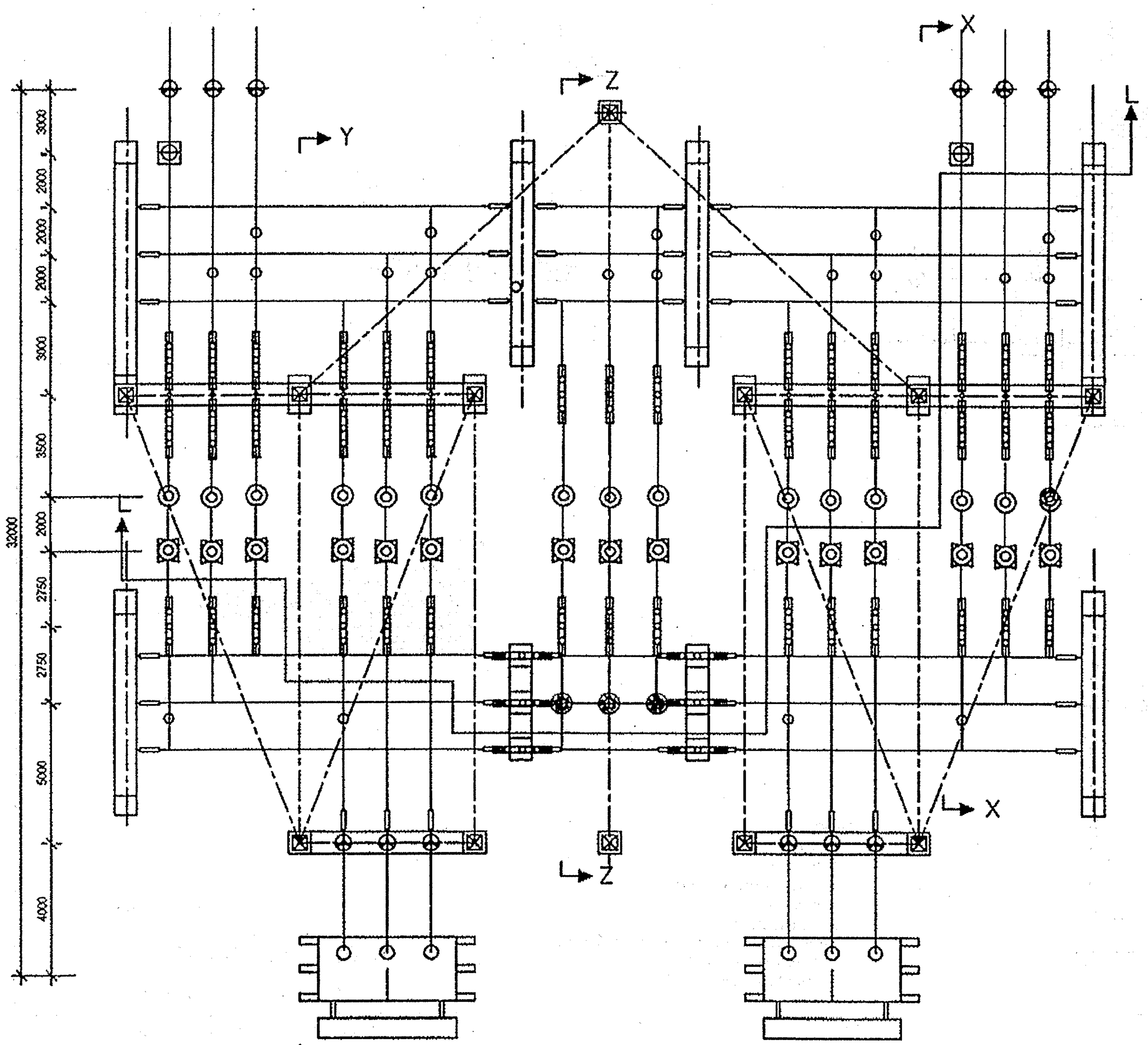
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. WAVE TRAP
5. LIGHTNING ARRESTER
6. COUPLING CAPACITOR WITH POTENTIAL DEVICE
7. POTENTIAL TRANSFORMER
8. POST INSULATOR

FIGURE-25

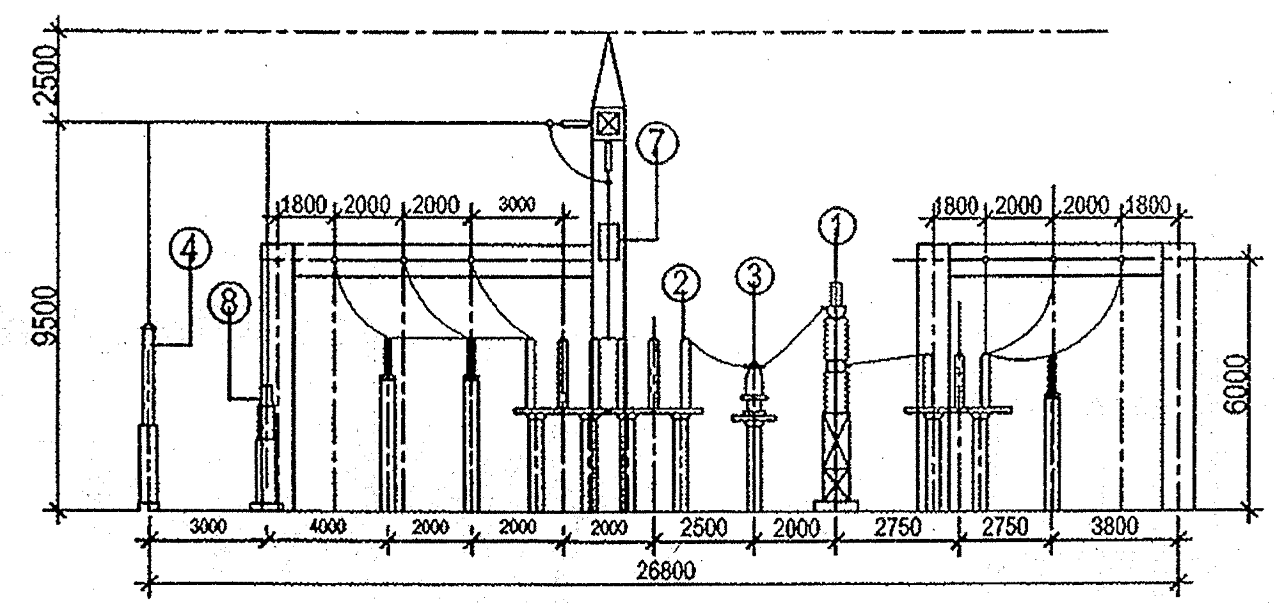
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
MAIN AND TRANSFER BUS ARRANGEMENT (HIGH LEVEL TYPE) 72.5 KV BIL 325 KVp		
	SHEET 1 OF 1	SCALE: NTS



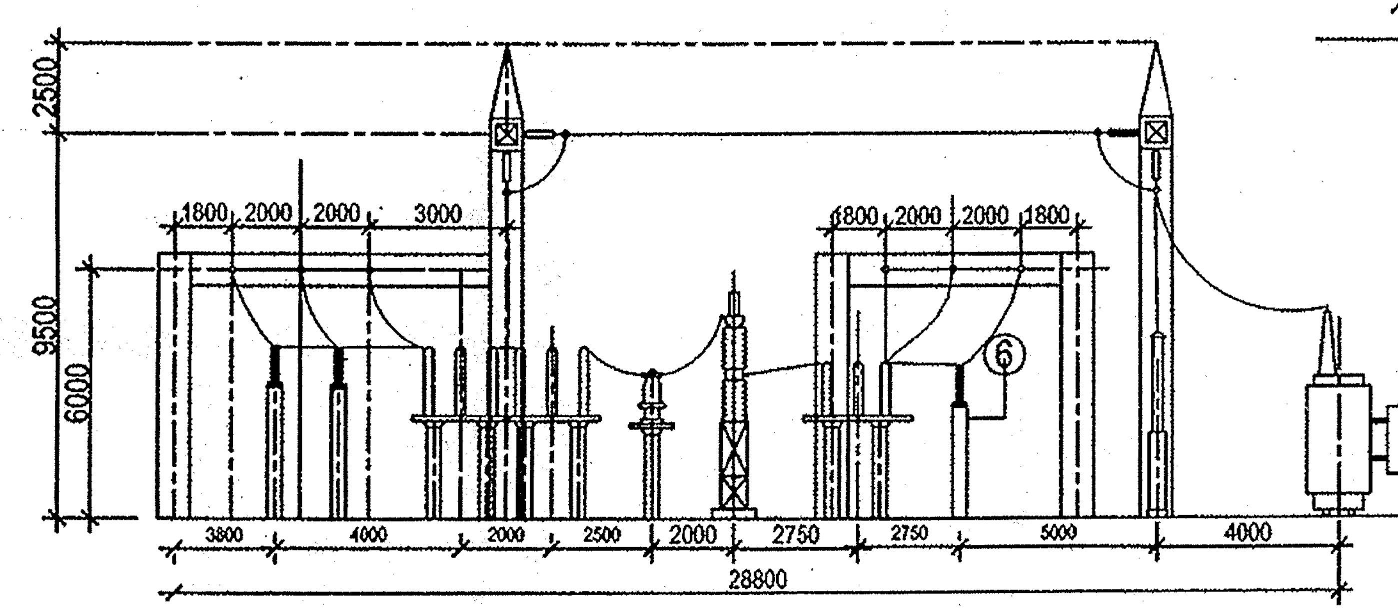
SECTION AT L-L



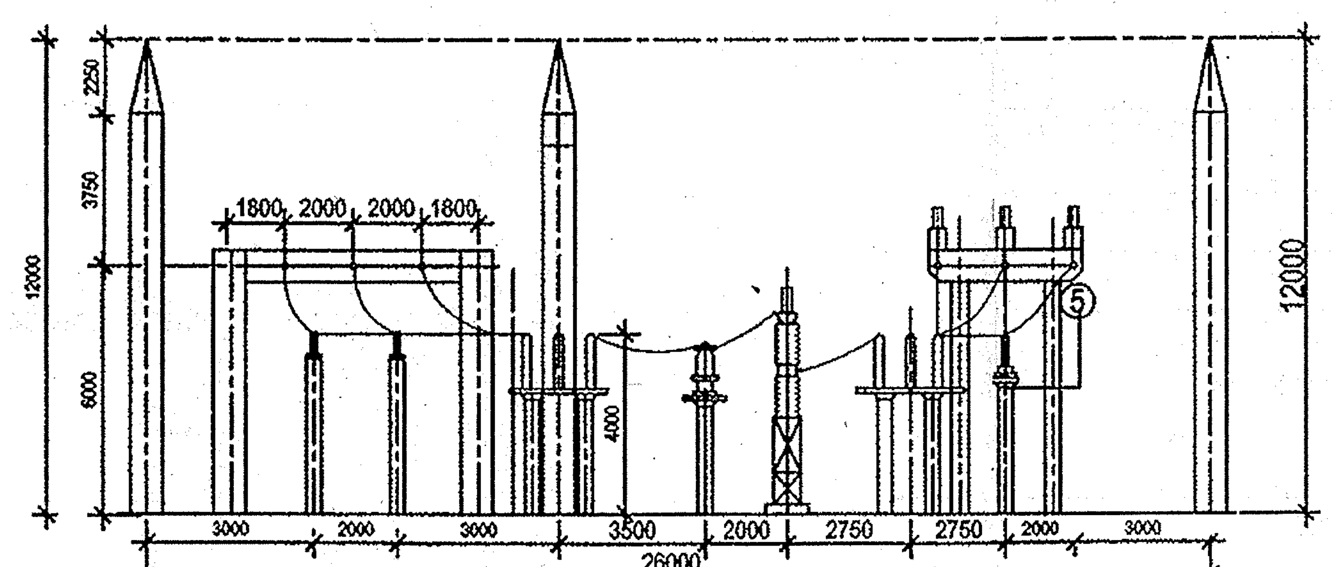
PLAN



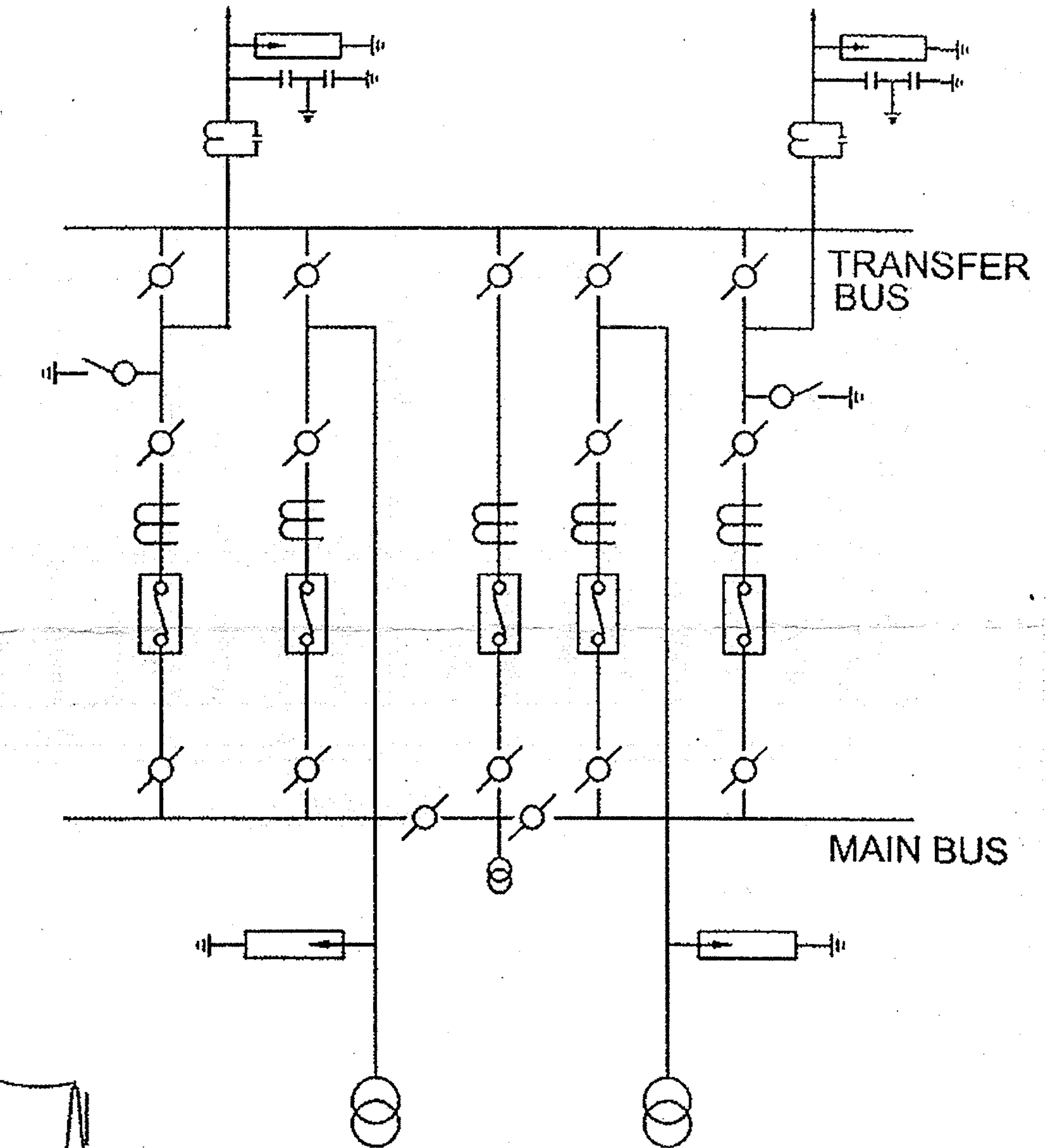
SECTION AT X-X (LINE BAY)



SECTION AT Y-Y (TRANSFORMER BAY)



SECTION AT Z-Z (BUS COUPLER BAY)



SINGLE LINE DIAGRAM

LEGEND

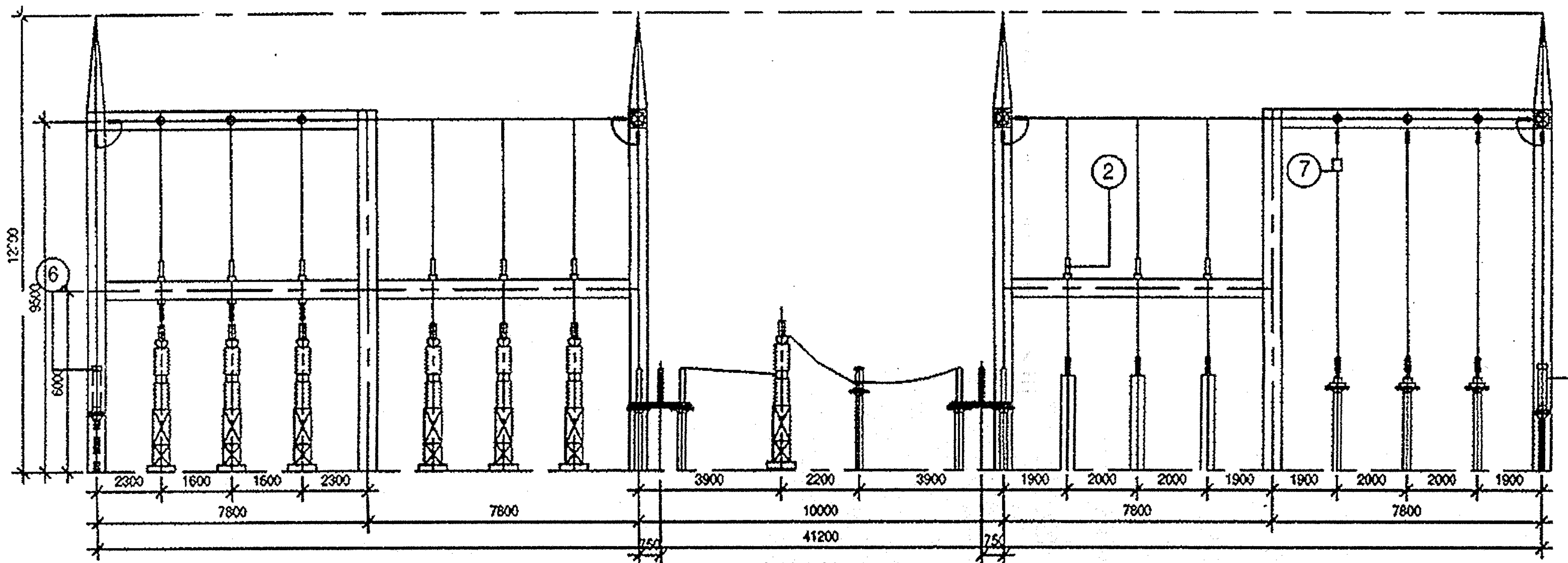
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. LIGHTNING ARRESTER
5. POTENTIAL TRANSFORMER
6. POST INSULATOR
7. WAVETRAP
8. COUPLING CAPACITOR WITH POTENTIAL DEVICE

NOTE

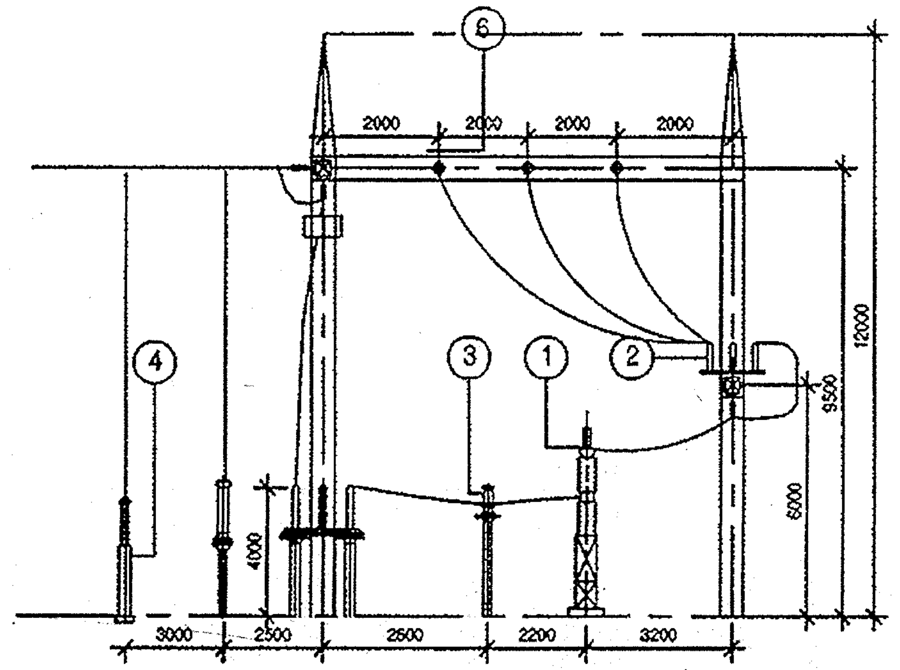
1. ALL DIMENSIONS ARE IN MM.
2. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-26

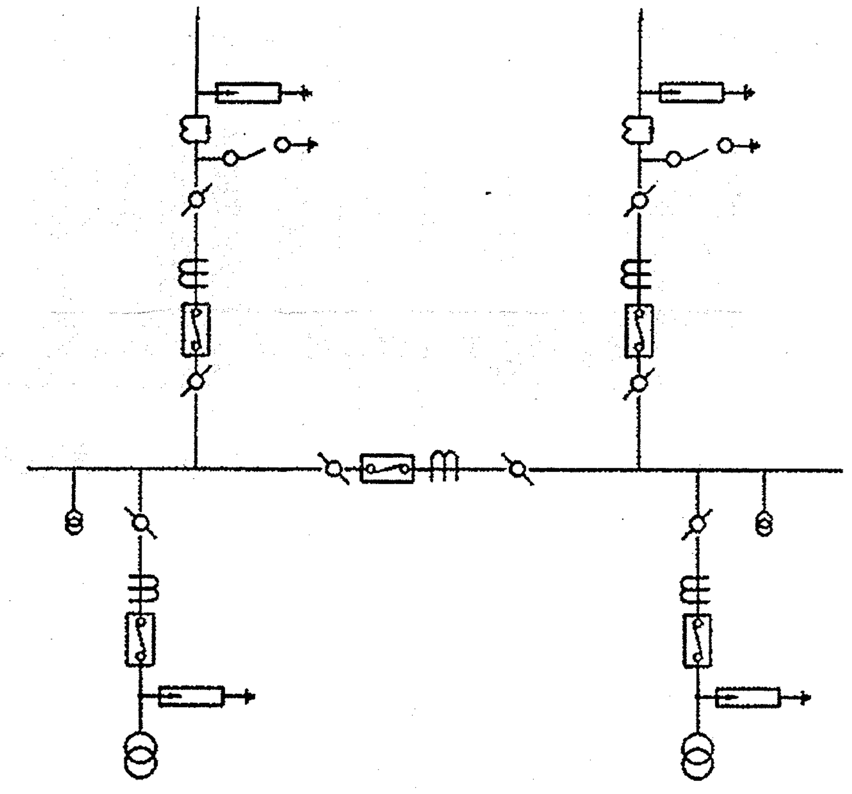
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
MAIN AND TRANSFER BUS ARRANGEMENT (LOW LEVEL TYPE) 72.5 kV, BIL 325 kVp	
SHEET 1 OF 1	SCALE: NTS



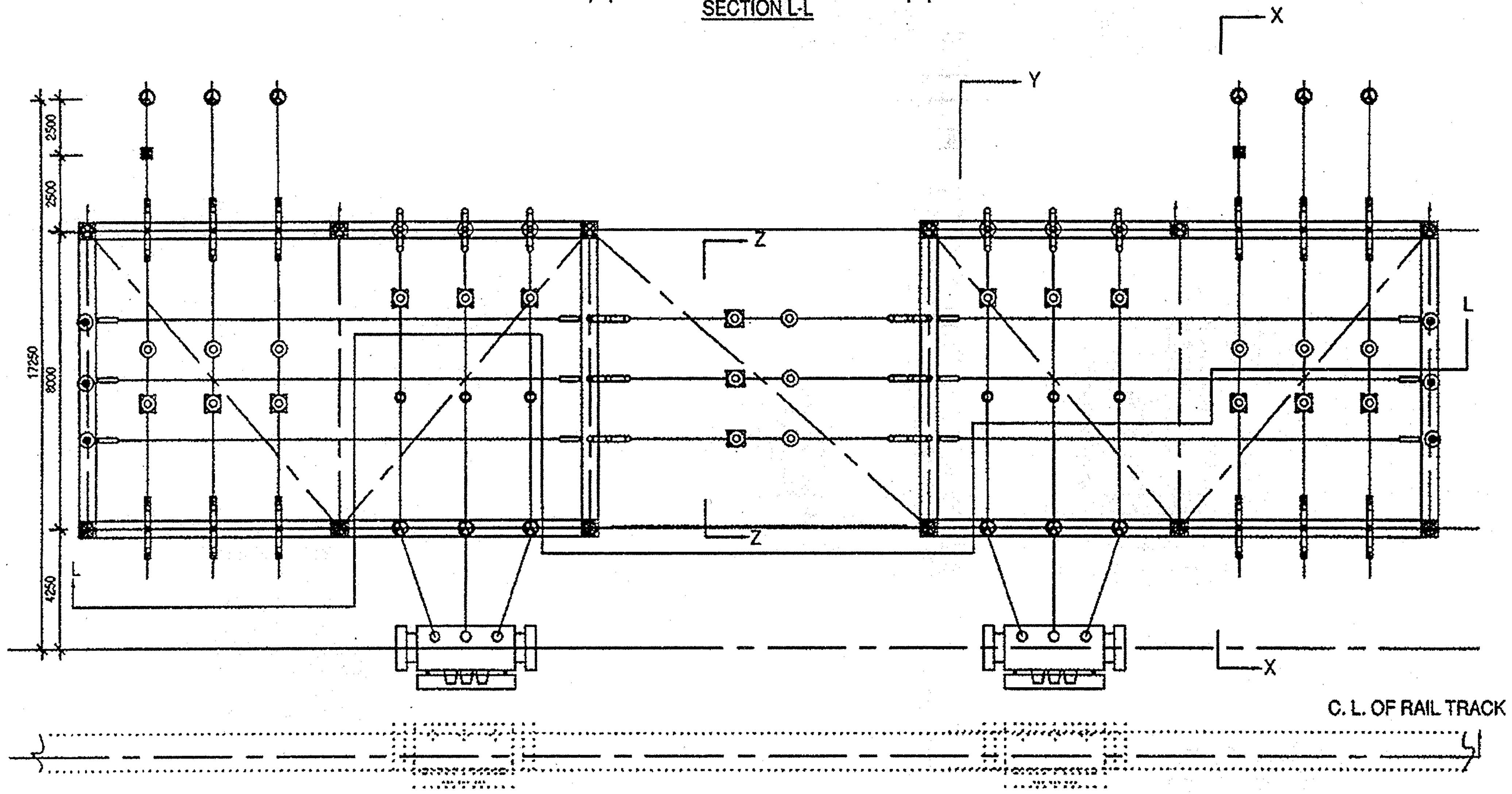
SECTION L-L



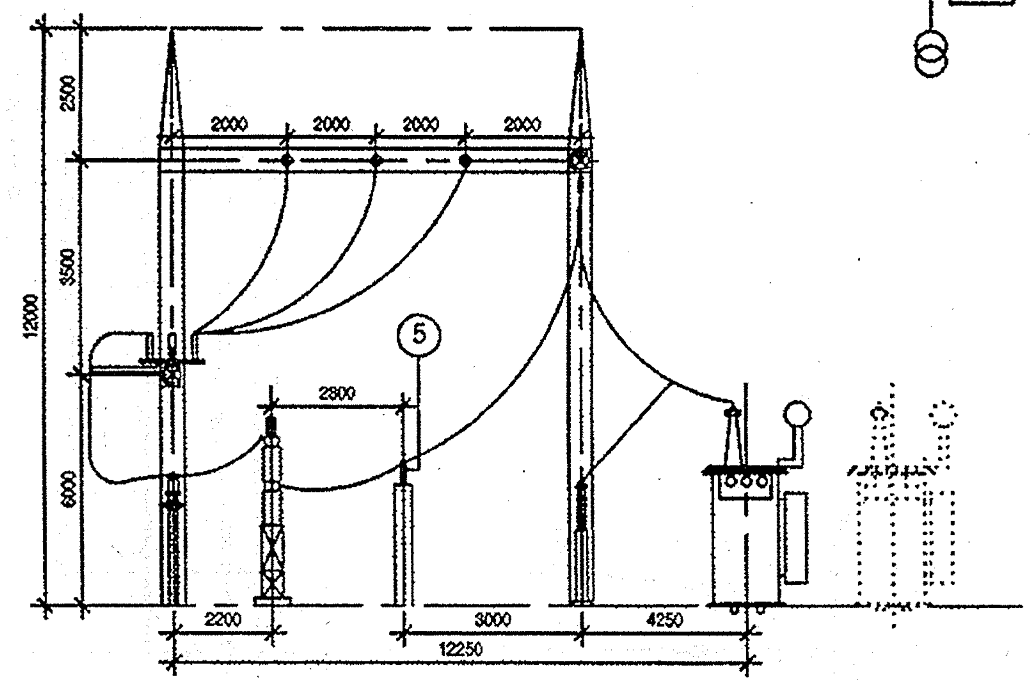
SECTION X-X (LINE BAY)



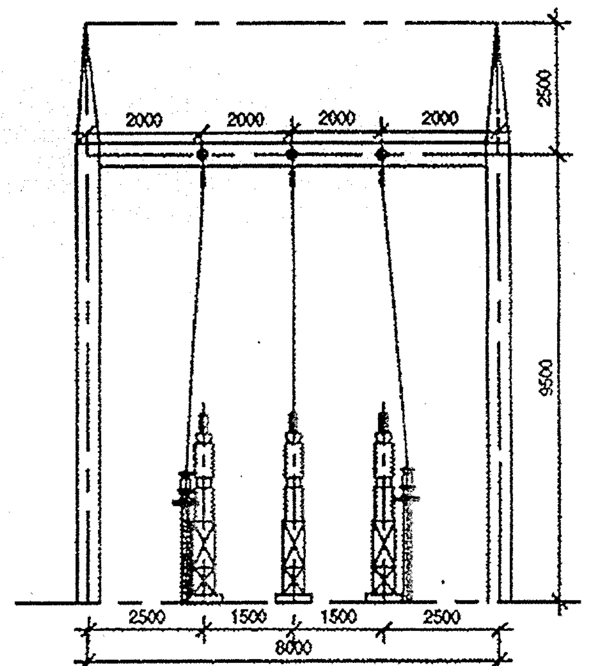
SINGAL LINE DIAGRAM



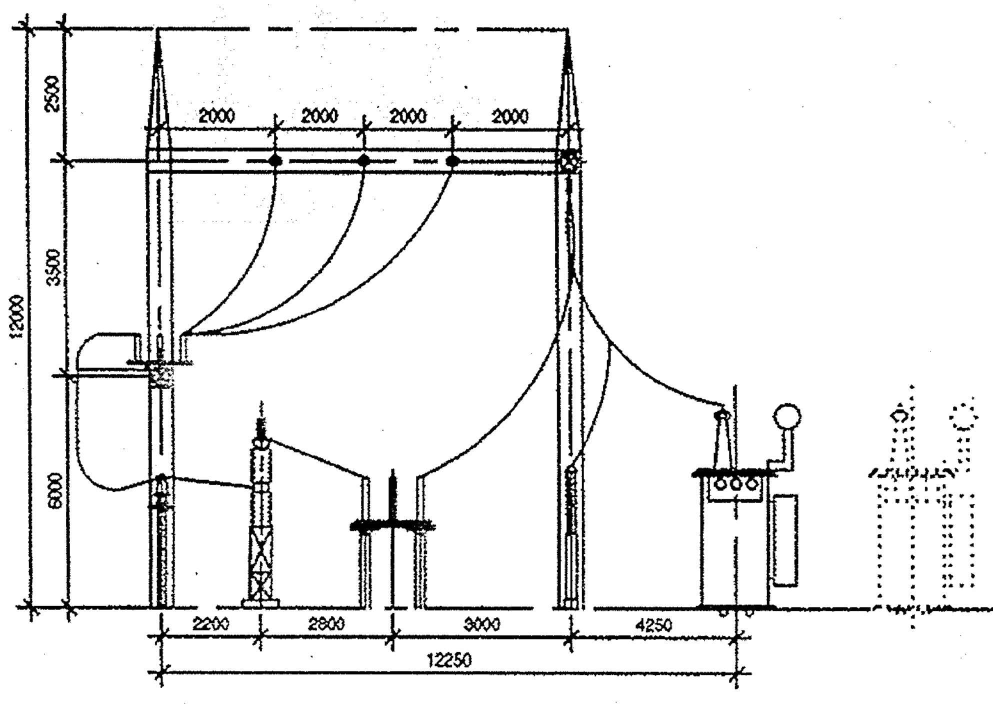
PLAN



SECTION Y-Y (TRANSFORMER BAY)



SECTION Z-Z



SECTION Y'-Y' (TRANSFORMER BAY)

LEGEND

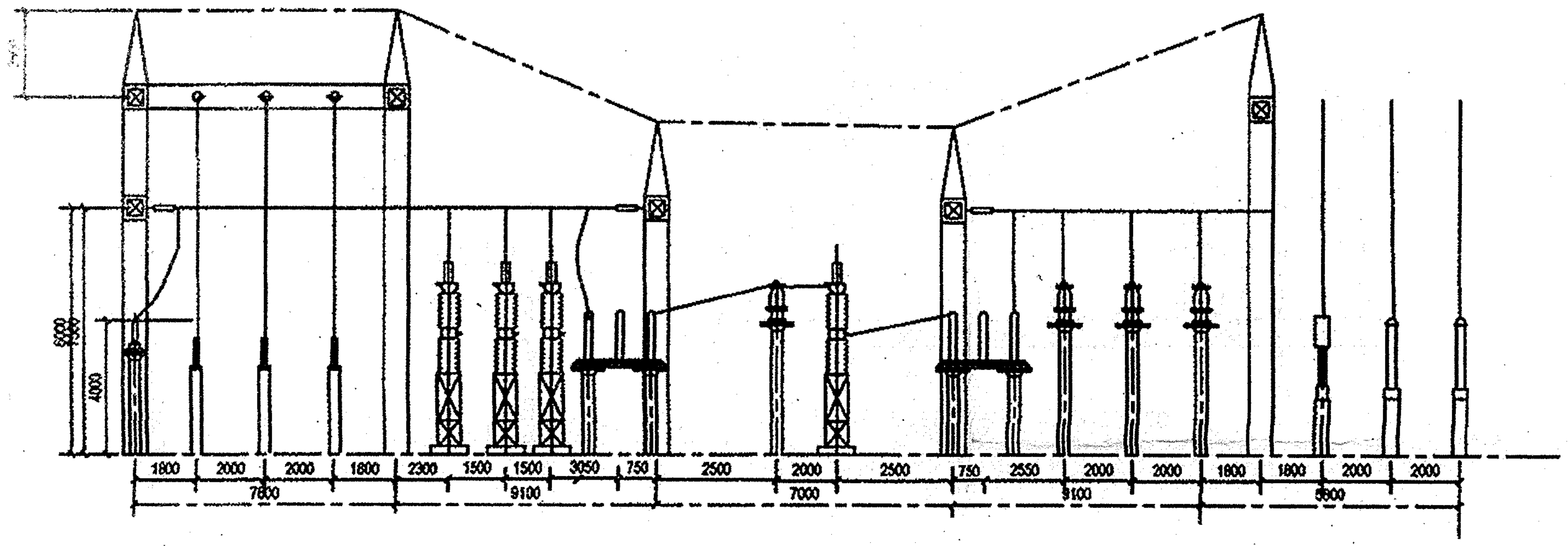
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. LIGHTNING ARRESTER
5. POST INSULATOR
6. POTENTIAL TRANSFORMER
7. WAVE TRAP
8. COUPLING CAPACITOR WITH POTENTIAL DEVICE

NOTE

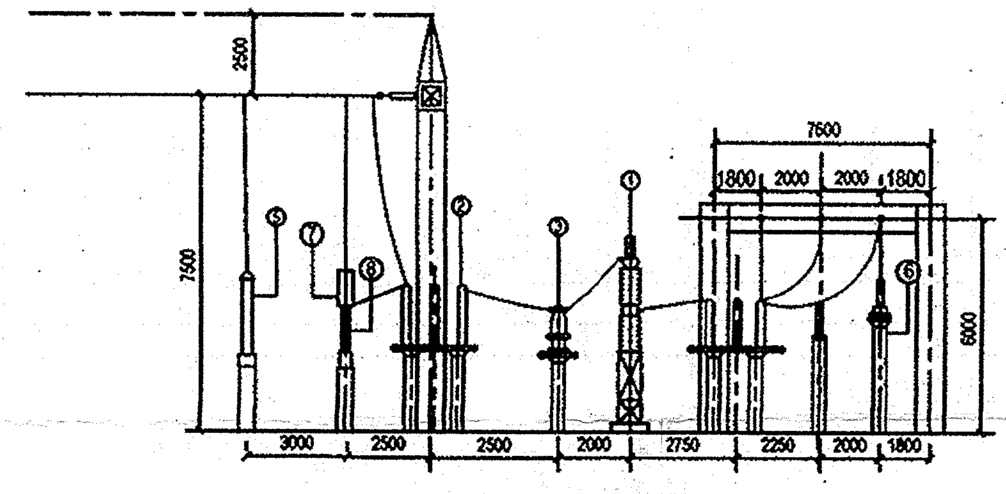
1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-27

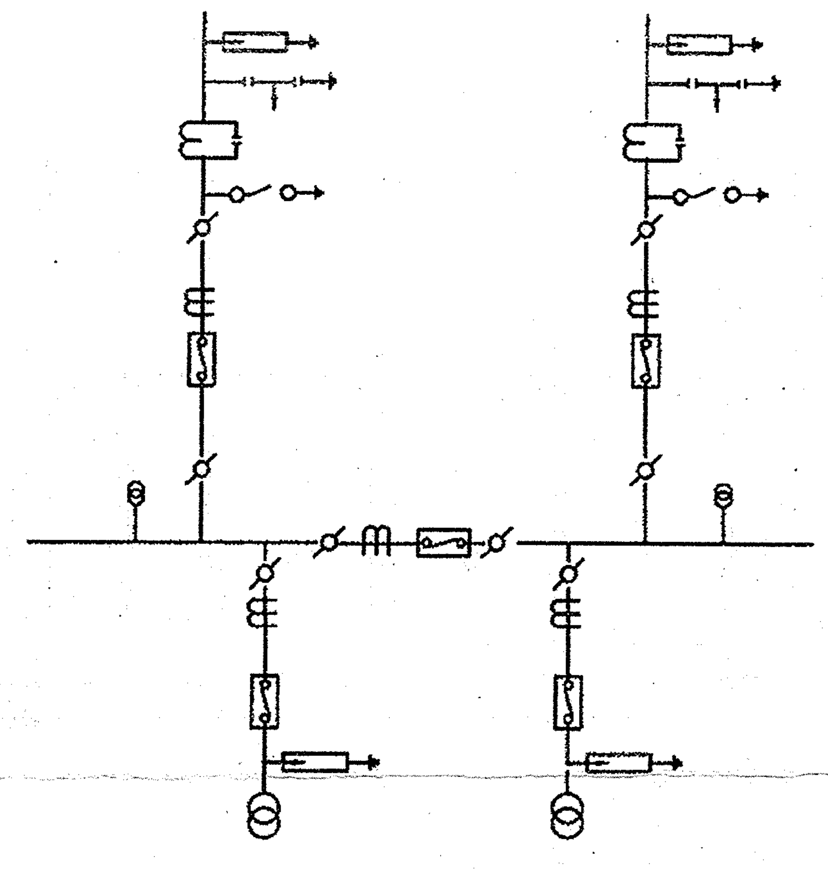
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
SINGLE BUS ARRANGMENT(HIGH LEVEL TYPE) 72.5 KV BIL 325 KVp	
SHEET 1 OF 1	SCALE: NTS



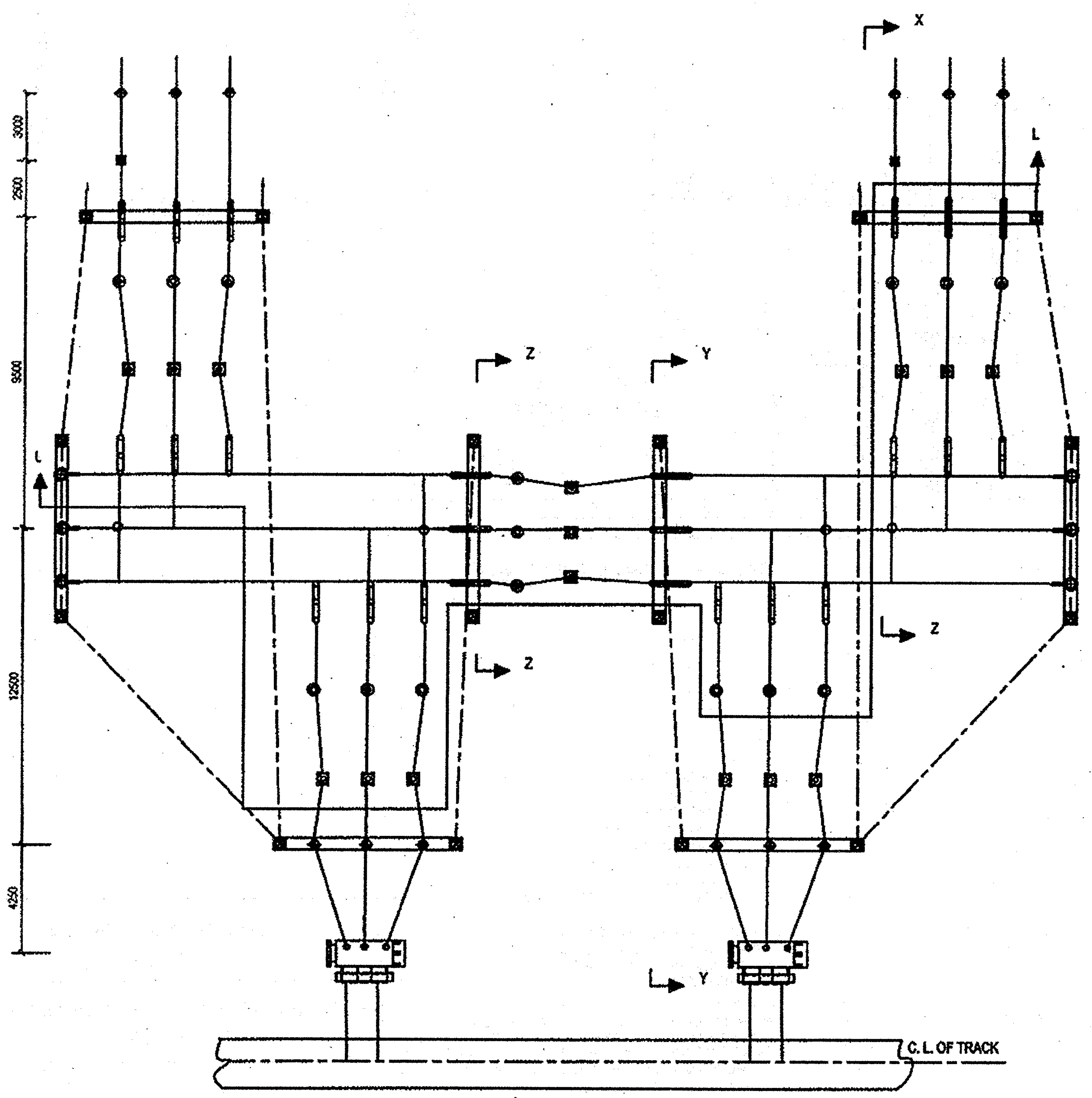
SECTION L-L



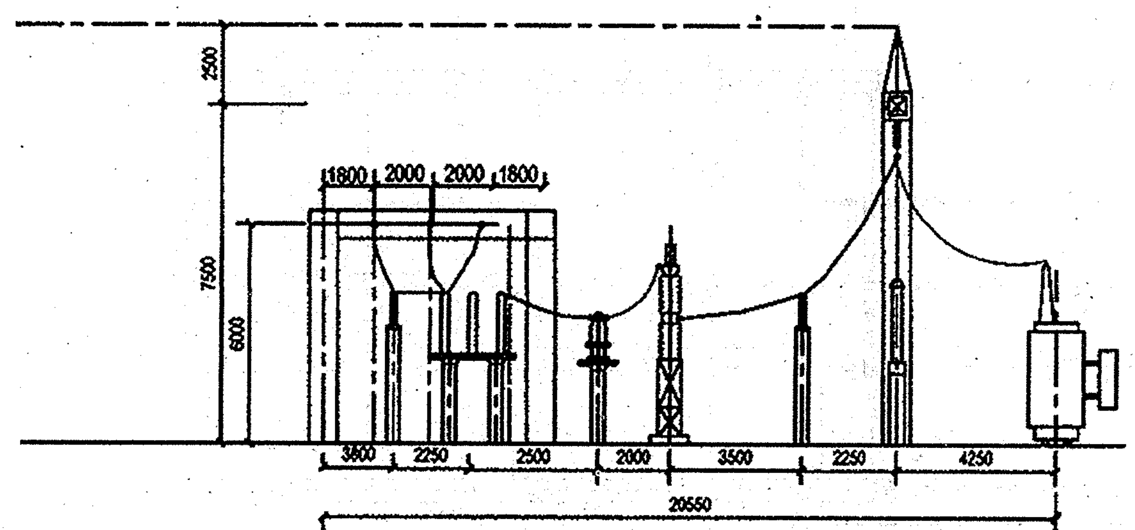
SECTION X-X (LINE BAY)



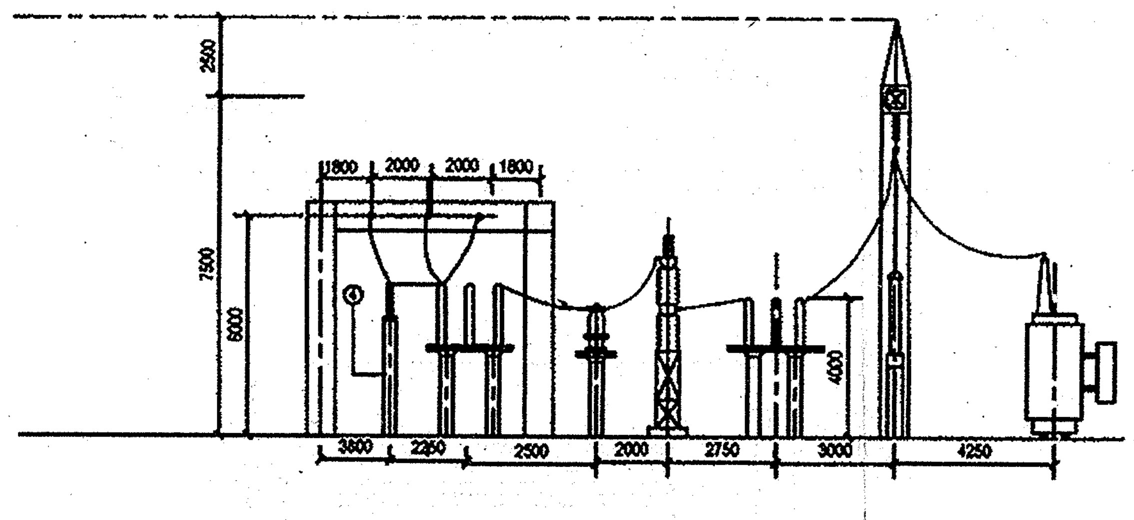
SINGAL LINE DIAGRAM



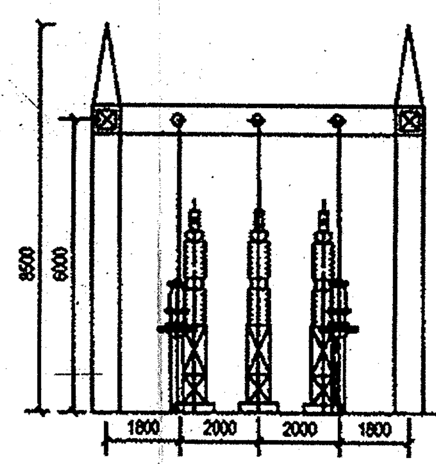
PLAN



SECTION AT Y-Y (TRANSFORMER BAY)



SECTION AT Y'-Y'(TRANSFORMER BAY)



SECTION AT Z-Z

LEGEND

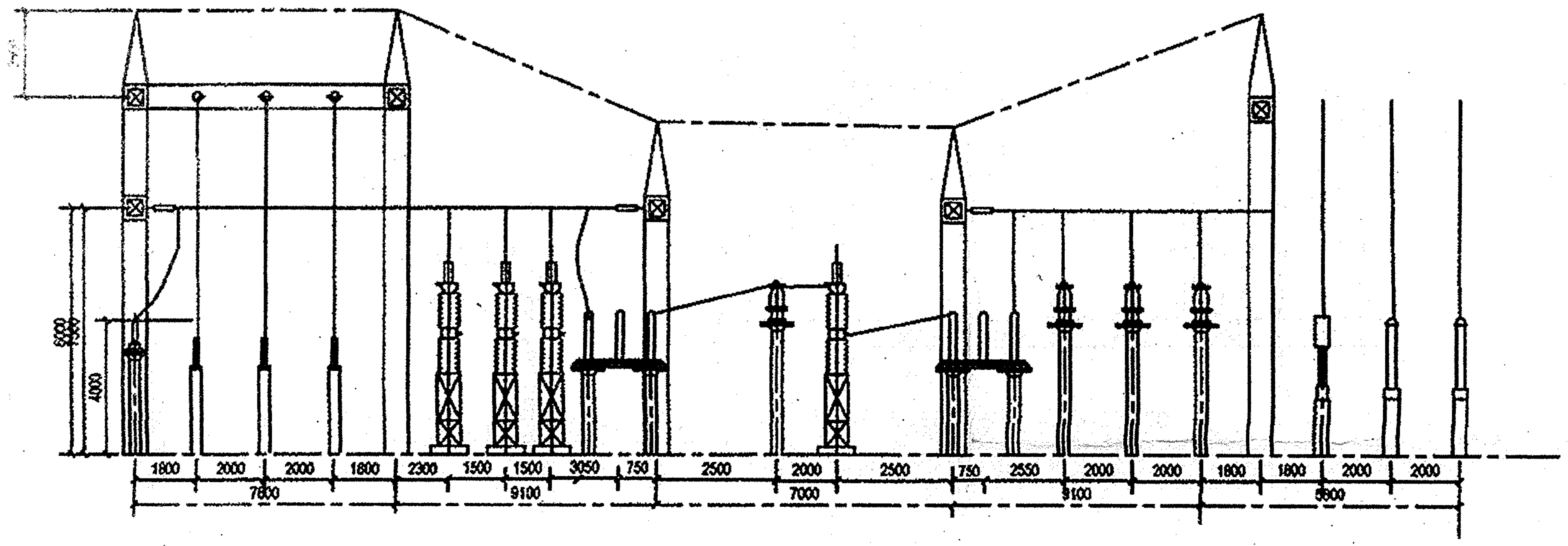
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. POST INSULATOR
5. LIGHTNING ARRESTER
6. POTENTIAL TRANSFORMER
7. WAVE TRAP
8. COUPLING CAPACITOR WITH POTENTIAL DEVICE

NOTE

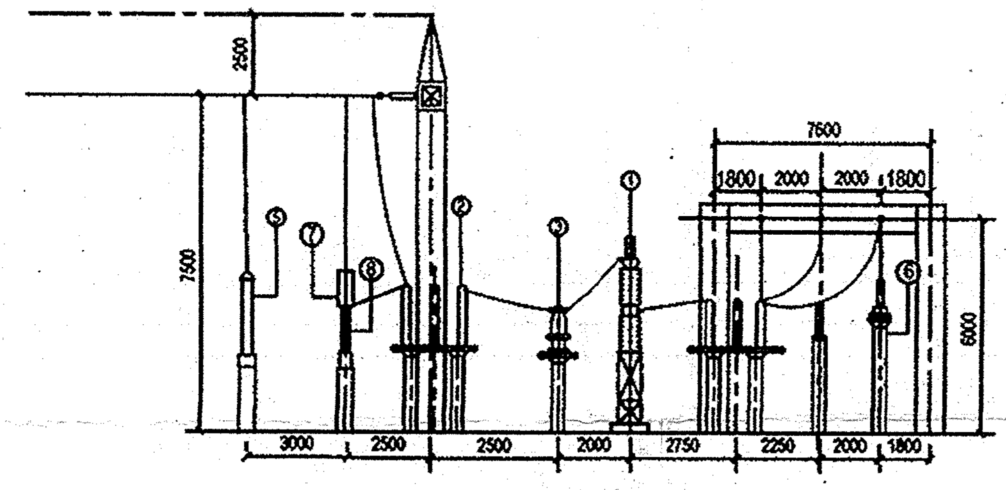
1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-28

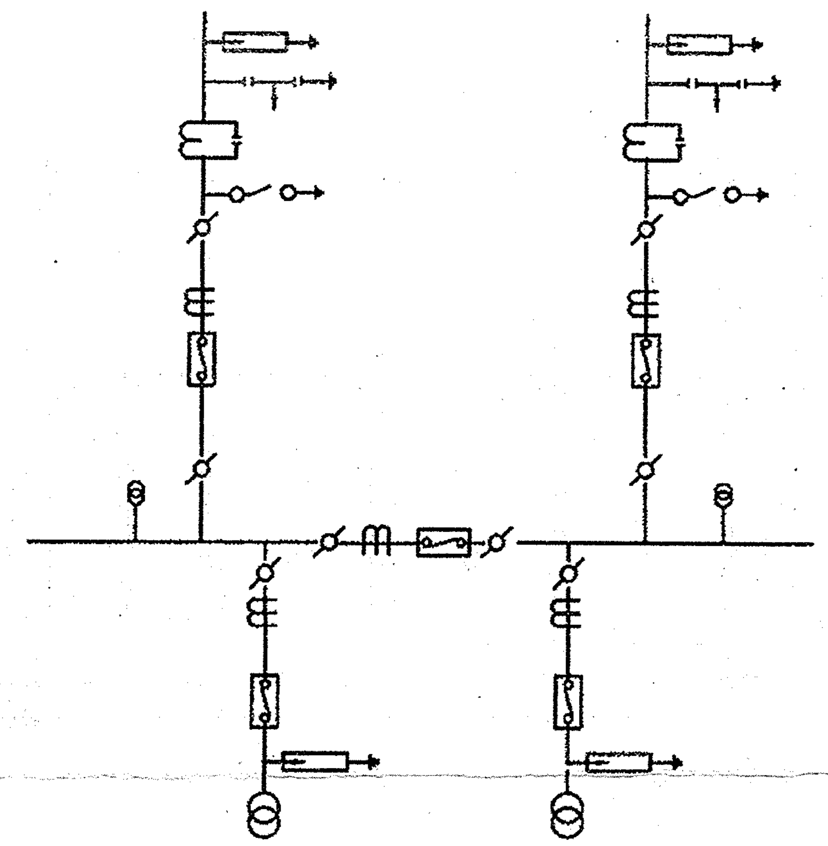
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
SINGLE BUS ARRANGMENT (LOW LEVEL TYPE) 72.5 KV BIL 325 KVp		
	SHEET 1 OF 1	SCALE: NTS



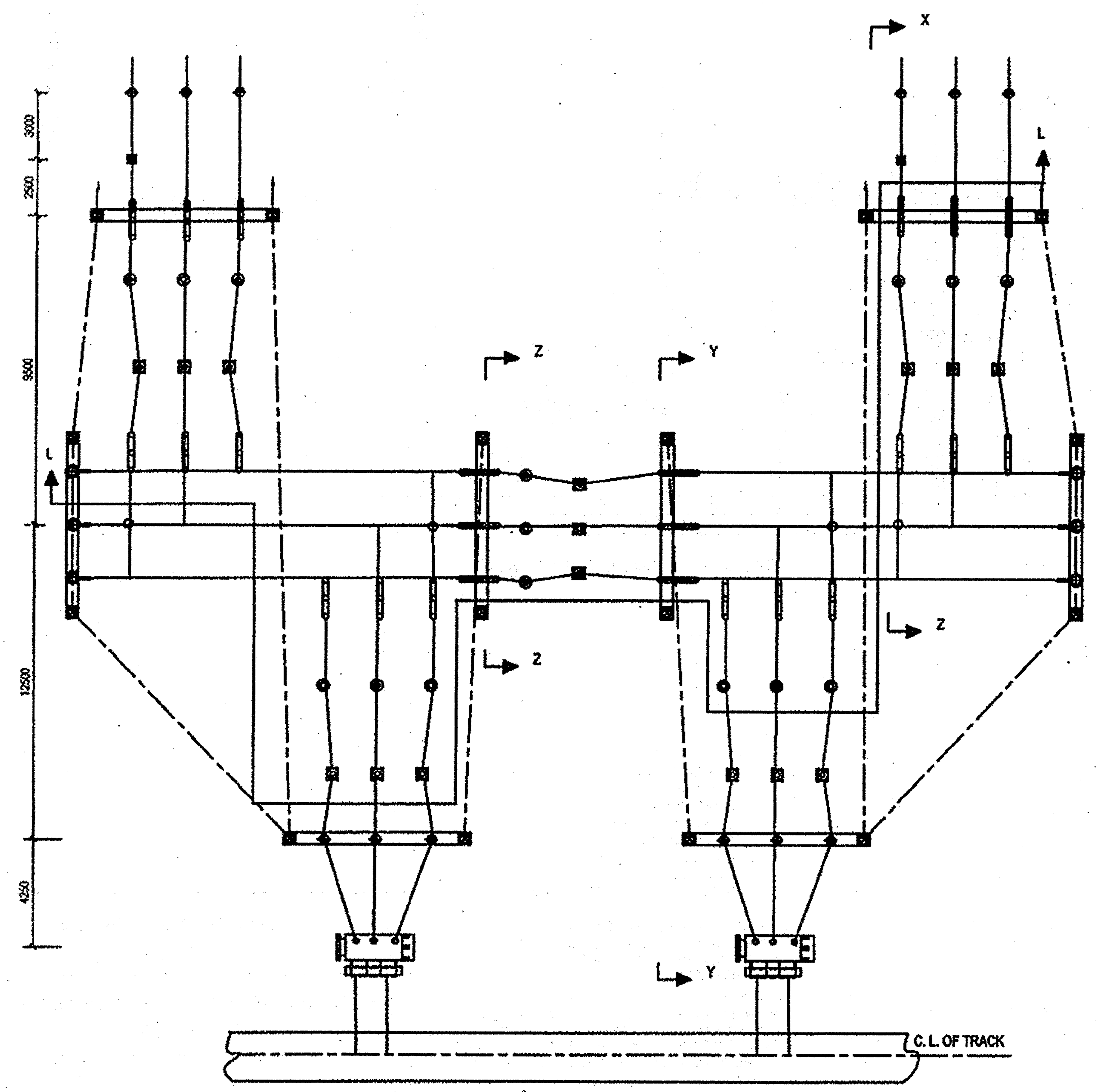
SECTION L-L



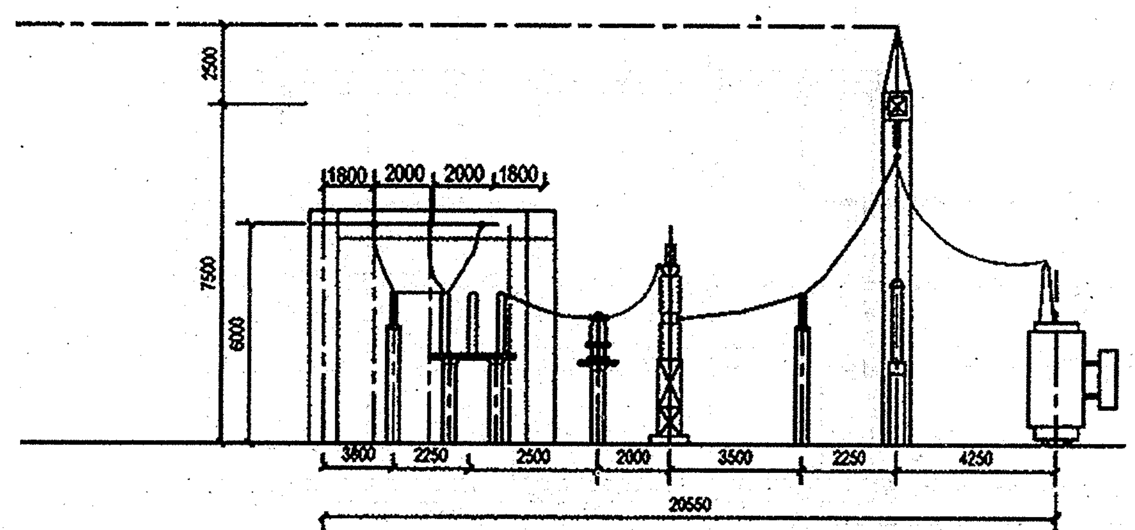
SECTION X-X (LINE BAY)



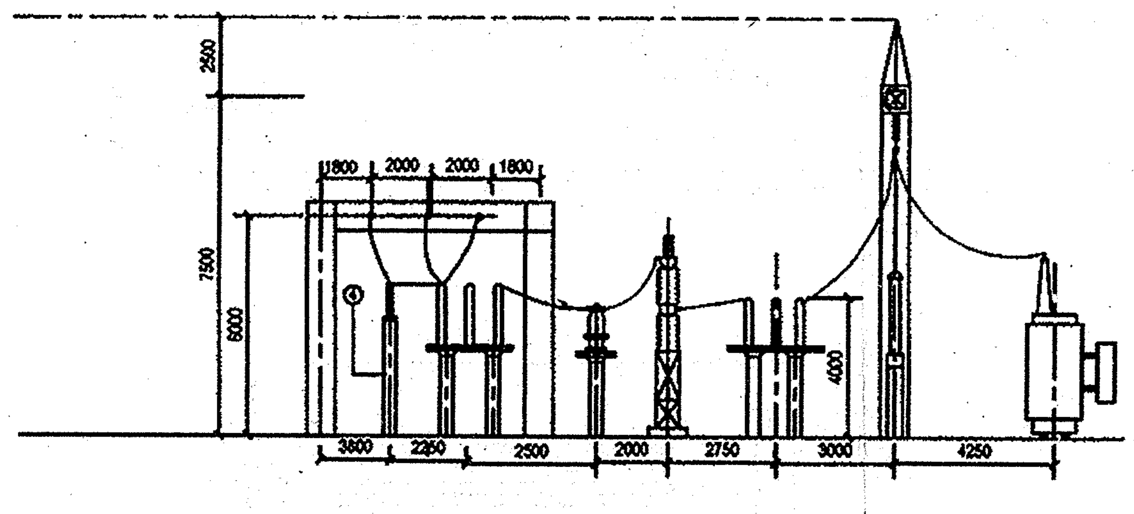
SINGAL LINE DIAGRAM



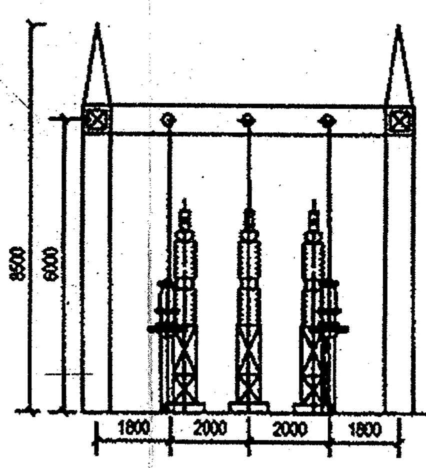
PLAN



SECTION AT Y-Y (TRANSFORMER BAY)



SECTION AT Y'-Y'(TRANSFORMER BAY)



SECTION AT Z-Z

LEGEND

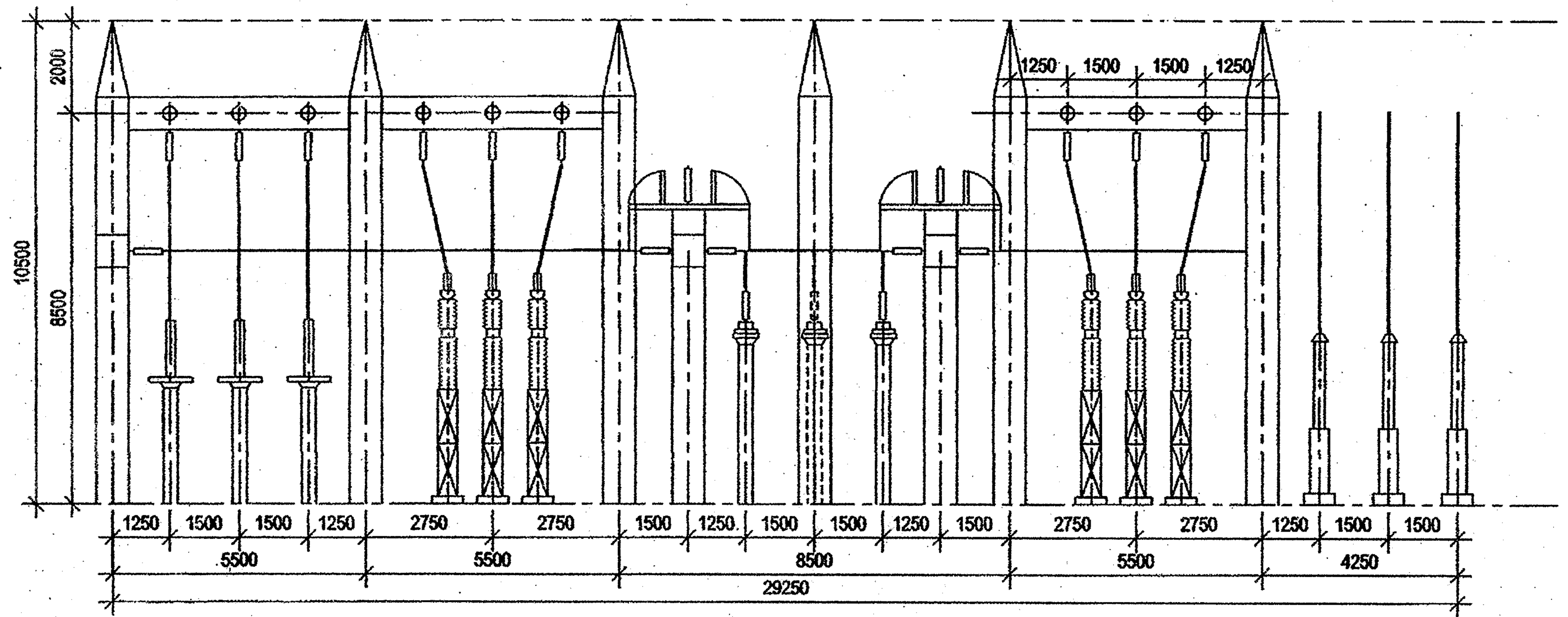
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. POST INSULATOR
5. LIGHTNING ARRESTER
6. POTENTIAL TRANSFORMER
7. WAVE TRAP
8. COUPLING CAPACITOR WITH POTENTIAL DEVICE

NOTE

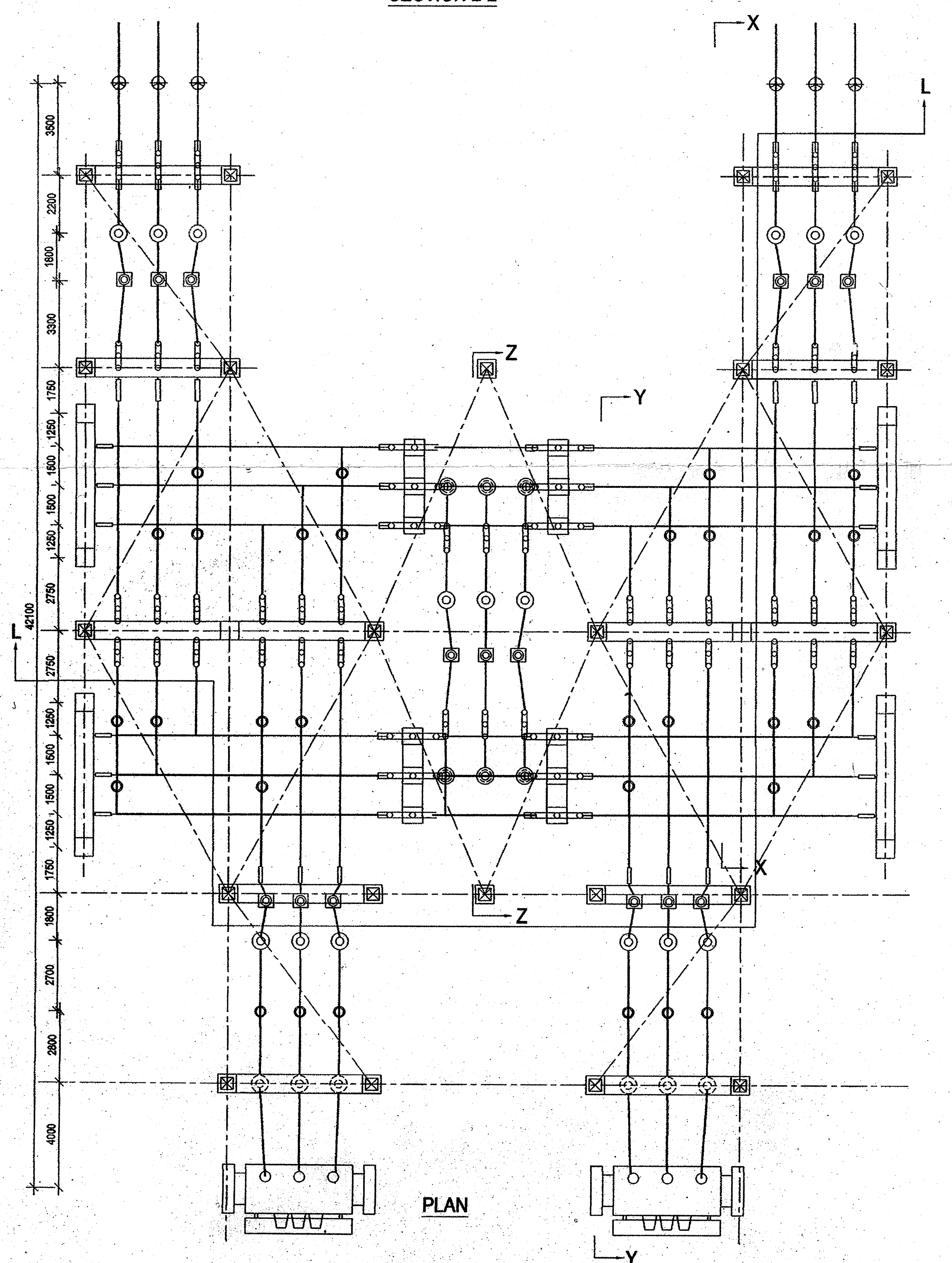
1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-28

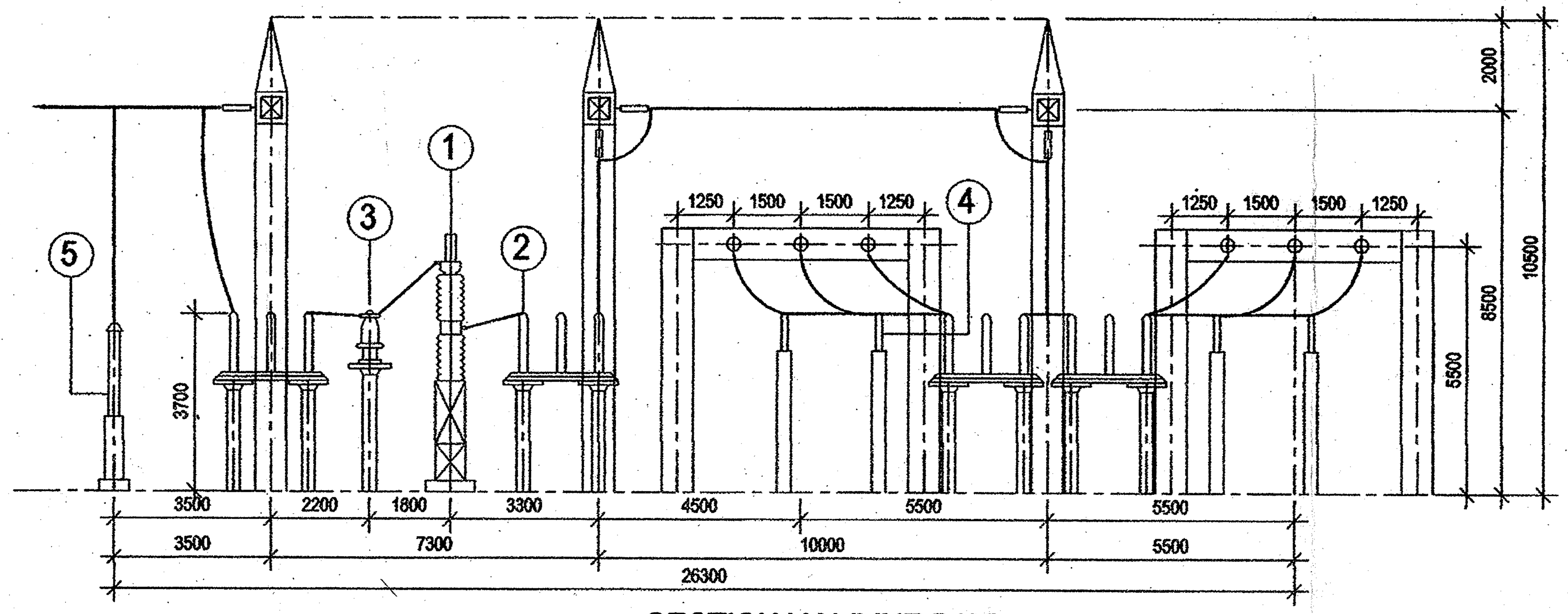
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
SINGLE BUS ARRANGMENT (LOW LEVEL TYPE) 72.5 KV BIL 325 KVp		
	SHEET 1 OF 5	SCALE: NTS



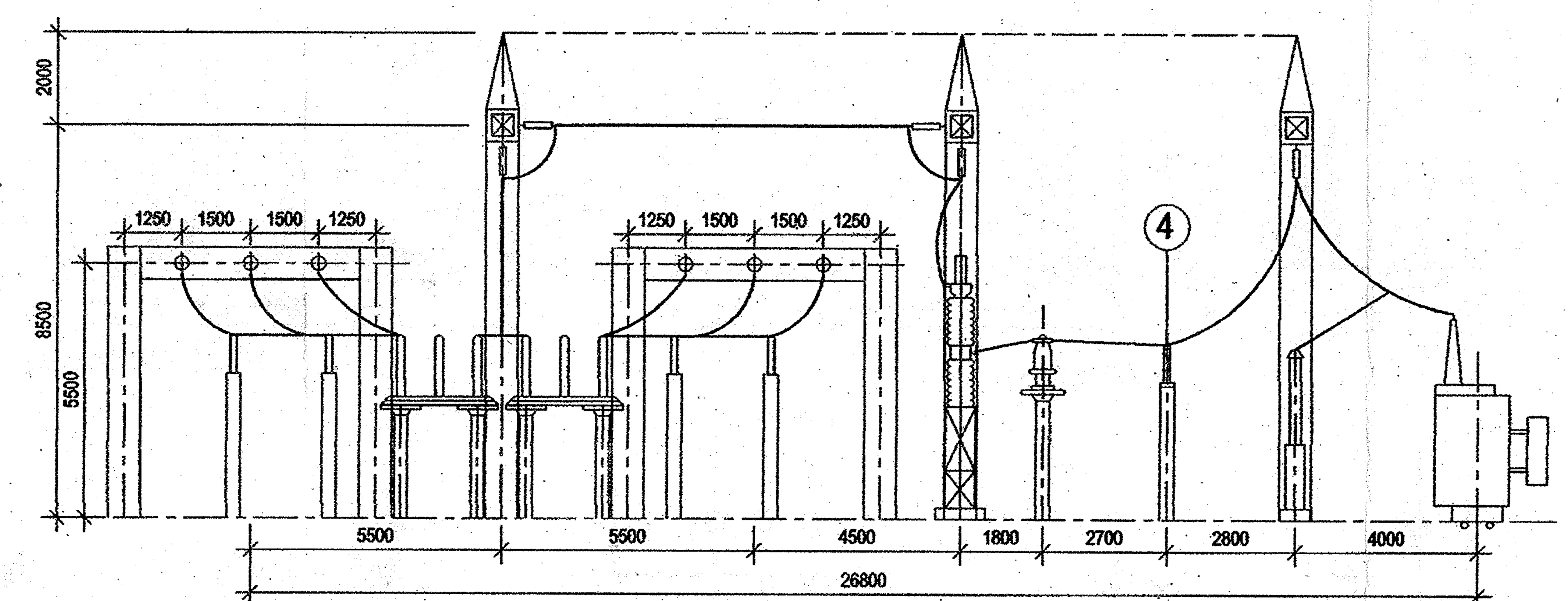
SECTION L-L



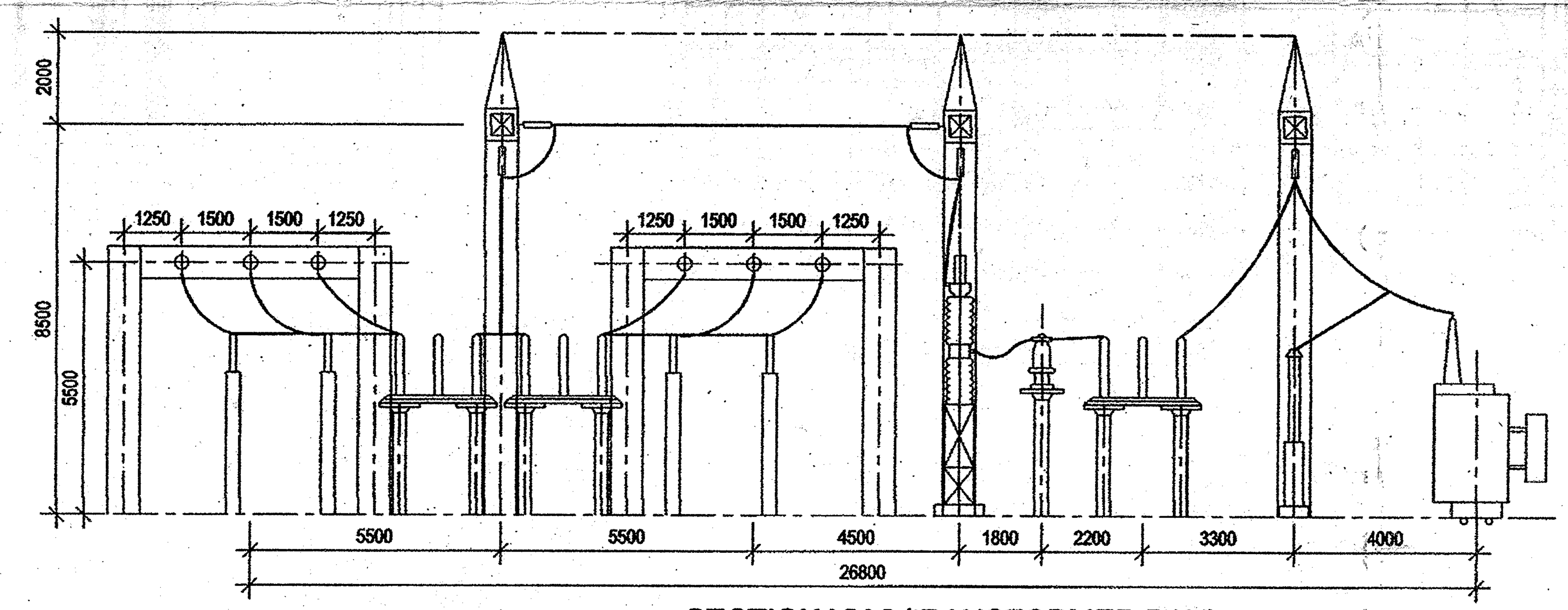
PLAN



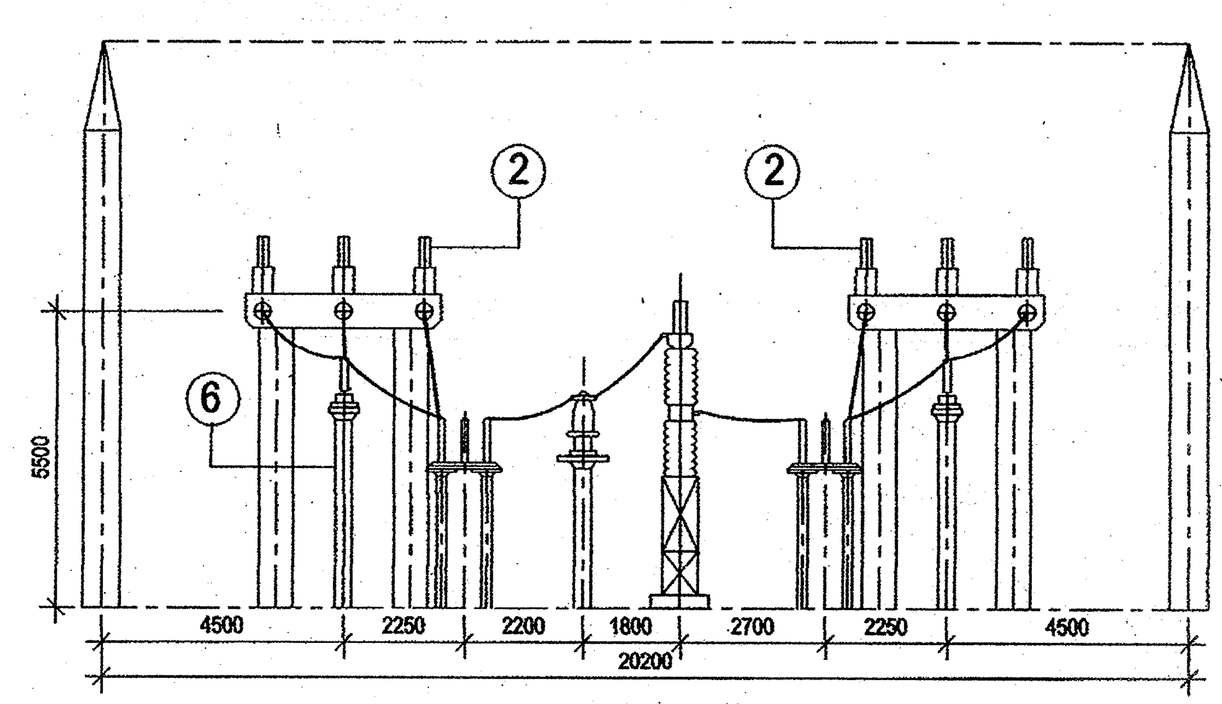
SECTION X-X (LINE BAY)



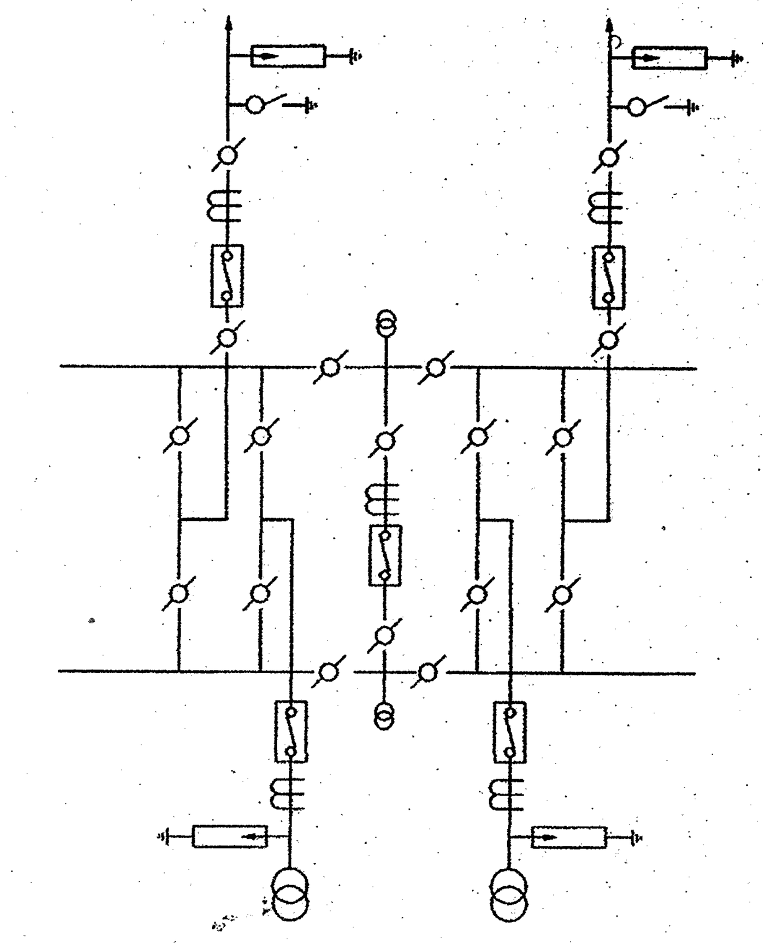
SECTION Y-Y (TRANSFORMER BAY)



SECTION Y'-Y' (tRANSFORMER BAY)



SECTION Z-Z (BUS COUPLER BAY)



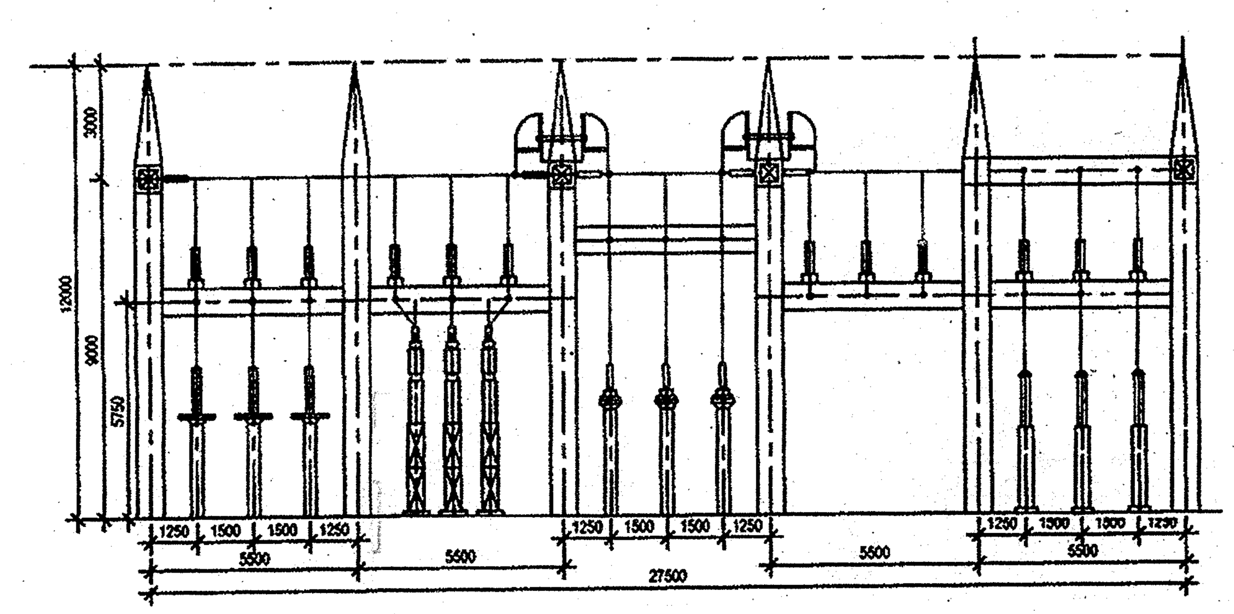
SINGLE LINE DIAGRAM

LEGEND
1. OIL CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. POST INSULATOR
5. LIGHTNING ARRESTER
6. POTENTIAL TRANSFORMER

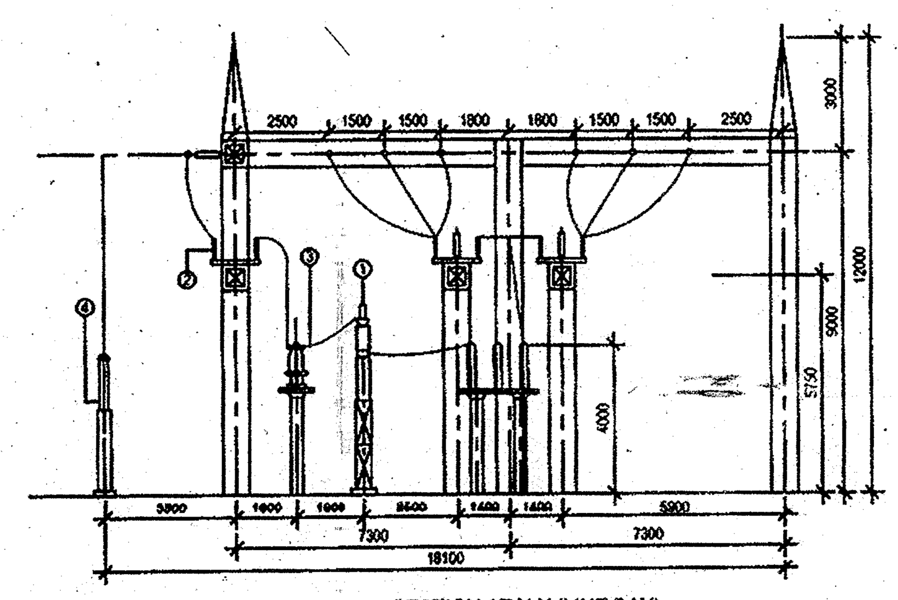
NOTE
1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-30

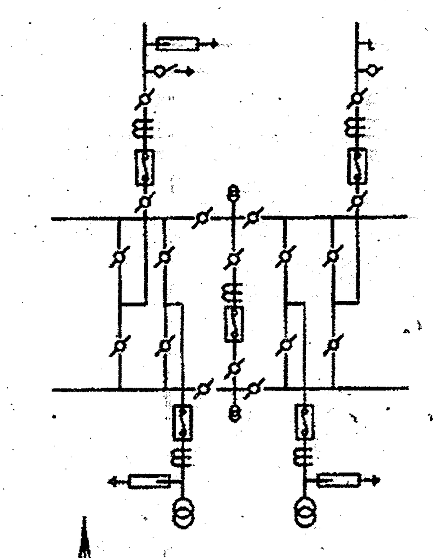
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
DOUBLE BUS ARRANGEMENT(LOW LEVEL TYPE) 36 KV BIL 170 KVp	
SHEET 1 OF 1	SCALE: NTS



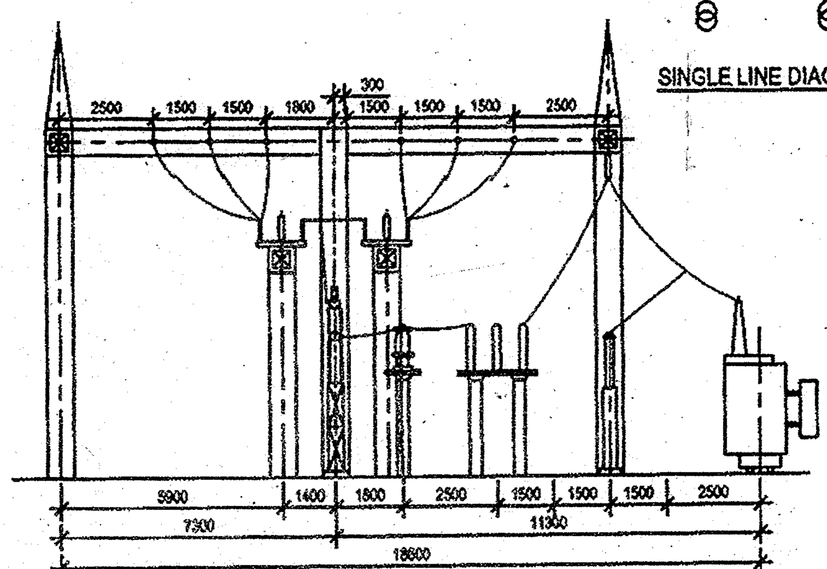
SECTION AT L-L



SECTION AT X-X (LINE BAY)



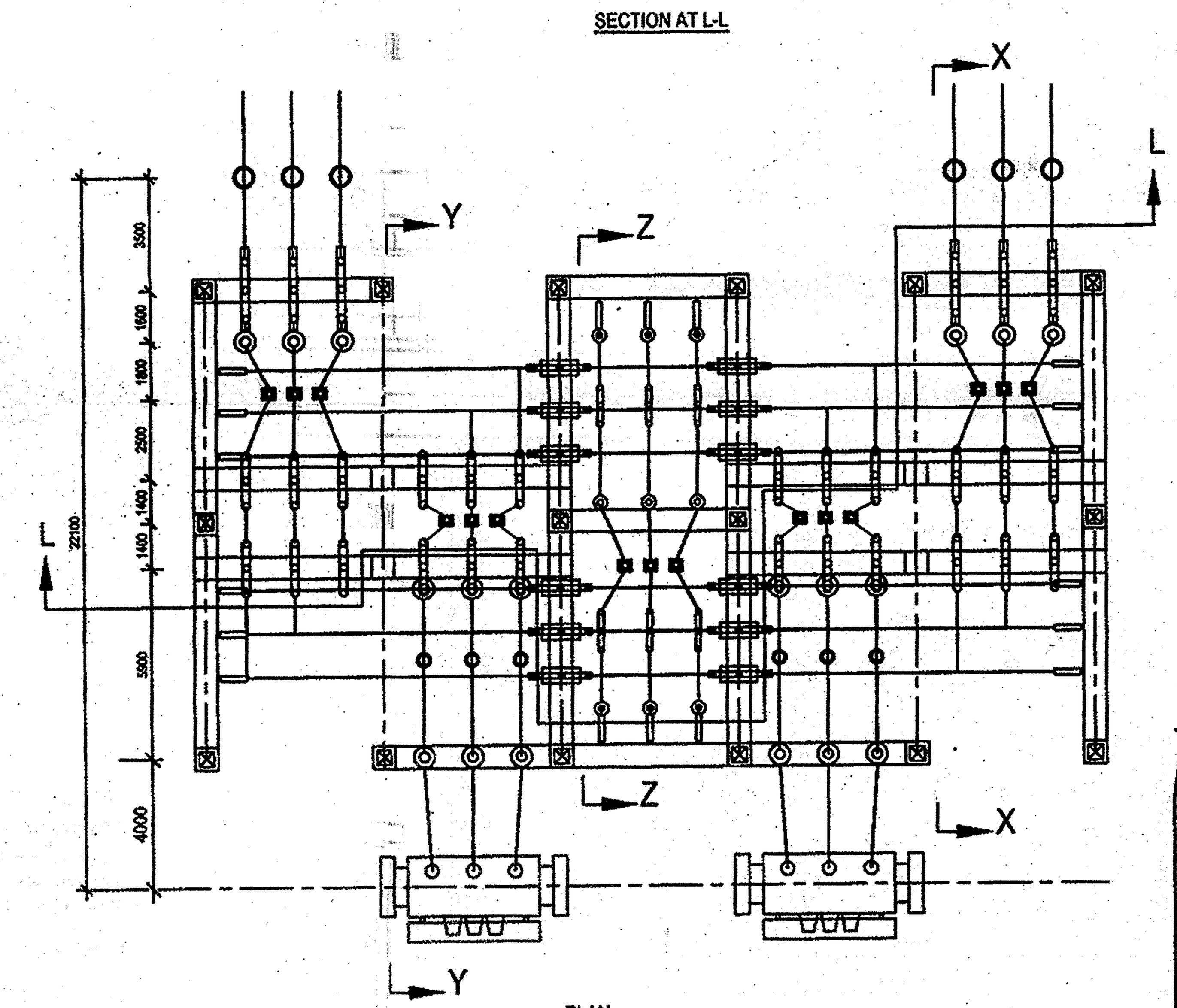
SINGLE LINE DIAGRAM



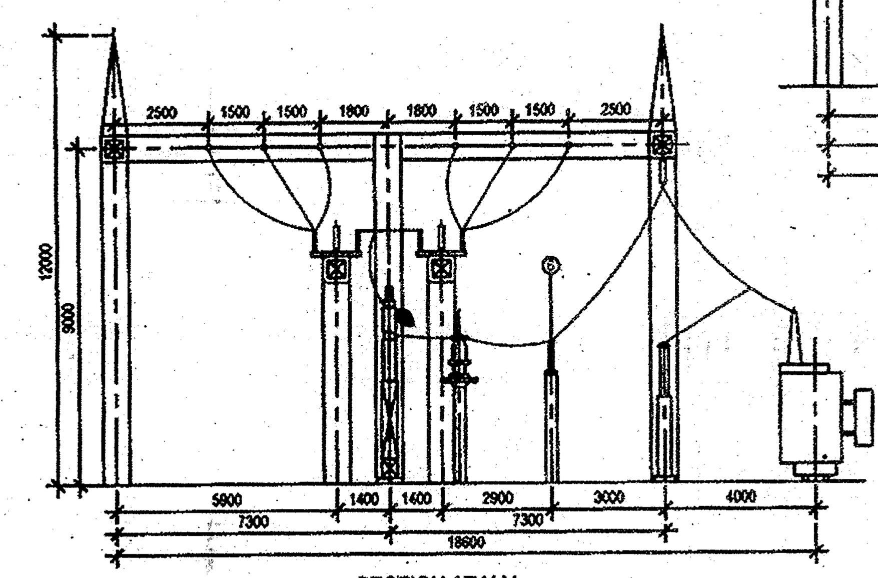
SECTION AT Y'-Y' (TRANSFORMER BAY)

LEGEND

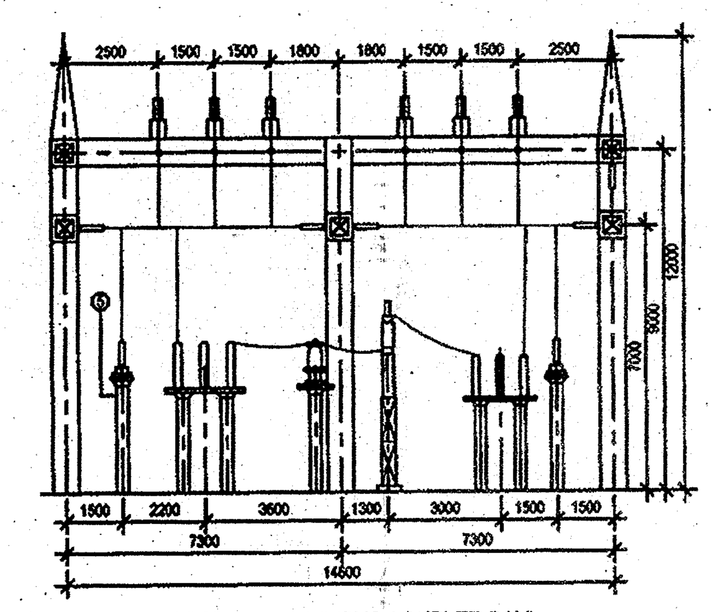
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. LIGHTNING ARRESTER
5. POTENTIAL TRANSFORMER
6. POST INSULATOR



PLAN



SECTION AT Y-Y



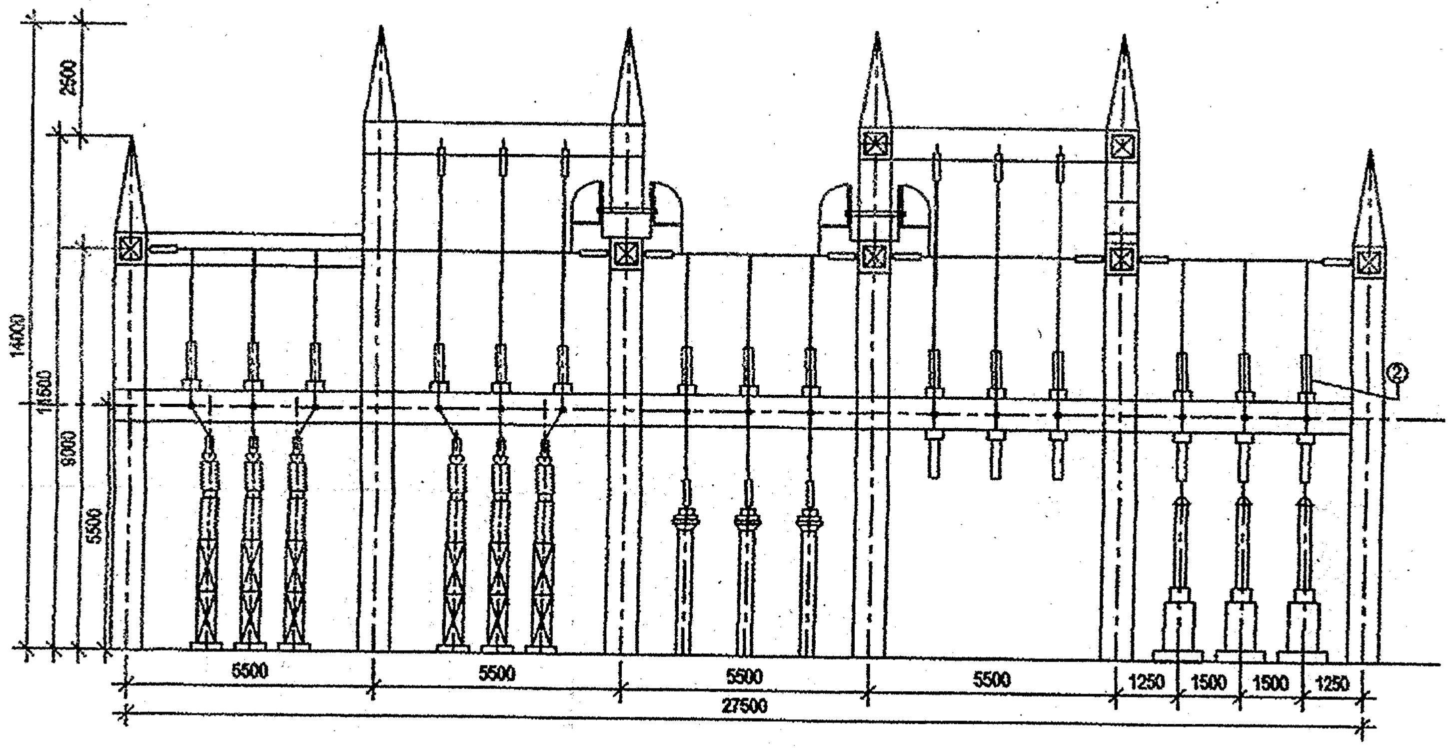
SECTION AT Z-Z (BUS COUPLER BAY)

NOTE

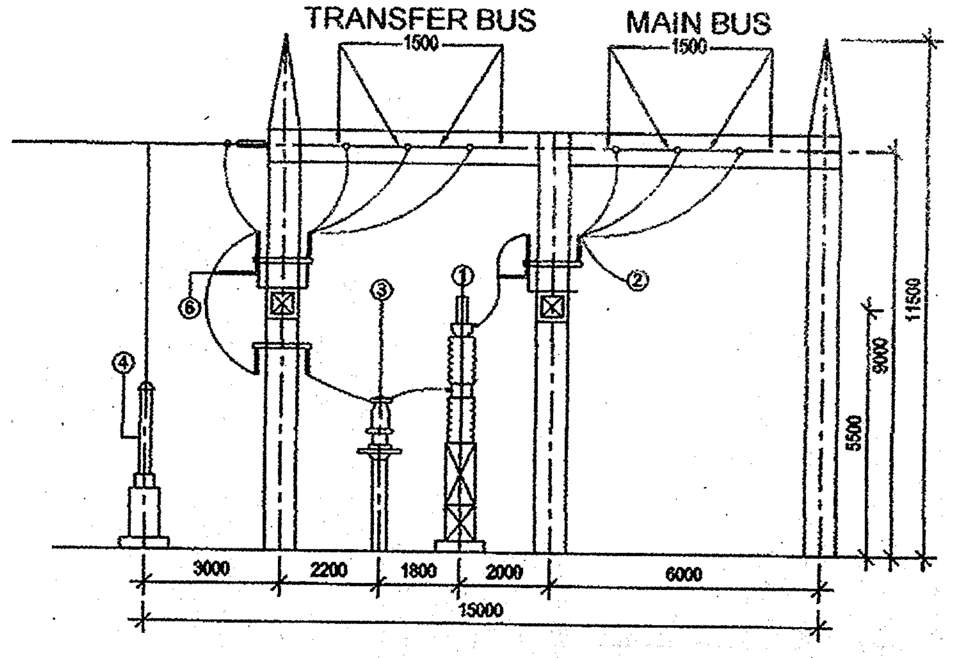
1. REPLACE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT.
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-29

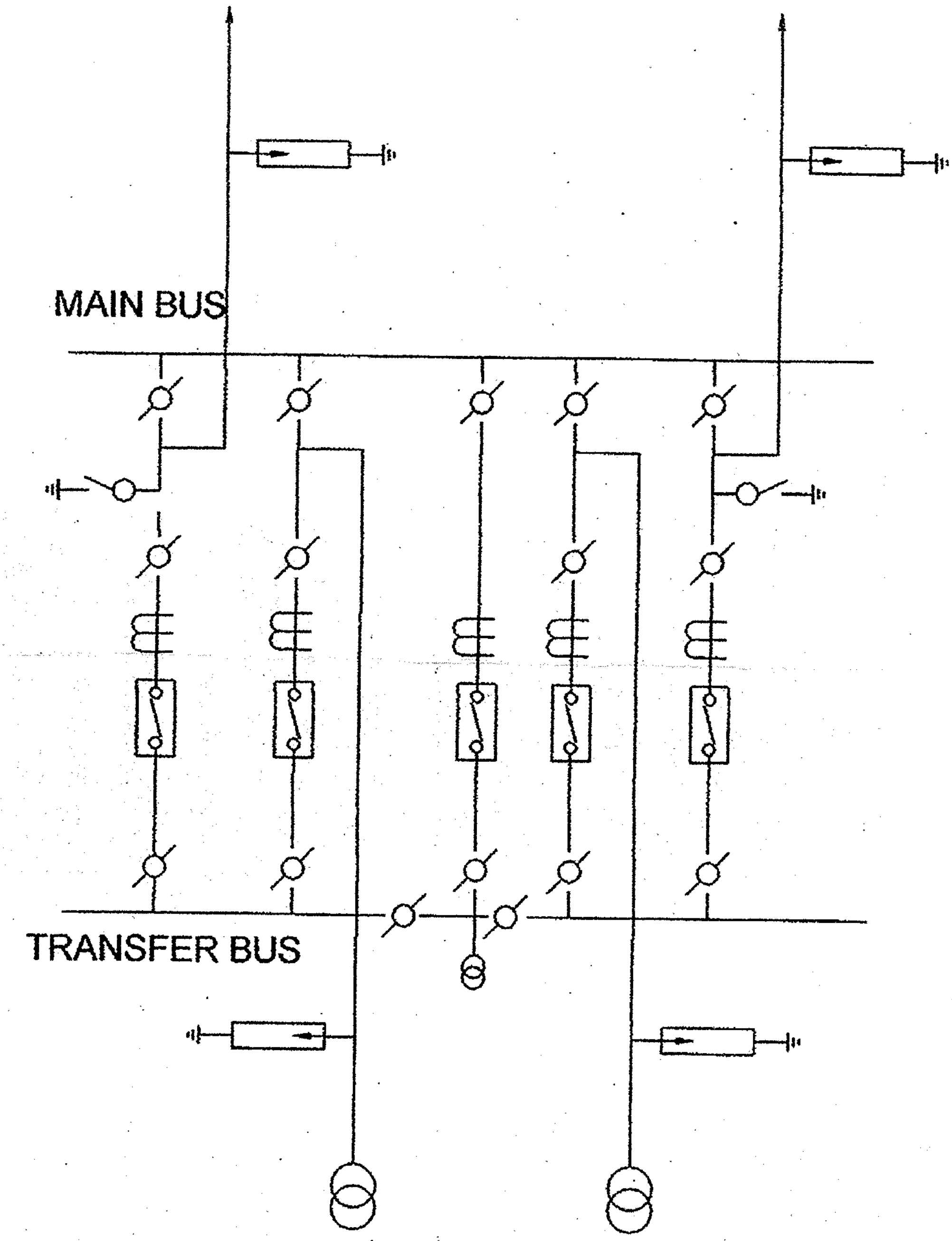
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
DOUBLE BUS ARRANGEMENT (HIGH LEVEL TYPE) 36 KV BIL 170 KVp	
SHEET 1 OF 1	SCALE: NTS



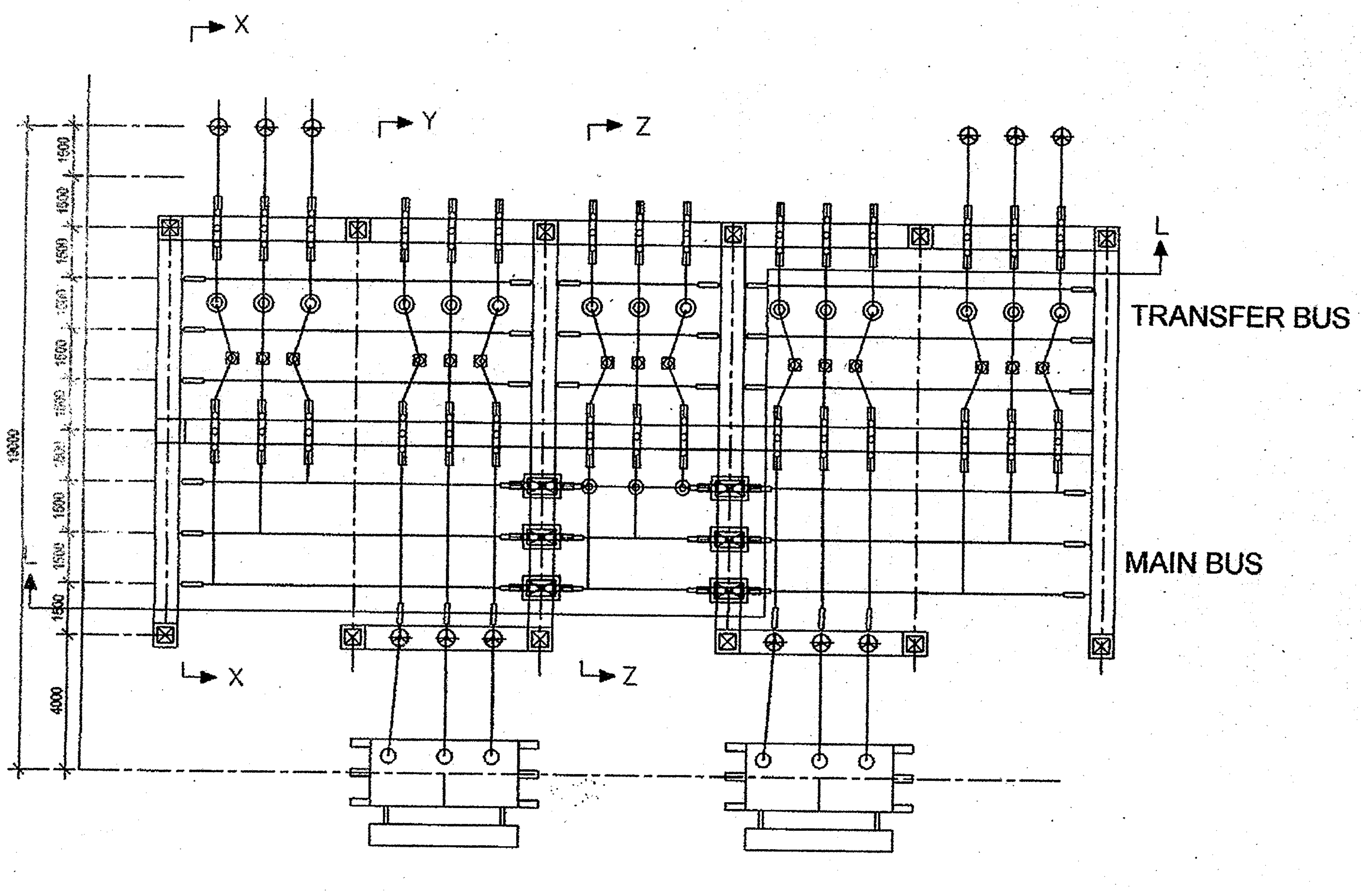
SECTION AT L-L



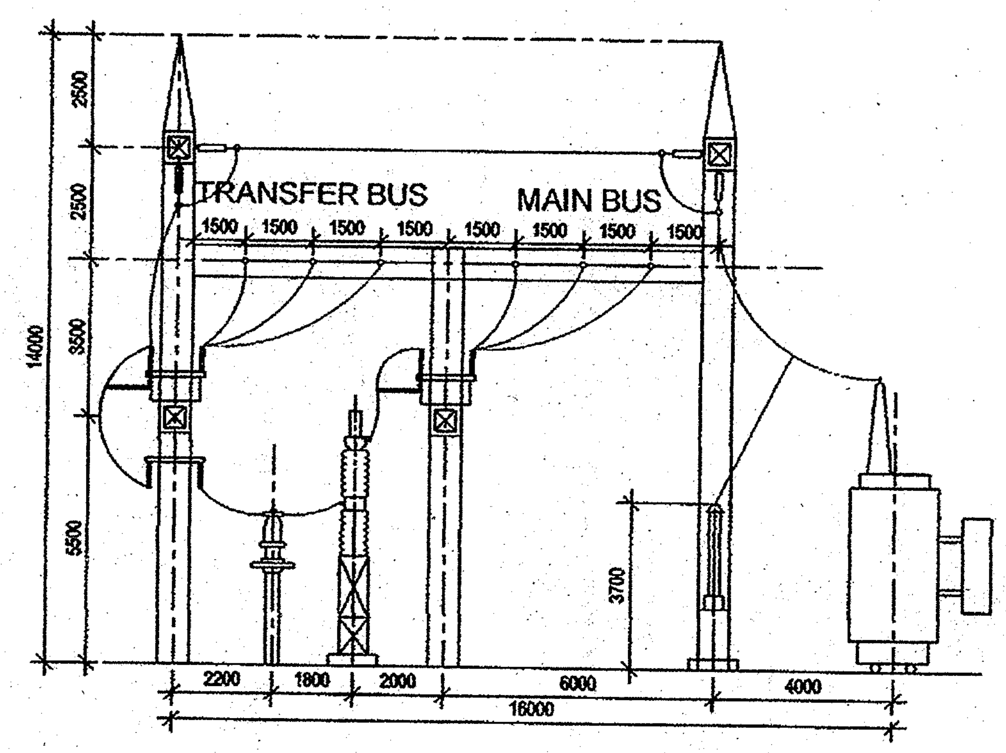
SECTION AT X-X (LINE BAY)



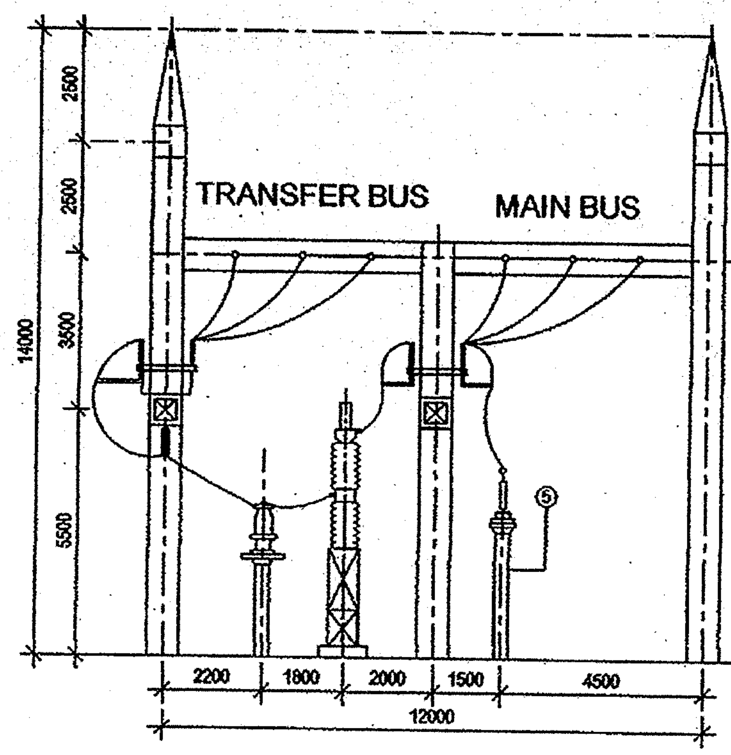
SINGLE LINE DIAGRAM



PLAN



SECTION AT Y-Y(TRANSFORMER BAY)



SECTION AT Z-Z (BUS COUPLER BAY)

LEGEND

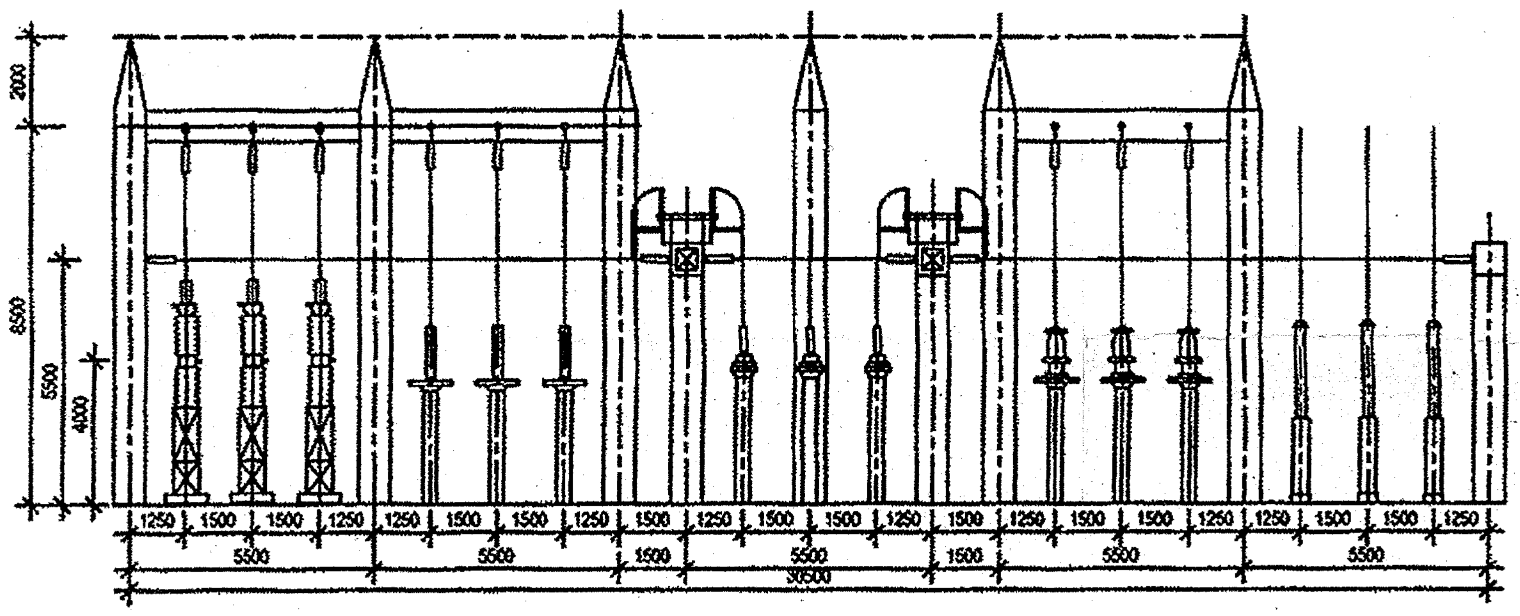
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. LIGHTNING ARRESTER
5. POTENTIAL TRANSFORMER
6. POST INSULATOR

NOTE

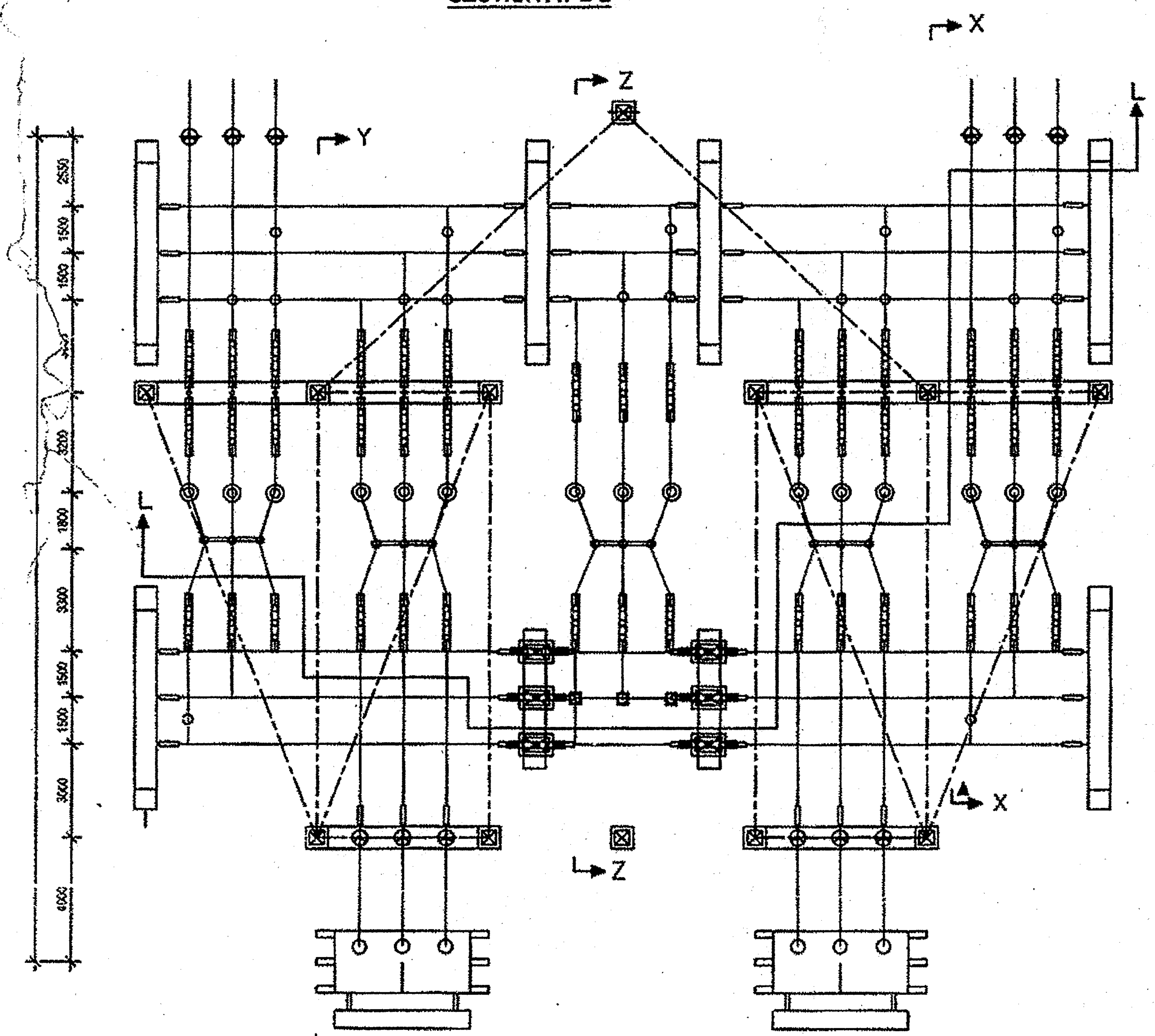
1. ALL DIMENSIONS ARE IN MM.
2. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-31

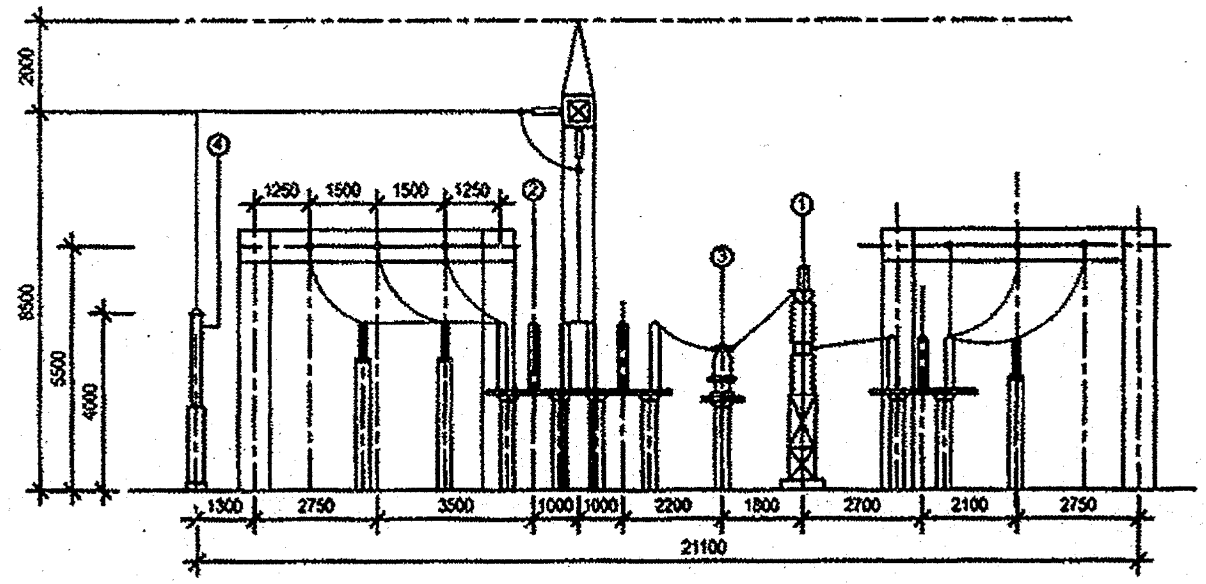
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
MAIN AND TRANSFER BUS ARRANGEMENT HIGH LEVEL TYPE 36 KV BIL 170 KVp	
SHEET 1 OF 1	SCALE: NTS



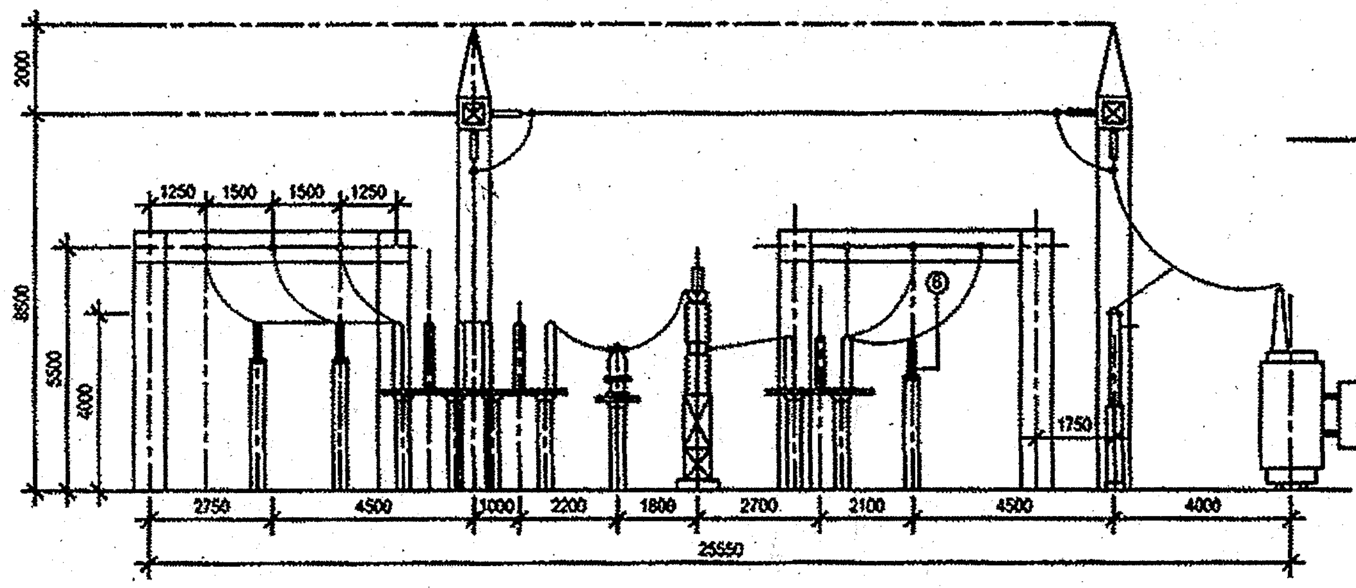
SECTION AT L-L



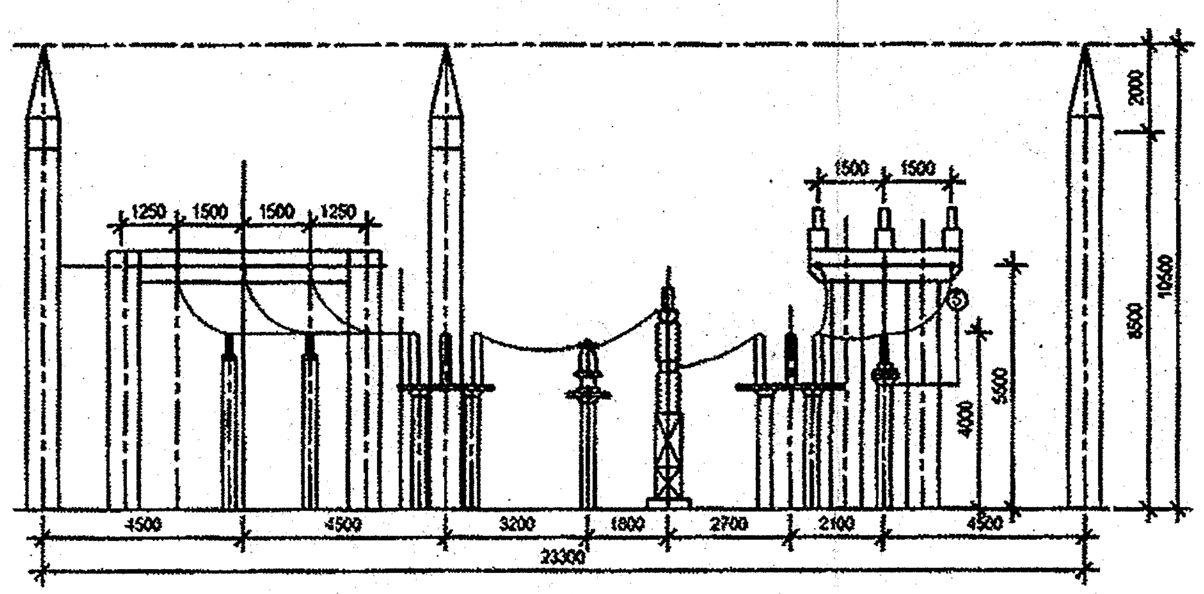
PLAN



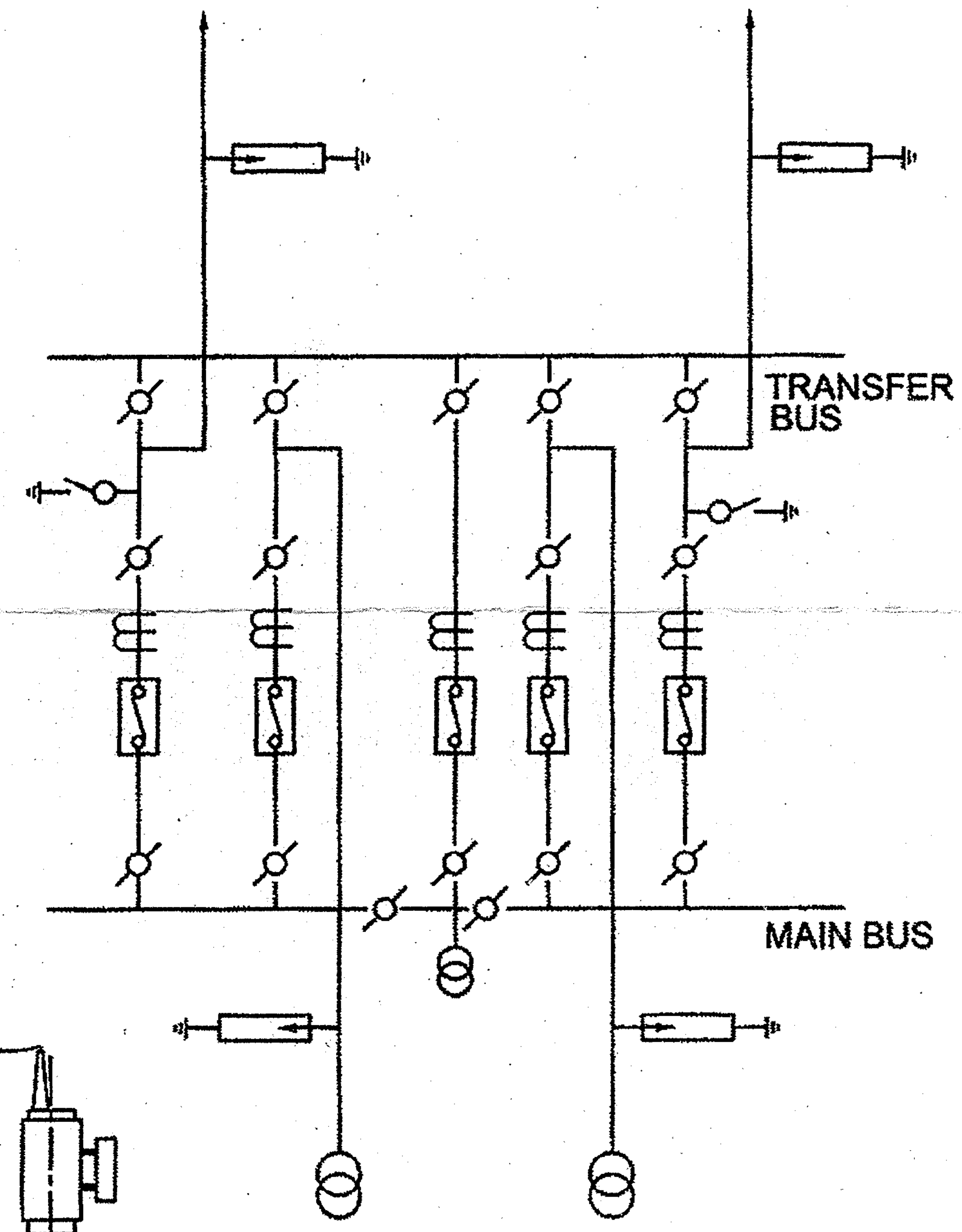
SECTION AT X-X (LINE BAY)



SECTION AT Y-Y (TRANSFORMER)



SECTION AT Z-Z (BUS COUPLER))



SINGLE LINE DIAGRAM

LEGEND

1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. LIGHTNING ARRESTER
5. POTENTIAL TRANSFORMER
6. POST INSULATOR

NOTE

1. ALL DIMENSIONS ARE IN MM.
2. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

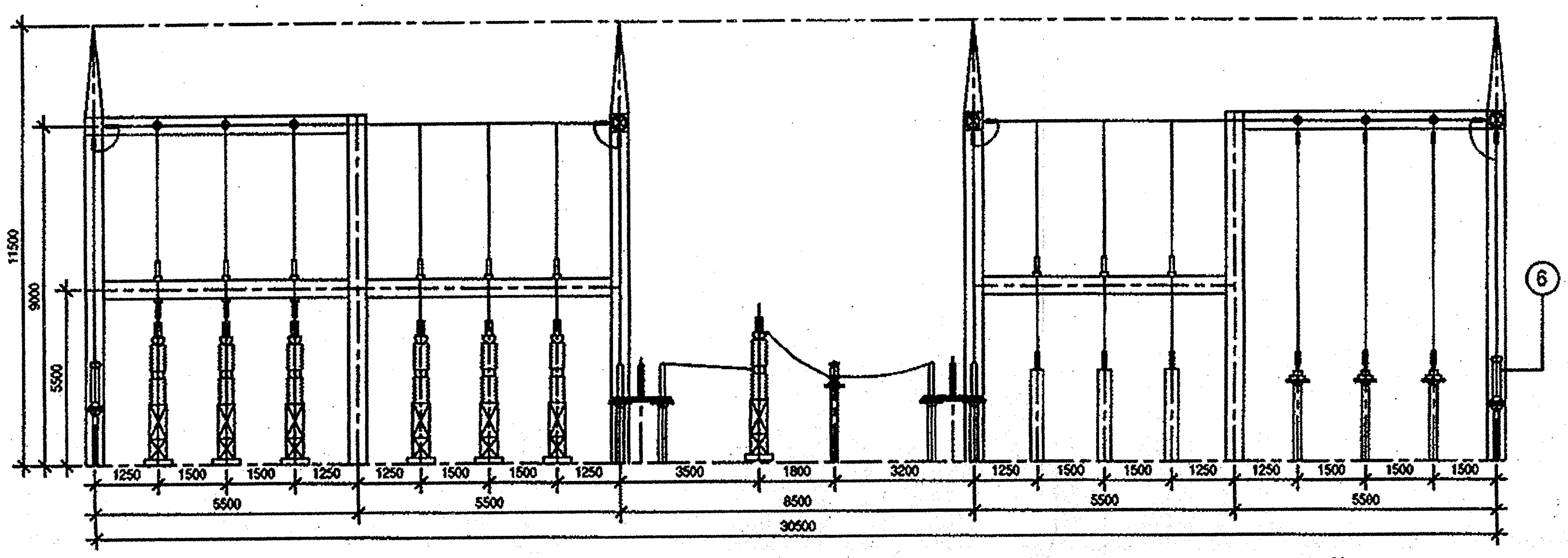
FIGURE-32

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)

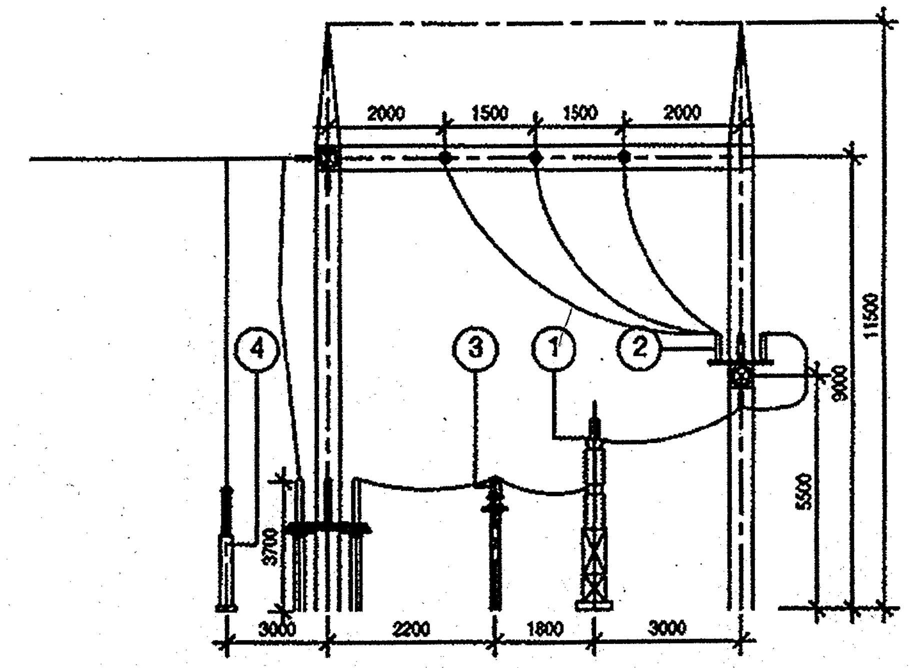
MAIN AND TRANSFER BUS ARRANGEMENT
LOW LEVEL TYPE
36 KV BIL 170 KVp

SHEET 1 OF 1

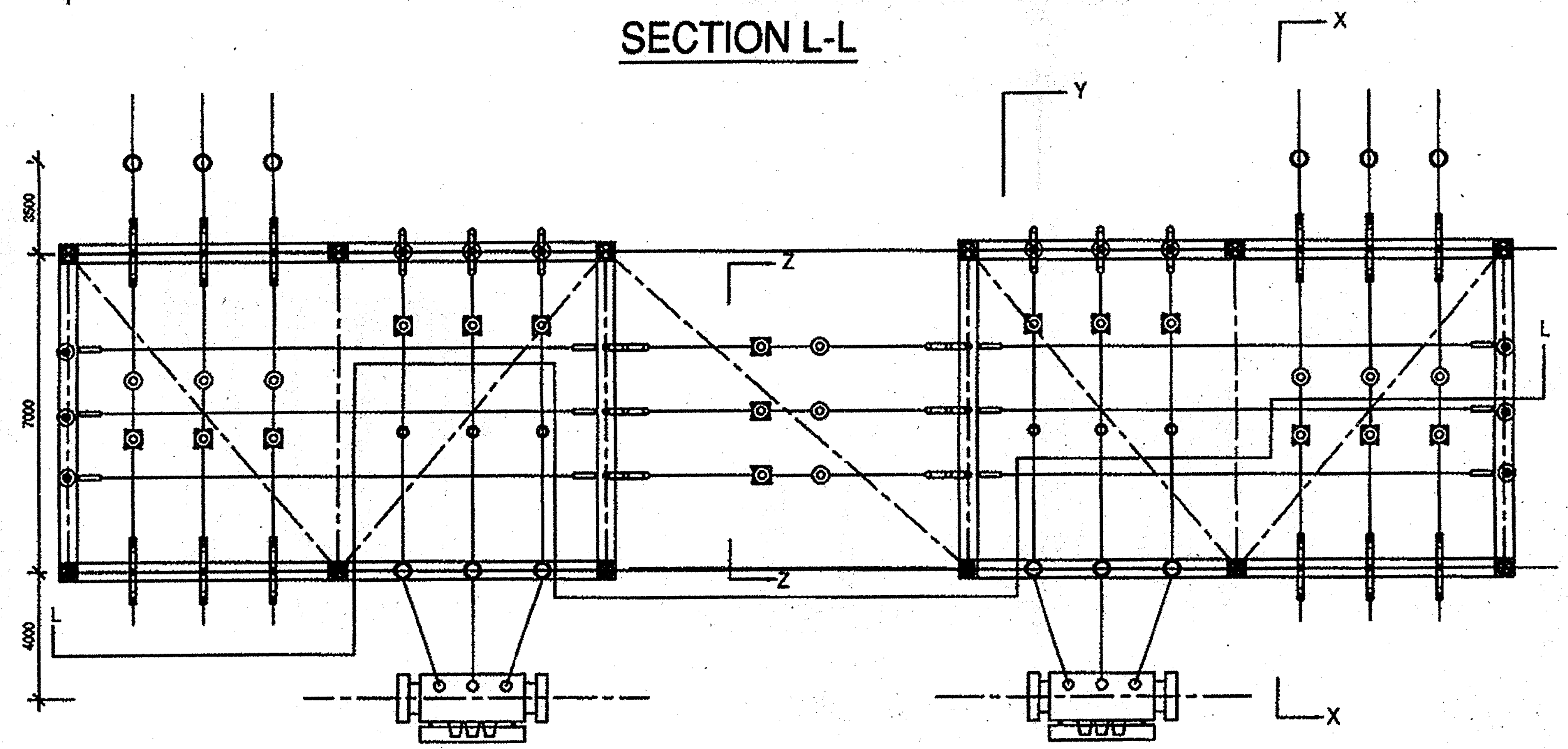
SCALE: NTS



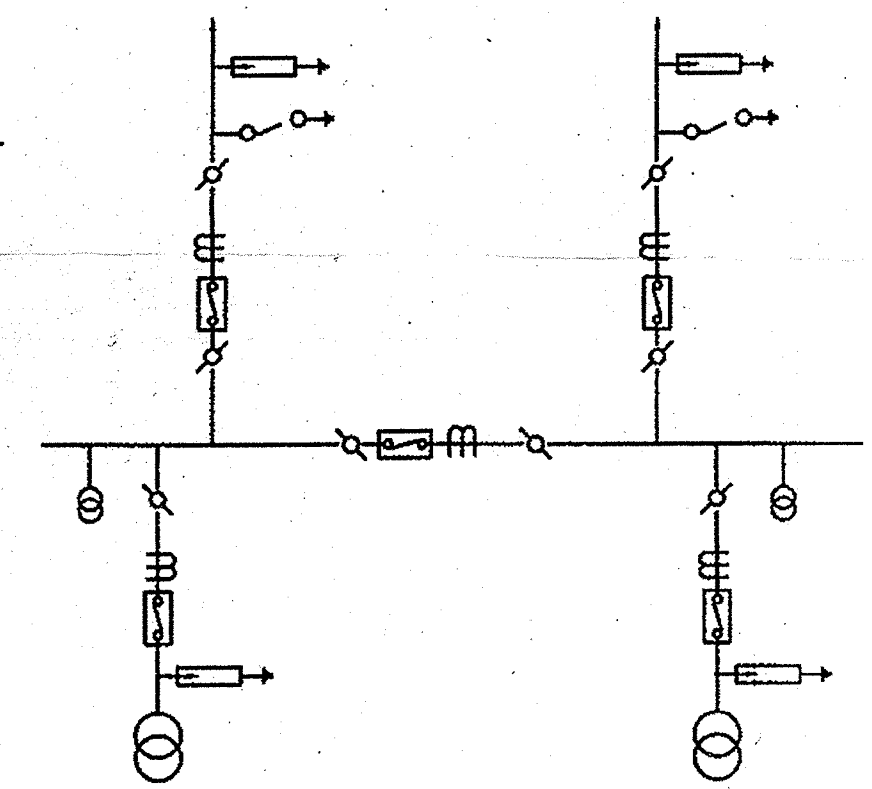
SECTION L-L



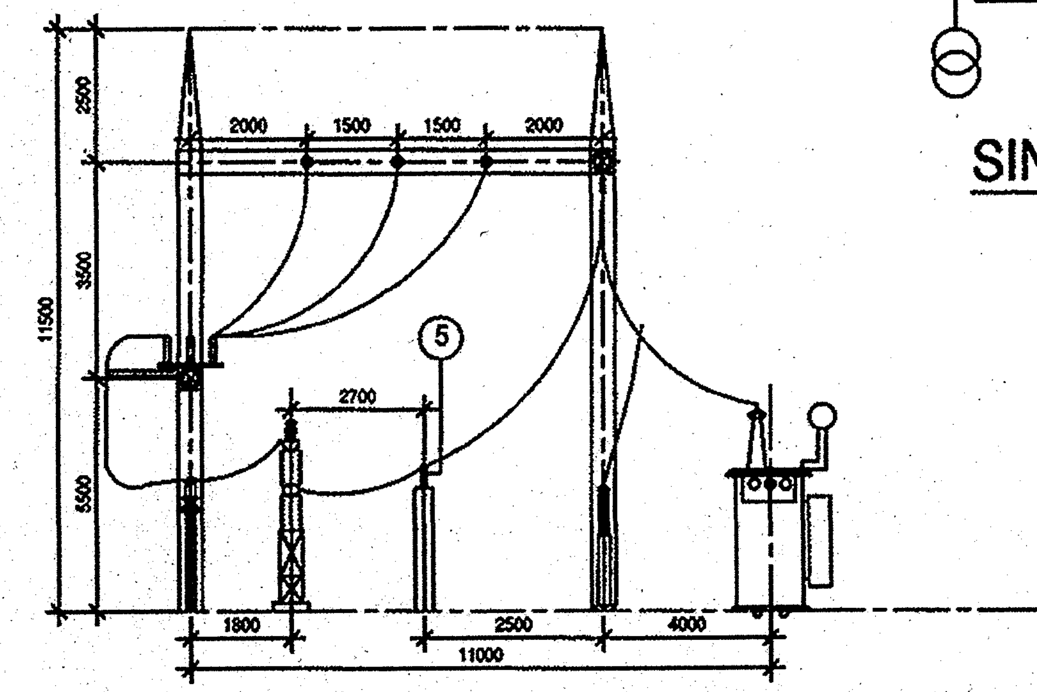
SECTION X-X (LINE BAY)



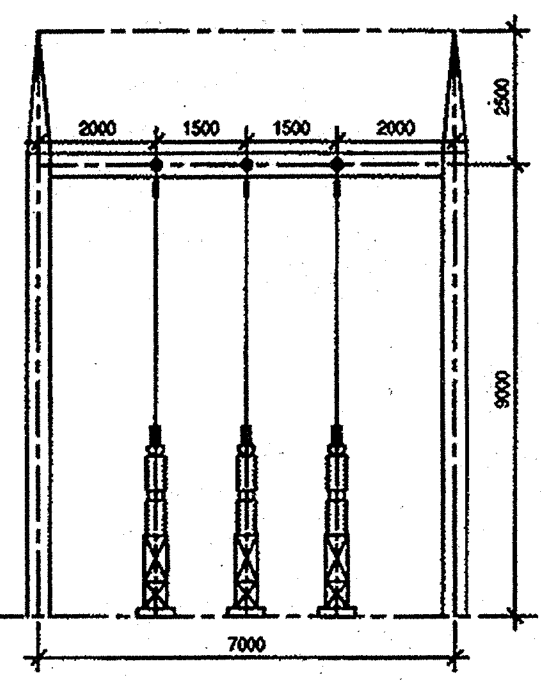
PLAN



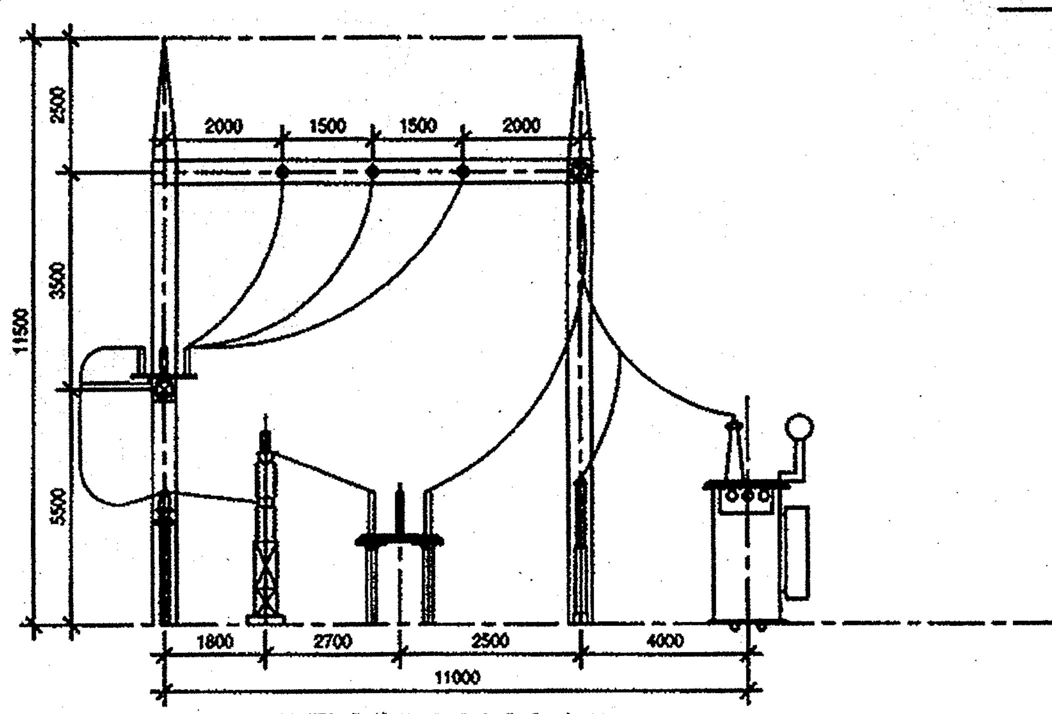
SINGAL LINE DIAGRAM



SECTION Y-Y (TRANSFORMER BAY)



SECTION Z-Z



SECTION Y'-Y'

LEGEND:

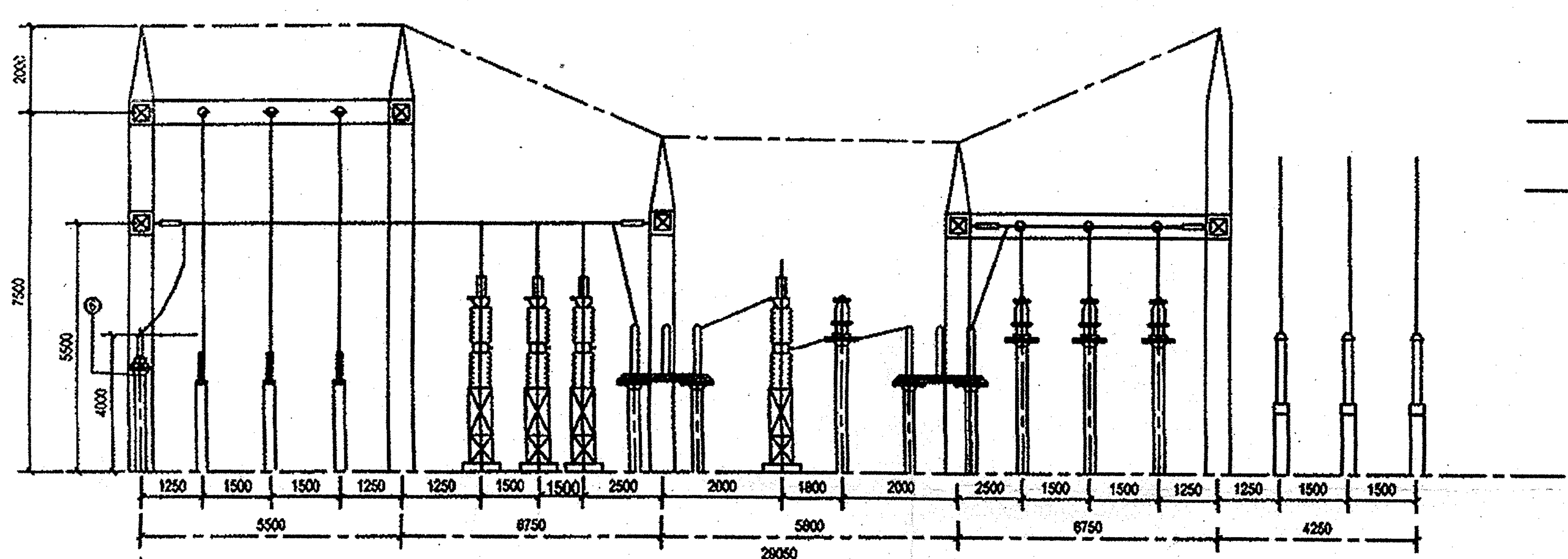
1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. LIGHTNING ARRESTER
5. POST INSULATOR
6. POTENTIAL TRANSFORMER

NOTE

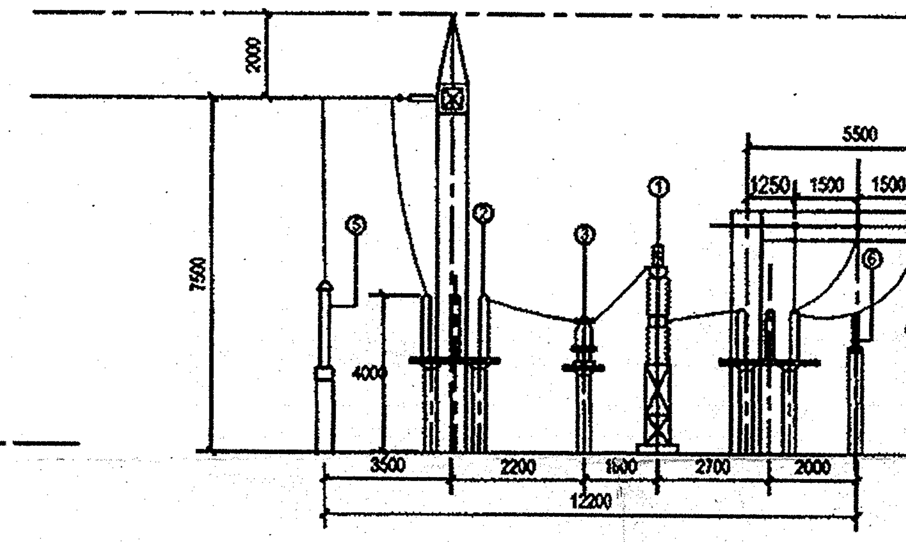
1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS TO BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.

FIGURE-33

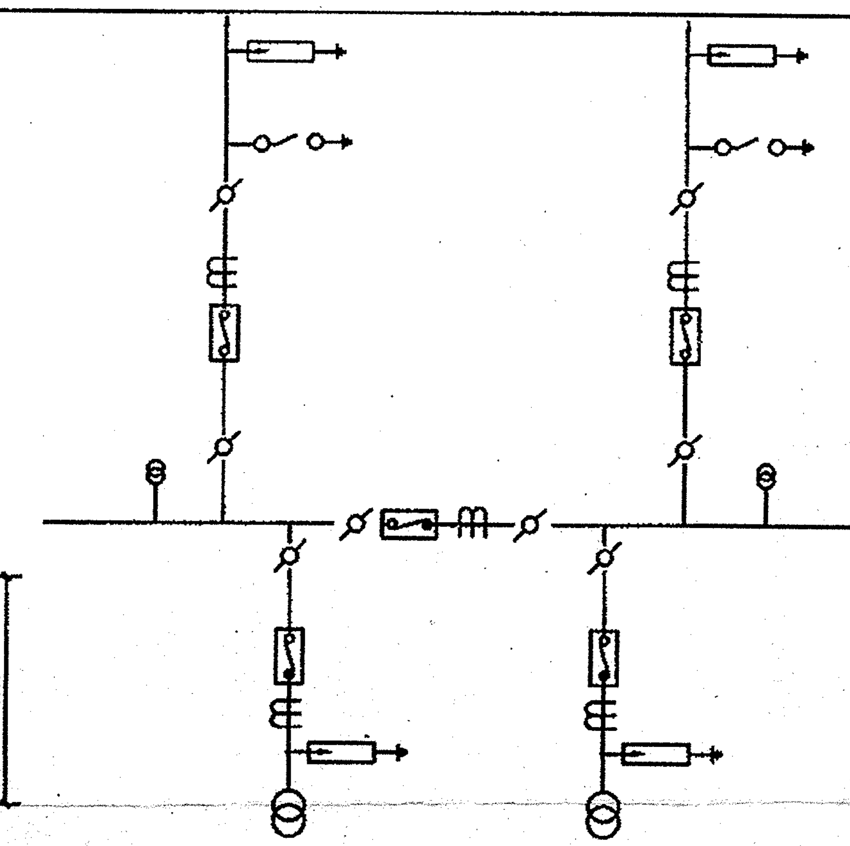
MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)		
SINGLE BUS ARRANGMENT(HIGH LEVEL TYPE) 36 KV BIL 170 KVp		
	SHEET 1 OF 1	SCALE: NTS



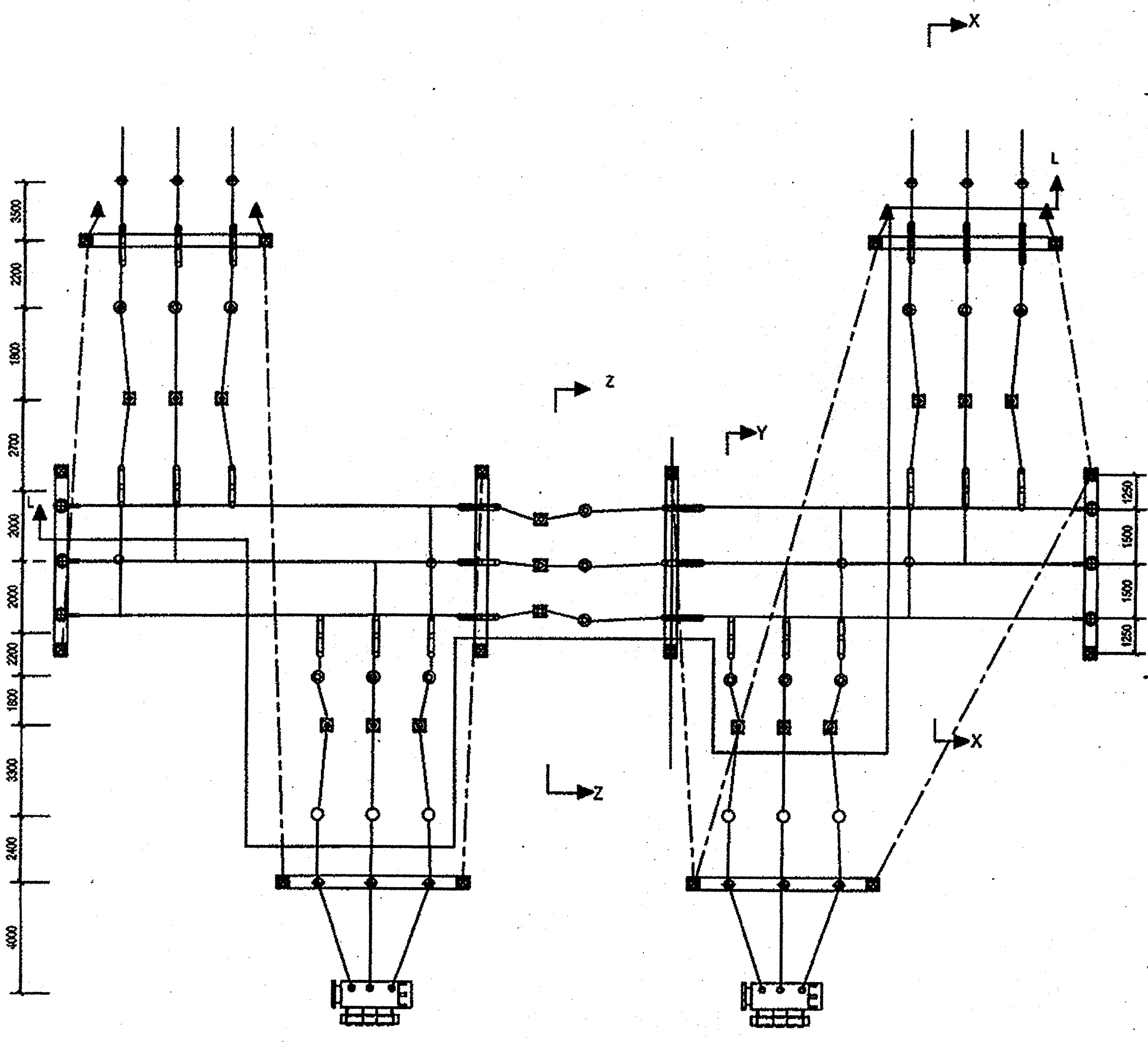
SECTION L-L



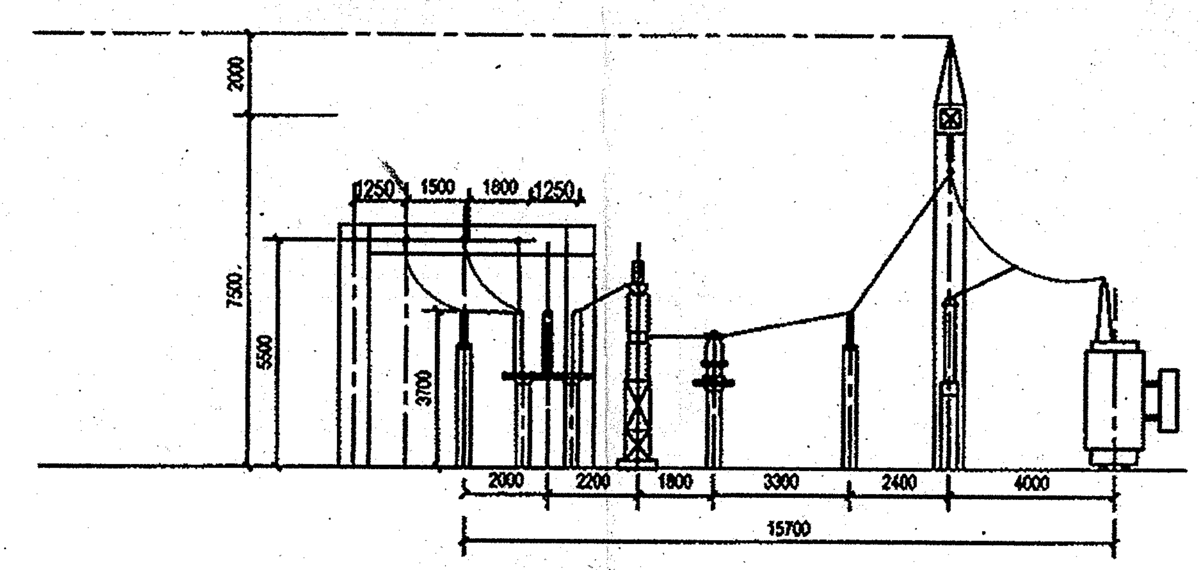
SECTION X-X(LINE BAY)



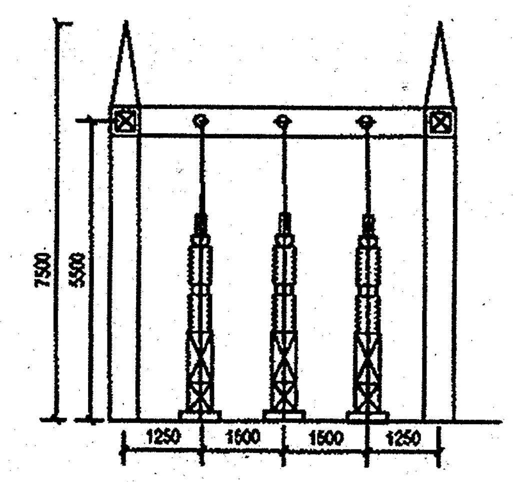
SINGAL LINE DIAGRAM



PLAN



SECTION AT Y-Y(TRANSFORMER BAY)



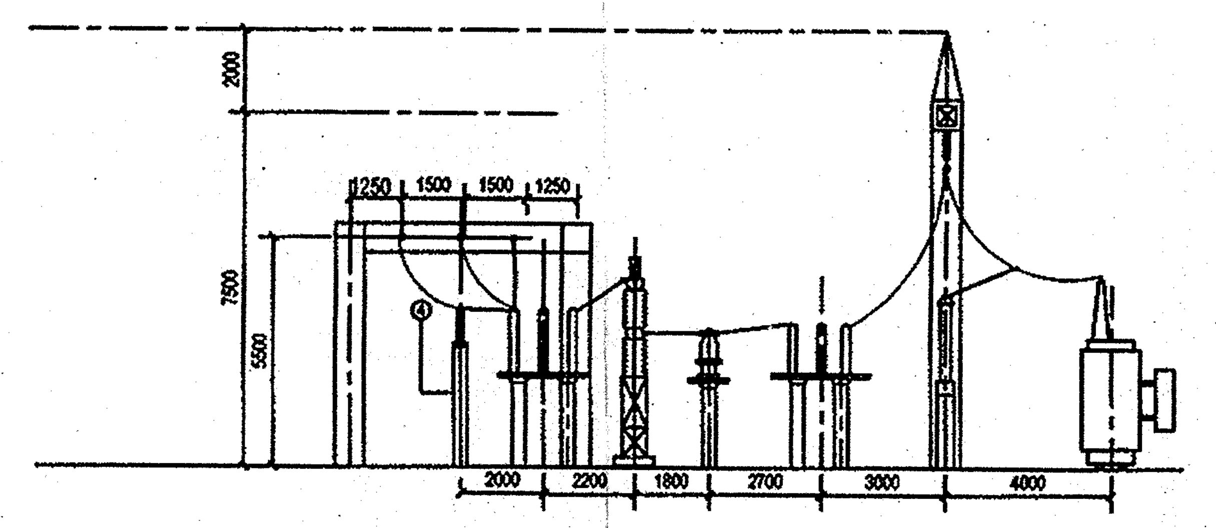
SECTION AT Z-Z

LEGEND

1. CIRCUIT BREAKER
2. ISOLATOR
3. CURRENT TRANSFORMER
4. POST INSULATOR
5. LIGHTNING ARRESTER
6. POTENTIAL TRANSFORMER

NOTE

1. REPLACE THE SECTION Y-Y WITH SECTION Y'-Y' WHEN AN ISOLATOR IS BE PROVIDED BETWEEN THE TRANSFORMER AND CIRCUIT BREAKER IN THE TRANSFORMER CIRCUIT
2. ALL DIMENSIONS ARE IN MM.
3. EQUIPMENT SPACING IN THE DRAWINGS ARE BASED ON OLD PRACTICE OF MOUNTING THE EQUIPMENT (e.g. LA, MOCB, CT etc.) DIRECTLY ON FOUNDATION WITH SCREEN AROUND IT. IN DRAWING EQUIPMENTS ARE MOUNTED ON STRUCTURE AND SCREEN IS REMOVED AS PER PRESENT PRACTICE. THEREFORE, INTER EQUIPMENT SPACING CAN FURTHER BE OPTIMISED BY USER.



SECTION AT Y'-Y'(TRANSFORMER BAY)

FIGURE-34

MANUAL ON SUBSTATIONS (LAYOUT & DESIGN)	
SINGLE BUS ARRANGMENT (LOW LEVEL TYPE) 36 KV BIL 170KVp	
SHEET 1 OF 1	SCALE: NTS