1 Overview of Site Management and Site Activities

In the modern power system (Electrical Power Network); Electrical Power (MW) flows from the *Supply Side* to the *Demand Side* (Load Side). Power is generated in generating stations, transmitted and distributed through a vast network and finally converted to useful forms in the various types of loads connected to the secondary side of the distribution systems. Power flow is controlled, monitored and supervised from grid control centers and control rooms of generating stations and various substations. Both the supply and demand sides depend on each other and must be managed well for reliable high-quality power supply at all times.

Supply Side

— Generation/Transmission/Distribution/Service Connections

— Control Centers and Control Rooms, SCADA, Communication Channels, WAN, LAN

Demand Side

— Connected Loads in Consumers Premises : *Sectors* : Residential, Commercial, Transport, Industrial, Agricultural, Scientific, Rural, Defense, Medical etc.

Energy management system covers various generating plants, transmission and distribution systems, utilization systems. Control is by means of the SCADA, communication channels and WAN, LAN. SCADA (Supervisory Control And Data Acquisition Systems) operates from National, regional, state and distribution *Control Centers* and various *Control Rooms* of generating stations, transmission and distribution substations and factory substations and communication network.

Each electrical plant, each equipment and machine , each subsystem must excel in *Total Quality* [design to final use]. Total quality includes field quality [Site Quality] during construction, operation and maintenance.

Managements at various hierarchical levels are responsible for total quality of energy management system, plants and equipment. Individuals need total awareness about wide area network and local area network. Individual needs perfection in the allocated small or big activity. *Perfection* in each small activity in the field (site) during erection, testing, commissioning; operation maintenance leads to satisfaction of consumers of electricity.

Q. 1. What is management? What are the facets of Site Management? Distinguish between construction phase, operation and maintenance phase of electrical plant/equipment/ subsystem.

Management is the science, art and skill of setting short term, mid term and long term objectives of the company (Organisation) and covers all the activities aimed at reaching those objectives. Management is a dynamic real-time process involving, planning, organizing, directing, monitoring, improving, and getting things done to achieve the objectives, set new objectives.

Site Management is the management of site personnel, plant, equipment and subsystems, materials, energy sources and environment. Site management includes broadly. Project Construction Management and Plant O & M Management [Fig. Q1].

The important aspects of site management of electrical plant and equipment are :

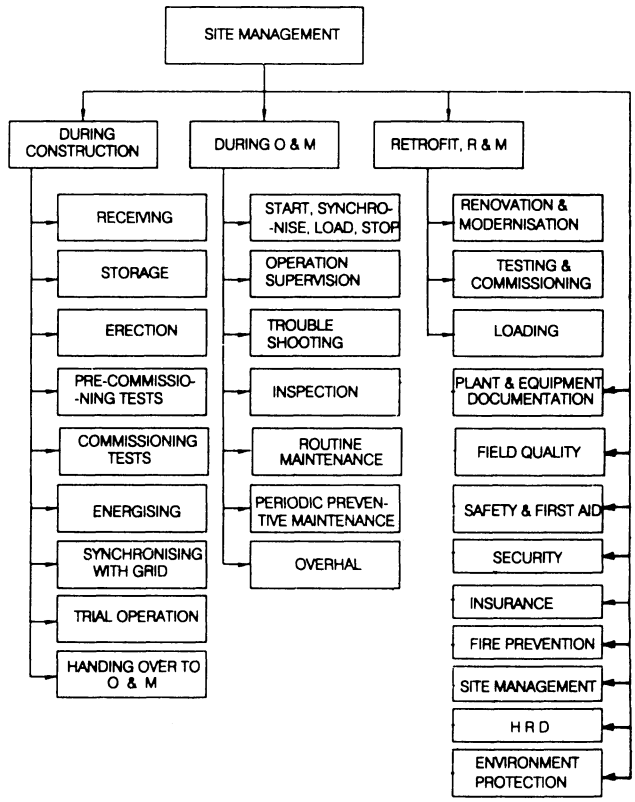


Fig. Q. 1A. Site Management stages and functions.

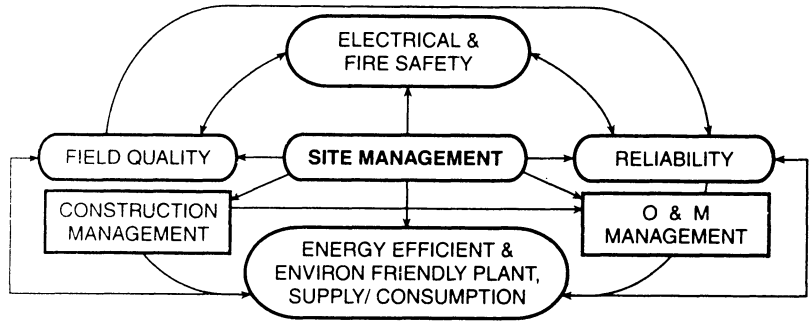
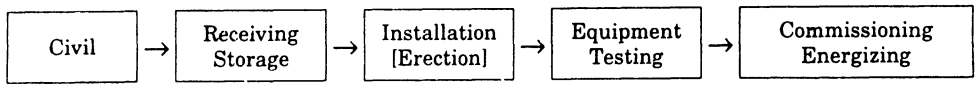
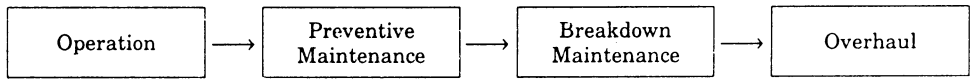


Fig. Q. 1B. Interfaces of Site Management.

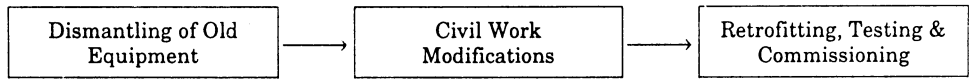
Site Activities, Phases of Site Work include : (1) Construction stage (project management). (2) Operation maintenance (O & M). (3) Renovation & Modernization. Each stage demands a different focus on Interfaces between sub activities. Site Activities during [1] *Construction Stage* :



Site Activities during (2) Operation and Maintenance



Site Activities during (3) Renovation & Modernization



The quality of site work at each stage has influence on the performance of the next stage, reliability and availability of the plant and equipment and power quality. Site work must be done by trained personnel. Site management is responsible for the performance and safety of the plant and personnel.

Civil Works

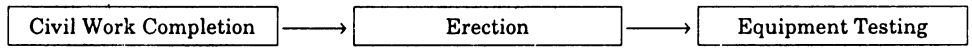
Civil Works precede the erection work and usually take longer time and higher cost. The civil work include: construction of stores, roads, foundation, cable trenches in switchyard, plant buildings, office buildings, fences. Galvanized steel structures may also be covered under a civil package.

Erection, Testing and Commissioning

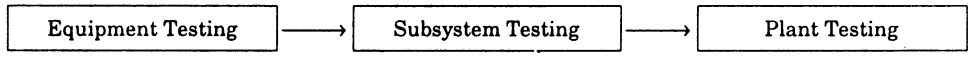
Erection (Installation) refers to assembly on foundation at site, making electrical terminal connections of main circuits and auxiliary circuits, and to make the equipment, plant and auxiliaries *ready for testing and commissioning.* Erection work is commenced after completion of the civil works and receipt of equipment. Some erection work (such as earth mat) is carried out along with civil works. After the satisfactory completion of Installation, the plant/equipment is handed over for *testing and commissioning.*

> *Work Permit System must be implemented before commencement of erection work for safety of construction workers, erection testing and commissioning persons.*

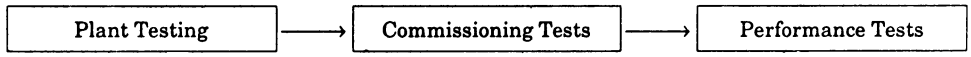
Erection Personnel are *trained* in advance at *other sites* and in *manufacturer's works.* and at *site* through special courses and comprehensive program.

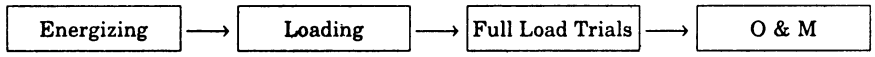


Testing refers to various operational, mechanical, electrical and performance tests of each equipment, *Subsystem Tests* of (each subsystem comprising a group of equipment). These are carried out after satisfactory completion of *Equipment Testing.*

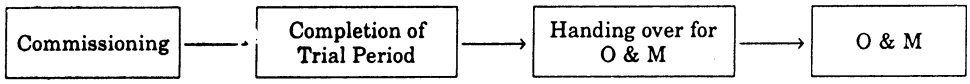


Commissioning tests and performance tests of equipment and plant are carried out after satisfactory completion of equipment tests and *subsystem tests.* Commissioning personnel are trained in manufacturer's works during factory tests.





Trial Period commences after completion of commissioning and energizing the plant. After successful completion of trial period the plant and equipment are handed over to regular operation and maintenance. *O* and *M* staff is associated with erection testing and commissioning for on the job training.



Operation and Maintenance (O and M)

O and M staff is trained during manufacturing, shop testing, erection, testing and commissioning and at other sites for on the job training.

After successful completion of commissioning, trial and training, the plant is handed over to the trained operation maintenance manager for commercial operation. During the operation of the plant, appropriate supervision is necessary to ensure safe and efficient performance of the plant. *Routine inspection and servicing* is very important.

Routine O and M Activities include, giving fuel inputs, giving consumable inputs, make the plant and equipment ready, security checks, sequential starting, switching on, observing, monitoring, charge over from manual to auto mode, synchronization, loading, logging, monitoring, supervising, switching off, shutting off etc. Operators supervise and monitor the plant performance from central control room and local control panels near the equipment/auxiliaries.

Routine Maintenance goes hand-in-hand with the operation. Some routine maintenance activities during every shift include visual observation, observing readings of variables (current voltage, p.f. frequency, temperatures, other variables) and logging events in main plant and auxiliaries.

Preventive Maintenance is regular periodic planned maintenance which eliminates breakdowns and outages.

The Breakdown Maintenance is carried out whenever breakdown (failure) occurs.

In case of serious problem *emergency shut down* is taken for carrying out repair and recommissioning the plant.

Maintenance includes a wide range of activities aimed at keeping the plant in healthy working condition for efficient and trouble free performance.

Type and Scope of Maintenance

Preventive Maintenance	*Corrective Maintenance*
— Housekeeping — periodic checks	— Locating problem
— Inspection-servicing examination	— Trouble shooting
— Maintenance-testing (Q. 19)	— Repairing
— Cleaning, Oiling	— Replace damaged items
— Repairing	— Recommissioning
— Overhauling	

Scope of Maintenance Management

Planning — Spare and consumables management — *Safety Management* — Testing Instruments — Vehicles and Cranes management — HRD documentation and record management — as built drawings — Fault Investigations and Elimination of repeated problems.

Safety Management. As per new concept safety is managements prime responsibility. Accidents, fires, electric shocks are not very uncommon. They must be prevented totally by effective safety management at each stage of site work.

Q. 2. Draw a single line schematic of a simple power system. Explain the configuration of various types of electric plants.

Ref. Fig. Q. 2. The essential plants are :

Supply Side	*Demand Side*
— Generating stations	— Factory substations and load
— Transmission system	— Substations of community centers and loads
— Distribution systems	— Traction substations and loads
— Rural distribution	— Residential consumers and loads
— Service connections	— Substations and loads of high rise bldgs.

Power flows from the *generating stations* to various *loads* via the transmission and distribution network, continuously. The MW demand by the demand side is fulfilled by the MW generated, transmitted and distributed by the supply side. It is a very large and complex power game in real time.

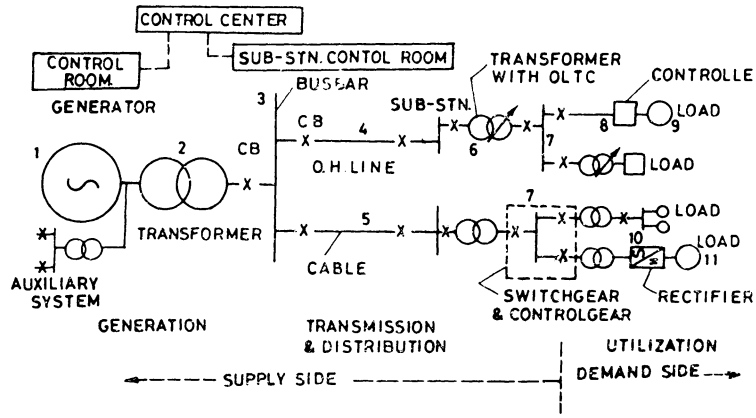


Fig. Q. 2A. Schematic of a Simple Electric Power System.

Major Parts in an Electrical Power System. State their Types and Functions.

Name Ref.	*Function Type*	*Location +*					
		GS	*SY*	*TSS*	*RSS*	*DSS*	*LS*
Generator Ch	To convert mech. energy into electrical energy. 3 ph. AC synchronous generator	*					
Power transformer Ch.	To step-up AC voltage or to step-down AC voltage at same frequency. 3 ph. AC. 50 hz, oil cooled	*	*	*	*	*	*
Distribution lines	To collect power from RS and deliver to DS and loads 3 ph. AC. 50 Hz Single or Double Circuit. Overhead 33 kV/22 kV/11 kV/440 V, ph. to ph. 220 V single phase, ph to n 3 ph. 3 wire or 3 ph. 4 wire.				⟷		
Load side	To collect power from supply side use it for various utilization processes.						*
Switchgear	— Switching power circuits during routine operation and — Switching power circuits automatically during abnormal conditions such as s.c. — Protection, measuring, interlocking, monitoring	*	*	*	*	*	*
Control Room	— Controlling, monitoring, data acquisition, supervision, communication, protection, automation.	*	*	*	*	*	*

+ Locations : GS = Generating Stn, SY = Switchyard in GS ;
TSS = Transmission substation, RSS = Receiving substation,
DS = Distribution substation ; LS = Load side.

— The GS, TS, RSS, DSS are located away from each other and are connected through conductors of main power circuit. Voltages are selected for required power transfer and length of line. Higher power or longer length : Higher voltage.

— Control centers and control rooms have SCADA and communication channels.

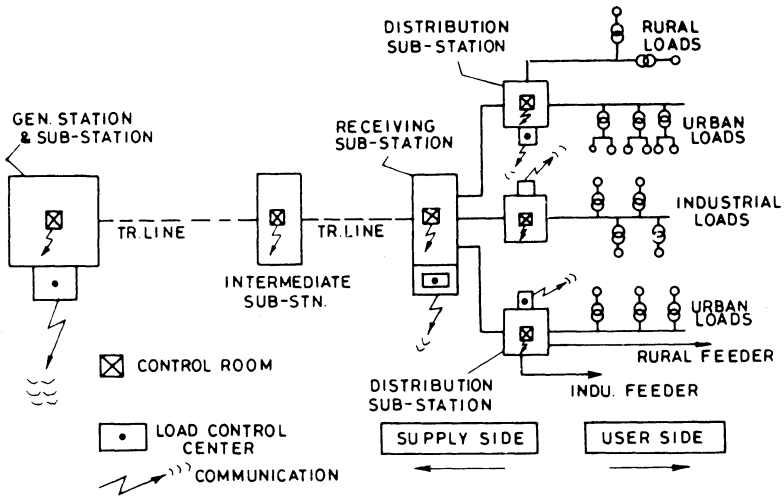


Fig. Q. 2B. Power flows from generating stations to loads. Load Control Centers and Control Rooms are linked by communication channels.

Power System Configuration and Operation

3 phase, 50 Hz AC power system has several power plants operating in parallel at a common synchronous frequency (50 Hz). Each AC electric plant has two or three *nominal voltage levels.* All the equipment connected to a particular voltage level have the same rated voltage. The *standard reference values of nominal ph. to ph-rms voltage levels are* : 400 kV, 220 kV, 132 kV, 66 kV, 33 kV, 22 kV, 11 kV, 6.6 kV, 3.3 kV, 440 V and *single phase* ph. to neutral 220 V. The rated voltage for an equipment is selected from standard reference list. *Higher voltage is necessary for high power rating or for longer length of transmission / distribution circuit.* Consecutive 3 phase AC voltage levels are obtained by means of 3 phase 2 winding (primary and secondary) Power transformers. Power system is formed by several electric plants operating in series/parallel at a common frequency and respective voltage level.

— *Electrical plants* include : Generating stations, substations, transmission links, distribution links, switching substations, utilization loads and controllers. Plant has main circuit and auxiliary circuits.

— *Several identical AC equipment* operate in parallel and in synchronism at each voltage level in the electrical plant.

— *Simultaneous and continuous remote control* of power (MW) flow, voltage (kV), current (kA), power factor (cos ϕ), etc. is carried out from load control center, and generating station control rooms, substation control rooms and utilization plant control rooms.

The *main electrical plants* and main subsystems are designed by a *building block principle.* Identical building blocks are connected in parallel to busbars at each voltage level. For example in a generating station two or more identical generator transformer units are connected to a common busbar system via switchgear. A substation has several identical bays connected in parallel to the busbar system via switchgear.

Main electric plant is responsible for energy transfer or/and energy conversion.

Auxiliary electric plants supports the main electric plant. Auxiliary electric plant is of lower power rating and is not in the main energy flow circuit.

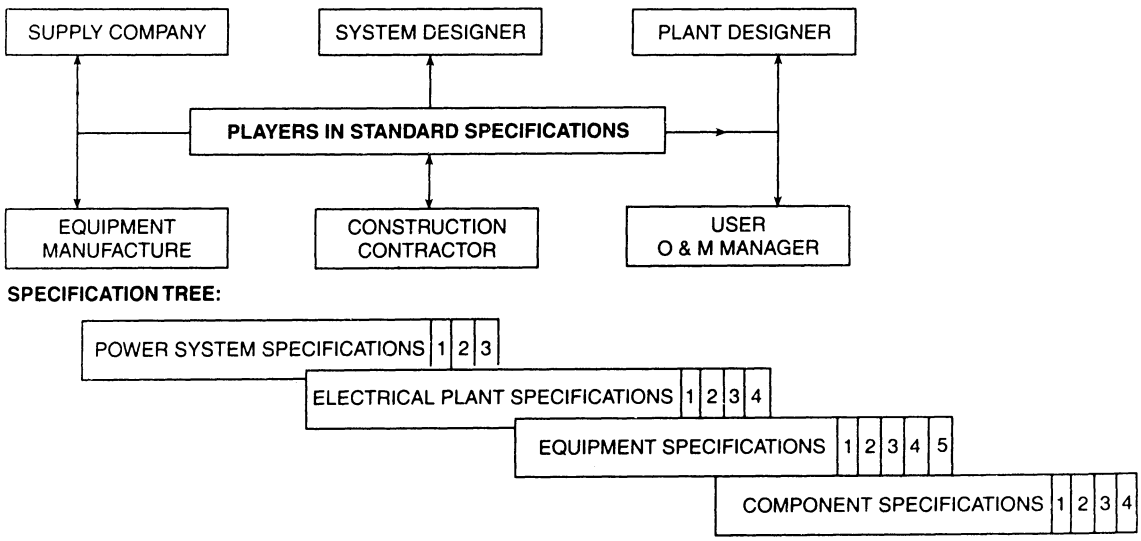
SPECIFICATIONS

Q. 3A. Explain the term "specifications". Distinguish between power system specifications, plant specification and equipment product specifications. Define related terms.

To *Specify* means to state the requirements in precise details.

Requirement Specifications. It is a document that specifies the requirement of a system, plant or equipment or components. *Typical coverage* includes (1) Ratings and functional requirements (2) Design requirements (3) Factory testing requirements (4) Transport requirements (5) Site requirements during construction of plant (6) Interface requirements (7) Commissioning and performance requirements (8) Operation and maintenance requirements. Requirements are stipulated in terms of standard specifications. Specifications cover the essential requirements including ratings, test requirements and test conditions, performance characteristics, recommendations for erection, testing commissioning, operation, and maintenance, safety, quality, terms and definitions.

Specification. It is a document that specifies the technical requirement for a system or a plant and an equipment. Typical coverage includes : functional requirements, performance requirements, interface requirements, design requirements, terms and definitions.



System Specifications

These include several requirements such as :

— *Voltage levels — Insulation level — Insulation Coordination
— High Voltage Test Requirements
— Control Specifications — System Neutral Earthing
— Frequency limits — Control Specifications
— Short circuit levels — Short circuit protection coordination
— Network related specifications.
— System configuration, Single line diagrams
— Types and ratings of Interconnections, Auxiliary and stand by supply.

Electrical plant specifications

These include several requirements such as :

— Plant configuration (how the equipment are connected ?), Single Line Diagrams : Main Power Circuit, Auxiliary Supply Circuits.
— Voltage levels for main power circuit, Auxiliary systems
— Insulation levels — Insulation coordination
— High voltage test requirements — Control specifications.
— System neutral earthing at each voltage level
— Short circuit levels — Short circuit protection coordination

Equipment Specifications

These include :

— Ratings
— Test requirements
— Electrical clearance requirements
— Performance requirements, limits of loading, efficiency
— Transport, erection, testing commissioning requirements
— Operation requirements, loading, safety, control.
— Maintenance requirements, spares, tools, safety, enivronment and reliability.

Q. 3B. Explain the role of standards organizations and the standard specifications. What are quality standards ? What is ISO 9000 ?

STANDARDS

Standards and Standard Organizations

Standards organizations [eg. Bureau of Indian Standards (BIS), International Standards Organizations (ISO), International Electrotechnic commission (IEC), American National Standards Institution (ANSI), publish standard specifications. These are useful to users, manufacturers, utilities (supply companies) for design to final use of electrical systems, plant and equipment. The various standards institution in the world publish the standards specifications of high voltage generators, transformers, busbars, circuit breakers, isolators and other substations equipment etc. These standards provide the guideline to the manufacturers and users regarding the following :

— Term and definition (vocabulary) — Ratings — Condition of service
— Test to be performed, standard test procedures, methods of evaluation of the test results.
— Guidelines for selection, erection and maintenance.

The standards are generally drafted for a wider application and they generally do not cover specific cases. IEC (International Elector Technical Commission) recommendations are generally accepted all over world and the IS (Indian Standards) specifications published by Bureau of Indian Standards (BIS) are generally based in IEC recommendations.

ISO Quality Standards and Certification

The ISO 9000 certificate is given to manufacturers and organizations as a recognition of the quality. ISO certification is essential for equipment manufacturers for effective marketing and ultimate customers satisfaction. The following standard organization are associated with the standard on quality.

— International standard organization are associated with the Geneva, Switzerland
— Bureau of Indian Standards, New Delhi (BIS)
— Bureau Veritas Quality International (BVQI)

ISO and IS Standard on Quality

ISO	*IS*	*Title*
ISO:9000	IS:14000	Quality management and quality assurance standard selection and use : 20 system elements
ISO:9001	IS:14001	Level 1 : Design/Development production testing in factory, installation and servicing
ISO:9002	IS:14002	Level 2 : Production and installation all element, some less stringent.
ISO:9003	IS:14003	Level 3 : Final inspection and tests half the elements, low stringency.
ISO:9004	IS:14004	Guidelines : Maximizing benefits and minimizing costs.

Q. 4A. Explain the significance of field quality.

Plant and equipment should operate reliably; efficiently; safely; and with modest maintenance. Field quality of site work during construction, operation and maintenance has significant influence on the reliability of the plant and equipment.

Field quality checks during erection reveal the defects and deficiencies which should be removed before testing. Testing and commissioning reveal the defects and deficiencies in erected plant. Regular periodic preventive maintenance and maintenance testing reveal defects/deterioration occurring during operation and aging. *Field quality checks include:*

- Checking of current carrying circuit
- Operational checks
- Performance checks
- Checks during routine operation
- Checking of insulation systems
- Checking of auxiliaries
- Checks during periodic maintenance

Q. 4B. Explain the international and national quality standards and their significance.

The internationally accepted quality standards are useful and essential for import and exports, global marketing. The standards organizations for quality standards include :

- International Standards Organisations (ISO, Head Quarters : Geneva, Switzerland.
- Indian Bureau of Standards (Former Indian Standards Institution), New Delhi.
- Bureau Veritas Quality International (BVQI).

The list of ISO and IS standards on quality is given below. These standards are followed by manufacturers, consultants and customers (users) of electrical plants and equipment.

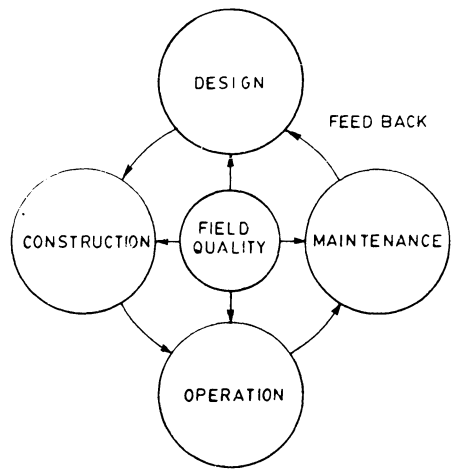


Fig. Q. 4A. Interfaces of field quality. Quality/Field Quality checks are necessary at each stage.

ISO	*IS*	*Title*
ISO:9000	IS:14000	Quality management and quality assurance standard. Selection and use : 20 systems elements
ISO:9001	IS:14001	Level 1 : Design/Development production, testing in factory installation and servicing
ISO:9002	IS:14002	Level 2 : Production and installation all elements, some less stringent.
ISO:9003	IS:14003	Level 3 : Final inspection and tests — half the elements, low stringent.
ISO:9004	IS:14004	Guidelines : Maximising benefits and minimising costs.

ISO 9000 Certification

ISO 9000 Certification is given to a manufacturer or an organisation as a recognisation of the quality. The duration of the certificate is 3 years. The certification is renewed after specified period (3 years) and re-audit. The European Economic Community and other buyers in the world have insisted on ISO certification. Products to be exported from India should have high quality. The manufacturer and the products must have an ISO 9000 Certification to be acceptable in the export market. For increasing exports, ISO Certification is essential. Other benefits are improved performance, reduced wastage of manpower/materials/paper work and time due to systematized Quality Approach. This helps in withstanding Global and local competition.

Under the recent economic reforms, India has ambitious plans for increasing export. The ISO 9000 certification is a target of various manufacturers aiming at increasing their exports and business.

BVQI Certificate of Quality

BVQI stands for "Bureau Ventas Quality International". It is an International Organisation dealing with Quality Assessment and Certification.

BVQI assesses the Quality of Design, Manufacture, Supply and Services etc and gives a Certificate of Quality to the Manufacturer.

BVQI certificate has reference to the following standards on Quality :

— EN 29001-1987 — ISO 9001-1987 — BS 5750-Part I, 1987.

Example of a BVQI Certificate is given below :

BVQI
Certificate of Approval

Bureau Veritas Quality International Certify that the Quality Management System of the Supplier :

M/s.....

has been assessed and found to be in accordance with the requirements of the Quality Standards for Design, Manufacture and Supply of Equipments and Plants as detailed below :

Scope of Supply : (as an example)

Power Station Equipments
Substation Equipments, Industrial Electrical Equipment
Switchgear and Controlgear
Transformers, Motors, Generators, Electronic Controllers.

Quality Standards

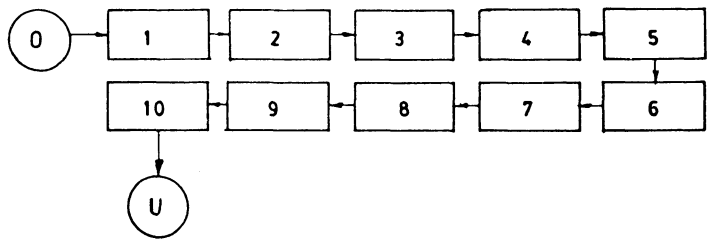
EN 29001-1987
ISO 9001-1987
BS 5750-Part 1, 1987

This certificate is valid for a period of three years from 1-7-1994 to 30-6-1997.

SEAL
and
SIGNATURE OF AUTHORITY

Total Quality Management (TQM)

TQM is a total professional quality system covering product, plant.



(0) Order (1) Specifications (2) Design (3) Production, Testing (4) Despatch, Transport (5) Receiving, Unloading, Storage (6) Civil Works (7) Installation (8) Testing Commission (9) Operation (10) Maintenance, Troubleshooting, (U) Performance
Fig. Q. 4B. Stages of TQM.
Note : 5 to U are covered by Field Quality Management.

After Sales Services and Field Quality Assurance

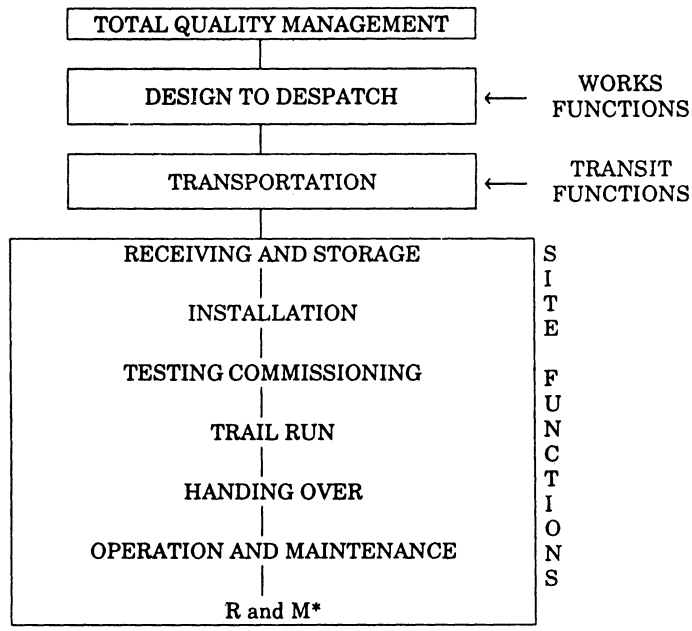
The *After Sales Services and Field Quality Assurance* are back bones of Total Quality Management. The objective of engineering organization is customer satisfaction regarding product and services. After sales services contribute immensely to reach the target of minimum customer complaints and satisfied customer. The industry usually has sufficient online expertise to deliver the goods based on past experience, infrastructure and management resources. The After-sales-service group of the organisation provides active support to industry for total field quality assurance and customer satisfaction.

In the well known TQM concept, more than 50% real time activities are in the domain after the dispatch of product from the manufacturer's works". These are covered by the field quality assurance (Site Quality Assurance).

Field quality assurance deals with quality during

- — Transportation
- — Receiving at site, storage
- — Installation, testing commissioning
- — Operation and Maintenance,
- — Safety, pollution control, energy conservation, recycling.
- — Trouble Shooting
- — Failure investigations
- — Training

Objective of After Sales Services Group
Customer Satisfaction Reliable, Efficient and Prompt Service at Reasonable Cost



*Renovation and Modernisation

Erection testing commissioning operation, maintenance and trouble shooting are totally *site functions.*

After sales service group of manufacturer interacts with site manager, site contractor and designers for effective field quality management. The step involved in site work are :

Steps in After Sales Services

— Liaison with site management
— Training to erection commissioning staff
— Interface inputs
— Field quality documentation
— Plant documentation
— Equipment documentation
— Participation in commissioning
— Speedy trouble shooting support
— Spares and tools supply in time
— Training to O and M staff
— Feedback from sites and improvements in product
— Field investigations of failures and corrective actions
— Renovation and modernisation

Q. 5. State the significance of safety precautions and explain management's responsibility.

Electricity can cause shocks and fires. Unsafe conditions may exist in electrical plants and equipments during construction and during O and M. Unsafe conditions may lead to accidents, fires, loss of life, loss of property and prolonged outage.

It is the prime responsibility of the site management to eliminate unsafe conditions, create safety organization, implement safety rules, train personnel, establish field safety procedures, arrange first aid and hospital facilities ; and prevent accidents.

Field quality and safety organization is established at site and responsibilities are assigned to manage (FQ and S).

Work permit system must be established and followed strictly. Work permit is issued for carrying out work in the plant. Before issuing work permit, the plant is switched off, isolated and earthed so that maintenance persons are not subjected to electric shock.

Safety rules must be followed during civil works, erection, testing commissioning, operation and maintenance. Each activity must be done with understanding, skill and perfection.

Site persons must be trained to do the work safely. All non current carrying parts must be earthed the earth resistance of the *earthing system* must be low.

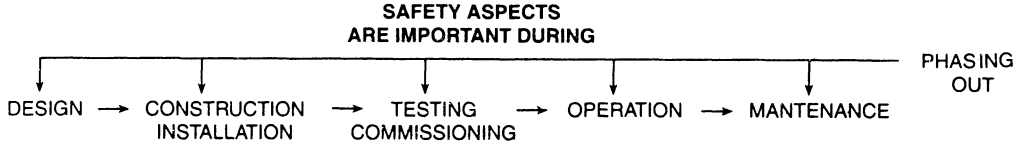
Connections of current carrying conductors must not be loose. Insulation should be dry and healthy.

Fire prevention and fire fighting systems must be provided in every electrical plant and in hazardous zone.

Plant must have earthed fence, security, good house-keeping and adequate safety provisions for improving safety.

Field Quality Audits (FOA) and Field Safety Audits (SA) are carried out during erection, testing, commissioning, operation and maintenance. Defects and deficiencies observed during the FQA and SA are removed. Details about safety are covered in Ch. 6.

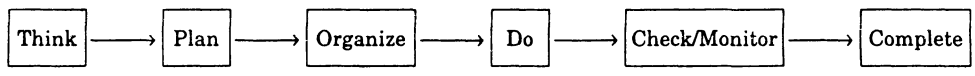
Safety principles and management must be applied from conceptual design to final phasing out of electrical plant and equipment. Acts and Rules must be followed.



Safety chain has above 5 links. Any weak link may lead to unsafe condition and subsequent accident.

Q. 6. Explain significance of planning and organizing of site work. Explain L1, L2, L3, L4 bar charts and PERT.

The steps in effective site work are



Planning is to decide the time frame for sequential activities in advance keeping in view real life situation. Planning helps in reaching the set target. The total task is divided into major parts and subpart. Required time and resources required are identified and presented in form of Bar Charts and/or PERT (Project Evaluation and Review Technique).

L1 to L5 Bar Charts

— *L1 Bar Chart* presents time frame for various major activities.

— *L2 Bar Charts* presents time frame for sub activities in each L1 step.

— *L3 Bar Charts* presents time frame for sub activities in each L2 step.

— Likewise *L4 and L5.*

L1-L5 Bar Charts are very useful and simple but do not show the interfacing (Interdependence) between activities and therefore fail to identify critical path (that takes longest time). This difficulty is overcome by means PERT.

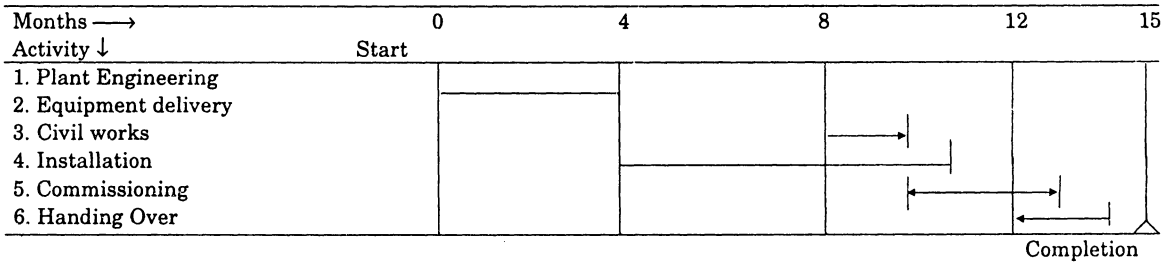


Fig. Q. 6A. Example of L1 Chart for electrical plant construction project
Name : XXX Combined Cycle Power Plant, Dahej, Gujrat.

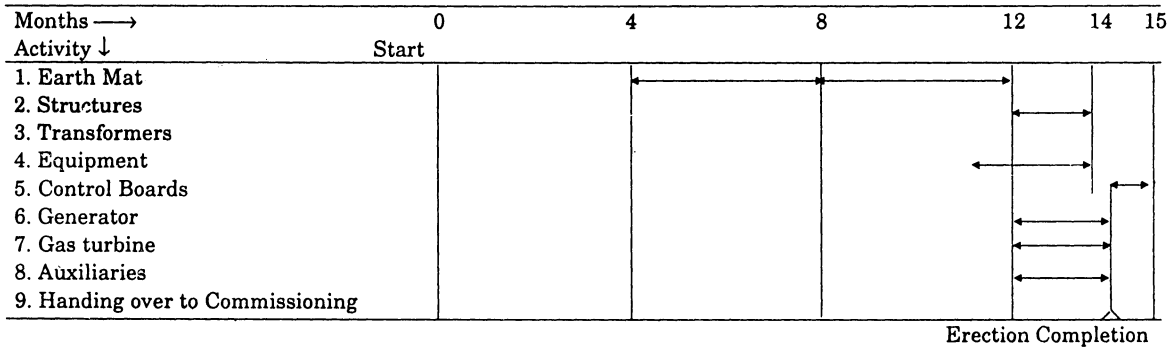


Fig. Q. 6B. Example of L2 chart for Erection
Name : XXX Combined Cycle Power Plant, Dehej, Gujrat.

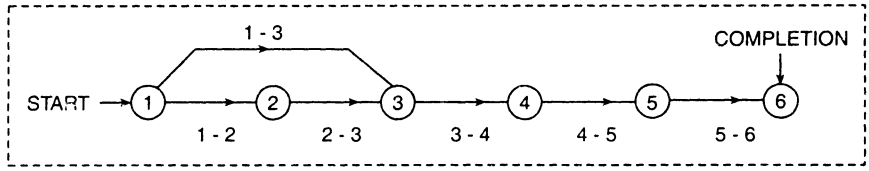


Fig. Q.6C. Example of simple PERT.

① Start
1–2 Plant Engineering
1–3 Civil works
4–5 Commissioning
1–2; 2–3; 3–4; 1–3; 4–5; 5–6 ACTIVITIES
2–3 Equipment delivery
3–4 Installation
⑥ Handing over, Completion
①, ②, ③, ④, ⑤, ⑥ STEPS
Use logic to link STEPS, ACTIVITIES & TIME

Project Evaluation and Review Technique (PERT)

PERT (Project Evaluation and Review Technique) is a tool for monitoring various activities and benchmarks of the project simultaneously by evaluating interface between distinct activities. The critical path (taking longest Time) is identified and bottlenecks are removed by focussing efforts on the critical path activities. Work is carried out simultaneously as per the guidelines of the PERT. Standard software packages of PERT are available in market. PERT is usually simulated on computer to identify critical path and for monitoring.

Q. 7. Describe the two distinct phases of site management.

The two distinct phases of the site work are (1) Plant construction (2) Plant operation and maintenance.

During the *Project Construction Phase,* Civil/Erection/Testing commissioning activities are carried out simultaneously/in phased manner. Time schedule is presented in L1 to L5 bar charts.

Objective of Construction Management is to complete the project within planned schedule, estimated financial outlay and with excellent field quality and safety and to train O and M staff. The completed project is handed over by the construction manager to the O and M manager.

During O and M phase, the civil, erection, testing commissioning activities are not permitted.

O and M phase has two distinct activities

Plant Operation. The focus is on smooth, trouble free, safe and efficient operation of plant, equipment and subsystems to deliver optimum output. *Shutdowns are not permitted.* Shift timings and overlap of operators during changeover is well scheduled. Log book records are well kept. Safety precautions and instructions for safe and efficient operation are documented.

Objectives of Operation Management is to operate the plant safely, efficiently, economically, with optimum productivity and minimum outage. The preventive maintenance is essential to achieve the objective. Hence O and M groups are under a common manager.

Plant Maintenance

1. **Preventive Maintenance.** The preventive maintenance is carried out in planned manner as per Daily, Weekly, Monthly, Quarterly, Annual Maintenance Plans. Live line maintenance is dangerous and is usually not called for/permitted. *Planned shutdowns are taken for preventive maintenance.* Work permits are issued for the same by the plant manager.

After completion of planned maintenance within stipulated time, the work permit is cancelled and the plant is taken over for operation.

2. **Emergency Repair or Breakdown Maintenance.** Emergency repair or breakdown maintenance is not preplanned and is carried out whenever breakdown takes place. However spares, tools and skilled/trained man power is always kept ready to carry out emergency repairs and put back the plant in operation within shortest time. Spares, tools and trained manpower are the essential means for maintenance.

Investigations of failure and taking preventive and corrective actions to avoid similar failures in future is the key to improvement. Guidelines and documents are prepared by maintenance management.

Q. 8. List the acceptable qualifications of site personnel at electrical plant site for doing ETCOM work.

ETCOM = (Erection/Testing/Commissioning/Operation and Maintenance)

The required qualifications of ETCOM site personnel for ETCOM electrical work depend on job description.

Fitness, skills and experience required for doing a particular job are generally specified while selecting a person. However further training is essential. Site personnel must have appropriate

educational qualification, post education training, factory training, site training and on-job training in the following : The truining includes (1) General (2) specific in given working area.

— Applied electricity and technical aspects regarding plant, machines, equipment, physics, electromagnetism.
— General electrical installation and maintenance techniques.
— Electrical safety rules, methods and practices. First Aid.
— Assembly and dismantling, design and operation of the equipment and system to be maintained.
— Plant layout and maintenance zones.
— Documentation and procedures.
— The maintenance and testing procedures of plant, equipment and system to be maintained and tested.

Critical tasks must be assigned only to trained, experienced personnel who have done similar work in the past on the same or closely comparable equipment, persons trained and worked under direct supervision of experienced instructors are preferred.

Training to ETCOM Electrical Personnel. All the ETCOM personnel are trained to ensure they are competent to carry out assigned work and have understanding knowledge and confidence. Training in electrical safety, fire safety and first aid trainings and mock-up rehearsals are is given to every person in the plant site, substation, power plant, transmission line crew etc. The activities in the training include.

— Study of documentation and procedures — Technical study
— Attending lectures and workshops — Practical demonstration
— Training in manufacturer's work and laboratory
— Training at other similar plants in operation
— On the job training under guidance of experiences staff
— Departmental examinations. Associate young O and M personnel in various ECT activities during the execution of the project. Qualifying Tests are helpful.

Record of training. Training manager and supervisor identifies the training needs of every person in the organization and underlines the long range and short range planning. Training card is made for every person. The training is reviewed on six monthly basis by the plant manager.

Q. 9. Describe the initial site activities in scope of site management.

Project management group and O and M management group plan various preparatory activities to meet L1 demands. These include :

— Acquiring land, right off way for line/land — Schedule for finalizing subcontracts
— Cash inflow and cash outflow schedule — Billing schedule
— Schedule for training
— Schedule of submission of drawing, documents, check lists to site.
— Schedule of equipment delivery to site.
— Schedule for inputs from the other sources (Governments agencies, land owners, main customers etc.)
— Communication facilities, telephones, telex, wireless, fax, internet, radio communication, power line carrier communication.
— Personal computer facility and networking. — Survey of transportation route
— Insurance policies for plant equipment and third party for ETC phase and O and M phase
— Schedule for safety facilities. — Schedule for safety procedures
— Schedule for site organization and manning for ETC phase and O and M phase.
— These schedules are also monitored on monthly basis.

Project execution work also includes administrative work, documentation, planning with regard to time, resources and economy, coordination with customers, consultants and subcontractors, feedback and accounting function such as wages, housing and personnel matters, permission from electrical inspectors, etc.

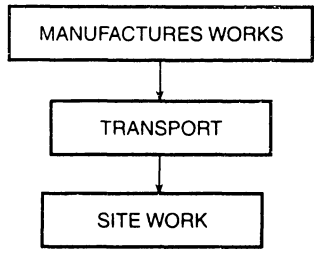
All these require knowledge and experience of project administration and at least general technical knowledge of the equipment to be erection, knowledge of the internal conditions of the country such as certain laws, taxation, rules, organization structures, procedures, red tapes to be overcome, electrical inspectors rules etc.

Project of a complete plant and outdoor substation in thus quite a comprehensive job which is based on an intimate cooperation between the contract, commercial, design, material management, and site management subdivisions of the contractors.

Civil and erection costs constitute a substantial part of the total price and must therefore be carefully studies already at the tender stage.

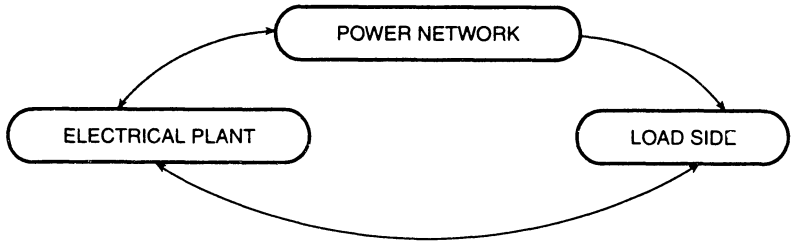
Design, manufacturing and erection aspects are closely related to each other. Equipment design must take into account transportation, erection and maintenance problems into account.

Owing to the individual and complex character of electrical power plants, switchyards, transmission lines and utilization plants an erection job usually requires overlapping between the three part activities manufacturer's works, transport, erection on site.



Transport damages can be beyond control and result in enormous delays, added costs. More than 40% of quality attributes belong to transportation and site work phases. This is an often ignored truth.

Importance of Site Work. Electrical plant forms a part of the total power system. This fact plays a very significant but often neglected role.



All the three are interdependent and react with each other in milliseconds, microseconds through galvanic conductor connections. It is a question of vast amount of on-line energy flow precisely. Site work is very important.

Q. 10. What are the areas of engineering support to site work ?

For effective and systematic ETCOM work, engineering support is essential in following areas :

— Preparing plant documentation
— Preparing equipment documentation
— Documents of maintenance engineering.
— Expert support to site.
— Specifications and documents of system engineering

— Design engineering, drawings, documents
— Spare parts and materials management
— Field quality audits
— Safety audits
— Site testing laboratory
— Failure analysis and corrective measures
— Training to ETCOM personnel
— Field quality plan, field quality check lists
— Safety documents and check lists
— Testing instruments and site testing plan
— Final as built drawings for site.
— Modernization planning.

Q. 11. Explain documentation for CETCOM (Civil, Erection, Testing, Commissioning, Operation, Maintenance)

Documentation is a backbone for project execution and goes a long way over entire life of the project. It is modified and reused for the next similar projects with great time saving, thanks to desk top printing facility and word packages in personal computer.

Broadly documentation includes :

— Civil drawing specification
— Structure drawings
— Test record formats
— Erection drawing
— Field quality plans
— Approval procedures
— Equipment specification, drawing, instruction manuals, test record
— Plant specification, drawing, plant circuit diagram, test record
— Commissioning documentation, instructions, test records

A comprehensive list of document is prepared in advance by project management group and a dedicated group looks after these important activities. Most essential documents for a substation project include :

— List of drawing
— Substation single line diagram
— Erection drawings, plant circuit diagram
— List of material and equipment
— Civil drawings
— Foundation plan and ground network
— Assembly drawings for galvanized steel work
— Service and erections manuals for high voltage apparatus with dimension prints and connection diagram
— Customer's and contractor's drawings
— Shipping specification
— General erection information for each auxiliary and equipment
— Field quality plans for civil, erection and commissioning
— Set of civil standard specification for steel work, cement reinforcement, connecting, finishing etc.
— Set of standards specification for equipment and plant.

The various *drawing revisions* must have correct identification relating to a certain substation within a project.

Modification made during the erection shall be marked in red pencil on the applicable document (As built) and the document shall then be sent back to project engineering division for final updating. The customer will thus receive a final, correct as built drawings.

Tests Report. It is good practice to have standard formats for test record in which test results are filled and signed by test engineers and customers representative. Such test records should be filed in corresponding file and transferred to *Master Documentation Room.* These are important as permanents records.

Q. 11. State the significance of safety precautions and explain management's responsibility.

Electricity can cause shocks and fires. Unsafe conditions may exist in electrical plants and equipments during construction and during O and M. Unsafe conditions may lead to accidents, fires, loss of life, loss of property and prolonged outage.

It is the prime responsibility of the site management to eliminate unsafe conditions, create safety organization, implement safety rules, train personnel, establish field safety procedures, arrange first aid and hospital facilities; and prevent accidents.

Field quality and safety organization is established at site and responsibilities are assigned to Manage (FQ and S).

Work Permit System must be established and followed strictly. Work permit is issued for carrying out work in the plant. Before issuing work permit, the plant is switched off, isolated and earthed so that maintenance persons are not subjected to electric shock.

Safety Rules and Acts must be followed during civil works, erection, testing commissioning, operation and maintenance. Each activity must be done with understanding, skill and perfection.

Site Persons must be trained to do the work safely. All non current carrying parts must be earthed the earth resistance of the *earthing system* must be low.

Connections of current carrying conductors must not be loose. Insulation should be dry and healthy. *Clearances* must be adequate. *Earthing* must be ensured.

Fire prevention and fire fighting systems must be provided in every electrical plant and in hazardous zone.

Plant must have earthed fence, security, good house-keeping and adequate safety provisions for improving safety.

Field Quality Audits (FQA) and field Safety Audits (SA) are carried out during erection, testing, commissioning, operation and maintenance. Defects and deficiencies observed during the FQA and SA are removed. Details about safety are covered in Ch...

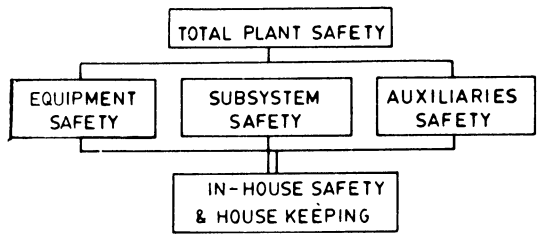


Fig. Q. 11. Safety Interfaces.

Q. 12. Explain the organization chart of project management during construction period of the plant.

Project Organization. An organization is the way in which authority is distributed to carry the work. The organization is represented by simple organisation charts. Organization is not the end in itself it is the means to achieve the objective. The organization structure is built by considering the following :

1. Listing the essential activities.
2. Grouping and assigning activities to the group.
3. Deciding line of authority delegation.
4. Co-ordination of the activities.

The project organization will depend on the size and complex of the plant for a large plant project manager is usually appointed and he report to the manager.

The project manager's responsibilities are listed in the construction policy. The total plant has a line organization. The safety manager co-ordinates the safety activities in association with other line managers.

During construction phase of the project the project manager interacts with civil/erection/ testing and commissioning/store manager and follows up safety requirements at various stages of the project. A typical organization chart may look like Fig. Q. 12.

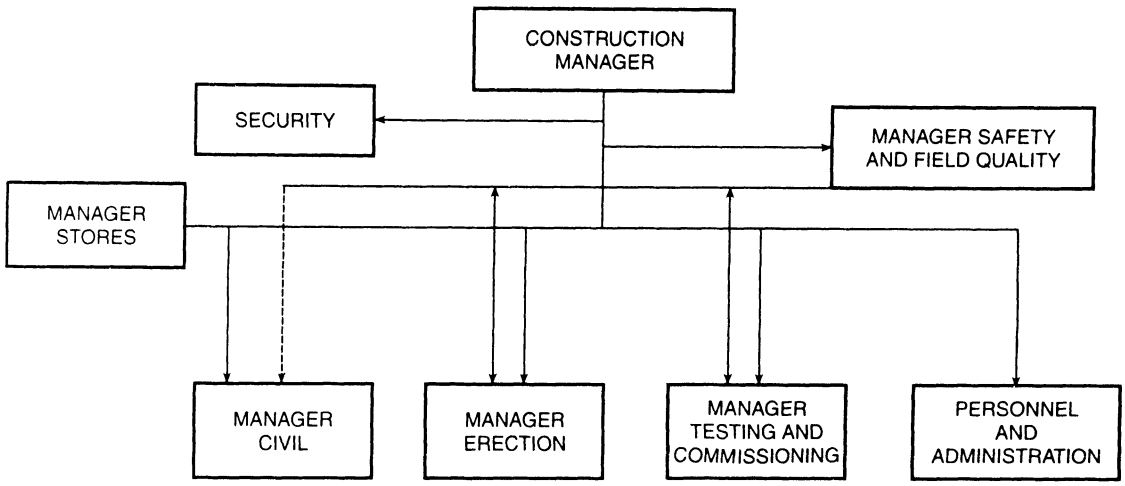


Fig. Q. 12. Organization chart for construction phase of project.

Safety Organization

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The safety manager's responsibilities are listed in the safety policy. The total plant has a line organization. The safety manager co-ordinates the safety activities in association with other line managers.

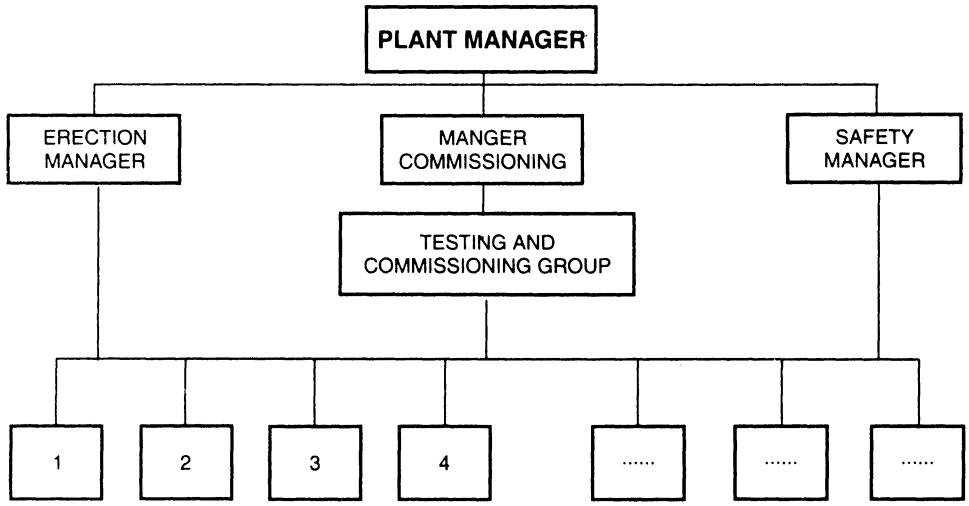
During construction phase of the project the safety manager interacts with civil/erection/testing and commissioning/store managers and follows up safety requirements at various stages of the project. A typical organization chart may lock like Fig. 18.2.

Q. 13. Explain the organization chart during commissioning phase of the plant.

During testing and commissioning phase of the electrical plant each equipment, subsystems, auxiliaries, group of equipment and total plant are checked and tested *to confirm* that erection has been done properly and all the deficiencies are removed, and the equipment is ready to be charged and operated. All the deficiencies are removed and plant is tested and commissioned. The activities are highly technical and require experienced, trained, expert groups and engineering, supply system, and manufacturer's support. Special testing instruments and documentation are used. Ref. Fig. Q. 13.

Q. 14. Explain the organization chart during O and M phase of the plant.

During operation and maintenance phase of the electrical plant O and M manager may report to plant manager and may interact with various line managers as shown in Fig. Q. 14.



For Example :

1. Civil Site and Site Services
2. Fire Safety
3. Generator Group
4. Turbine Group
5. Boiler Group
6. Auxiliary Groups
7. Switchyard Group
8. Protection Group
9. Control and Instrumentation
10. Plant Control Engineer
11. Others, as necessary
12. .....

Fig. Q. 13. Organization chart for commissioning an Electrical plant.

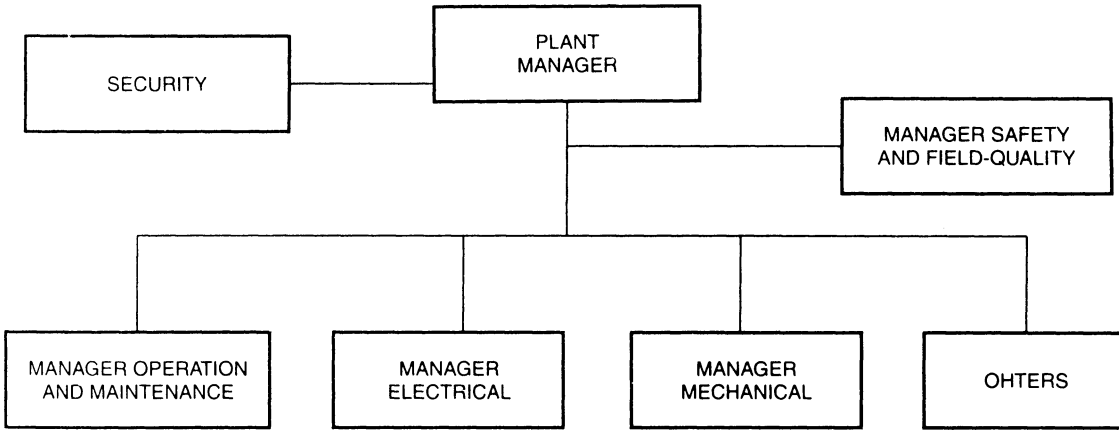


Fig. Q. 14. Organization chart for operation maintenance mode of the plant.

Q. 15. Explain the organization chart of safety and field quality organization at plant site.

The safety department may be combined with field engineering and field quality department. The responsibility of safety manager may be include conducting safety audits, getting safety documents prepared, establishing safety procedures, eliminating unsafe conditions monitoring safety etc. organization of safety department may be as shown in Fig. Q. 15. Supervisor/foreman is the most important person in the line organization. He monitors the functional line activities. He gives guidance and instructions to workers. He checks the safety requirements. The safety department interacts with line managers and line supervisors.

Q. 16. Explain safety and field quality audit at the plant site.

Safety and Field Quality Audit. The safety and field quality audit is the process that identifies unsafe conditions unsafe acts, and quality deficiencies in the plant and recommends safety

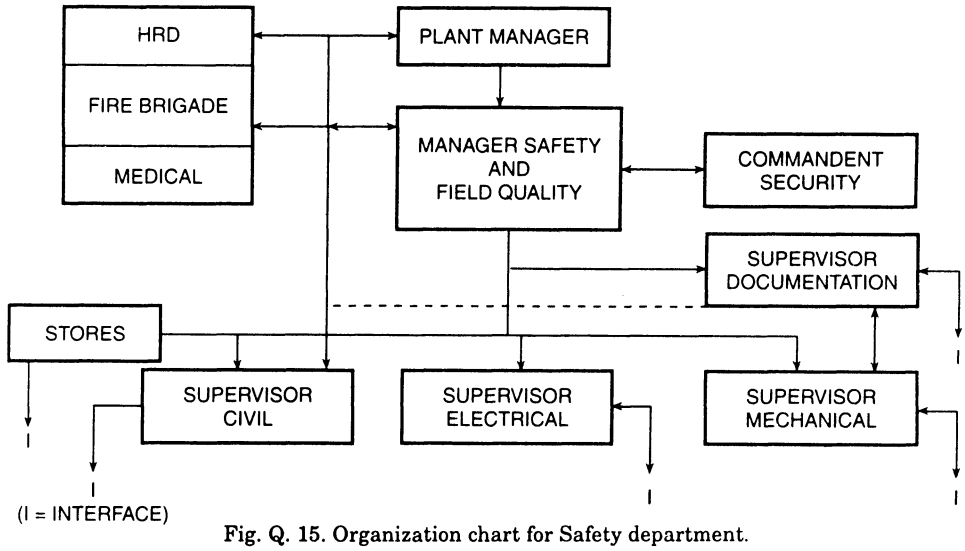


Fig. Q. 15. Organization chart for Safety department.

improvement and quality improvements. Safety and field quality audit gives recommendation to safety and quality manager.

There can be three types of safety and field quality audits

1. Walk through safety and field quality audit.
2. Intermediate safety and field quality audit.
3. Comprehensive safety and field quality audit.

These safety and field quality audits are segregated but they do not have rigid boundaries. They may have some overlap.

Walk through safety and field quality audit. It is least expensive safety and field quality audit it evaluated the unsafe conditions noticeable to key eye during walk through the plant with keen observation from safety view. During the walk through many unsafe conditions may be noticed. These are listed discussed and commitments for there dissolving are taken from line manager/ supervisors.

During construction phase walk through safety and field quality audit may be carried out for stores, civil works, are erection works, documentation, commissioning work. Security requirement are also audited.

During operation and maintenance, safety and field quality audit observe the processes, unsafe acts and unsafe conditions, operaters working enviroments.

Security requirements are also audited.

The safety and field quality auditors discuss their observation with safety and quality manager, line managers and line supervisors. Audit report and recommendations are submitted to the plant manager and safety manager for taking corrective actions to eliminate unsafe conditions and prevent unsafe acts.

The team for walk through safety and field quality includes

1. Safety and field quality manager
2. Safety and quality consultant
3. Insurance inspector
4. Electrical inspector
5. Manager civil/erection/commissioning/operation maintenance.

The entire plant and its stores, documents, procedures are reviewed, interviews are conducted, observation are noted, report is submitted. The report gives recommendations.

Q. 17. State the interface between field quality and safety. Explain the field quality procedure during construction of a plant.

Field Quality and Safety. Main activities during construction of an electrical project include :

— Receiving and storage of construction material and equipment.

— Civil works. (Foundation, super structures, roads, trenches, fencing, structures, control room, building, administrative buildings, auxiliary buildings etc.
— Installation (erection) work : Earthing system, galvanised steel structure, overhead shielding system, equipment, transformers, generators, motors, power cables, control cables, station auxiliaries.
— Testing of equipment, auxiliaries, sub-systems.
— Precommissioning tests on subsystems.
— Final commissioning and energizing. Trial operation.
— Operation and maintenance.

The objectives of field quality and safety during the construction are :

— To ensure excellent quality of work during every stage of the project construction.
— To ensure that the personnel and plant are safe during construction and during regular plant operation and maintenance.
— The plant and its equipment give long, trouble free and safe service with minimum down time/maximum efficiency, lowest cost and with good environment.

Poor quality of site work (field work) results in defects and subsequent mishaps/accidents/ failures/fires.

Quality of the equipment is checked at manufacturer's works during manufacture, testing and dispatch. The role of filed quality begins with receipt of equipment at site.

FIELD QUALITY IS CLOSELY LINKED WITH SAFETY DURING CONSTRUCTION AND REGULAR OPERATION OF PLANT

Field Quality Control Procedures :

1. Plant documents are issued by project management division to site manager in required number of copies. (e.g. 6 No. each). Plant document include drawings specification, field quality checks, safety checks, for the plant.

2. Equipment document are issued by project management to site manager in required number of copies (e.g. 6 No. each) equipment documents include drawings, specs, field quality checks, testing schedule, safety checks for the equipment.

3. One copy of each plant document and each equipment document (called master copy) is kept in master documentation room in the custody of manager (field quality and safety). This copy is stamped as master copy.

4. One copy (working copy) of each plant document and equipment document is given to site manager, concerned manager (e.g. Civil/Erection/Testing).

5. Revised sheets if any, are placed in the document file and corresponding previous sheets are withdrawn and cancelled.

6. Field quality checks (as per specified plant document/equipment document) are carried out by respective working groups (storage/civil/erection/testing/energizing). The field quality check list is filled up, signed and approved in confirmation that quality norms have been followed. Examples of field quality check list are given in.

7. One master copy of field quality check list duly complete/signed/approved is kept in master documentation room for future reference.

One working copy of the field quality check list duly completed/signed/approved is kept with concerned manager (e.g. civil/erection/testing/commissioning) for ready reference.

Example of Field Quality Check-Erection

FQC No.			Activity : Erection	
Zone :			Name/Designation	
			(Manager Erection)	
Equipment :				
Spec. No. :			FQ Document No.	
Sl No.	*Description*	*Doc. No.*	*Date*	*Remarks*
1.	Visual checks of installation			
2.	Tightness of hardware and continuity main circuit *R, Y, B*			
3.	DC resistance, main circuit (*R, Y, B*)			
4.	Insulation resistance main circuit (*R, Y, B*) to ground			
5.	Auxiliary supply voltage			
6.	Earthing			
7.	Site tests			
8.	Any other point			
9.	Performance tests (report attached)			
Signatures :				
and Date				
	Manager (Erection)	Manager (Testing)		Manager (Safety and Quality)

Q. 18. State the responsibility of field quality and safety manager.

Responsibility of Field Quality Manager

The responsibility of field quality and field safety is of the following participants :

— User (owner) of the plant.

— Main contractor for construction till handing over after commissioning.

— Design consultant.

— Supplier of equipment.

— Managers of stores, civil works, erection work, testing and commissioning work, operation and maintenance work.

Field quality and safety chief is usually appointed for overall responsibility and implementation of field quality plans and safety systems. In small organisation, the chief executive handles safety.

Field Quality and Safety Manager to Ensure :

Field quality and safety is ensured at every stage of construction and operations.
Activities are done properly, with excellent quality and full safety.
Trouble are attended promptly and safely. Permanent solution are found and troubles do not repeat.
Field quality control system is formulated, enforced and monitored.
Awareness about field quality and safety is created. Human resources are developed for field work, quality, safety.
Records are maintained in master documentation room and working documentation room.

Stages of field quality checks and responsibility

Total Field Quality (TFQ)	Manager (Quality and Safety)
Receiving, unloading, storage	Manager (Stores)
Civil works	Manager (Civil)
Erection work	Manager (Erection)
Testing, commissioning Energization	Manager (Commissioning)
Operation and maintenance	Manager (O and M)

Q. 19. State the procedure of handing over. Give example of handing over documents.

Stagewise internal handing-over procedure. During the project construction period, the total activities are divided into distinct major stages and procedure for handing-over from one stage to the next-stage is defined.

Stages in Project Construction, Handing over and Taking over

	Construction Stage	*Pre-condition for starting*	*Handing-over / Taking-over*
1.	Receiving and storage	— Roads ready — Site office opened — Stores ready	— By transporter to store keeper
2.	Civil Works	— Soil investigations and civil designs completed — Construction water, power arranged — Subcontracts finalised — Construction material arranged	— Manager civil takes-over the site and begins civil works.
3.	Erection Works (Zonewise)	— Completion of civil work in the zone	— Manager (civil) to manager (Erection)
4.	Equipment testing and subsystem test (Zonewise)	— Completion of erection work in the zone — Auxiliary ready	— Manager (Erection) to manager (Testing)
5.	Commissioning tests	— Completion of Eqpt. tests, subsystem tests — Auxiliary power available — Loads available.	— Manager (Testing) to manager commissioning or : (One manager for testing/commissioning)
6.	System energizing and performance tests	— Completion of commissioning tests in every zone — Associated transmission lines/loads/ generating stations available.	— Jointly by manager commissioning, Plant owner and concerned transmission/generating agency under responsibility of manager commissioning

The **Safety Responsibilities** are owned by each and every group under the leadership of concerned group manager and **Total Site Manager** and Safety Manager.

Example of Handing Over Document and Taking Over Document

Hod No. _____ Date _____

Plant _____ Zone _____ Eqpmt _____

Ref. Drg No. _____ Ref. Document No. _____

XXX POWER PLANT CONSTRUCTION WING HANDING OVER DOCUMENT (INTERNAL)

Following plant/equipment installation has been jointly inspected by Manager (Civil) (Name) _____

Manager Erection (Name) _____

Manager Testing Commissioning (Name) _____

Site Manager (Name) _____on Date _____ : Joint inspection report enclosed.

The following Zone/Equipment _____ has been handed over :

BY		*TO*
* Manager Civil	To	* Manager Erection
* Manager Erection	To	* Manager Testing
* Manager Testing	To	* Manager Commissioning
* Manager Commissioning	To	* Manager Operation

(Mark (✔) which ever applicable)

List of pending points given in Annexure. All the other work _____ has been completed.

Signature/Date (BY) Signature/Date (TO)

Internal handing over document is signed by the handing over manager and taking over manager.

Final handing over to owners trained operation staff

The owner's operation and maintenance staff is trained during project construction period (storage, civil, erection, testing, commissioning activities). The plant is operated by the commissioning group and operating group under close observation for an adequate period (One months to three months). After successful completion of trial operation, the plant is handed over by the site manager (construction) to plant manager (operation and maintenance). The **Safety Responsibilities** are transferred accordingly. Table gives an example of final handing over document. After taking over the plant, the responsibility of issuing safety documents, safety keys, issue of various permits etc. is taken over by the manager operation and maintenance.

Example of Final Handing over Document
(Manager Construction or Main Contractor to Manager Plant Operation and Maintenance)

Final HOD No. _____ Dt. _____

PLant : _____

Contract No. _____

XXX Power plant operation and maintenance wing final handing over document.

Following plant/equipment/installation has been jointly inspected by us and joint inspection report is attached here with.

Name of Plant : _____

Subsystems in the plant : _____

_____

_____

The plant and subsystems have been successfully commissioned and performance tests have been successfully completed. The plant and systems and safety responsibilities are being handed over By : (Name/Designation/Organization) _____

_____

To : (Name/Designation/Organization) _____

_____

on Date : _____ at (Time) _____

(Signature/Date) Handed over By

(Signature/Date) Taken Over By

Q. 19. Planning of commissioning O and M and maintenance testing

Plant and equipment commissioning tests are conducted to confirm that the equipment shall not fail after energizing and shall perform assigned duties with high efficiency and reliability.

Factory tests are on individual new equipment under simulated condition and low power. Site tests are under in site installed condition along with other auxiliaries, plants and subsystems, with actual supply and loads and full power. Site tests are more convincing.

Variables in the power system include : V, I, MW, MVAr, cos, f, rate of rise, ambient temperature, environmental stresses, operating duty, severity, mechanical variables, etc.

Individual equipment, group of equipment and subsystems, and the total plant are tested at site step by step to verify that they do not fail to perform under sever practical abnormal conditions occurring in simultaneously in practice. In practice, tests are segregated and carried out step by step.

Categories of Electrical Tests. Tests principles and procedures of factory tests and site tests are similar. However test specifications and protocols (Broad sequence of test schedule with major steps and responsibilities) vary during type tests, routine tests, equipment commissioning tests, plant commissioning tests, maintenance tests.

Factory Tests : Type Tests ; Routine Tests. *Factory type tests* confirm the capabilities of *a few newly designed machine/equipment of particular type,* against assigned ratings and standard test specifications. The type tests are not repeated on each equipment and are conducted only once. Type tests confirm the design and ratings of particular type.

Factory routine test are conducted routinely on each equipment before dispatch to site to confirm that equipment is manufactured well and is capability of performing well at site. These are carried out as per recommendations of relevant standard specifications. These type tests are *repeated* on each equipment and are conducted at manufacturer's works before passing for dispatch.

Electrical Commissioning Tests (EC-Tests). These are comprehensive tests include equipment tests, subsystem tests and plant tests. These are conducted in situ on assembled/erected plant and equipment, to confirm that the erection has been satisfactory and there are no defects/deficiencies and the equipment can be safely energized, operated and handed over to O and M.

Electrical Preventive Maintenance Tests (EPM-Tests). Electrical equipment and plant operate in conjunction with power system on one side and some form of non-electrical energy consuming load on other side. Abnormal operating conditions, short circuit, unbalanced supply, voltage surges etc.; vibrations, temperature cycles, dust/moisture/fumes etc produce sever stresses, deterioration and partial/total failures. Electrical preventive maintenance program (EPMP) covers the total plant, maintenance schedules and maintenance test program, test facilities etc.

Categories of Electrical Tests. Site tests include tests on current carrying paths, tests on earthing system, tests on insulation system, tests on control/protection and auxiliary systems, tests on materials and field quality control tests. A short list of site tests is :

1. Mechanical operation tests
2. Measurement of resistance of main circuits.
3. Power frequency voltage withstand test on main circuit of each phase to earth, each phase to phase.
4. Voltage withstand test and insulation resistance on auxiliary circuits.
5. Measurement of insulation resistance of main circuits
6. Measurement of insulation resistance of auxiliary circuits.
7. Insulating liquid testing in test cell
8. Partial discharge tests on insulation systems
9. Circuit breaker time travel characteristic and oscillographic tests for simultaneous touch.
10. Earth resistance test on earthing system
11. Oil gas analysis
12. Infrared inspection testing of hot contacts.
13. Stage fault tests.
14. Sequential tests
15. Interlock tests
16. Protective device testing

Maintenance and Commissioning Program

The commissioning and maintenance program must meet the objective of site management. Management may hesitates to investment in a maintenance program even though maintenance is essential. It is up to electrical maintenance personnel to convince the management and get it approved a properly planned electrical maintenance and testing program.

Q. 20A. List the plant diagrams required at site for ECTOM.

Accurate data about the plant, electrical power system and equipment, plant diagrams for main circuit and auxiliary circuits are necessary during erection, commissioning and O and M. Single line diagrams wiring and control diagrams and other data that can be used for reference for future maintenance and testing. The purpose of these diagram is to document and serve as an official record of equipment and circuit installation. The type of diagram and drawing include are the following :

1. **Single-line Diagram** shows main power circuit and equipment therein by means of single lines and graphic symbols.

Three phase system is represented by single lines. The circuit connections and components, switching points, isolating points can be identified. Zones of protection; maintenance zones can be identified. Alternate supply routes can be determined.

2. **Process for flow diagram.** A conceptual diagram of the functional interrelationship of subsystem in pictorial form.

3. **Block diagram.** A group of interconnected blocks, each of which represents a device or subsystem.

4. **Schematic (Elementary Diagram).** Shows all circuits and device elements of the equipment. This emphasizes the device elements and their functions, and it is always drawn with all device shown in de-energized mode. A typical elementary diagram is shown in Fig.

Control Sequence (Truth Table) Diagram. A description of the contract positions, or connections, that are made for each position of control action or device.

5. **Wiring Diagram (Connection Diagram).** Locates and identifies electrical devices, terminals, and interconnecting wires in an assembly. This diagram may shown interconnecting wiring by lines or terminal designations. A typical wiring diagram is shown.

6. **Interconnecting Diagram.** Shows only the external connections between controllers and associated equipment or between various housing units of an diagram is shown.

7. **Circuit layout and routine diagram** shown the physical layout of the facility and equipment and how the circuit to the various equipment is run.

8. **Short circuit levels study** indicates short circuit levels at different points in the system.

The data is useful in setting protective relays and selecting circuit breakers and fuses.

9. **Auxiliary system diagrams.** Such diagram may consist of the following

— Control and monitoring
— Lighting system
— Ventilation system
— Heating and air conditioning system
— Emergency system
— Fire protection systher system

All the system diagram may interface with one another, such as electrical diagram, fire and security diagram, emergency power, hydraulic, pneumatic and/or mechanical systems. Therefore it is important to know how these interfaces work and how they can be coordinated in the commissioning and maintenance program.

Q. 20B. List various electrical equipment in main circuit of electrical power stations and substations. State their functions. Explain the single line diagram and principle of connections.

Electrical Equipment and Layout

The electrical plants can be classified as (1) Generating stations (2) Substations (3) Transmission links/overhead line or underground cable (3) Power consuming plant (load).

Every *generating plant* has following essentials :

— Generators/prime mover/auxiliaries
— Transformers
— Busbars
— Power cables or overhead lines or busducts
— Switchgear
— Control room
— Auxiliary systems

Every *substation* has following essentials :

— Busbars
— Transformers
— Power cables or overhead lines or busduct.
— Control room/communication/ SCADA systems —
— Auxiliary systems.

Every *utilization plant* has following essentials :

— Outdoor or indoor substation with
— Busbars
— Transformers
— Power cables or overhead lines or Busducts
— Switchgear
— Controlgear
— Utilization equipment, Motors
— Control room
— Auxiliary systems.

The consumer may also have *standby generating plant* and *uninterrupted power supply system (UPS).*

Generating plants, substations, load plants have similar configurations. *Identical branches are connected in parallel* to busbars. The busbars receive power from incoming circuits and deliver power to outgoing circuits. Switchgear (CB, isolator) is provided to each incoming circuit, outgoing circuit and each major equipment in the plant to facilitate switching and protection.

Main power circuit is of high voltage, high power with larger cross section of conductors, connectors, power cable conductors. *Conductors* are of high conductivity aluminium or high conductivity copper.

Main circuit has *busbars* at two or three or four voltage levels obtained by means of *power transformers.* For example a 220 kV/132 kV substation has two power transformers connected in parallel between the 220 kV, 3 ph. bus and 132 kV, 3 ph. bus.

Power Transformers are either dry type or oil immersed type. Oil-immersed transformers need transformer oil for cooling and insulation of windings. Transformer is accompanied by cooling system, unload tap changer, bushings, conservator, marshaling kiosk, protection panel, surge arresters, neutral earthing, body earthing etc.

High current busbars (rated 4 kA, 6 kA, 10 kA continuous) in generating stations, between generator and main transformer are in the form of *Isolated phase busducts.* The aluminium conductors are enclosed in aluminium enclosures (earthed) to reduce electromagnetic field outside the enclosures and simplify the support insulator design due to reduced electrodynamics forces during short circuit current flow.

Busbars in substations are in the form of either (1) rigid tubular aluminium conductors supported on solid porcelain post insulators or (2) flexible conductors supported on string insulators. Conductors may be of ACSR (aluminium Conductor Steel Reinforced) or All Aluminium Alloy (AAA).

(AAC) or All Aluminium Alloy Conductors (AAAC) *Switchgear (CB, Isolator)* is provided to each incoming circuit, outgoing circuit and each major equipment in the plant to facilitate switching during routine O and M operations and door protection of the equipment under abnormal conditions such as over-loads, short circuits, earth faults.

Current Transformers (CTs) are provided in each branch circuit to step down the current (e.g. 1200 A to 5 A) for measurement, control, protection, automation, SCADA.CTs are separate porcelain enclosed or epoxy resin enclosed or bushing turret mounted. Several cores of CTs are usually provided in each branch/bay for protection, measurement, control systems. *Voltage Transformers* are provided with each busbars and outgoing circuit, incoming circuit to step down the voltage (e.g. 11 kV to 110 V) for measurement, control, protection, automation, SCADA. *Coupling Capacitor Voltage Transformer (CCVT)* combines the functions of power line carrier coupling capacitor and capacitor voltage transformer.

Protective Relays are connected on the secondary, low voltage side of the CTs, VTs and other transducers such as thermal, speed, frequency transducers.

Controllers such as On Load Tap Changers (OLTC), Automatic Voltage Regulators (AVR), Static VAR sources (SVS), Thyristor Controlled Switch/Controller (TCS) etc are provided in the power circuit and are controlled through the control relay panels in the control room and near the controller.

Surge Arresters are installed near incoming over head lines, near power transformer terminals, near generator and large motor terminals. They divert the lightning and switching surges to earth. *RC surge suppressors* (R = 100 ohm, C = 0.1 micro farads) are installed near every large rotating machine and near every vacuum circuit breaker terminal. Surge arrester and surge suppressors are connected phase to ground.

Power cables are provided between bus bars, switchgear and power utilization equipment control gear. *Control gear* is provided with each power consuming device.

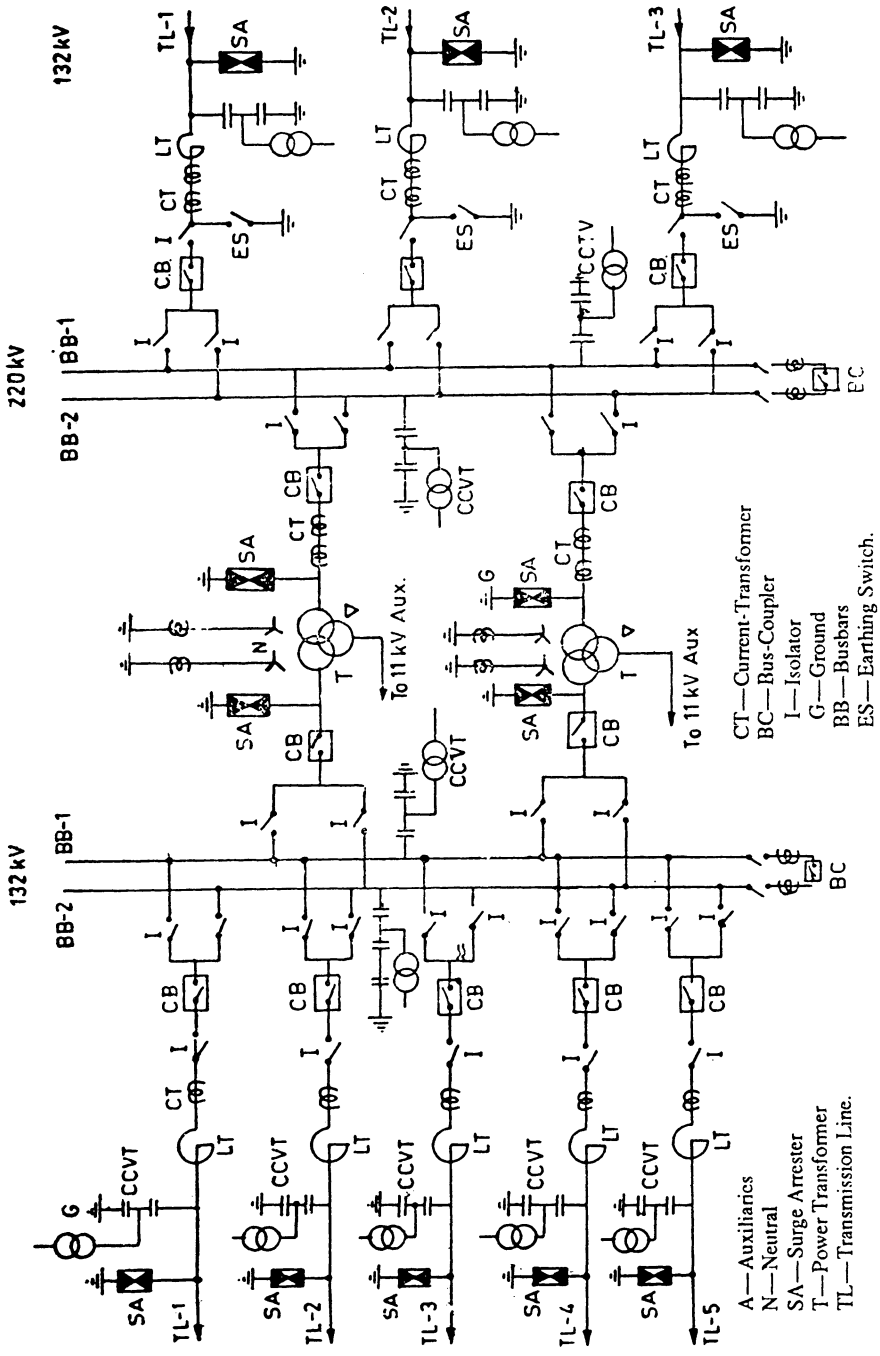


Fig. Q. 20A. Single-line Diagram of a 220 kV/132 kV substation with Duplicate Busbar System.

Identical bays (branch circuits) are connected in parallel to busbars. The busbars receive power from incoming circuits and deliver power to outgoing circuits. Switchgear (CB, isolator) is provided in each incoming circuit, outgoing circuit and with each major equipment in the plant to facilitate switching and protection. Each bay (branch circuit) requires CB, isolator, earthing switch, CT, VT, surge arrester.

Glazed porcelain insulators are provide in outdoor installation. They are either post type (rigid) or string type (strain or suspension application). *Epoxy solid insulators* are only for indoor applications. Auxiliary systems are supplied via auxiliary power transformer and auxiliary switchgear. *The electrical plant is built by selecting standard equipment of appropriate ratings and connecting them as per single line diagram designed to meet functional requirements during operation; protection and maintenance.*

System Description

Fig. Q. 20 illustrates a typical configuration of a 220 V/132 kV substation. Power transformers are connected between two voltage levels. *Bus bar system* : Bus bars are conductors to which several incoming and outgoing circuits are connected. Bus bars are either solid tubular/rectangular aluminium bars supported on post-insulators or flexible ACSR conductors supported on string insulators. Double bus bar system has two 3 phase bus bars, one main and the other standby. One of them is energized at a time for normal operation. During maintenance/repair, the other bus bar is taken in service. Ratings include : Rated voltage, rated insulation level, rated normal current, rated short circuit current for a short time of 3 sec. *Circuit Breaker (CB)* is a switching device capable of switching on and off the circuits automatically during normal operation and during short circuits.

Ratings of Circuit-Breakers (CB)

Rated voltage, rated insulation level, rated normal current, rated short circuit current for a short time of 3 sec rated short circuit breaking current, rated short circuit making current, rated operating sequence, etc. Special switching duties include capacitor switching, inductance switching, line switching, cable switching.

Classification of CB based of voltages include :

— Low voltage AC (< 1000 V rms ph. to ph.)
Medium high voltage AC (< 33 kV rms ph to ph)
High voltage AC (33 kV to 220 kV rms ph to ph)
Extra high voltage AC (400 kV AC rms ph to ph)

Classification of CB based on arc quenching medium of circuit breakers include :

— SF_6 circuit breaker
— Minimum oil circuit breaker
— Air break circuit breaker
— Vacuum circuit breaker
— Bulk oil tank type circuit breaker

Protective Zone. The entire plant is covered by several overlapping protective zones. The protective systems include protective relays, current transformers (CTs), potential transformers (PTs), circuit breakers, protection panels. Important protection zone include transformer protection zone, bus protection zone, feeder protection zone, generator/transformer protection zone. Neighbriring protection zones overlap so that there is no dead zone (unprotected zone). During fault or abnormal condition in a particular protection of that zone operates and circuit breakers open and faulty part is switched off from the rest of the system.

Circuit breakers, Isolators and Earthing Switches

Circuit breakers are accompanied with Isolators and Earthing Switches on one or both sides depending upon infeed.

During opening of a circuit : (1) CB opens first as it has current breaking capability (2) Isolators open only after opening of CB. (3) Earthing switches are closed after opening the isolators. Earthing switch connects conductor to earth and thereby discharges the charges trapped on the disconnected circuit to earth.

During Closing of a Circuit. (1) Earthing switches are opened first. (2) Isolators closes only after opening of earthing switch. (3) CB closes last as it has current making. The plant layout is designed such that every equipment is protected, every equipment can be maintained with least disturbance to the rest of system, alternate path is available during maintenance shut down.

Functions of Equipment in Electrical Plant (Fig. Q. 20)

Equipment	*Function*	*Remarks*
Busbars — Single — Double — One and half breaker — Ring	Various incoming and outgoing circuits are connected to busbars. Busbars receive power from incoming circuits and deliver power to outgoing circuits.	— Either rigid aluminium tubular busbars supported on post-insulators. *Or* — Flexible ASCR or All-aluminium stranded busbars supported from two ends by strain insulators. — Two levels or three levels — Indoor or outdoor — Air insulated or SF_6 gas insulated
Surge arresters (Lightning arresters) R-C surge suppressor	To discharge the over-voltage surges to earth and protect the equipment insulation from switching surges and lightning surges.	— Connected between phase conductor and ground. — Located as the first equipment as seen from the incoming overhead line and also near transformer terminals phase to ground. — Two types : gapped arresters and gapless zinc-Oxide arresters.
Isolators (Disconnecting Switch)	To provide isolation from live parts for the purpose of maintenance.	— Located at each side of circuit breakers. — Does not have any rating for current breaking or current making. — Interlocked with circuit breaker.
Earthing switch	Discharging the voltage on the circuit to earth for safety.	— Mounted on the frame of the isolators — Location generally for each incomer and each busbar section.
Current transformer	Stepping down current measurement, protection and control	— 1. Protective CT — 2. Measuring CT — Location decided by protective — zone measurement requirements.
Voltage transformer (Potential Transformer)	Stepping down current for measurement, protection and control	— Types : 1. Electro magnetic 2. Capacitive VT (CVT) — Location on feeder side of circuit breaker
Circuit-breaker 1. SF_6 2. Vacuum 3. Air blast 4. Minimum oil. 5. Air-break	Switching during normal and abnormal operating condition. To interrupt short circuit currents. Operations include : — closing — opening — auto-reclosing	— Located near every switching point. Located at both end as every protected zone. — Types : Depending on rated voltage : Low voltages, medium high voltage, high voltage, extra high voltage. — Types : Depending on medium of arc quenching.

Equipment	*Function*	*Remarks*
Power transformers	To step-up or step-down a.c. voltages and to transfer electrical power from one voltage level tc another.	— Usually oil filled for outdoor use. — Two winding or three winding
On-load Tap-changer 14′ or off circuit tap switch	Tap changers used for voltage control. For very large transformers. Transportation, rail permit etc. should be decided in advance. Off circuit tap switch for seasonal voltage adjustment.	— Three single-phase units to form a three bank used when single three phase unit becomes too large to transport. — Provided with coolers — Provided with tap-changers/tap switch.
Shunt reactors	Used for long EHV transmission lines to compensate shunt capacitance of transmission line during low load periods.	— Usually oil filled, gapped core, shielded. — Usually unswitched.
Shunt capacitor	For compensating reactive power of lagging power factor. To improve power factor. For voltage control during heavy lagging power factor loads.	— Located at receiving stations and distribution substations. — Bank rated 132 kV, 66 kV, 33 kV, 11 kV, 6.6 kV, etc. — Switched in during heavy loads, switched-off during low loads.
Series capacitor	Used for some long EHV a.c. lines to improve power transferability.	— Capacitor bank located at sending-end and/or receiving-end of line. — Provided with by-pass circuit-breaker and protective spark-gaps.
Carrier equipment — Line trap unit — Coupling Capacitor — Electronic Equipment	Used for protection and communication signalling, voice communication, protection signalling, telex channel, control and monitoring signals.	— Line trap unit usually mounted above CVT or on separate structure. — Coupling capacitor mounted on structure. — Tunning unit. — PLCC panels located in control-room
Marshalling Kiosks	To mount monitoring instruments, control equipment and to provide access to various transducers.	— Located in switchyard near every power transformer ; a group of equipment in a bay.
Metering panels, control and relay panels (Indoor)	To house various maeasuring instruments, control instruments, protective relays.	— Located in air-conditioned building. Control cables are laid between switchyard equipment and these panels.
Medium voltage A.C. switchgear and low voltage A.C. switchgear (Indoor)	To provide a.c. power to auxiliaries, station lightning system, etc. at respective voltage levels.	— Located inside switchgear building.
Station earthing system	To provide a low resistance earthing for — discharging currents from surge arresters, overhead shielding, earthing switches. — for equipment body earthing — Neutra earthing — for safe touch potential and step potential in substation. — for providing path for neutral to ground currents for earth fault protection.	— Earth-mat and earth electrodes placed below ground level. Connected to equipment structures, neutral points for the purpose of equipment earthing and neutral point earthing.

Equipment	*Function*	*Remarks*
Lightning protection	To protect substation equipment from direct lightning strokes, lightning surges.	— Lightning masts located in outdoor yard. — Alternatively, overhead shielding wires to cover entire outdoor yard.
Series reactors (Current Limiting Reactor)	To limit short-circuit current and to limit current surges associated with fluctuating loads.	— Located at strategic locations such that fault levels are reduced. Now no more preferred.
Isolated phase bus system	Provides connection between generator and main transformer. High normal currents.	— Aluminium enclosures for each phase conductor. Can withstand high
	To provide connection between LV side of power transformer and indoor metalclad switchgear.	— Short-circuit currents due to magnetic shielding provided by enclosures.
Neutral grounding equipment — Resistor — Reactor	To limit short-circuit current during ground fault.	— Short-time rated. Connected between neutral point and ground.
Static VAr Sources (SVS)	To provide stepless, variable shunt compensation for voltage control	— Thyristor controlled shunt reactor and shunt capacitor — Rapid control of voltage.
Line trap	Inductive coil usually outdoor	— Connected in outdoor yard incoming line. — Past of PLCC requirement.
Power cables	— Single core — Three core	— PVC insulated — XLPE insulated — Armoured
Control cables	— Multicore copper-conductor — Fiber-optic cable	— PVC insulated — shielded — For protection, control, measurement etc — Low voltage.
Insulators — Porcelain — Glass — Epoxy for indoor use	— String insulators 1. Tension 2. Suspension — Post insulators — Solid core	— For flexible ASCR conductors — For tublar conductors — For apparatus
Power transformers	To step down voltage or to step up voltage and to transfer power at same frequency	— Oil immersel or dry type — Cooling system, marshalling kiosk, OLTC neutral earthing, bushings
Synchronous generators (Alternator) with AVR	To generate electric power	3 phase, 50 Hz synchronous generators driven by prime mover

Generating Stations. Function : To convert energy to electrical form and to supply electric power at specified voltage, waveform, current, power factor, power quality at all times with high efficiency, low losses and high reliability, modest maintenance, highest safety, lowest pollution and lowest cost. Generating station has two or more identical generator-prime mover *units* operating in parallel.

Each unit has generator, transformer, switchgear and prime-mover, boiler plus auxiliary transformer, auxiliary switchgear and various generator auxiliaries, prime mover auxiliaries, boiler

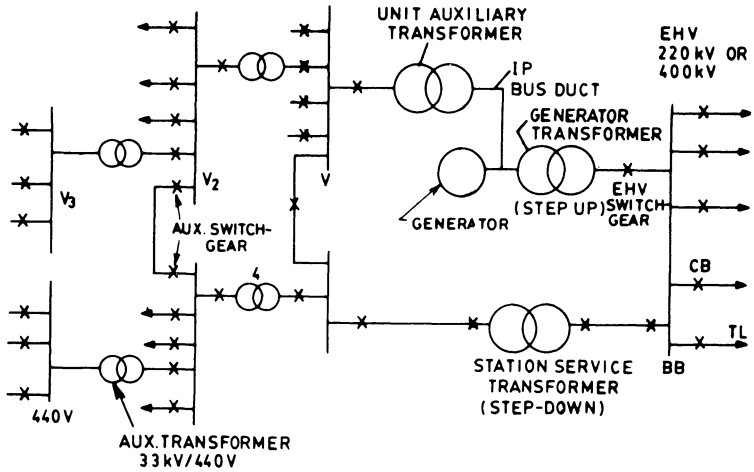


Fig. Q. 20B. Electrical Schematic of a generating station main circuit and auxiliary system (only *one unit* shown)

auxiliaries, protection system, control system, automatic voltage regulator, speed governor, pollution controlling equipment and fire safety apparatus, etc.

Generator. 3 phase AC synchronous generators, operates synchronously with bus frequency of 50 Hz. Generator has 3 ph. star connected distributed AC stator winding with neutral earthed. The rotor has DC excited field winding. Rotor DC excited poles are 2 or 4 or 6 or 8 depending upon type of prime-mover (steam turbine, gas turbine, hydro turbine, diesel engine etc.)

Prime mover drives the rotor shaft and *Governor* regulates the speed. Synchronous generator shaft rotates at synchronous speed only.

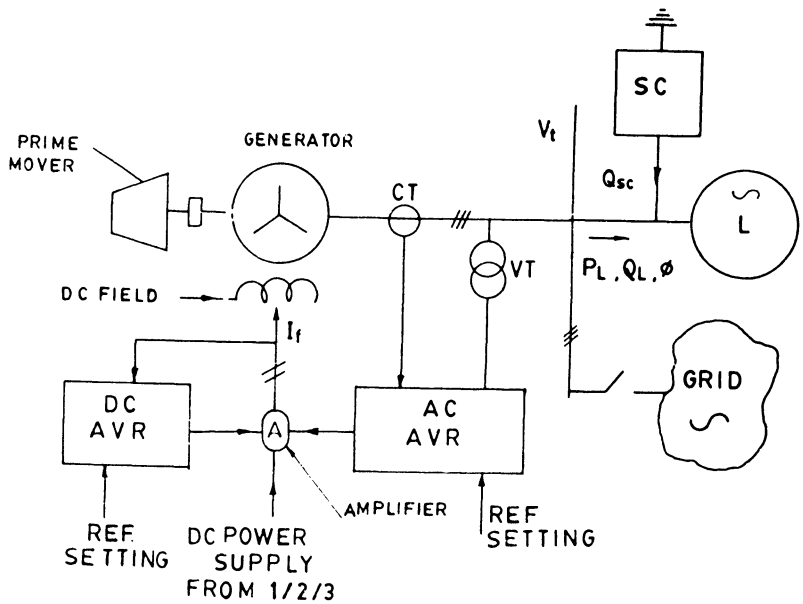


Fig. Q. 20C. Schematic of a Generator unit, load and AVR.

1. DC Generator 2. Controlled Thyristor Rectifier 3. Uncontrolled Diode Rectifier.

SC = Shunt Compensation *REF* = Reference setting

A = Amplifier *CT* = Current Transformer

VT = Voltage Power Transformer not shown for simplicity.

Automatic Voltage Regulator (AVR). The terminal voltage of generator, power factor and reactive power is controlled by synchronous machine regulator (AVR). The AVR also performs certain limiting functions (power limit, reactive power limit, field current limit, etc.) and dynamic stability functions (super excitation to retain stability during power swings.)

Isolated Phase Busducts. High current connection between generator and main transformer and unit auxiliary transformer are in the form of tubular busducts. The aluminium conductors are enclosed in aluminium enclosures (earthed) to reduce electromagnetic field outside the enclosures and simplify the support insulator design due to reduced electrodynamics forces during short circuit current flow.

Main Transformer (Generator Transformer) is connected directly to generator isolated phase bus duct to step up the voltage from generator voltage level to transmission voltage level.

Unit Auxiliary Transformer is connected directly to generator isolated phase bus duct to step down the voltage from generator voltage level to auxiliary voltage level (11 kV or 6.6 kV or 3.3 kV).

HV main switchgear (Circuit Breaker + Isolators) are connected between HV side of main generator transformer and outdoor HV bus.

Switchyard. The main HV switchgear, HV bus, terminations of outgoing transmission lines are located in outdoor switchyard or in *SF_6 GIS* (SF_6 *gas insulated substation).*

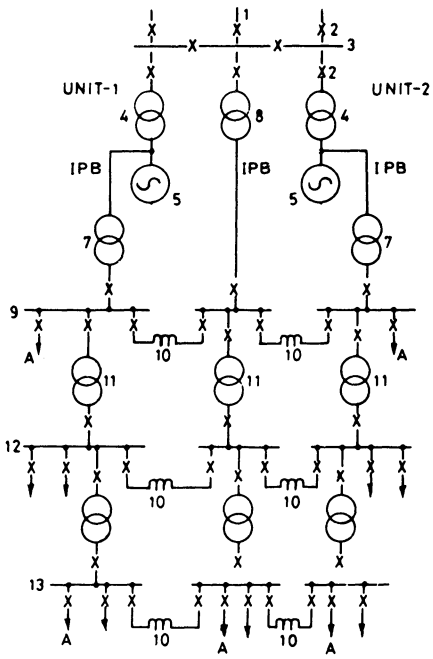
Station Service Transformer is connected between HV bus in switchyard and indoor auxiliary busbars.

Auxiliary common to all the generating units and miscellaneous station auxiliaries are supplied through the unit auxiliary switchgear.

AUXILIARY SYSTEM AND AUXILIARY SWITCHGEAR

Power Station Auxiliaries and Auxiliarys Supply Systems

The boiler auxiliaries, turbine auxiliaries, generator auxiliaries, station auxiliaries, various auxiliary systems are supplied power at specified auxiliary voltage level (11 kV, 6.6 kV, 3.3 kV, 440 V 3 ph, AC and 220 V single phase AC. Protection, control, metering, monitoring, SCADA systems need auxiliary low voltage DC and low voltage AC supply.



1. EHV AC transmission lines (Y = in Yard)
2. EHV AC C.B. (Y)
3. EHV AC Bus (Y)
4. Gen. Transformer (Y)
5. Generator (I = Indoor)
6. Isolated phase Bus
7. Unit Auxiliary Transformer (Y)
8. Station Transformer (Y)
9. Aux. Bus 11 kV (I)
10. Reactor (I).
11. Aux Transformer (I)
12. Aux. Bus 6.6kV (I)
13. Aux Bus 400 V(I).

Fig. Q. 20D. Station Auxiliary System and Auxiliary Switchgear.

Auxiliary AC Power Supply in Power Plants and Substations

The electrical auxiliaries in a power plant include :

Unit auxiliaries and station auxiliaries. Unit auxiliaries are for respective generator units (Generator/voltage regulator/turbine/boiler etc.

Station auxiliaries (lighting/air conditioning/feed water/ coal handling etc.) are dispersed in the total power station and are common for the plant.

The voltage and power ratings cover a wide range from low voltage ; fractional kW to high voltage ; several hundred MW. The end-use loads are located in various plant buildings. Each load has associated switching/ controlling/protection panel and power transformer as necessary).

A plant has internal electrical distribution system at two or three voltage levels (*e.g.* 11 kV, 6.6 kV, 400 V). The power at various voltage levels is obtained from step-down auxiliary power transformers.

The underground power cables are provided between *factory substation* and the *load group switchgear.* The individual loads are fed from the nearest group switchgear of that voltage level.

The auxiliary switchgear is usually indoor metalclad drawout type switchgear with truck mounted vacuum of SF. Circuit breakers. Auxiliary transformers are dry type resin-cast.

AC Distribution System in the electrical plant or auxiliary system

Fig. 20 E illustrates a typical schematic. High voltage cables feed the HV side of the step down auxiliary transformer (AT). The low voltage switchgear has busbars, circuit breakers and outgoing cable lines (L). Standby DG set is normally open (NO). During outage of hv supply from the grid, the DG set is started and switched on as the mains side switchgear is locked open. Automatic bus transfer schemes may be provided.

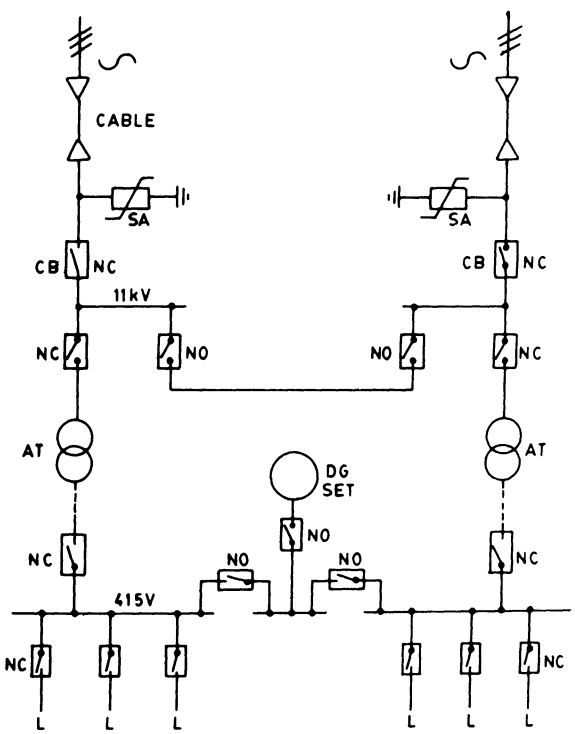


Fig. Q. 20E. Internal AC Distribution System in and Electrical Plant or Auxiliary Switchgear in a power plant.

Low Voltage Auxiliary DC Supply (LVDC)

The protection, control and communication, SCADA systems require auxiliary low voltage DC supply at three or four voltage levels (220 V, 110 V, 45 V DC). The DC is obtained from static rectifier sets and storage batteries kept constantly charged and floating on the DC side of battery charger.

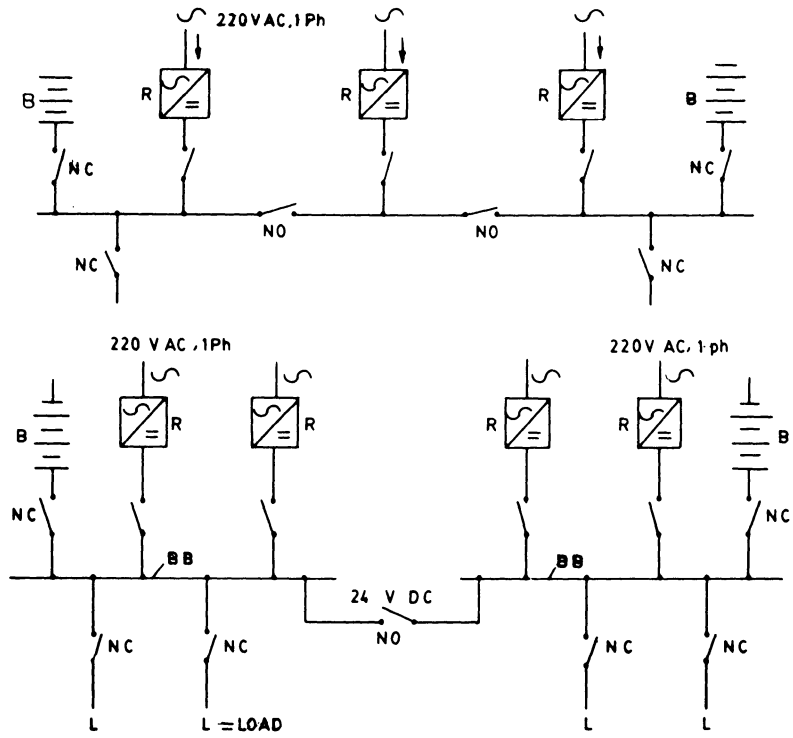


Fig. Q. 20F. Low Voltage Auxiliary DC Supply (LVDC) System in an electrical plant.

T = Transformer *CT* = Current Transformer
CB = Circuit-Breaker *I* = Isolator
TB = Transfer Bus *MB* = Main Bus

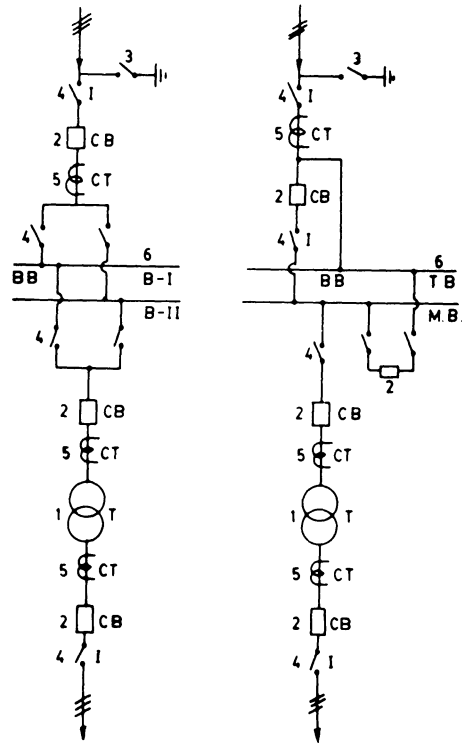


Fig. Q. 20G. Typical Transformer and Switchgear Connections.
(Single line diagram 01 3 phase AC System.)

Power Transformer and Switchgear Schematic

The busbar system usually has one main bus and one standby bus. Main bus is usually in operating circuit. Standby bus is taken in service during maintenance of main bus or during fault/repair of main bus.

Standard equipment including circuit breakers (CB), isolators (I), current transformers, busbars BB, transformers (T) are shown in the figure. Similar bays are provided in parallel for other circuits connected to the busbars (BB).

Switchgear are necessary at each switching point in the main circuit and in auxiliary circuit. *Circuit breakers* are the main switching devices capable of automatic opening the circuits even during short circuit conditions. Switchgear comprises busbars, CBs, Isolators, CTs, PTs, measuring and protecting and controlling devices. Switchgear rated 33 kV and above are either outdoor air insulated switchyards or SF Gas Insulated Switchgear (GIS).

Control Relay and Protection Panels are installed in control room from where the supervision, control, monitoring, communication, man machine interface facility is provided.

Before 1980s protection and control functions were segregated. With availability of microprocessor based systems after 1990s, the various functions including protection, control, supervision, data acquisition, monitoring etc. are performed by SCADA (Supervisory Control and Data Acquisition) systems located in control rooms of generating stations, substations and control centers.

Power Transformers are necessary between consecutive AC voltage levels in substations and power stations. A 3 phase, 2 winding transformer has one 3 phase (HV) winding and one 3 phase (LV) winding. A 3 phase 3 winding transformer has 3 sets of 3 phase windings. Transformers upto 11 kV are either dry type epoxy insulated or oil immersed.

Principles of Operation of electrical plant

Busbars are made live by closing circuit breakers in incomer circuit on supply side. Loads are energized by closing the circuit breaker in corresponding load circuit. The power flows from generating stations to loads via the various series, parallel branches in the power network. Voltage is controlled by means of on load tap changers, static voltage sources, shunt capacitors in respective substations. Frequency is controlled by matching MW generation with MW load, from action of turbine governor and import of power as per instructions of load control centers. Control gear controls power consuming devices. Switchgear performs routine switching functions during normal O and M, and automatic switching and protective functions during abnormal conditions such as short circuits. Surge arresters provide protection against lightning and switching surges, surge suppressors reduce the peak and rate of rise of switching surges. Each branch of the series/parallel network has certain essential equipment. Electrical plant has identical parallel branches (bays) at each voltage level which can be switched on or off by appropriate circuit breakers.