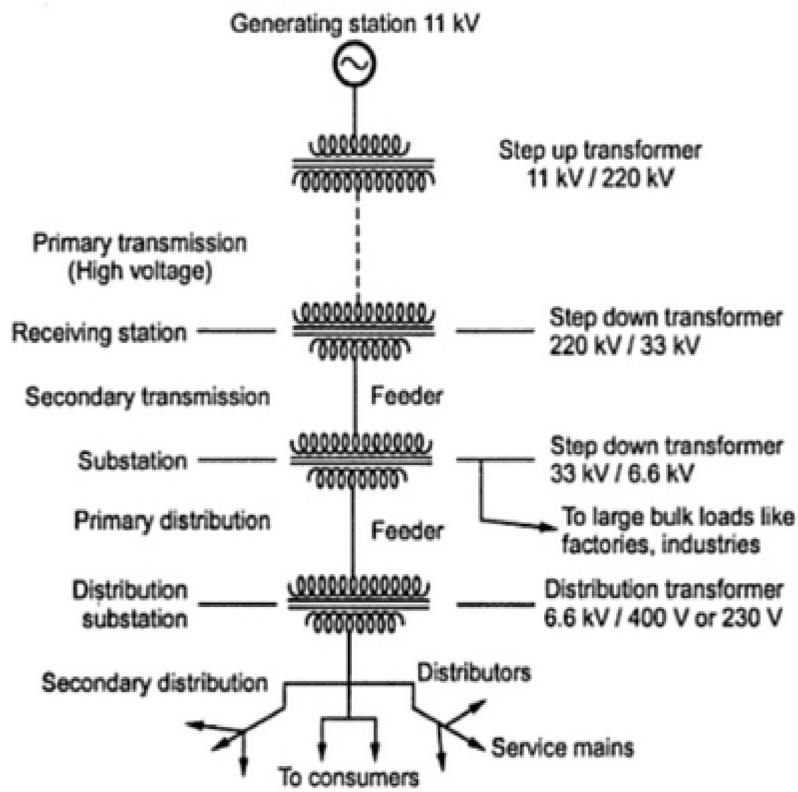
# UNIT-I

## 1.1 STRUCTURE OF POWER SYSTEMS—

A typical power system can be divided into different parts. These are generation, transmission and distribution systems.




At present, the vertically integrated utilities (state electricity boards) can import or export a pre-decided amount of power from neighboring states or generators owned by other entities like National Thermal Power Corporation or independent power producers(IPP).

Individual power systems are arranged in the form of electrically connected areas known as power pools or regional grids, which cover a particular region. These regional grids are interconnected through tie lines to form a national grid. By this arrangement each area is contractually tied to other areas in respect to generation and scheduling features.

## 1.2 SCADA SYSTEM-

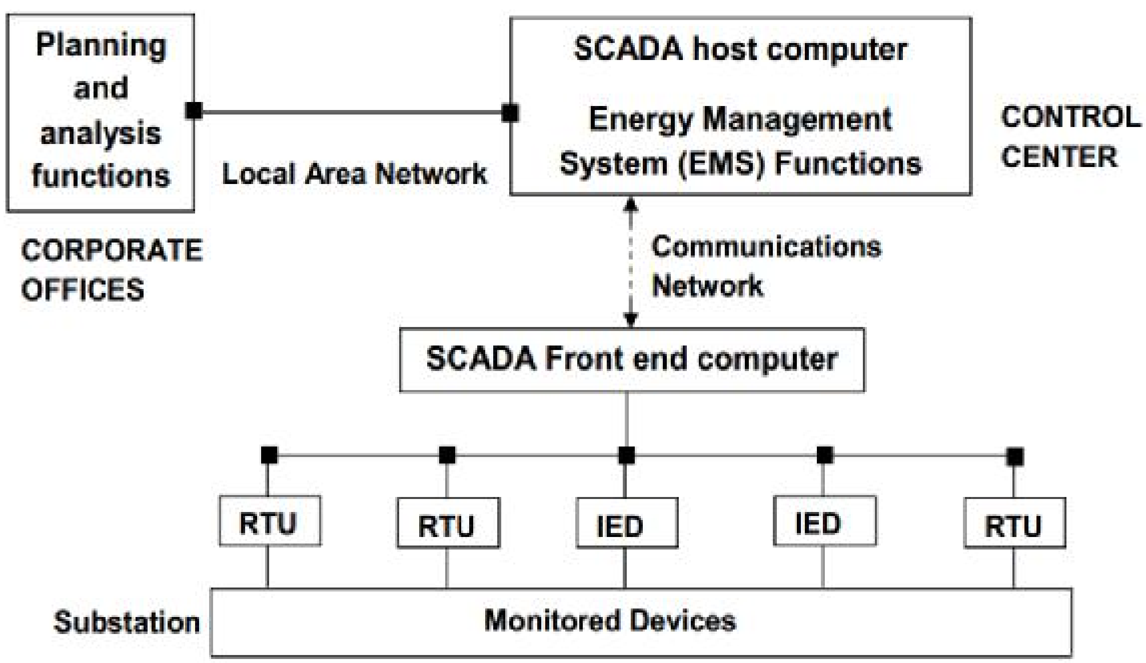
In SCADA system measured values, i.e. analogue (measured value) data (MW, MVAR, V, Hz Transformer tap position), and Open/Closed status information, i.e. digital data (Circuit Breakers/Isolators position i.e. on/off status), are transmitted through telecommunication channels to respective sub-LDCs. Secondary side of Current Transformers (CT) and Potential Transformer (PT) are connected with 'Transducers'. The output of transducers is available in dc current form (in the range of 4mA to 20mA). A/D converter converts this current into binary pulses. Different inputs are interleaved in a sequential form and are fed into the CPU of the RTU. The output of RTU, containing information in the form of digital pulses, is sent to sub LDC. At sub LDC end, data received from RTU is fed into the data servers. In general, a SCADA system consists of a database, displays and supporting programmes. The brief overview of major 'functional areas' of SCADA system is as below:

1. **Communications -** Sub-LDC's computer communicates with all RTU stations under its control, through a communication system. RTU polling, message formatting, polynomial checking and message retransmission on failure are the activities of 'Communications' functional area.
2. **Data Processing -** After receipt of data through communication system it is processed. Data process function has three sub-functions i.e. (i) Measurements, (ii) Counters and (iii) Indications.

- '*Measurements*' retrieved from a RTU are converted to engineering units and linearised, if necessary. The measurement are then placed in database and are checked against various limits which if exceeded generate high or low limit alarms.
- The system has been set-up to collect 'Counters' at regular intervals: typically 5 or 10 minutes. At the end of the hour the units is transferred into appropriate hour slot in a 24-hour archive/history.
- '*Indications*' are associated with status changes and protection. For those statuses that are not classified as 'alarms', logs the change on the appropriate printer and also enter it into a cyclic event list. For those statuses, which are defined as an 'alarms' and the indication goes into alarm, an entry is made into the appropriate alarm list, as well as in the event list and an audible alarm is generated in the sub-LDC.

3. **Alarm/Event Logging -** The alarm and event logging facilities are used by SCADA data processing system. Alarms are grouped into different categories and are given different priorities. Quality codes are assigned to the recently received data for any 'limit violation' and 'status changes'. Alarms are acknowledged from single line diagram (or alarm lists) on display terminal in LDCs.

4. **Manual Entry -** There is a provision of manual entry of measured values, counters and indications for the important sub-station/powerhouse, which are uncovered by an RTU or some problem is going on in its RTU, equipment, communication path, etc.
5. **Averaging of Measured Values -** As an option, the SCADA system supports averaging of all analogue measurements. Typically, the averaging of measured values over a period of 15 minutes is stored to provide 24 hours trend.
6. **Historical Data Recording (HDR) -** The HDR, i.e. 'archive', subsystem maintains a history of selected system parameters over a period of time. These are sampled at a pre-selected interval and are placed in historical database. At the end of the day, the data is saved for later analysis and for report generation.
7. **Interactive Database Generation -** Facilities have been provided in such a way that an off-line copy of the SCADA database can be modified allowing the addition of new RTUs, pickup points and communication channels.
8. **Supervisory Control/Remote Command -** This function enables the issue of 'remote control' commands to the sub-station/powerhouse equipment e.g. circuit breaker trip command.
9. **Fail-over -** A 'Fail-over' subsystem is also provided to secure and maintain a database of devices and their backups. The state of the device is maintained indicating whether it is 'on-line' or 'failed'. There is a 'backup' system, which maintains database on a backup computer and the system is duplicated.



**ENERGY MANAGEMENT SYSTEM (EMS) & REAL TIME COMPUTER-CONTROL-**

For energy management of the power system, control personnel and application software engineers use SCADA data available in the database by using EMS software. Important features are as below:

1. The Data Base Compiler provides a consistent source of data usable for the applications in an efficient form. The Data Base Compiler does final checking for completeness and consistency of the entries for a specific application and prepares those special tables which are needed for the efficiency of specific application programmes.
2. Recording of 'Sequence of Events' (SOEs) is the most innovative feature provided in this system. A RTU has the ability to accurately time tag status change and report this information to sub-LDC. All RTUs in the system are 'time synchronized' with the master station. In the event of any tripping, sequence of events can be well established on time scale with a resolution of 10 milliseconds.
3. Normally, 'Automatic Generation Control' (AGC) function issues control commands to generating plants using the concept of Area Control Error (ACE). It is based on deviations in 'standard frequency (50 Hz)' and 'scheduled area interchanges' from that of the 'actual frequency' and 'actual area interchanges' In the event of unavailability of sufficient generation to satisfy the AGC requirement, the System Control Officer can enforce required quantum of load shedding.
4. For 'Operation Scheduling' the application software has 'short-term' and 'long-term' 'System Load Forecasting' functions to assist dispatching Engineer/control Officer in estimating the loads that are expected to exist for one to several days in advance. This function provides a scientific and logical way of scheduling of resources in a very effective manner.

- Under 'Short-term Load Forecasting' function, application software engineers are able to forecast weekly peak demands and load duration curves for several months into the future.
- Under 'Long-Term Load Forecasting' function, forecasting of monthly peak demands and load duration curves for several years into the future can done for the use of 'Power System Planner'.

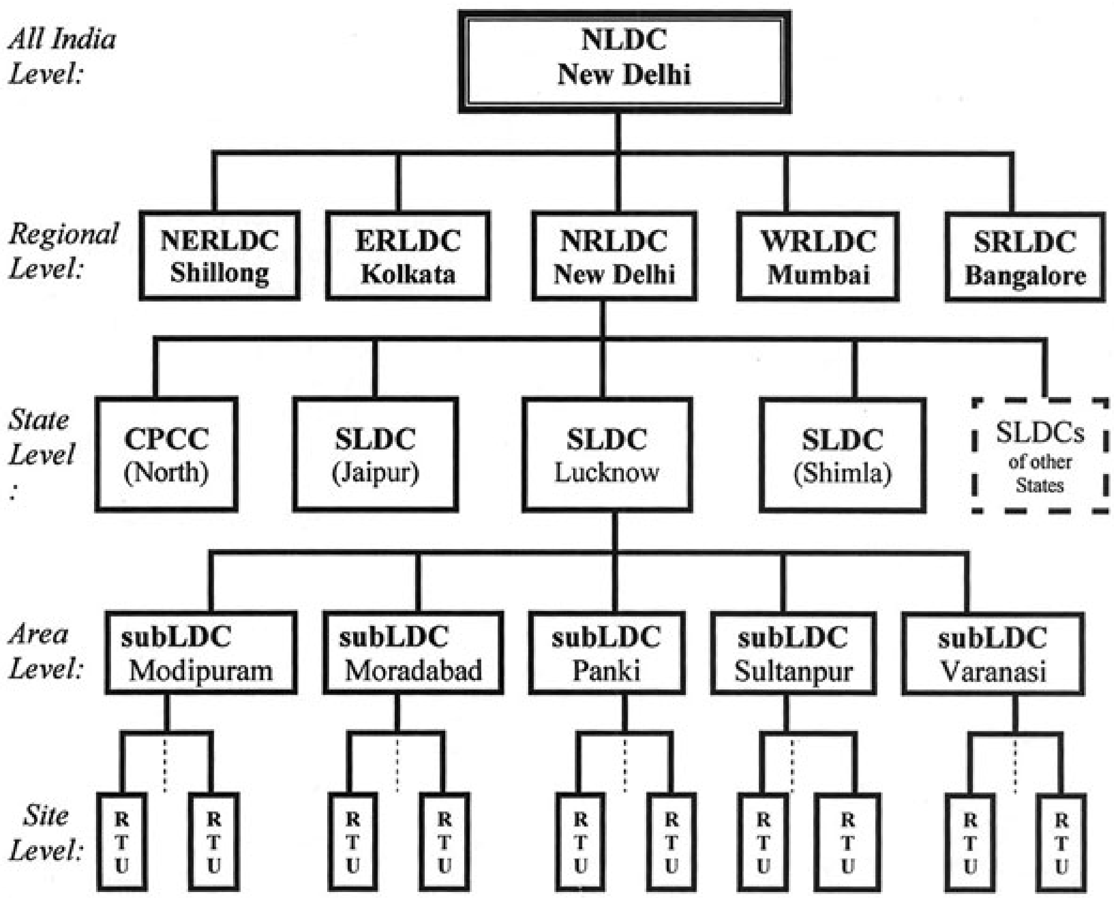
5. The other functions like economic dispatch, reserve monitoring, production costing, inter system transactions scheduling, etc. are available to guide System Control Officer to optimally use available resources.
6. Power System Control Officer/Analyst would be able to use contingency analysis function to assess the impact of specified contingencies that would cause line (s) overloads, abnormal voltages, and reactive limit violations.

7. The EMS software system may have many other applications for use, which include network topology, performing of state estimation, optimal power flow (OPW) programme, stability programme, power flow displays, help and instructional displays, tabular displays, single line diagram displays, etc.

**1.3 <u>LEVEL DECOMPOSITION IN POWER SYSTEM-</u>**

.A hierarchy of Control centers has been formed---

In the diagram National Load Dispatch Centre (NLDC) has been shown at the top. Its Control Centre has been setup at New Delhi and became operational in January 2014. Below this, five nos. regional level Load Dispatch Centers have been shown The role of the NRLDC is to monitor and supervise the grid and power generation of the region. It focuses attention on the regional interconnected network. By using 'Energy Management System' (EMS) and advanced application programmes, NRLDC coordinates with all inter-region and inter-state power exchange.




*Hierarchical Structure of Power System Control Centres*

Below NRLDC, State level SLDCs and Central Project Coordination & Control Centre (CPCC) have been shown. The primary role of SLDCs is to monitor, control and coordinate the generation, transmission and distribution of power within the State while ensuring safety and continuity of its transmission and sub-transmission power networks. CPCC (North) coordinates with all Central sector projects of northern region such as those of NTPC, NHPC, Power Grid, Tehri, etc. CPCC gets data from Central Sector projects and that data is added at regional level. Each RLDC has the ability to exchange data with other RLDCs as well as with NLDC, but direct data transmission does not take place between SLDC of one State with SLDC of another State.

## 1.4 POWER SYSTEM SECURITY –

Power system security is defined as the probability of the system's operating point remaining within acceptable ranges, given the probabilities of changes in the system (contingencies). Normal operating condition usually means that all the apparatus are running within their prescribed limits, and all the system variables are within acceptable ranges. The system should also continue to operate `normally' even in the case of credible contingencies. The operator should `foresee' such contingencies (disturbances) and take preventive control actions (as economically as possible) such that the system integrity and quality of power supply is maintained.

Major components of security assessment:

(1) System monitoring (2) Contingency analysis (3) Preventive and corrective actions

(1) System monitoring: Monitoring the system is the first step. Measurement devices dispersed throughout the system help in getting a picture of the current operating state. The measurements can be in the form of power injections, power flows, voltage, current, status of circuit breakers, switches, transformer taps, generator output etc., which are telemetered to the control centre. Usually a state estimator is used in the control centre to process these telemetered data and compute the best estimates of the system states. Remote control of the circuit breakers, disconnector switches, transformer taps etc. is generally possible.

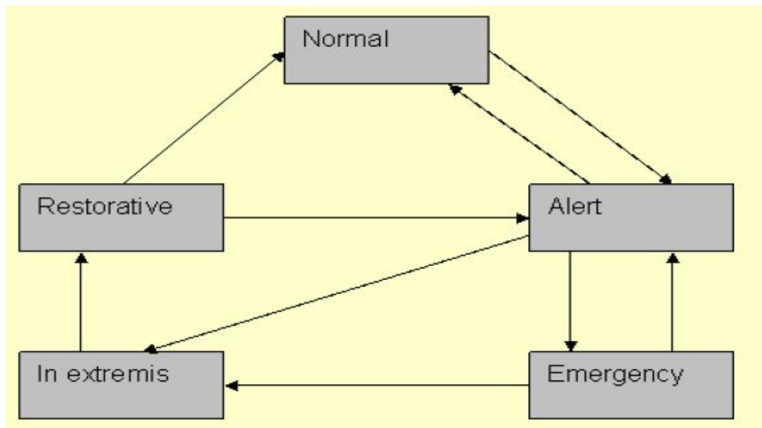
(2) Contingency analysis: Once the current operating state is known, next is the contingency analysis. Results of contingency analysis allow the system to be operated defensively. Major components of contingency analysis are:

Contingency definition, Contingency selection and Contingency evaluation

(3) Preventive and corrective actions: Preventive and corrective actions are needed to maintain a secure operation of a system or to bring it to a secure operating state. Corrective actions such as switching of VAR compensating devices, changing transformer taps and phase shifters etc. are mainly automatic in nature, and involve short duration. Preventive actions such as generation rescheduling involve longer time scales. Security-constrained optimal power flow is an example of rescheduling the generations in the system in order to ensure a secure system operation.

## 1.5 VARIOUS OPERATIONAL STAGES OF POWER SYSTEM—

A *normal* (secure) state is the ideal operating condition, wherein all the equipment are operating within their design limits. Also, the power system can withstand a contingency without violation of any of the constraints. The system is said to be in the *alert* (insecure) state, if voltage and frequency are reaching beyond the specified limits. The system is "weaker" and may not be able to withstand a contingency. Preventive Control actions like shifting generation (re-scheduling), load shedding are required to get the system back to the normal state.




If preventive control actions do not succeed, a power system remains insecure (in the alert state). If a *contingency* occurs, the system may go into the *emergency* state where overloading of equipment (above the short term ratings of the equipment) occurs. The system can still be intact and can be brought back to the alert state by Emergency Control actions like fault tripping, generator tripping, load tripping, HVDC power control etc. If these measures do not work, integrated system operation becomes unviable and a major part of the system may be shutdown due to equipment outages. Load shedding and islanding is necessary to prevent spreading of disturbances and a total grid failure. The small power systems (islands) are reconnected to restore the power system to normal state (Restorative Control).

## 1.6 POWER SYSTEM VOLTAGE STABILITY-

Voltage Instability occurs under heavy loading conditions. This problem causes extremely low voltages below acceptable limits. As the load resistance decreases, the voltage at the load bus falls while power is expected to increase. However, a point comes beyond which the load power decreases as resistance falls.

Normally, a power system has connected loads which are lesser than the maximum power transfer capability of the generation and transmission network. However, loss of lines may significantly increase transmission reactance. Generators may also hit their reactive capability limits resulting in inability to maintain voltage at key points in the network. A stronger transmission network and adequate reactive power reserves, to maintain voltages at key points in the network, are needed to avoid voltage instability.

**Small-disturbance Voltage Stability-**A power system at a given operating state is small-disturbance voltage stable if, following any small disturbance, voltages near loads are close to the pre-disturbance values. The concept of small-disturbance voltage stability is related to steady-state stability and can be analyzed using small signal (linearized) model of the system.

**Voltage Stability-**A power system at a given operating state and subjected to a given disturbance is voltage stable if voltages near loads approach post-disturbance equilibrium values. The concept of voltage stability is related to transient stability of a power system.

**Voltage Collapse-**Following voltage instability, a power system undergoes voltage collapse if the post-disturbance equilibrium voltages near loads are below acceptable limits. Voltage collapse may be total (blackout) or partial. The absence of voltage stability leads to voltage instability and results in progressive decrease of voltages. Thus abnormal voltage levels in steady state may be the result of voltage instability which is a dynamic phenomenon. The voltage instability and collapse may occur in a time frame of fraction of a second. In this case the term 'transient voltage stability' is used.

**Control of Voltage Instability-** Voltage instability along with angle instability pose a threat to the system security. Uncontrolled load rejection due to voltage collapse can cause system separation and blackouts. Hence the system must be planned in such a way as to reduce the possibility of voltage instability. Also the system must be operated with adequate margin for voltage stability. In the event of voltage instability due to unforeseen contingencies, the system - control must prevent widespread voltage collapse and restore the loads as quickly as possible. The incidence of voltage instability increases as the system is operated close to its maximum load stability limit.

Countermeasures for the problem:

(1) The reactive power compensation close to the load centers as well as at the critical buses in the network is essential for overcoming voltage instability.

(2) The SVC and STATCON provide fast control and help improve system stability.

(3) The application of under voltage load shedding, controlled system separation and adaptive Q intelligent control are steps in this direction.

(4) Use of OLTC.