MODULE 1: Introduction

Structure

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Objectives

1. To describe various levels of controls in power systems and the vulnerability of the system.
2. To explain components, architecture and configuration of SCADA.
3. To define unit commitment and explain various constraints in unit commitment and the solution methods.

1.1 Operating States of Power System

The objective of the **control** strategy is to generate and distribute **power** in an interconnected **system** as economically and reliably as possible while maintaining the frequency and voltage within permissible limits. Changes in real **power** mainly affect the **system** frequency.

Table 1.1: Various elements of power system operation and control

	Operation and control action	Time period
1	Relaying execution control, system voltage control	Multi seconds
2	System frequency control tie-line power control	Few seconds to few minutes
3	Economic dispatch	Few minutes to few hours
4	System security analysis	Few minutes to few hours
5	Unit commitment	Few hours to few weeks
6	Maintenance scheduling	One month to one year
7	System planning	One year to 10 years

The system operation is governed by equality and inequality constraints. Equality constraints are power balance between generation and load. Inequality constraints set the limits on different operating parameters such as voltage, generation limits, currents etc.

The system states are classified as:

1. Normal state
2. Alert state
3. Emergency state
4. Extremis state
5. Restorative state

1. **Normal state:**

A system is said to be in normal if both load and operating constraints are satisfied .It is one in which the total demand on the system is met by satisfying all the operating constraints.

2. **Alert state**:

- Ø A normal state of the system said to be in alert state if one or more of the postulated contingency states, consists of the constraint limits violated.
- Ø When the system security level falls below a certain level or the probability of disturbance increases, the system may be in alert state.
- Ø All equalities and inequalities are satisfied, but on the event of a disturbance, the system may not have all the inequality constraints satisfied.
- Ø If severe disturbance occurs, the system will push into emergency state. To bring back the system to secure state, preventive control action is carried out.

3. Emergency state

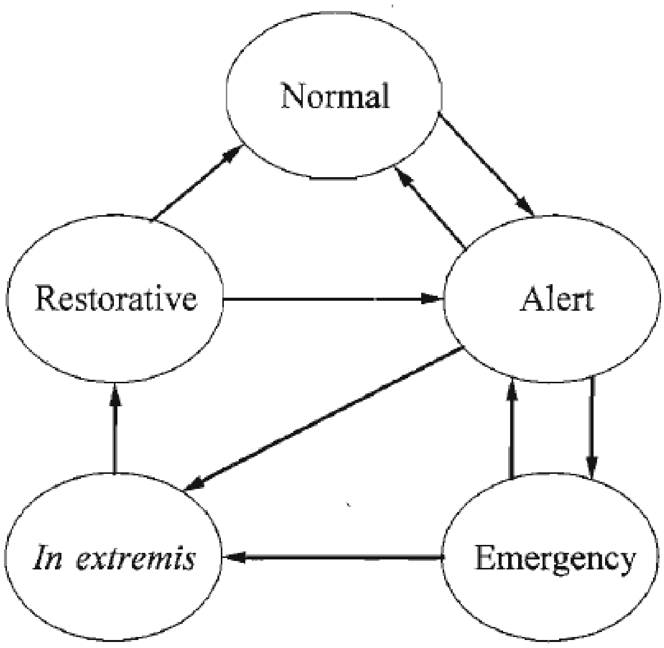
- Ø The system is said to be in emergency state if one or more operating constraints are violated, but the load constraint is satisfied .
- Ø In this state, the equality constraints are unchanged.
- Ø The system will return to the normal or alert state by means of corrective actions, disconnection of faulted section or load sharing.

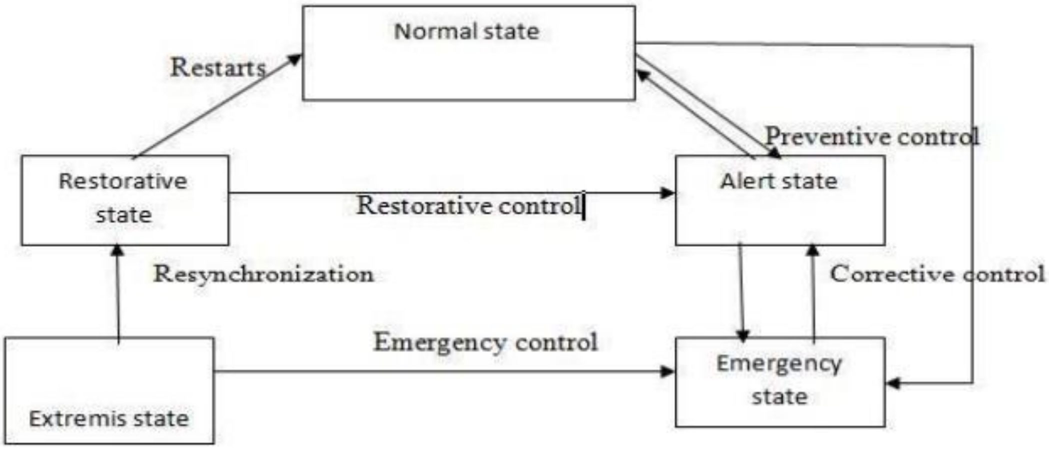
4.Extremis state:

- When the system is in emergency, if no proper corrective action is taken in time, then it goes to either emergency state or extremis state.
- In this regard neither the load or nor the operating constraint is satisfied, this result is islanding.
- Also the generating units are strained beyond their capacity .
- So emergency control action is done to bring back the system state either to the emergency state or normal state.

5. Restorative state:

- From this state, the system may be brought back either to alert state or secure state .The latter is a slow process.
- Hence, in certain cases, first the system is brought back to alert state and then to the secure state .
- This is done using restorative control action.





Operating states

Fig.1.1: Operating states of a power system

1.2 Objectives of Power system Control

1. The system must be able to meet the continually changing load demand for active and reactive power. Unlike other types of energy, electricity cannot be conveniently stored in sufficient quantities. Therefore, adequate "spinning" reserve of active and reactive power should be maintained and appropriately controlled at all times.

2. The system should supply energy at minimum cost and with minimum ecological impact.

3. The "quality" of power supply must meet certain minimum standards with regard to the following factors:

   (a) constancy of frequency;

   (b) constancy of voltage; and

   (c) level of reliability.

Several levels of controls involving a complex array of devices are used to meet the above requirements. These are depicted in Figure 1.2 which identifies the various subsystems of a power system and the associated controls. In this overall structure, there are controllers operating directly on individual system elements. In a generating unit these consist of prime mover controls and excitation controls. The prime mover controls are concerned with speed regulation and control of energy supply system variables such as boiler pressures, temperatures, and flows. The function of the excitation control is to regulate generator voltage and reactive power output. The desired MW outputs of the individual generating units are determined by the system-generation control.

The primary purpose of the system-generation control is to balance the total system generation against system load and losses so that the desired frequency and power interchange with neighbouring systems (tie flows) is maintained.

The transmission controls include power and voltage control devices, such as static var compensators, synchronous condensers, switched capacitors and reactors, tap-changing transformers, phase-shifting transformers, and HVDC transmission controls.

The controls described above contribute to the satisfactory operation of the power system by maintaining system voltages and frequency and other system variables within their acceptable limits. They also have a profound effect on the dynamic performance of the power system and on its ability to cope with disturbances.

The control objectives are dependent on the operating state of the power system. Under normal conditions, the control objective is to operate as efficiently as possible with voltages and frequency close to nominal values. When an abnormal condition develops, new objectives must be met to restore the system to normal operation.

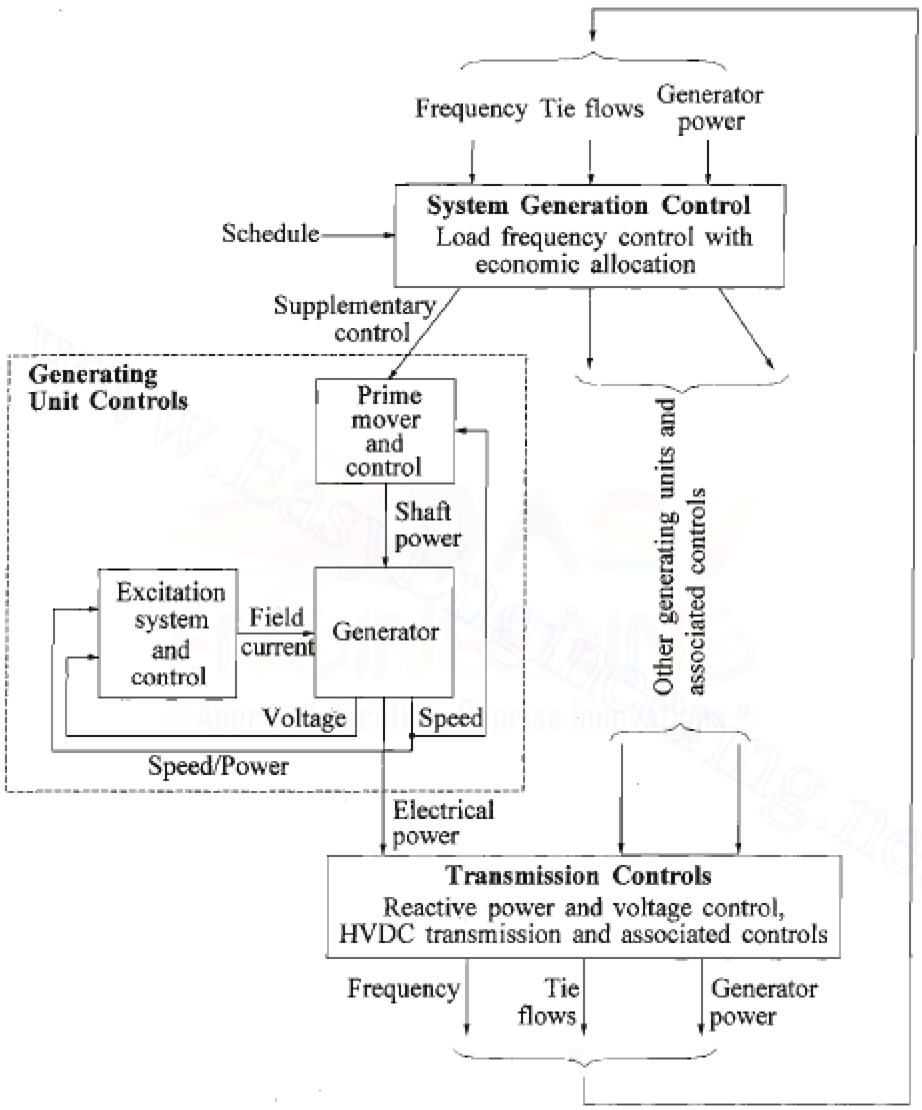


Fig.1.2: Various Controls in a power system

1.3 Key Concepts for Reliable Operation, Preventive and Emergency Controls

1. .

1.4 Energy Management Centres.

Electrical energy management systems (EMS) are an important function for the reliable and efficient operation of power systems. EMS is related to the real time monitoring, operation and control of a power system. The information from the power system is read through Remote Terminal Units (RTUs), an integral part of SCADA to an EMS or Energy Control Centre (ECC).

1. EMS consists of both hardware and software. Hardware part of EMS consists of RTU, Intelligent Electronic Device (IED), Protection, Computer networking, .etc. Software part of EMS consists of Application programs for network analysis of power systems.

2. In EMS, application programs are run in a real time as well as extended real time environment to keep the power system in a secure operating state.

3. **EMS is an integral part of any power system**. It is used as a part of Substation Automation System (SAS), Demand Side Management (DSM), Protection, and Distribution Management Systems (DMS) for renewable energy and so-on.

4. An energy management system (EMS) is a system of computer-aided tools used by operators of electric utility grids to monitor, control, and optimize the performance of the generation and/or transmission system. The monitor and control functions are known as Supervisory Control and Data Acquisition (SCADA), followed by several on-line application functions.

5. A.Primary Objectives: Security and Stability of the system
   B.Secondary Objectives: Economic Operation and Control
   C.Tertiary Objectives: Optimization, Operational Planning and Maintenance Scheduling

1.4.1 Primary Objectives:

1. Maintaining the power system in a secure and stable operating state by continuously monitoring the power flowing in the lines and voltage magnitudes at the buses.

2. Maintaining the frequency within allowable limits.

3. Maintaining the tie-line power close to the scheduled values.

1.4.2 Secondary Objectives:

1. Economic Operation of the power systems through real time dispatch and Control.

2. Optimal control of the power system using both preventive and corrective control actions.

3. Real time Economic Dispatch through real power and reactive power control

1.4.3 Tertiary Objectives:

1. Optimization of the power system for normal and abnormal operating scenarios.

2. Optimal control of the power system by appropriate using both preventive and corrective control actions

3. Maintenance scheduling of generation and transmission systems.

1.5 Supervisory Control and Data acquisition (SCADA): Introduction to SCADA and its Components, Standard SCADA Configurations

1.5.1 Introduction

SCADA is an acronym that stands for Supervisory Control and Data Acquisition. SCADA refers to a system that collects data from various sensors at a factory, plant or in other remote locations and then sends this data to a central computer which then manages and controls the data. SCADA systems are used not only in industrial processes: e.g. steel making, power generation (conventional and nuclear) and distribution, chemistry, but also in some experimental facilities such as nuclear fusion.

The size of such plants range from a few 1000 to several 10 thousands input/output (I/O) channels.

Definition of SCADA: A collection of equipment that will provide an operator at remote location with enough information to determine the status of a particular piece of a equipment or entire substation and cause actions to take place regarding the equipment or network.

- What is SCADA? How : By collecting Information from plant / Load centre bend reducing it to the EMS
- Where : Control Centre. Both at Plant and Load

- Why : To gather Information as here (voltage, current, frequency, power, circuit breaker status) and To perform online actions

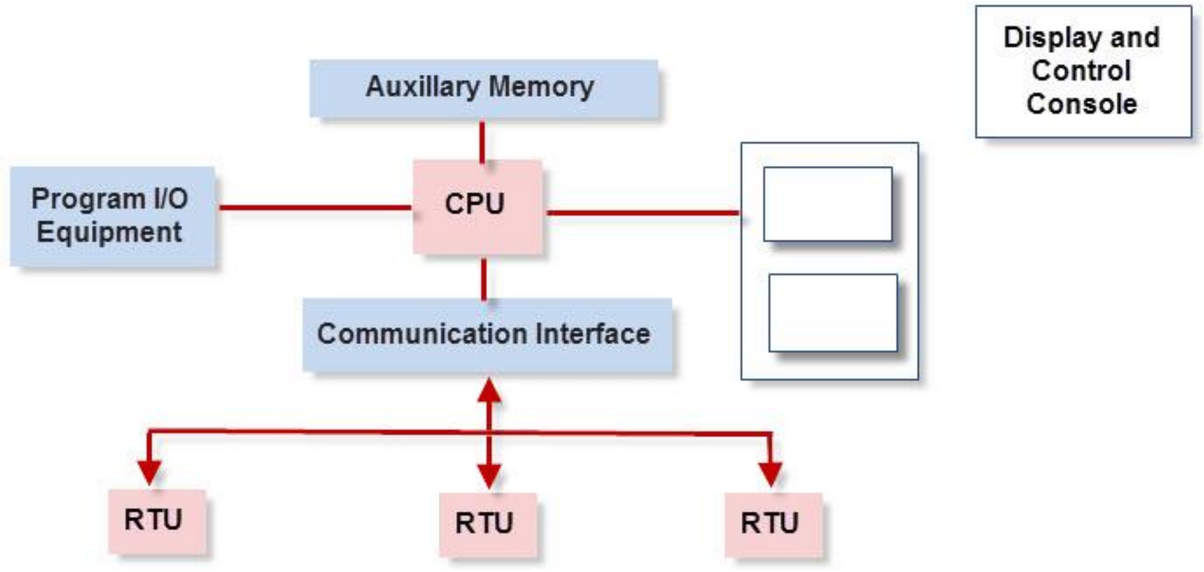


Fig.1.3: Functional Units

The figure shown above is a simple SCADA system with a single computer, which represents the simplest configuration of SCADA with a single computer. The computer receives data from remote terminal units through the communication interface. One or more CRT terminals for display is controlled by operators. With this system, it is possible to execute supervisory control commands and request the display of data in alphanumerical formats.

The I/O SCADA programming is used to change the supervisory software. In the basic SCADA system, all the data and programs are stored in the main memory. The more complicated version of SCADA has additional secondary memories in the form of magnetic disc units.

1.6 Users of Power Systems SCADA, Remote Terminal Unit for Power System SCADA

1.6.1 Users of Power Systems SCADA

SCADA can be used to manage any kind of equipment. Typically, SCADA systems are used to automate complex industrial processes where human control is difficult. For example in systems where there are more control factors unable to be managed by operators in a control centre. SCADA systems are widely used for control in the following domains

1. Electric power generation, transmission and distribution: Electric utilities use SCADA systems to detect current flow and line voltage, to monitor the operation of circuit breakers, and to take sections of the power grid online or offline.

2. Water and sewage: State and municipal water utilities use SCADA to monitor and regulate water flow, reservoir levels, pipe pressure and other factors.

3. Buildings, facilities and environments: Facility managers use SCADA to control HVAC, refrigeration units, lighting and entry systems.

4. Manufacturing: SCADA systems manage parts inventories for just-in-time manufacturing, regulate industrial automation and robots, and monitor process and quality control.

5. Mass transit: Transit authorities use SCADA to regulate electricity to subways, trams and trolley buses; to automate traffic signals for rail systems; to track and locate trains and buses; and to control railroad crossing gates.

6. Traffic signals: SCADA regulates traffic lights, controls traffic flow and detects out-of-order signals.

1.6.2 Remote Terminal Unit for Power System SCADA

A **remote terminal unit** (**RTU**) is a microprocessor-controlled electronic device that interfaces objects in the physical world to a distributed control system or SCADA (supervisory control and data acquisition) system by transmitting telemetry data to a master system, and by using messages from the master supervisory system to control connected objects.[1] Other terms that may be used for RTU are **remote telemetry unit** and **remote telecontrol unit**.

1.6.2.1 Architecture

An RTU monitors the field digital and analog parameters and transmits data to the Central Monitoring Station. It contains setup software to connect data input streams to data output streams, define communication protocols, and troubleshoot installation problems.

An RTU may consist of one complex circuit card consisting of various sections needed to do a custom fitted function or may consist of many circuit cards including CPU or processing with communications interface(s), and one or more of the following: (AI) analog input, (DI) digital (status) input, (DO/CO) digital (or control relay) output, or (AO) analog output card(s).

a) Power supply

A form of power supply will be included for operation from the AC mains for various CPU, status wetting voltages and other interface cards. This may consist of AC to DC converters where operated from a station battery system.

RTUs may include a battery and charger circuitry to continue operation in event of AC power failure for critical applications where a station battery is not available.

b) Digital (status) inputs

Most RTUs incorporate an input section or input status cards to acquire two state real world information. This is usually accomplished by using an isolated voltage or current source to sense the position of a remote contact (open or closed) at the RTU site. This contact position may represent many different devices, including electrical breakers, liquid valve positions, alarm conditions, and mechanical positions of devices. Counter inputs are optional.

c) **Analog inputs**

A RTU can monitor analog inputs of different types including 0-1 mA, 4–20 mA current loop, 0–10 V., ±2.5 V, ±5.0 V etc. Many RTU inputs buffer larger quantities via transducers to convert and isolate real world quantities from sensitive RTU input levels. An RTU can also receive analog data via a communication system from a master or IED (intelligent electronic device) sending data values to it.

The RTU or host system translates and scales this raw data into the appropriate units such as quantity of water left, temperature degrees, or Megawatts, before presenting the data to the user via the human–machine interface.

d) Digital (control relay) outputs

RTUs may drive high current capacity relays to a digital output (or "DO") board to switch power on and off to devices in the field. The DO board switches voltage to the coil in the relay, which closes the high current contacts, which completes the power circuit to the device.

RTU outputs may also consist of driving a sensitive logic input on an electronic PLC, or other electronic device using a sensitive 5 V input.

e) Analog outputs

While not as commonly used, analog outputs may be included to control devices that require varying quantities, such as graphic recording instruments (strip charts). Summed or processed data quantities may be generated in a master SCADA system and output for display locally or remotely, wherever needed.

e) Software and logic control

Modern RTUs are usually capable of executing simple programs autonomously without involving the host computers of the DCS or SCADA system to simplify deployment and to provide redundancy for safety reasons. An RTU in a modern water management system will typically have code to modify its behavior when physical override switches on the RTU are toggled during maintenance by maintenance personnel. This is done for safety reasons; a miscommunication between the system operators and the maintenance personnel could cause system operators to mistakenly enable power to a water pump when it is being replaced, for example.

Maintenance personnel should have any equipment they are working on disconnected from power and locked to prevent damage and/or injury.

f) Communications

A RTU may be interfaced to multiple master stations and IEDs (Intelligent Electronic Device) with different communication media (usually serial (RS232, RS485, RS422) or Ethernet).