Computer control of Power Systems
ENERGY CONTROL CENTERS

Today’s power systems are very huge in terms of Installed capacity, Energy generated, Transmission and Distribution system, Number of customers and Total investment. Installed capacity in India exceeds 206 GW with annual energy generated energy exceeding 1000 Billion KWh (1000 x 10^{12} KWh). The power system feeds a very large number of domestic, commercial, industrial, agriculture and other customers. Operation and control of such a big interconnected power system is really challenging task and it cannot be done manually. Therefore **power systems are controlled by using powerful computers installed at Energy Control Centers.**

The various functions of an energy control center can be enumerated as under:

1. Load forecasting
2. Planning studies
3. System monitoring
4. State estimation
5. Unit commitment and economic dispatch
6. Automatic generation control
7. Reactive power management
8. Security control
9. System maintenance
LEVELS OF POWER SYSTEM OPERATION AND CONTROL

The total power system in India is not being operated in totally integrated manner. However, attempts are being made to achieve full integration.

National Load Dispatching Center, having headquarters at New Delhi, is the coordinating agency.

There are FIVE Regional Loading Dispatching Centers as described below.

1. **Northern region** load dispatching center at New Delhi covering states of HP, J and K, Haryana, Punjab, Rajasthan, UP, Delhi, Uttaranchal and Chandigarh.

2. **Western region** load dispatching center at Mumbai covering Gujarat, MP, Maharashtra, Chhattisgarh, Goa, Daman Diu, Dadra and Nagar Haveli.

3. **Southern region** load dispatching center at Bangalore covering AP, Karnataka, Tamil Nadu, Kerala, Pondicherry and Lakshadweep.
4. **Eastern region** load dispatching center at Kolkata covering WB, Bihar, Orissa, Sikkim and Jharkhand.

5. **North eastern** load dispatching center at Shillong covering Assam, Manipur, Meghalaya, Nagaland, Tripura, Arunachal Pradesh and Mizoram.

Installed capacity in different regions are as follows:

<table>
<thead>
<tr>
<th>Region</th>
<th>Capacity (GW)</th>
</tr>
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<tbody>
<tr>
<td>Northern</td>
<td>56.1</td>
</tr>
<tr>
<td>Western</td>
<td>67.6</td>
</tr>
<tr>
<td>Southern</td>
<td>53.3</td>
</tr>
<tr>
<td>Eastern</td>
<td>26.8</td>
</tr>
<tr>
<td>North eastern</td>
<td>2.4</td>
</tr>
</tbody>
</table>

The third level of consists of state load dispatching stations in each state capital.
SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM (SCADA)

Proper and efficient energy management system requires lot of data about the operating conditions. Further, many control actions are to be carried out at far off places. Executing such control actions manually will cause time delays resulting long outage duration and poor reliability. SCADA systems have been developed to overcome such problems. The following are the some of the main functions of SCADA.

i) *Data Acquisition:* To provide data, measurements and status information to the operator.

ii) *Automatic generation control:* To control the generations at the power plants.

iii) *Load Shedding:* To make automatic load shedding in emergent conditions to avoid system collapsing.

iv) *Load Restoration:* To restore the loads in steps to bring the system to normal state.

v) *Supervisory Control:* To operate the circuit breaker remotely.
vi) *Logging*: To log all data and information in a systematic manner.

vii) *Alarms*: To send alarm signals in case of undesirable operating conditions

To fulfill the above operations SCADA has the following components.

**Sensors and Control Relays**: Analog and digital sensors along with control relays which can interface with the system.

**Remote Terminal Units (RTU)**: RTUs are microprocessor controlled electronic devices deployed in field at specific sites and locations. They collect necessary data and transmit them to SCADA for processing.

**Master Unit**: Large computer system which serves as a central processor.

**Communication Links**: Fiber optic / satellite / microwave communications are employed to link RTUs with SCADA.

**Necessary Softwares**: To execute different operational problems
Figure 1 shows the layout of a typical SCADA system.
OPERATING STATES OF POWER SYSTEM

For purpose of analyzing power system security and designing appropriate control systems, it is helpful to conceptually classify the system operating conditions into the following five states.

Normal, Alert, Emergency, In extremis (or extreme emergency) and Restorative. Figure 2 depicts these operating states and the ways in which transition can take place from one state to another.

![Diagram of power system operating states](image-url)
NORMAL STATE:

In the **normal state**, all system variables are within the normal range and no component is being overloaded. The system operates in a secure manner and is able to withstand a contingency without violating any of the constraints.

ALERT STATE:

The system enters the **alert state** if the security level falls below a certain limit of adequacy, or if the possibility of disturbance increases because of adverse weather conditions such as the approach of severe storms. In this state, **all the system variables are still within the acceptable range and all the constraints are satisfied**. However, the system has been weakened to a level where a contingency may cause an overloading of a component that places the system in an emergency state. If the disturbance is very severe, the **in extremis state** may result directly from the alert state.
EMERGENCY STATE:

The system enters the emergency state, if a sufficiently severe disturbance occurs when the system is in the alert state. In this state, voltages at many buses are low and/or component loadings exceed the short-term emergency ratings. The system is still intact and may be restored to the alert state by initiating emergency control actions such as fault clearing, excitation control, fast-valving and load curtailment. If the above measures are not applied or are ineffective, the system will move to in extremis state.
IN EXTREMIS STATE:

If the control action taken during the emergency state is insufficient, then the system enters into in extremis state. The result is cascading outages and possibly a shut-down of major portion of the system. Control actions, such as load shedding and controlled system separation, are aimed at saving as much system as possible from a widespread blackout.

RESTORATIVE STATE:

Preventive action, such as generation shifting or increased reserve, can be taken to restore the system to the normal state. If the restorative steps do not succeed fully, the system will move into the alert state.

In case the control action taken are effective, the system moves to restorative state in which further action is being taken to reconnect all the facilities and to restore the system load. The system transits from the restorative state to either alert state or normal state, depending on the system conditions.
CONTROL STRATEGIES

The control strategies which are to be adopted when the system is not in normal state can be summarized as under.

Alert State: Preventive control to restore adequate spinning reserve, generation shifting, tie-line rescheduling and voltage reduction (if extremely needed)

Emergency State: Immediate control to clear component overload, fast-valving, exciter control, load control, capacitor switching and all controls mentioned in alert state.

In extremis State: Heroic action to control disruption of entire system, load shedding, controlled islanding and all controls mentioned in emergency state.

Restorative State: Corrective control to re-establish viable system, generator units restarting and synchronization, load restoration, re-synchronization of different islands and areas.