The operation of EMS is based on the working of the operating states. The power system operates in two important areas, namely normal and abnormal states.

### Operating States of a Power System:

- Normal operating state
- Abnormal operating state
- Restorative state

#### Normal or secure state
In the normal operating state, the system is said to be secure and all constraints like voltages at nodes, real and reactive power generation, real and reactive power flows are satisfied. The aim of the power system is to keep the operating state of the power system to lie in the normal state. Even though this is a stable operating state, any slight disturbance will take it to the abnormal state.

#### Abnormal or insecure state:
In the event of a disturbance, like generator outage or line outage, the operating conditions change and the variables like nodes voltages and powers (real and reactive); real and reactive power flows violate the operating limits or constraints.

The abnormal state or insecure state is further classified in to the following states;
- alert
- emergency
- in-extermis (or islanding)

#### Restorative state:
The power system disturbance, based on its nature, can lead the power systems to a blackout or brownout state. In the blackout state, the entire load is separated from the generators, through
either the tripping of the generators or the transmission lines. No load is supplied. In the brownout state, partial load is supplied through the transmission network. The blackout state is more severe than the brownout state and requires several stages for restoring in back to the normal operating state.

After the disturbance has occurred, the operator in an EMS tries to bring back the power system to normal operating state through measures known as restorative strategies. In this process the generators and lines which have tripped will be bought back to service through a sequence of steps known as restorative measures.

![Operating States of Power systems](image)

(a) connectivity of operating states
(b) Constraints in Operating States

<table>
<thead>
<tr>
<th>No</th>
<th>Operating State</th>
<th>Equality Constraint</th>
<th>Inequality Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal</td>
<td>[E]</td>
<td>[I]</td>
</tr>
<tr>
<td>2</td>
<td>Alert</td>
<td>[E]</td>
<td>[I]</td>
</tr>
<tr>
<td>3</td>
<td>Emergency</td>
<td>[E]</td>
<td>[I]</td>
</tr>
<tr>
<td>4</td>
<td>In-Extremis</td>
<td>[E]</td>
<td>[I]</td>
</tr>
<tr>
<td>5</td>
<td>Restorative</td>
<td>[E]</td>
<td>[I]</td>
</tr>
</tbody>
</table>

Figure 3.1 Various operating States of a power system

Figure 3.1(a) shows the various operating states of a power system. Fig 3.1 b shows the equality (EQ) and inequality (INEQ) operating states during the different operating states. The working of figure 3.1(a) can be described as following.

a. **Normal**: All constraints (EQ and INEQ) are satisfied, but enough power generation reserve is available. In case of any generator outage, the reserve from other generators can supply the load without any interruption.
b. **Alert**: All constraints (EQ and INEQ) are satisfied, but reserve power generation is zero. As a result, in the event of a loss of generator, the remaining generators cannot supply the load, load shedding as to be resorted to. The operator in an EMS monitors this situation continuously so as to take effective decision for preventing the power system from going into emergency or islanding mode. The power system can be bought back to the normal state through preventive control actions.

c. **Emergency**: In this state, the equality constraint if violated, while the inequality constraint is satisfied. Corrective control is used to bring the system back to normal operating state directly or through alter state.

d. **In-extermis or islanding**: In this state the power system enters in to an islanded mode of operation, where both EQ and INEQ states are violated. Once the system comes to this state it cannot go back to the emergency mode. In this state the large power system is separated into small areas or islands, where the loads are supplied from local generations. All the tie lines connecting the areas are open and they work in an independent mode of operation. System reliability is more important in this stage than economic operation.

e. **Restorative Mode**: In this mode the, the power system has to be restored through several steps by switching generators and transmission lines. This is a difficult task and requires strategies for bringing on the generator and synchronizing it to the grid. Improper sequence will cause tripping.
Figure 3.3 shows the various forward and feedback control between operating states of the system. The transition between various operating states is provided. The mathematical formulation in terms of equality constraints $h(x,u)=0$ and inequality constraints $g(x,u)\leq 0$. The various feedback control functions like preventive control, corrective control, emergency control and restorative control can be observed. The satisfaction and violation of the each of the equality constraints $h(x,u)=0$ and inequality constraints $g(x,u)\leq 0$ can be inferred from this diagram.

**Summary:**
This section describes the various operating states of a power system and other functions which use these modules.