Operation of Electric Power Systems

Chapter 1: Overview of technical and economic operation of PS (Part III c&d-Networks & e-Control)

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Basic technical characteristics and functions

Content

• Part I: Introduction and basic concepts
  • The role of electric power systems in economy
  • The need to transport the electricity: a global perspective
  • The particular characteristics of electricity
  • Activities involved by the electricity sector

• Part II: Historic evolution
  • Historic evolution of technical aspects and demand
  • How can be the sector organized?

• Part III: Basic characteristics and technical aspects
  a) Consumption
  b) Generation
  c) Transmission
  d) Distribution
  e) Control and protection of power systems

• Part IV: Two management paradigms
Technical aspects

Transmission

• Connects generation with consumption centers
  • Different geographical determining factors for G & D
  • This is carried out in high voltage
    • Lower intensity means lower losses

• If transmission capacity is not binding (high enough) the dispatch simplifies
  • As if G & D located in the same node
    • Ignoring the effect of losses
    • Demand could be supplied by the lower cost gen
  • But we will see that this is not always the case

• The role of transmission in the market context is fundamental
Technical aspects
Transmission

• Transmission lines are usually meshed
  • 😊 Increases reliability & reduces local reserve margins
  • 😊 Allows a more efficient short-term dispatch
    • System ≈ Single node
  • 😞 Increases the short-circuit power
Technical aspects
Transmission

• Interconnecting with neighboring system
  • 🎉 Increases reliability and reduces reserve margin
  • 😊 Complementarities among technologies
    • Wind and solar are more predictable over large areas
    • Draught periods differ
  • 😊 Demand profiles
    • Peak demand

Source: wikipedia
Technical aspects
Transmission

• Overhead double circuit line

Inductance depends on phases’ position relative to the tower.
During the day lines are inductive, during the night capacitive.

- The higher the section
  - Higher intensity allowed
  - Higher strength but higher weight
  - Duplex: reduces the crown effect

Ground cable (cable de guarda)
Conductors (dúplex)
Insulators (aisladores)
Tower (torre)

Security distance criteria
Technical aspects
Transmission

• Overhead double circuit line
Technical aspects

Transmission: maintenance

Source: Ricardo Reinoso, 2014, “Inspección y Mantenimiento de líneas de alta tensión mediante SARP”, REE
Transmission

The transmission in Spain

Source: www.unesa.net and www.ree.es
HV transmission 42.986 km  
84,544 MVA transformation cap. Year 2015.

### Red de transporte peninsular y no peninsular

<table>
<thead>
<tr>
<th>Km de circuito</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 - 132 - 110kV</td>
<td>272</td>
<td>272</td>
<td>272</td>
<td>272</td>
<td>398</td>
</tr>
<tr>
<td>&lt; 110kV</td>
<td>2.011</td>
<td>2.014</td>
<td>2.014</td>
<td>2.014</td>
<td>2.022</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>40.364</td>
<td>41.174</td>
<td>41.978</td>
<td>42.572</td>
<td>42.986</td>
</tr>
</tbody>
</table>

### Posiciones de subestaciones peninsulares y no peninsulares

<table>
<thead>
<tr>
<th>Número de posiciones</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>400kV</td>
<td>1.253</td>
<td>1.319</td>
<td>1.374</td>
<td>1.394</td>
<td>1.441</td>
</tr>
<tr>
<td>220kV</td>
<td>2.813</td>
<td>2.936</td>
<td>3.026</td>
<td>3.077</td>
<td>3.124</td>
</tr>
<tr>
<td>150 - 132 - 110kV</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>84</td>
</tr>
<tr>
<td>&lt; 110 kV</td>
<td>743</td>
<td>743</td>
<td>745</td>
<td>769</td>
<td>779</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4.861</td>
<td>5.050</td>
<td>5.197</td>
<td>5.292</td>
<td>5.428</td>
</tr>
</tbody>
</table>

### Capacidad de transformación peninsular y no peninsular

<table>
<thead>
<tr>
<th>Potencia (MVA)</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>72.869</td>
<td>78.629</td>
<td>81.289</td>
<td>83.939</td>
<td>84.544</td>
</tr>
</tbody>
</table>

Source: [http://www.ree.es/es/actividades/gestor-de-la-red-y-transportista](http://www.ree.es/es/actividades/gestor-de-la-red-y-transportista)
Substations

• Three chief purposes
  • Line interconnection buses
  • Transformation nodes that feed the distribution grids that reach consumers
  • Centers where system measurement, protection, interruption and dispatch equipment is sited.
Technical aspects
Transmission
Technical aspects
Transmission
Technical aspects
Transmission

Instalaciones de maniobra blindadas y aisladas con SF$_6$ para altas tensiones hasta 765 kV
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Technical aspects
Structure of the distribution network
Centros de transformación: potencias

CT con alimentación en bucle

MT   BT

20 kV / 380 V

En poste (rurales): 25, 50, 100, 160 kVA

En caseta: 50, 100, 160, 250, 400, 630, 1000 kVA

Source: wikipedia
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Technical aspects
Control of power systems
Technical aspects
Control of power systems

Primary control (frequency)

• Type of control
  • Local and automatic
  • In seconds (2 – 20)
    • Acts directly over the turbine

• What for?
  • Reestablishes the generation demand balance
    • But at a frequency different to the nominal value

• Essential technical requirements
  • Need for upward and downward reserves, known as “Frequency Containment Reserve”
Secondary control (frequency)

• Type of control
  • Centralized evaluation & communication (AGC)
    • Automatic or manual
  • From seconds (10 – 20) to minutes (15 – 20)

• What for?
  • Restores frequency, cross-border exchanges (fundamental when interconnections) and primary reserve

• Need for upward and downward reserves, known as “Frequency Restoration Reserves” in the EU
Tertiary control (frequency)

• Type of control
  • Centralized evaluation
  • Minutes (>15)
  • Manual

• What for?
  • Replaces secondary reserves

• Spining reserve or fast start units. Known as “Replacement Reserves” in the EU
Technical aspects

Protections

• Equipment is protected with systems that prevent potential damage in case of a fault
  • In generators: the AC generator, pumps, turbines and all other vital components
  • Substations

• The protection relays must detect and locate faults, the automatic circuit-breakers clear them and the disconnectors isolate the failure

• Protection relays must be sensitive enough to detect the fault, selective to minimize the impact of clearance