Seminar on
African Electrical Interconnection

Module 8 - Interconnected Systems Operating Conditions
Module 8 - Interconnected Systems
Operating Conditions

Contents

1) Technical Operating Agreements
2) Frequency Control
3) Generation Operating Reserve
4) Generation Controls
5) Conditions for a Secure Operation
6) Organizing the Operation
Module 8 - Interconnected Systems Operating Conditions

**Highlights**

- Importance of a *proper frequency control approach*, well adapted to the nature of the interconnected power systems
- Necessity of a sufficient *well controlled generation reserve capacity*
- Imperative need for a *comprehensive defense plan*
- Strategic importance of carefully *planning and organizing all aspects of operation*
  - Need for harmonized National Grid Codes
Module 8 - Interconnected Systems Operating Conditions

Contents

1) Technical Operating Agreements
2) Frequency Control
3) Generation Operating Reserve
4) Generation Controls
5) Conditions for a Secure Operation
6) Organizing the Operation
Technical Operating Agreements

Coordination of planning and operation of generating and transmission facilities

- Technical rules to obey for the operation of the interconnected grid
  - Secure and adequate operation

- National Grid Codes
  - Regional agreements
  - Agreements on specific tie-lines
  - Agreements on specific generators or customers

Secure and adequate operation
National Grid Codes

Generators
Transmission assets owners
Transmission assets operators
Major industrial customers

Subject to an agreement between all interconnected systems operators
Could be replaced by a Regional Grid Code

DETAILED TECHNICAL REQUIREMENTS

Harmonized on a regional basis

<table>
<thead>
<tr>
<th>GRID CODE</th>
<th>GRID CODE</th>
<th>GRID CODE</th>
</tr>
</thead>
</table>

Control area 1
Control area 2
Control area 3

Generators
Transmission assets owners
Transmission assets operators
Major industrial customers

Responsible for reliable operation within the area

Generators
Transmission assets owners
Transmission assets operators
Major industrial customers
Main Grid Codes Items

- Generation operating reserve
- Generation controls
  - Transmission system operating criteria
- Voltage control
- Equipment connection requirements
- Operation organization and planning
  - Information sharing
  - Power exchange schedules
  - Maintenance coordination
  - Emergency operations
  - Power system restoration
  - Operating personnel training
Module 8 - Interconnected Systems
Operating Conditions

Contents

1) Technical Operating Agreements
2) Frequency Control
3) Generation Operating Reserve
4) Generation Controls
5) Conditions for a Secure Operation
6) Organizing the Operation
Frequency Control

A specific requirement with interconnected power systems

- To properly address the impact of the overall frequency control method on interconnection links having a limited capacity

Control method dependent on either:
- Frequency deviation
  - Flat frequency control (FFC), or
- Power flow deviation on interconnection lines
  - Flat tie-line control (FTC), or
- Both frequency and power flow on interconnection lines deviations
  - Tie-line load frequency bias control (TBC)
Frequency Control Strategy

**FFC**
To avoid an overall frequency control error on the interconnected grid

**TBC**
- To control load imbalance
- To control load imbalance
- Preventing large power transfers across the grid
- Reducing the risk of system instability
- Sufficient generation reserve capacity
Module 8 - Interconnected Systems Operating Conditions

Contents

1) Technical Operating Agreements
2) Frequency Control
3) Generation Operating Reserve
4) Generation Controls
5) Conditions for a Secure Operation
6) Organizing the Operation
Generation Operating Reserve

- Available in sufficient quantity within each control area to cover local imbalances
  - To minimize the impact on other control areas

- Amount required should be specified in the regional operating requirements
  - Control performance criteria, for instance:
    - To return to pre-disturbance conditions within 10 minutes
    - To take proper measures to be ready for a next contingency
Types of Operating Reserve

Generating capacity in excess of demand to cover load demand variations and forced outages

Categorization based either on:

- **Functions:** Regulating and contingency, or Primary and secondary controls
- **Operating characteristics:** Spinning and non-spinning

**Most significant feature:** Response time

- Immediately available
- Available with some delay
Regulating-Contingency Reserve

Synchronized and immediately responsive to Automatic Generation Control

Spinning

To maintain nominal frequency in the event of a mismatch between generation and load

Slowly evolving normal operating conditions

Contingency

Sudden disturbances and unforeseen events

Non-spinning

Not synchronized but available within a short time delay

The largest loss of generation resulting from a credible single contingency (N-1 criterion)

Regulating RESERVE

To cover forced outages (generation or transmission) and uncertainties

Reduced availability of hydroelectric resources

Errors in load forecasting

Reduced availability of hydroelectric resources
Module 8 - Interconnected Systems Operating Conditions

Contents

1) Technical Operating Agreements
2) Frequency Control
3) Generation Operating Reserve
4) Generation Controls
5) Conditions for a Secure Operation
6) Organizing the Operation
Generation Controls

Designed to maintain nominal frequency in spite of the continuous variation of the load demand

- Closely related to
  - Operating reserve requirements (spinning)
  - Characteristics of load demand variations

- Speed-governor control
- Automatic Generation Control (AGC)
Generation Controls

Speed-governor control
Fast variations with a cycle of less than one minute
- May have a significant impact on generator stability
- May interact with the voltage regulator
  - Especially important when designing a PSS for a fast-action excitation system

Automatic Generation Control (AGC)
Variations with a cycle of a few minutes
- Final adjustment of frequency
- Re-balance generation
An Example of Control Strategy

As applied in Europe by the Union for the Coordination of Transmission of Electricity (UCTE)

- In proportion to its share of the total generated power on the interconnected grid
- Takeover from the primary control
  - Maintain scheduled power exchanges
  - Restore the frequency to nominal value
- Each control area must contribute
  - Only in the control area responsible for the imbalance

- Power imbalance
- 30 seconds
- Primary control
- 15 minutes maximum
- Secondary control

- Takeover from the primary control
  - Maintain scheduled power exchanges
  - Restore the frequency to nominal value
Primary Control Response

Deployment of the primary control reserve on the UCTE interconnected grid

3000 MW total available

<table>
<thead>
<tr>
<th>Seconds</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>1000</td>
</tr>
<tr>
<td>20</td>
<td>2000</td>
</tr>
<tr>
<td>30</td>
<td>3000</td>
</tr>
</tbody>
</table>
Module 8 - Interconnected Systems
Operating Conditions

Contents

1) Technical Operating Agreements
2) Frequency Control
3) Generation Operating Reserve
4) Generation Controls
5) Conditions for a Secure Operation
6) Organizing the Operation
Conditions for a Secure Operation

Determining safe operating conditions

Implementing safe operating conditions

System-wide defense plan

Determining safe operating conditions
Determining safe operating conditions

To analyze all foreseeable operating conditions
More comprehensive than the “limited” number of simulation studies in the planning stage

In view of the performance requirements to be met as previously assumed in the system planning studies

Basic design criteria (N-1 and N-2)

Overload of equipment across the interconnected grid

Instability
Uncontrolled separation
Voltage collapse

Extensive power system simulation studies
Implementing safe operating conditions

Specific, comprehensive and detailed power transfer limits

Maintain power transfers within well identified safe limits
Maintain adequate voltage and provide necessary reactive power

Strict operating rules

Within each control area
Strict operating rules

Determined by an RTO or through coordination between control areas

Respecting power interchanges within specified limits
System-wide Defense Plan

- Strategically very important
  - To prevent
  - To mitigate the effects

"Catastrophic" events

- System-wide blackout
- Severe damage to the equipment

Provides coverage beyond the basic design criteria requirements *(rare but very severe contingencies)*

- Loosing a whole substation
- Tripping of all transmission lines in a corridor
- Three-phase-fault with a circuit breaker failure

Must cope with the cascading effect of severe faults

Relatively complex to properly design a suitable defense plan
Defense Plan Strategy

Typically uses technical solutions well adapted to the lower probability of very severe contingencies

Automatic Schemes

Controlled switching of power system components

Fast equipment-switching
Shunt reactors
Special protective devices

Fast opening of interconnection links
To isolate severe faults
To prevent affecting adjoining areas

Generation rejection and remote load shedding
Under-frequency load shedding

Pre-existing schemes must be revised in view of the new interconnected operation of previously isolated control areas
Module 8 - Interconnected Systems
Operating Conditions

Contents

1) Technical Operating Agreements
2) Frequency Control
3) Generation Operating Reserve
4) Generation Controls
5) Conditions for a Secure Operation
6) Organizing the Operation
Organizing the Operation

Essential requirement for the secure operation of interconnected power systems

Proper coordination between

- System Planning
- Operation Planning
- Real-Time Operation

Regional reliability organization

Effective exchange of information

Essential elements
Operation Essential Elements

GRID CODE

1. Information sharing
2. Power exchange schedules
3. Maintenance coordination
4. Emergency operations
5. Power system restoration
6. Operating personnel training
1. Information Sharing

Interconnection capabilities
Short-term load forecasts
Generating capabilities
Network configuration parameters and models

Very important from a strategic point of view

Equipment status
Power flow conditions
Frequency conditions

Information to be exchanged between control areas

Critical for actual minute-to-minute operation
Real-time Operation Information

Depends on the form and complexity of operation between control areas

- Independently operated control areas
  - Limited to interconnection facilities
- Control areas operated as a POOL
  - Also generation and transmission facilities within the areas

Required on a continuous basis

- Monitoring facilities using telemetry and computers
- Proper metering plays an important role
  - Especially in an open market environment
    - Power purchase and wheeling services
2. Power Exchange Schedules

Actually confirmed and implemented between the control areas involved

Point of origin
Where transmission is provided
Point of delivery

Power flow distribution calculated by a common, agreed upon, network model

Due to the various “electrical paths” for a scheduled power transaction

May require a common set of power system simulation computer programs
3. Maintenance Coordination

Maintenance of facilities

- Planned and coordinated by the concerned control areas
  - Where the outages may affect the reliability of the interconnected grid operation

- Requires proper procedures for disseminating information about scheduled outages

- Carefully scheduled with a well defined plan
  - To assure the availability of required generation and transmission capacities at all time
4. Emergency Operations

Focused on maintaining the interconnections operational as much as possible

- To provide maximum assistance to the systems in trouble

Based on emergency plans that have been agreed upon

- Prompt rescheduling of generation
- To balance supply and demand in all control areas
- To avoid a prolonged use of the regional emergency reserves

A program of load shedding in each area

- To avoid high transmission loading and extreme voltage deviations

Coordinated between all control areas across the grid
5. Power System Restoration

Returning the system to a normal condition after a very severe contingency

- A number of steps determined and agreed upon within the interconnected grid
  - For a number of basic scenarios
    - Since severe abnormal conditions are difficult to estimate beforehand
  
- Procedures verified through actual testing or simulation
  - Eventually revised to reflect changes in the network configuration
6. Operating Personnel Training

To assure making appropriate decisions in actual situations

- Situations not perfectly covered by prescribed rules and procedures
- Operation skills
- Changes of operational conditions
- Power system restoration process for all possible abnormal conditions
- New type of equipment put in service
- A new interconnected mode of operation
- Provided on a regular basis