Seminar on
African Electrical Interconnection

# Module 8 - Interconnected Systems Operating Conditions

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*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

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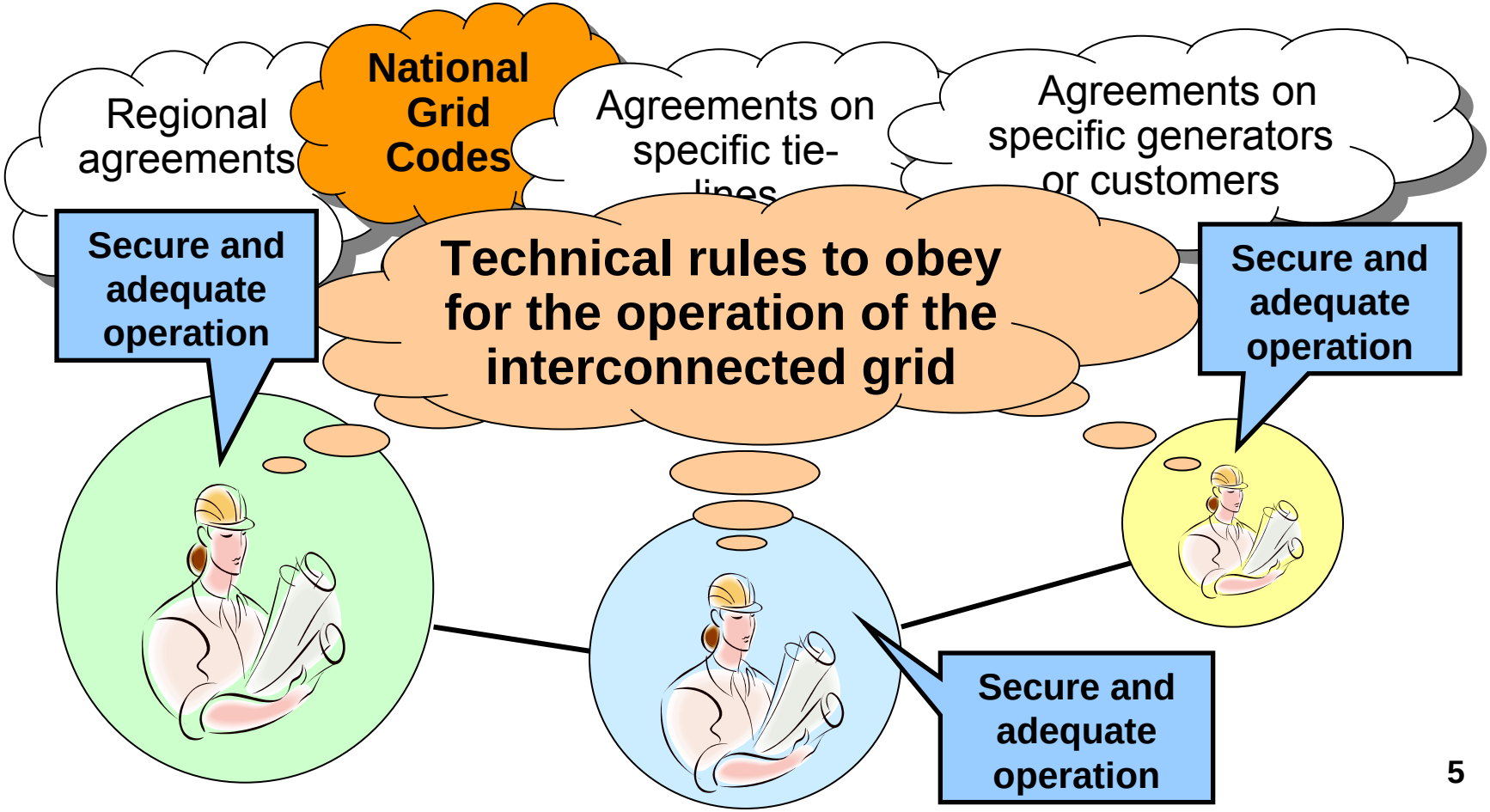
# Technical Operating Agreements

**Coordination of <u>planning</u> and operation of generating and transmission facilities**



# National Grid Codes

**Generators**
**Transmission assets owners**
**Transmission assets operators**
**Major industrial customers**

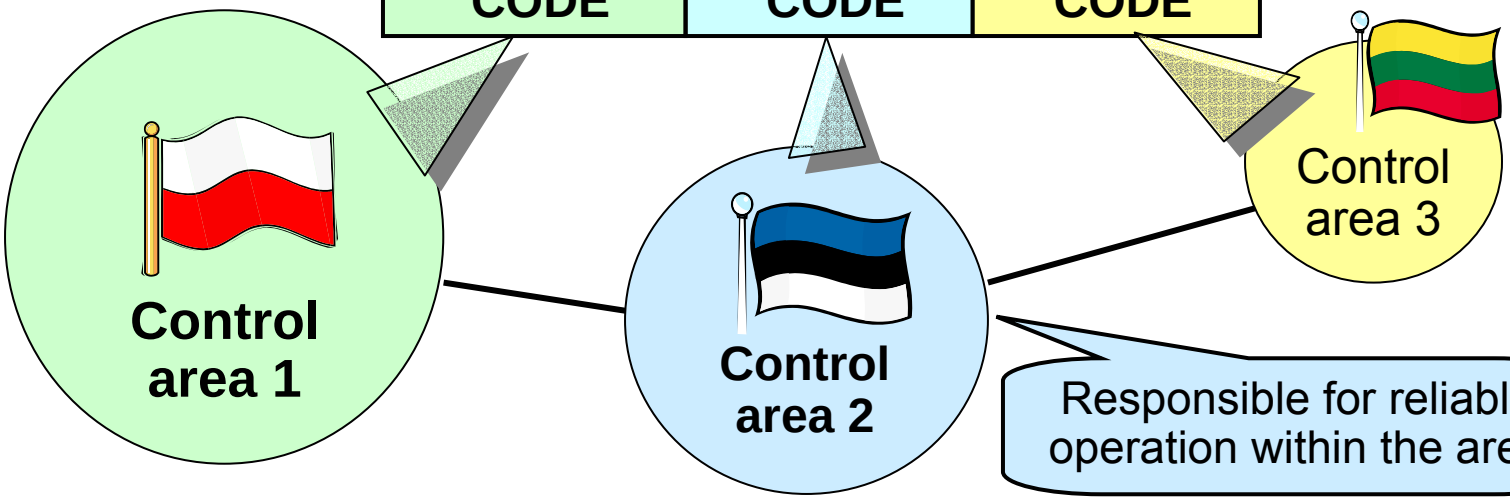
Subject to an agreement between all interconnected systems operators

Could be replaced by a **Regional Grid Code**

**DETAILED TECHNICAL REQUIREMENTS**

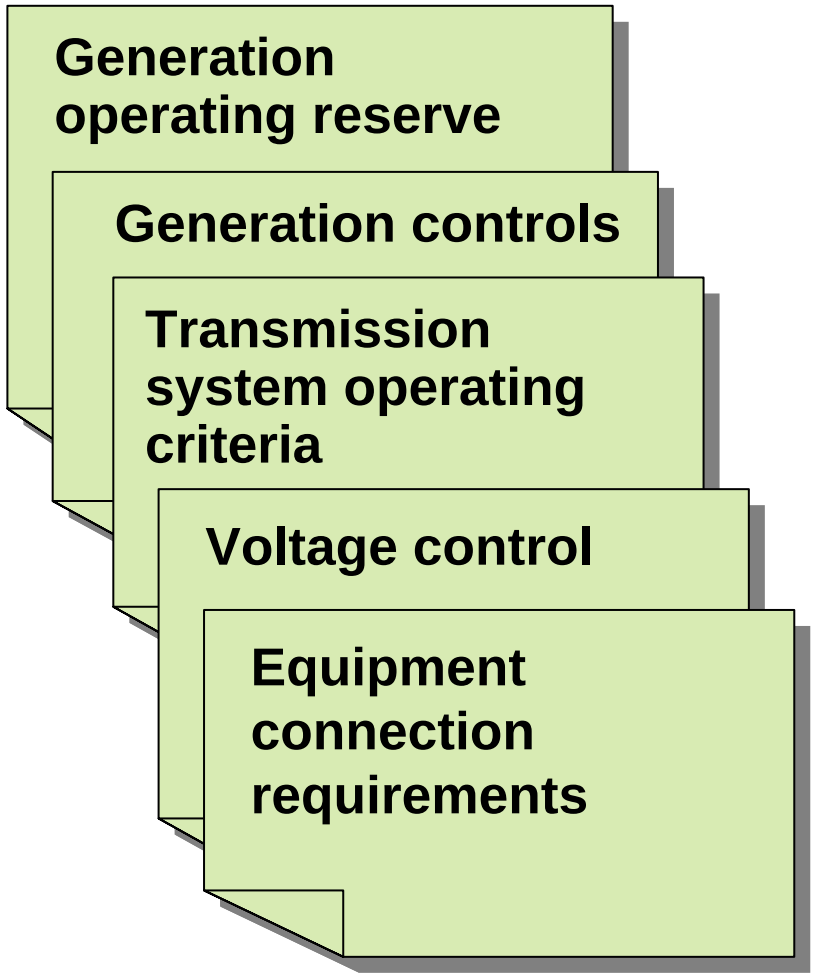
**Harmonized on a regional basis**

| GRID CODE | GRID CODE | GRID CODE |
|---|---|---|




Responsible for reliable operation within the area

# Main Grid Codes Items




**Operation organization and planning**

Information sharing

Power exchange schedules

Maintenance coordination

Emergency operations

Power system restoration

Operating personnel training

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2) **Frequency Control**
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# Frequency Control

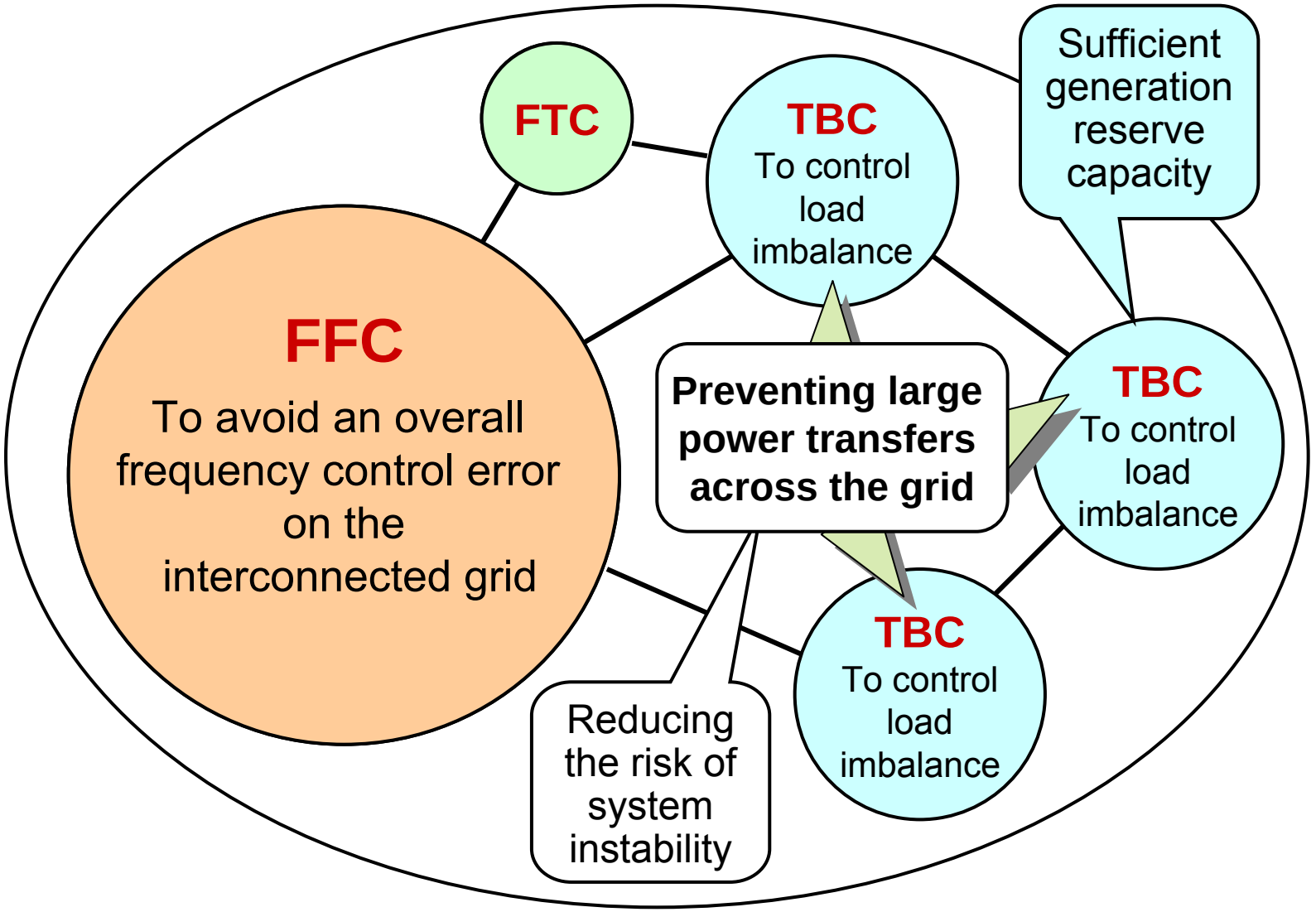
**A specific requirement with interconnected power systems**

- 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



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# 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

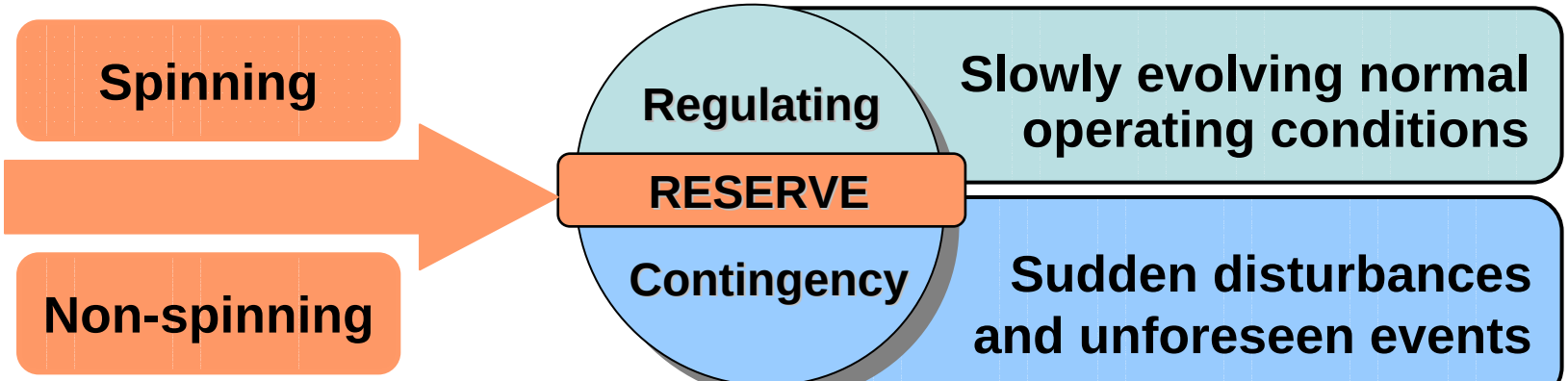
**Most significant feature**: Response time

- Immediately available
- Available with some delay

# Regulating-Contingency Reserve

Synchronized and immediately responsive to Automatic Generation Control

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




Not synchronized but available within a short time delay

**To cover forced outages ( generation or transmission ) and uncertainties**

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

Reduced availability of hydroelectric resources

Errors in load forecasting

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# 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**

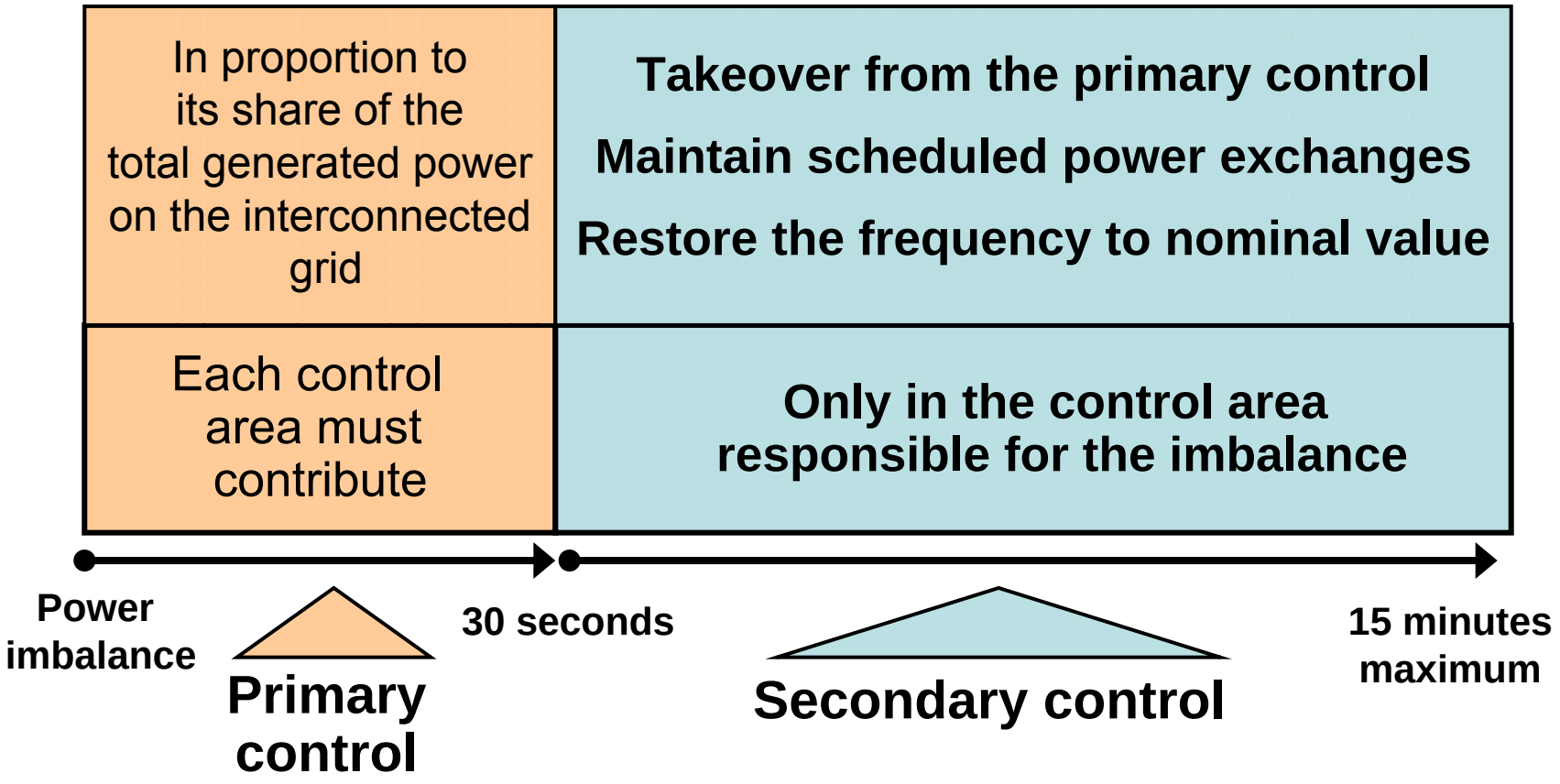
## Automatic Generation Control (AGC)

Variations with a cycle of a few minutes

- Final adjustment of frequency
- Re-balance generation

# An Example of Control Strategy

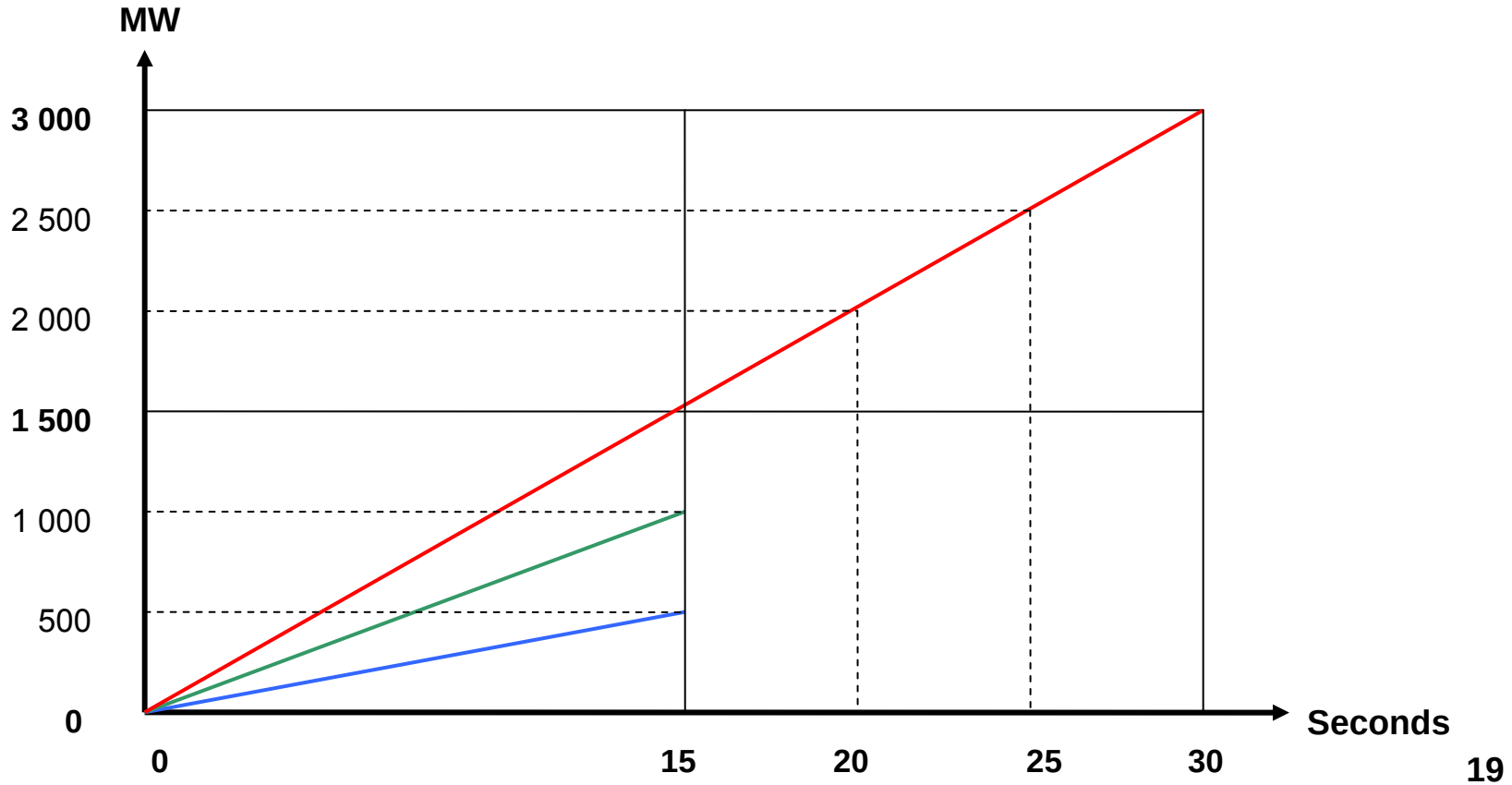
As applied in Europe by the Union for the Coordination of Transmission of Electricity (UCTE)



# Primary Control Response

## Deployment of the primary control reserve on the UCTE interconnected grid

## 3000 MW total available



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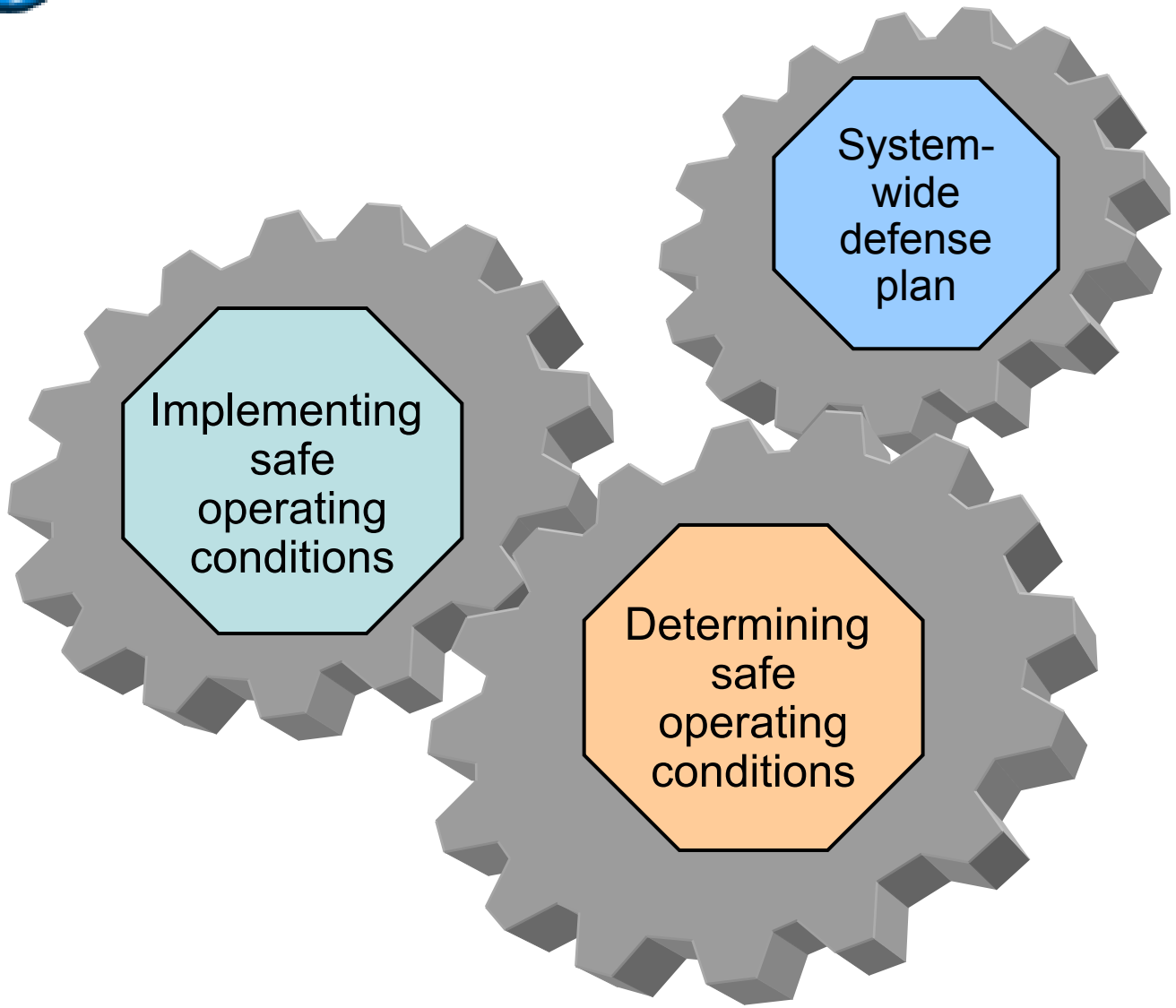
# Conditions for a Secure Operation



# 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)**

**TO PREVENT**

**Overload of equipment across the interconnected grid**

**PREVENT TO**

**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

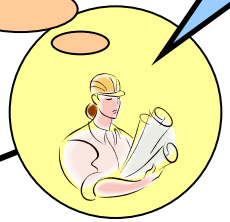
Maintain adequate voltage and provide necessary reactive power

Within each control area

**Strict operating rules**

**Strict operating rules**

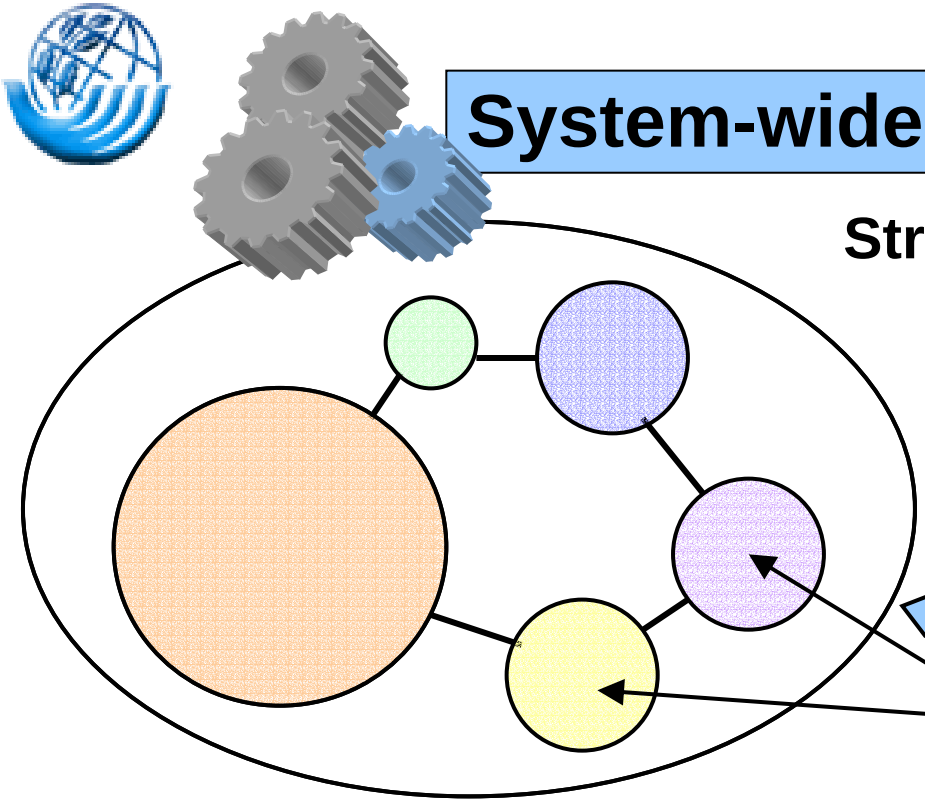
**Strict operating rules**



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)**

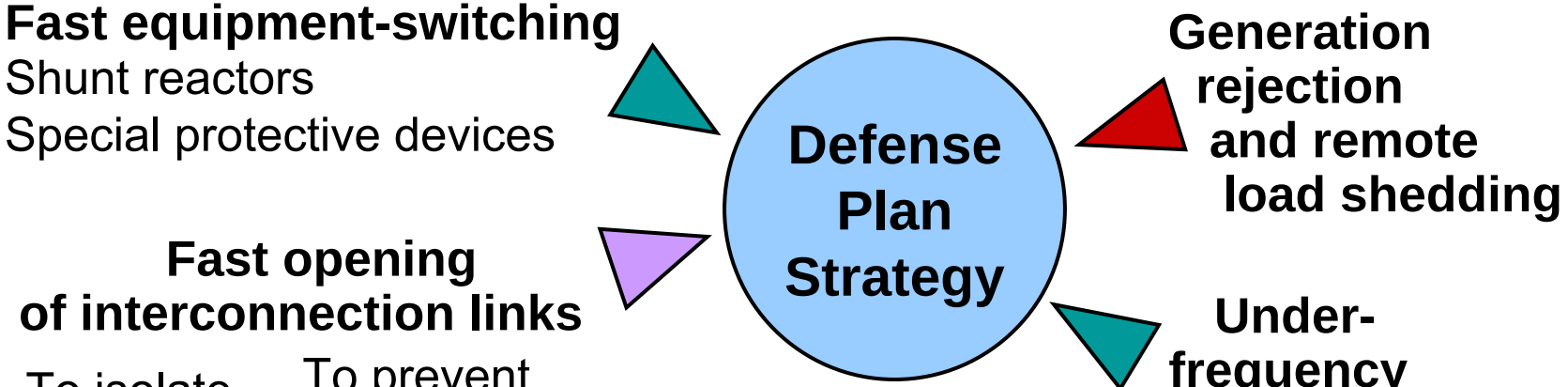
Loosing a whole substation
Tripping of all transmission lines in a corridor
Three-phase-fault with a circuit breaker failure

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 | |




**Pre-existing schemes must be revised in view of the new interconnected operation of previously isolated control areas**

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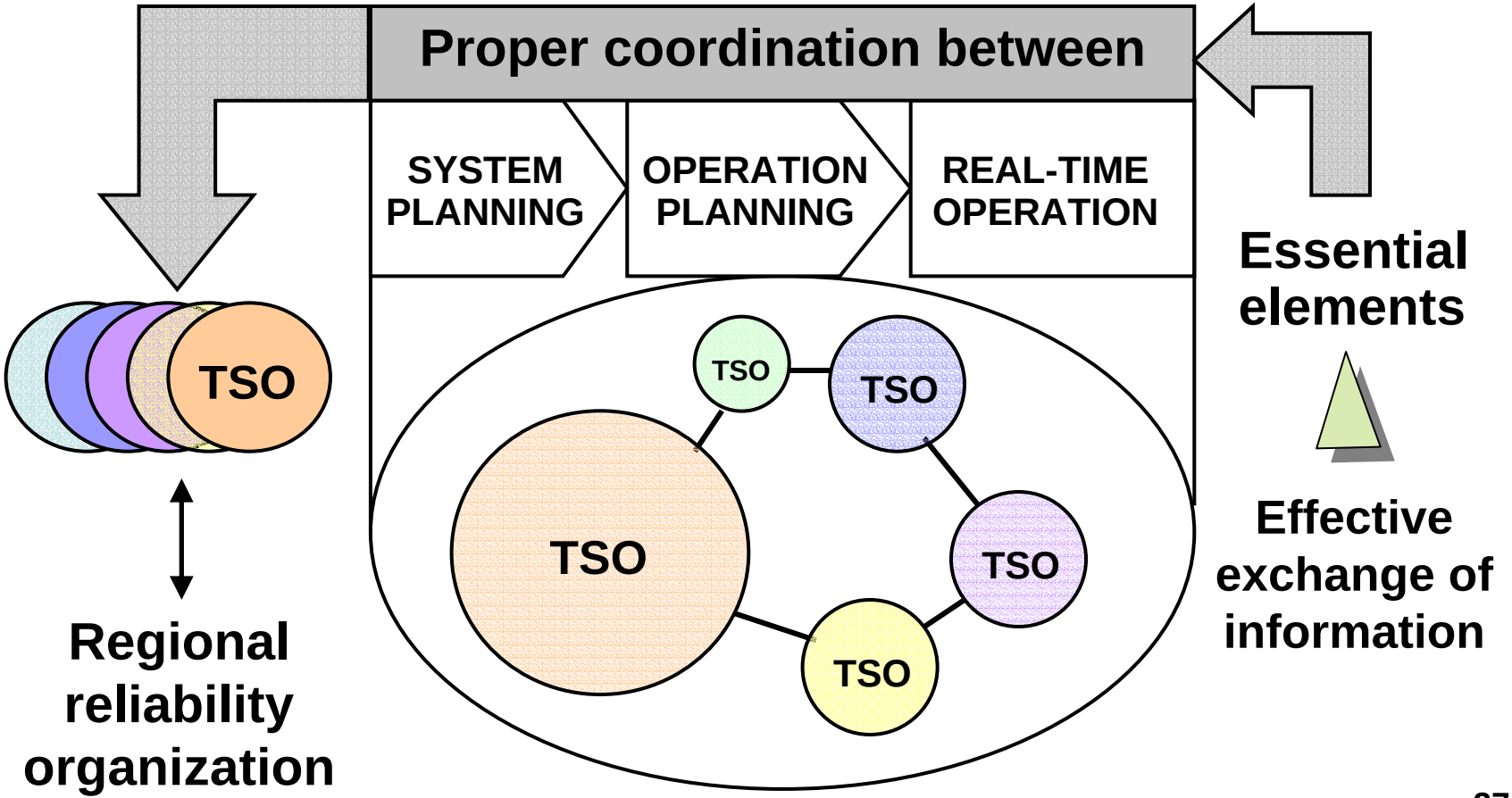
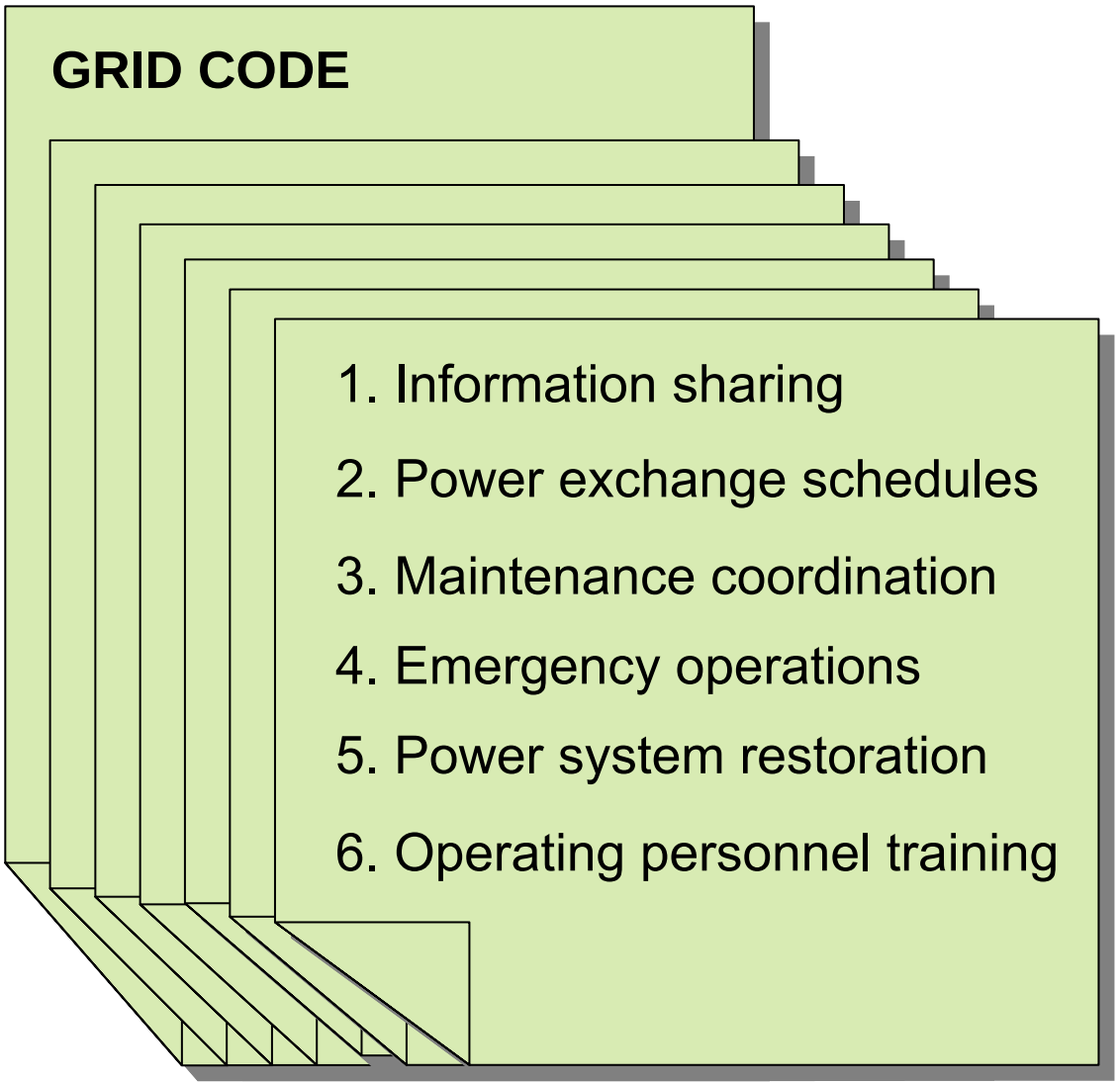
# Organizing the Operation

## Essential requirement for the secure operation of interconnected power systems



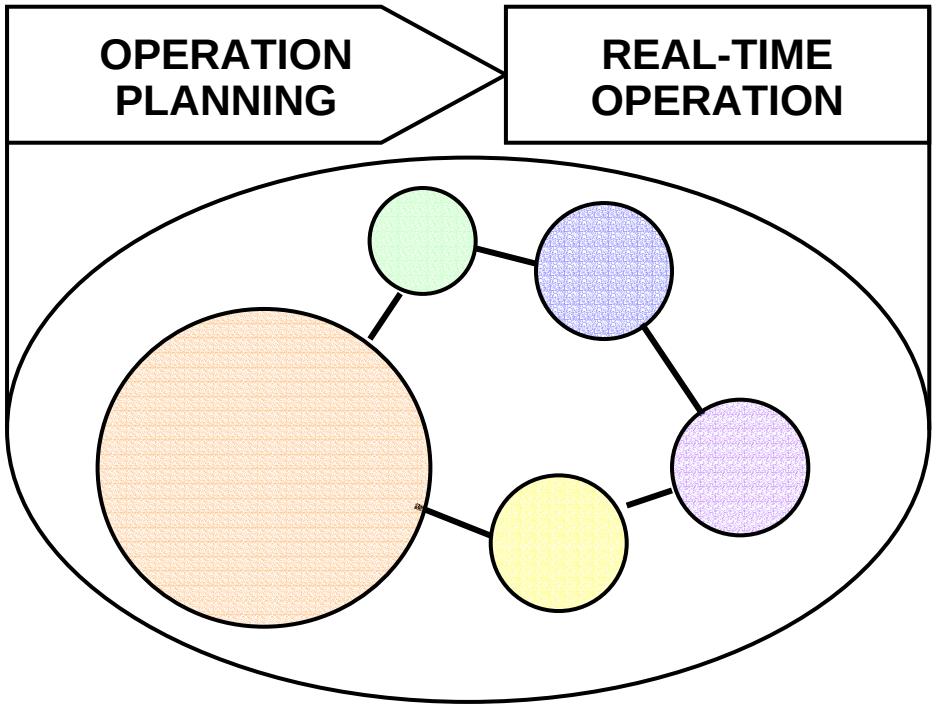
# Operation Essential Elements



# 1. Information Sharing

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

Equipment status
Power flow conditions
Frequency conditions




**Very important from a strategic point of view**

**Critical for actual minute - to - minute operation**

**Information to be exchanged between control areas**

# 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

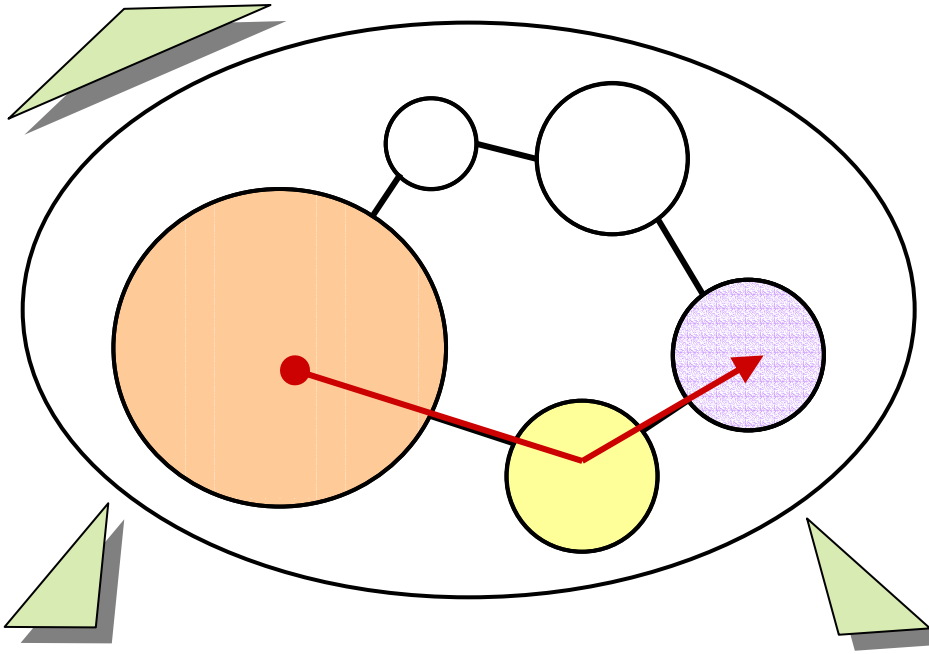
# 2. Power Exchange Schedules

**Actually confirmed and implemented between the control areas involved**

Point of origin

Where transmission is provided

Point of delivery



May require a common set of power system simulation computer programs

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

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

# 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