Power System Stability Analysis

Fundamentals of Electrical Power Systems - Week 9

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Outline

Power System Stability Definition

Definition

Power system stability is the ability of a power system to return to a stable operating condition after being subjected to a disturbance.

Key aspects:

- Maintaining synchronous operation of generators
- Restoring equilibrium after disturbances
- Preventing cascading failures

Important

Stability is crucial for reliable power system operation!

Why Power System Stability Matters

Reliability Aspects:

- Prevents blackouts and system collapse
- Maintains quality of service
- Ensures continuous power delivery

Economic Impact:

- Avoids costly system failures
- Maintains operational efficiency
- Supports market stability

Classification of Stability Types

Classified by time frame and nature of disturbance:

1. **Rotor Angle Stability**
   - Maintains synchronous operation between generators
   - Related to generator rotor dynamics
2. **Voltage Stability**
   - Maintains acceptable voltage levels
   - Related to reactive power balance
3. **Frequency Stability**
   - Maintains system frequency within limits
   - Related to active power balance

Swing Equation

Fundamental equation for rotor dynamics:

$$M\frac{d^2\delta}{dt^2} = P_m - P_e \tag{1}$$

Where:

- M = inertia constant of the generator
- δ = rotor angle
- P_m = mechanical power input
- P_e = electrical power output

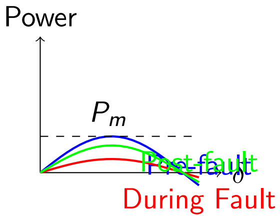
Design Tip

The swing equation forms the basis for transient stability analysis!

Equal Area Criterion

Concept for analyzing transient stability:

- Compares accelerating and decelerating energy
- Determines stability without solving differential equations
- Critical clearing angle and time concepts



Voltage Stability Concepts

Voltage stability is the ability of a power system to maintain acceptable voltages at all buses.

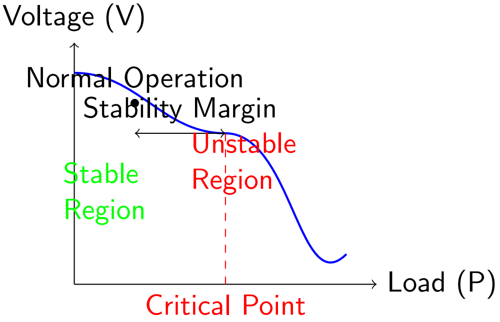
Key factors:

- Reactive power balance
- Load characteristics
- Network strength
- Generator reactive capabilities

P-V and Q-V Curves

These curves show voltage stability margins and critical points.

PV Curve Analysis



Critical Point

The "nose" of the PV curve represents the voltage collapse point.

Frequency Stability Overview

Frequency stability concerns the ability to maintain frequency within acceptable limits.

Key aspects:

- Balance between generation and load
- Inertia response of generators
- Automatic generation control (AGC)
- Load-frequency control mechanisms

Frequency Response

System frequency changes when there's an imbalance between generation and load.

Load-Frequency Control

Primary and secondary frequency control:

Primary Control:

- Governor action
- Immediate response (seconds)
- Droop characteristic
- Maintains generation-load balance

Secondary Control:

- AGC systems
- Slower response (minutes)
- Restores frequency to nominal
- Economic dispatch integration

Key Point

Both primary and secondary controls work together to maintain frequency!

Problem Set: Power System Stability

C1 (Remember): What are the three main types of power system stability?

C2 (Understand): Explain the physical meaning of the swing equation and its terms.

C3 (Apply): For a generator with H=5 MJ/MVA and rated power of 100 MVA, calculate the inertia constant M in the swing equation.

C4 (Analyze): Compare the stability characteristics of a system with high renewable penetration versus a conventional system.

C5 (Evaluate): Evaluate the importance of virtual inertia in systems with high converter-based generation.

C6 (Create): Design a control strategy for enhancing stability in a microgrid with high renewable penetration.

Thank You!

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