

The Siemens logo is displayed in a bold, teal, sans-serif font in the upper right corner of the slide. The background of the slide is a photograph of an offshore wind farm with several white wind turbines on a blue sea under a clear sky.

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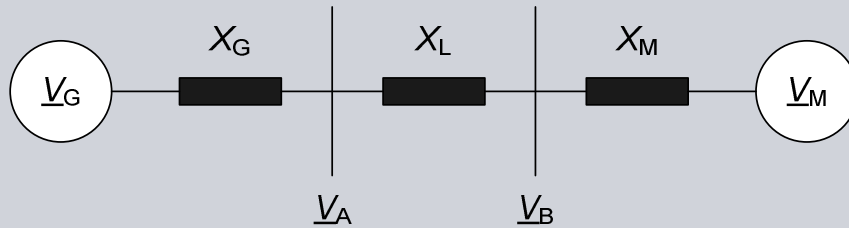
Energy Automation

**Proper detection and
treatment of power swing
to reduce the risk of
Blackouts**

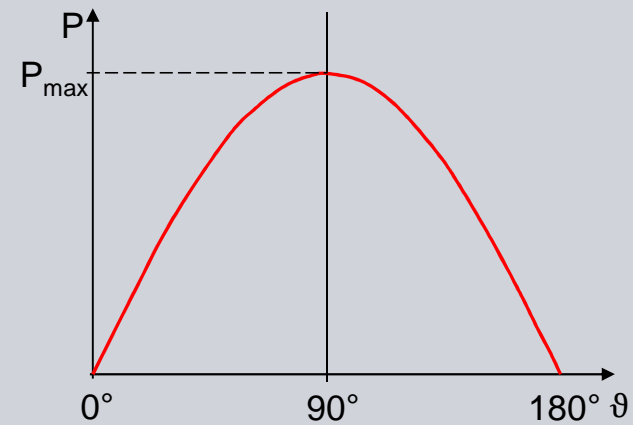
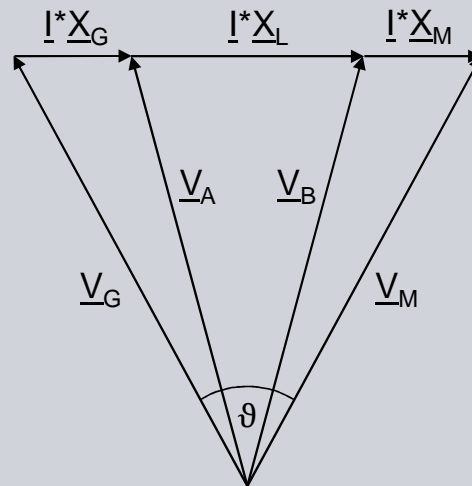
Gustav Steynberg

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Energy Sector

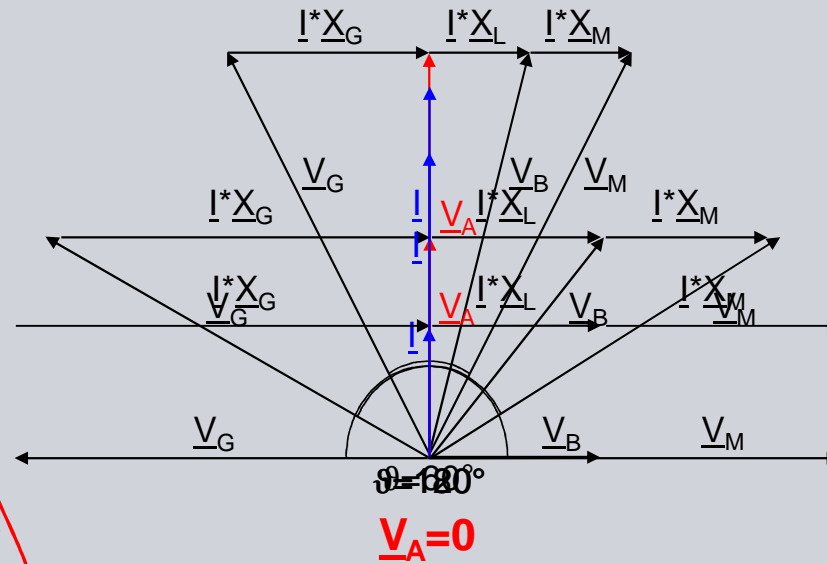
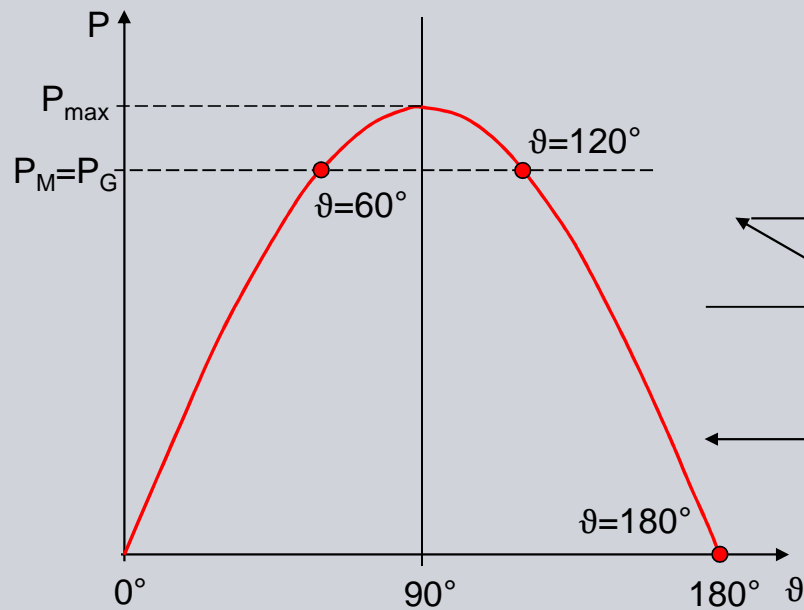
Basics



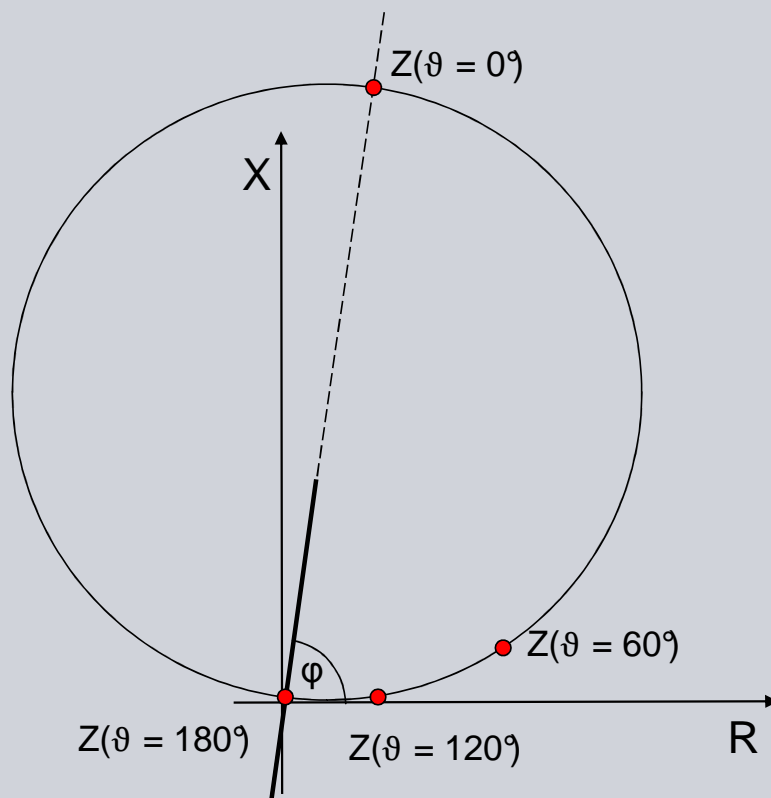
$$P = \frac{V_G \cdot V_M}{X_G + X_L + X_M} \sin(\vartheta)$$



Influence of voltage angle



Typical impedance trajectory

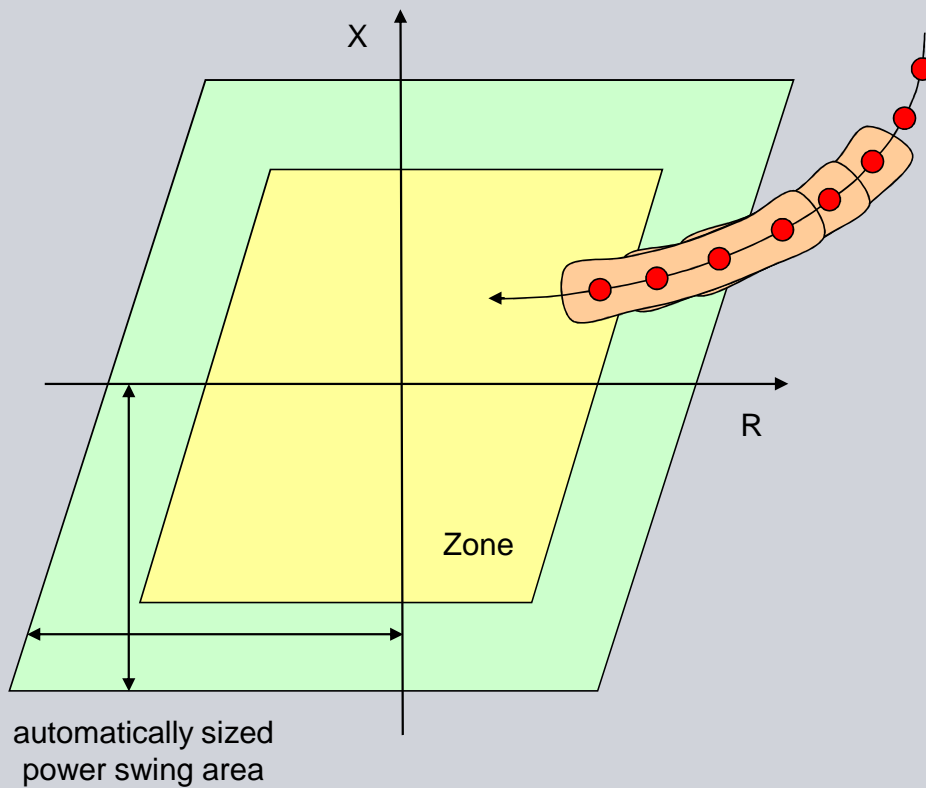


- $\vartheta = 60^\circ$
normal load condition
- $\vartheta = 120^\circ$
dangerous for
distance protection
- $\vartheta = 180^\circ$
unstable power swing
out of step tripping

Required characteristics for power swing detection

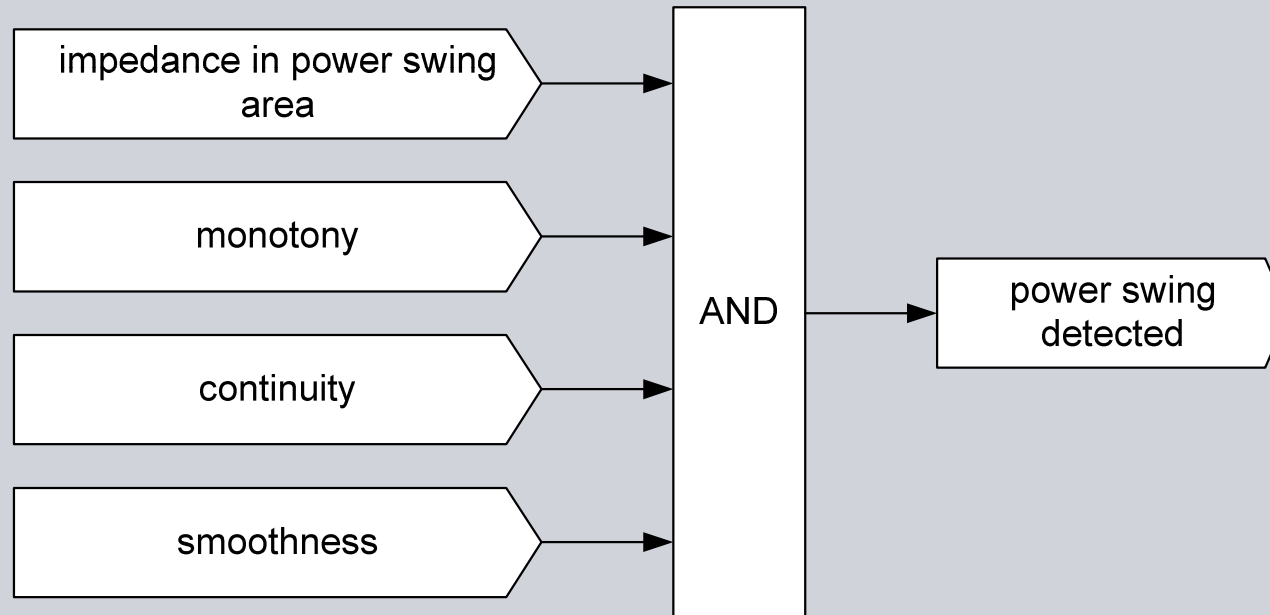
- **No settings** are required, thus no complex calculation is needed.
- Detection of power swing with **frequencies up to 7Hz**.
- Detection of power swings that occur **during single-pole open** condition and during faults.
- Immediate **unblocking of distance protection** on all kind of faults occurring during power swing.
- Quick detection of **reappeared power swing** after fault clearance.
- **Out-of-step tripping** in case of unstable power swing

Principle of power swing detection

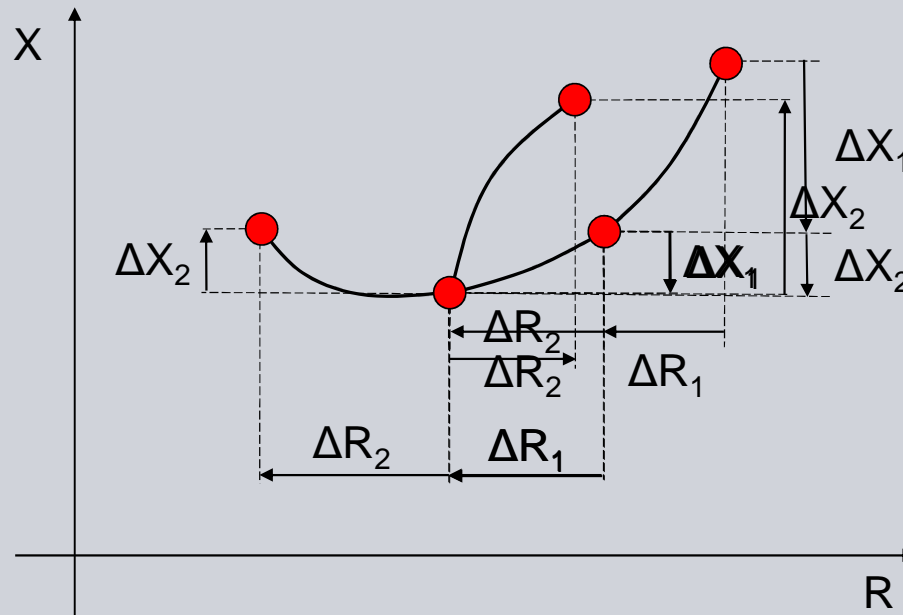


- Continuous calculation and monitoring of Impedances
- First impedance in power swing area: algorithm starts to analyze the impedance trajectory

Main criteria for power swing detection

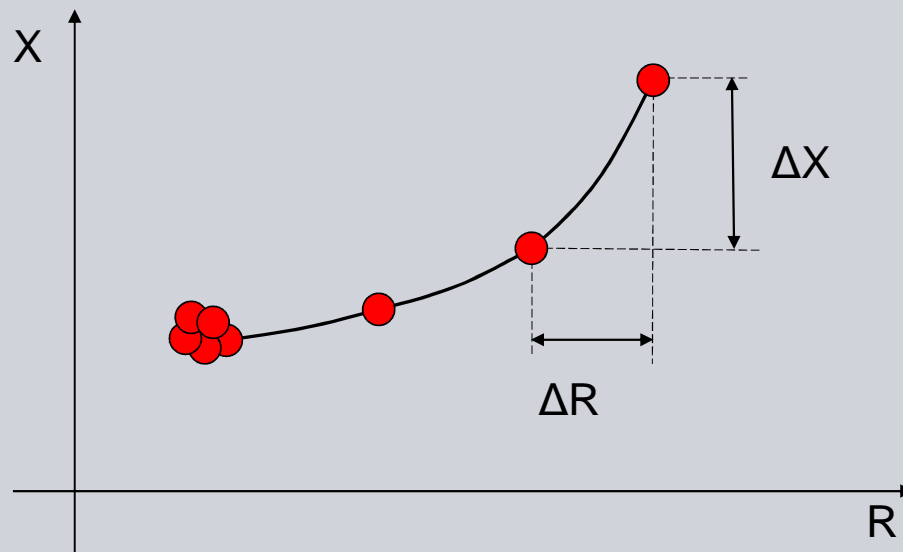


monotony criterion



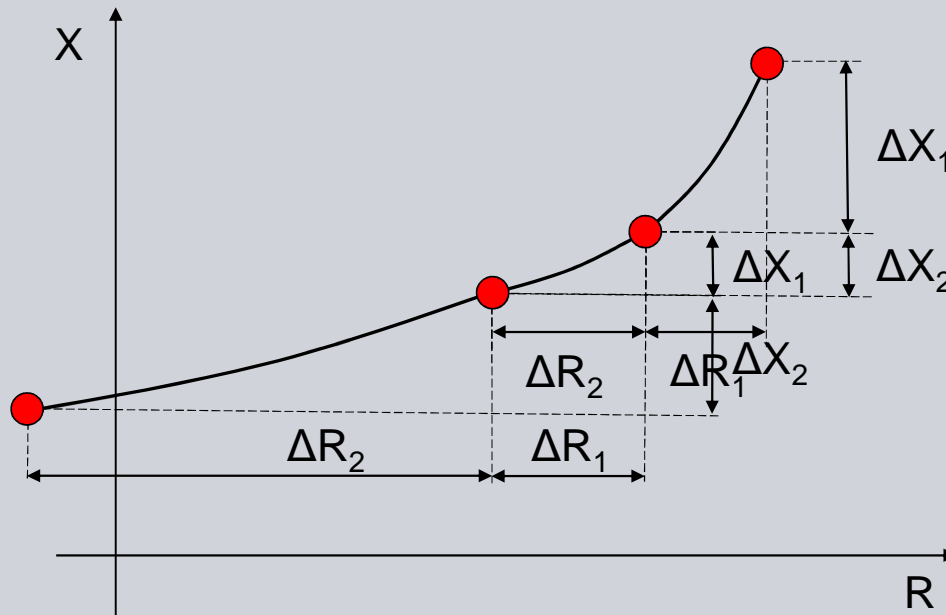
- power swing if ΔR_1 and ΔR_2 and ΔX_1 and ΔX_2 have same directions
- no power swing if ΔR_1 and ΔR_2 and ΔX_1 and ΔX_2 have different directions

continuity criterion



- power swing if ΔR or ΔX exceed a threshold
- no power swing if ΔR and ΔX are below the threshold

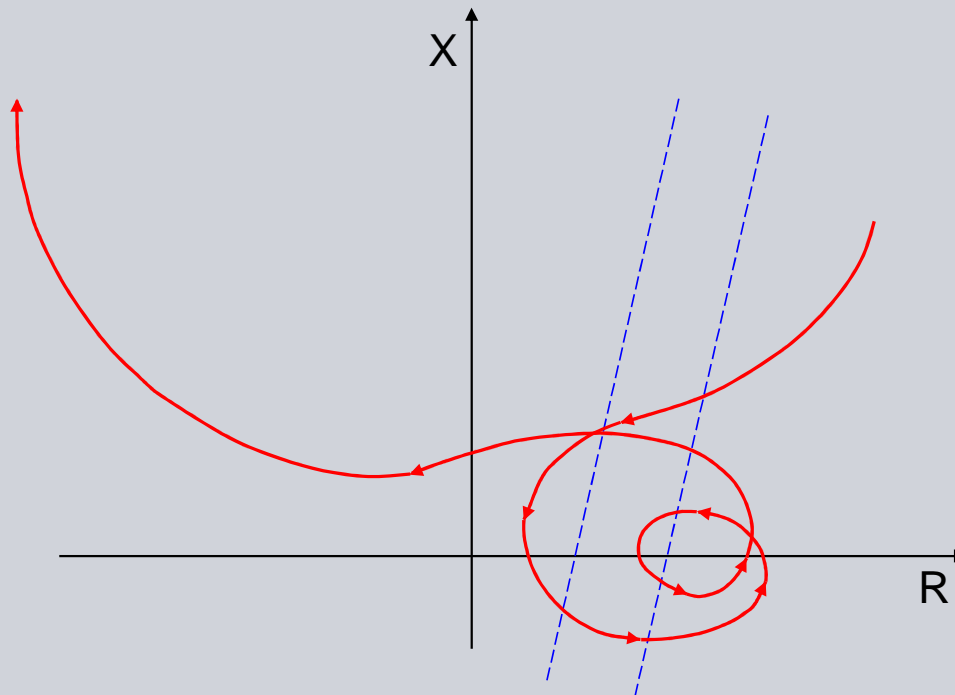
smoothness criterion



- power swing if ΔR_1 nearly ΔR_2 and ΔX_1 nearly ΔX_2

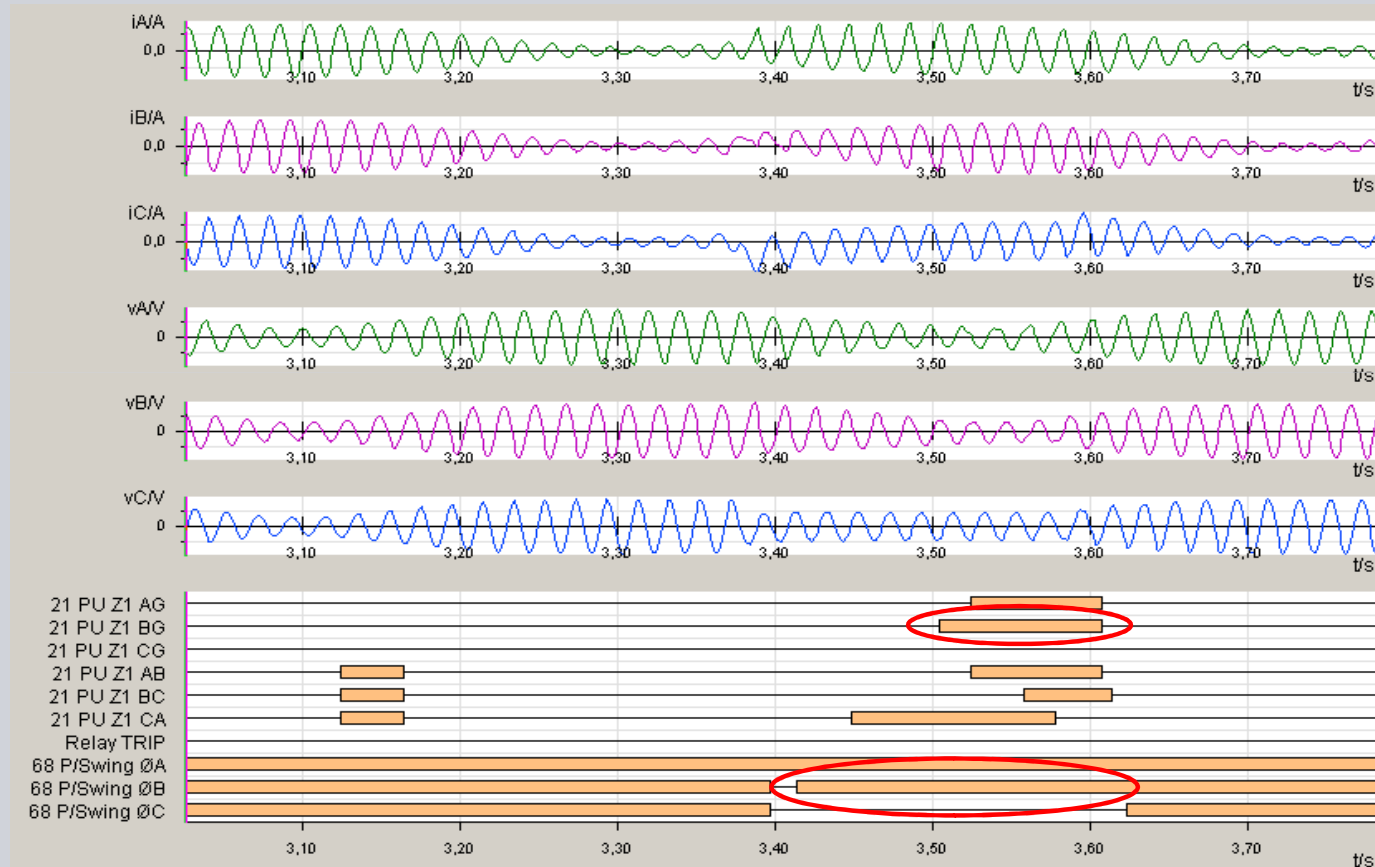
- no power swing if ΔR_1 strong vary from ΔR_2 or ΔX_1 strong vary from ΔX_2

If three machines oscillating against each other



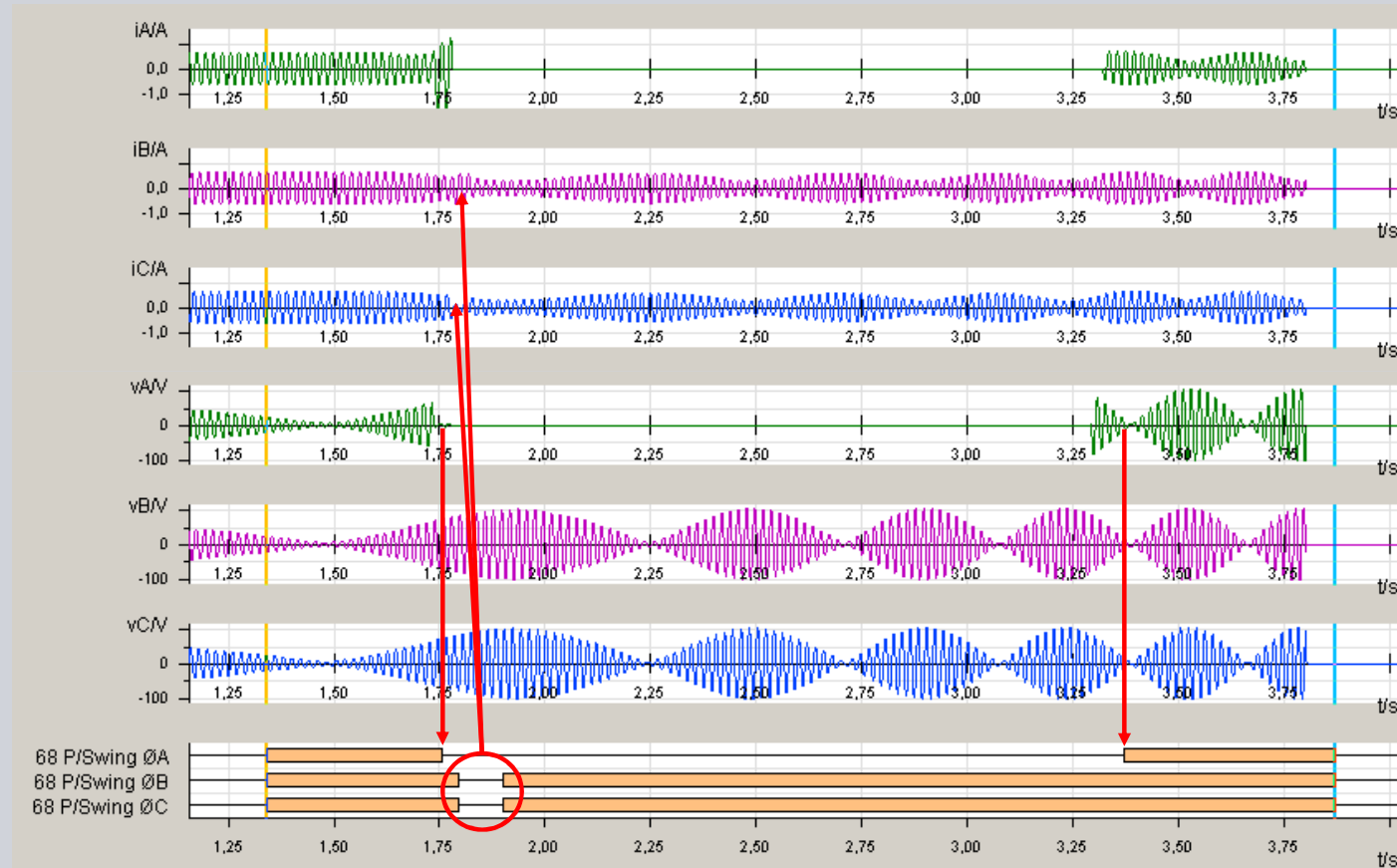
- Impedance trajectory will not follow a perfect elliptical path
- difficult to manage with blinders
- easy to detect with criteria monotony, continuity and smoothness

Quick redetection of power swing after fault inception



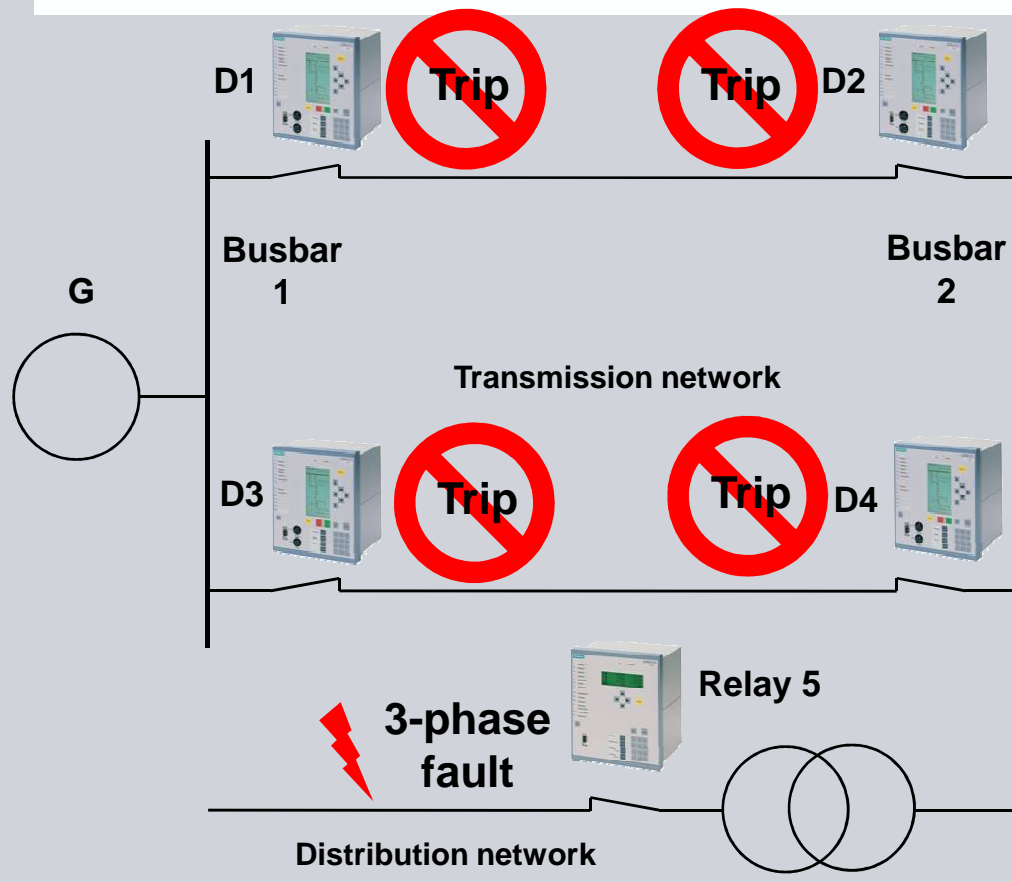
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Secure power swing detection during open pole condition

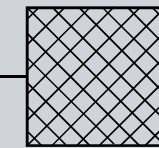


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Necessity of power swing detection, example

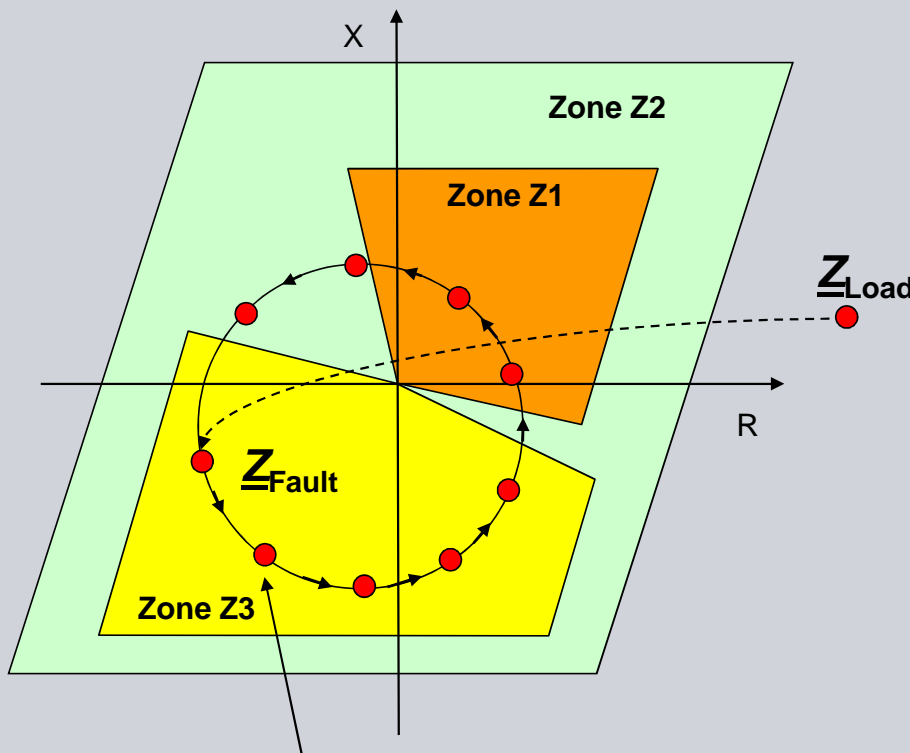


- 3-phase-fault initiates a power swing in the transmission network



- Power swing blocking function prevents the distance relays D1 .. D4 from unselective tripping

Impedance Vector for Distance Relay D4



Power Swing Detection

3-phase reverse fault:
 → Impedance vector jumps to \underline{Z}_{Fault}

power swing is initiated by the reverse fault:
 → The impedance moves on a circular trajectory

The power swing blocking function prevents an unselective trip, before the impedance vector enters the tripping zone Z1