Equal-Area Criterion: Critical Clearing Angle and Time

Critical clearing angle of a generator connected to an infinite bus by the equal-area criterion, and the critical clearing time from the swing equation.

Method: Equal-area criterion and the classical swing equation

Input parameters

Unit system: SI

Parameter	Value	Unit
Mechanical power (pu)	0.80000	
Peak electrical power before the fault (pu)	1.8000	
Peak power during the fault as a share of P_max	0	%
Peak power after clearing as a share of P_max	80.000	%
Inertia constant	5.0000	s
System frequency	50.000	Hz

Calculated results

Parameter	Value	Unit
Initial rotor angle	26.388	°
Largest angle after clearing	146.25	°
Critical clearing angle	70.686	°
Critical clearing time	248.04	ms

Notes for this case

• During a fault the generator accelerates because it cannot deliver its mechanical power; after clearing it decelerates. It stays in step if the decelerating area under the post-fault power curve, up to δ_max = π − arcsin(P_m/r₂P_max), at least equals the accelerating area. Setting them equal gives the critical clearing angle; integrating the swing equation (2H/ω_s) d²δ/dt² = P_m − r₁P_max sin δ to that angle gives the critical clearing time. For a bolted fault at the terminals (r₁ = 0) this matches t_c = √[4H(δ_c − δ₀)/(ω_s P_m)]. Classical model: no damping, constant voltage behind transient reactance.

Formula and method

$$\cos\delta_c = \frac{P_m(\delta_{max}-\delta_0) + r_2 P_{max}\cos\delta_{max} - r_1 P_{max}\cos\delta_0}{(r_2 - r_1)P_{max}}, \quad \frac{2H}{\omega_s}\frac{d^2\delta}{dt^2} = P_m - P_e$$

Variables

P_m	Mechanical power (pu)	-
P_{max}	Peak electrical power before the fault (pu)	-
r_1	Peak power during the fault as a share of P_max	-
r_2	Peak power after clearing as a share of P_max	-
H	Inertia constant	s
f	System frequency	1/s
δ_0	Initial rotor angle	rad
δ_{max}	Largest angle after clearing	rad
δ_c	Critical clearing angle	rad
t_c	Critical clearing time	s

Method and standards

Equal-area criterion.

Assumptions and limits

- Single machine on an infinite bus; classical model; no damping.

References

Equal-area criterion and the classical swing equation

Report details

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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/electrical/power/equal-area-critical-clearing

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.