# Economic Conductor Size (Kelvin's Law)

Economic conductor size by Kelvin's law from load current, hours, energy price, conductor cost per mm²·km and capital charge, with current density.

**Method:** Kelvin's law for economic conductor size (annual loss cost = annual capital charge on the area-dependent cost)

## Input parameters

Unit system: SI

| Parameter | Value | Unit |
|---|---|---|
| Load current (rms, per conductor) | 400.00 | A |
| Equivalent full-load (loss-load) hours per year, Σ I²t / I² | 6,000.0 | h |
| Energy cost per kWh | 8.0000 | |
| Conductor cost per mm² per km (variable part) | 8,000.0 | |
| Annual capital charge rate | 12.000 | % |
| Resistivity at operating temperature | 2.1000e-08 | Ω·m |
| Conductors per circuit | 3.0000 | |

## Calculated results

| Parameter | Value | Unit |
|---|---|---|
| Economic cross-section | 409.88 | mm² |
| Annual loss cost per km at A_econ | 1,180,449 | |
| Annual capital charge per km at A_econ | 1,180,449 | |
| Economic current density | 0.97590 | A/mm² |

**Notes for this case**

- Kelvin's law: at the economic size the annual cost of losses equals the annual charge on the part of conductor cost proportional to area. Check thermal rating and voltage drop separately; IEC 60287-3-2 refines this with load growth and discounting.

## Formula and method

$$A_{econ} = I\sqrt{\frac{\rho\, t_a\, c_e}{c_c\, r}} \ \text{(per conductor, consistent units)}, \quad C_{loss} = C_{cap}$$

### Variables

| | | |
|---|---|---|
| $I$ | Load current (rms, per conductor) | A |
| $t_a$ | Equivalent full-load (loss-load) hours per year, Σ I²t / I² | s |
| $c_e$ | Energy cost per kWh | - |
| $c_c$ | Conductor cost per mm² per km (variable part) | - |
| $r$ | Annual capital charge rate | - |
| $\rho$ | Resistivity at operating temperature | Ω·m |
| $n$ | Conductors per circuit | - |
| $A_{econ}$ | Economic cross-section | m² |
| $C_{loss}$ | Annual loss cost per km at A_econ | - |
| $C_{cap}$ | Annual capital charge per km at A_econ | - |
| $J$ | Economic current density | A/m² |

### Method and standards

Kelvin's law.

### Assumptions and limits

- Cost linear in area. t_a is the loss-load ($I^2$-weighted) equivalent hours, $\Sigma I^2t / I^2$ for the I entered, not the operating hours.
- Energy cost per kWh and conductor cost per $mm^2$ per km are converted to SI inside (per J and per $m^3$ of conductor).

### References

- Kelvin's law for economic conductor size (annual loss cost = annual capital charge on the area-dependent cost)

## Report details

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|---|---|
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| Release checks | 2 reference cases of this calculator, computed independently, are checked on every release |

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

### This calculator online

https://calc.firecad.com/electrical/cables/kelvin-economic-conductor

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.