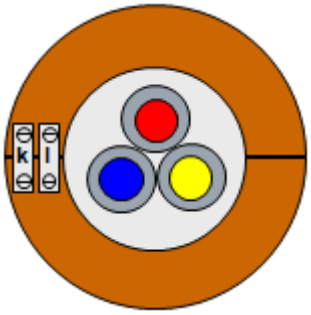
Earth-Fault Protection with Cable Type CT's

For **certain** earth-fault protection applications with cable type CT's, sensitive settings are required (e.g. directional or also non-directional stator earth-fault protection on generators and motors).
Siprotec 4 devices always have a lowest possible setting value of 2 mA or in some cases 1 mA.

Problem:
Even in the case where the 3 conductors are centrally bundled, when passing through the cable type CT, an error current I_{error} will arise in the secondary circuit. This error current is generally proportional to load current flowing through the CT.
In the case of non-bundled conductors or when the conductors are not in the center of the cable type CT, the error current I_{error} may be substantially larger.
I_{error} therefor obstructs the application of sensitive settings or has a significant influence thereon.



$$\Sigma \underline{I} = \underline{I}_{L1} + \underline{I}_{L2} + \underline{I}_{L3} = 0 \text{ (theoretical)}$$

This error current is not considered in the present standards and norms. There is only one CT class provided, (e.g. 1FS10), which specifies the required measuring tolerance for the actually transformed earth current I_E during a fault, which however does not state the error tolerance when no earth current is flowing, and the signal should be zero.

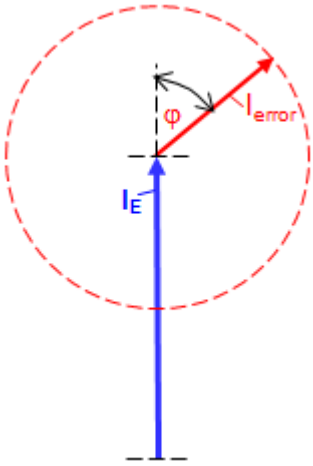
The CT class does not state anything regarding the error current I_{error}.

Setting value I_E>
In general the setting value is defined by the applications. If, for example a certain amount of protection coverage for the stator winding of an electrical machine is required, then the setting value of I_E> is directly determined, based on the available earth-fault current.

Conclusion: **I_E> is given with the required sensitivity (protection coverage)**
(as sensitive a setting as possible),
it must however allow sufficient margin against the maximum error current
(higher setting value with margin against error current
→ compromise may be required

IC SG Energy Automation
Product Management
email: support.ic@siemens.com
Telefon: +49 (180) 524 8437
Fax : +49 (180) 524 2471

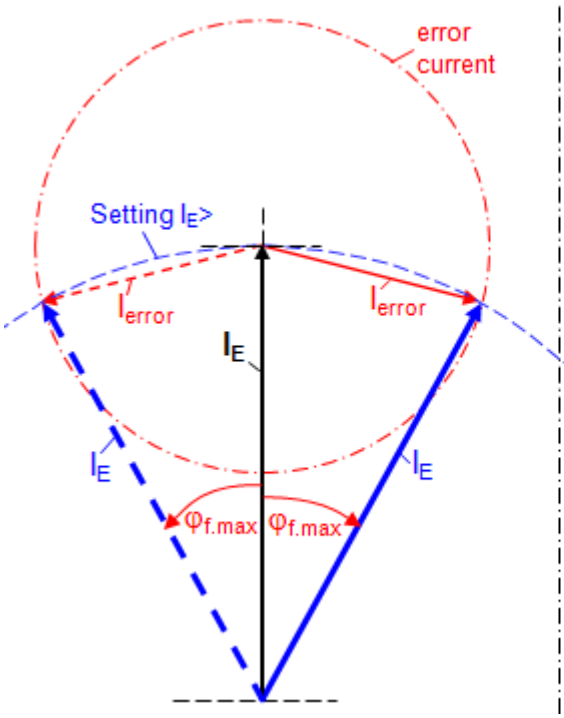
7UM6: Stator earth fault protection with cable type CT



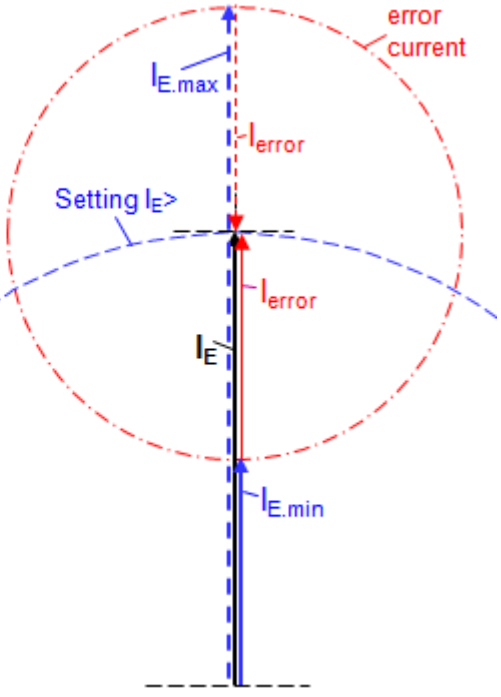
The angle (φ) between the error current I_{error} and the actual earth fault current I_E may assume any value from 0 to 360 degrees. It may not even be assumed to remain constant in a particular application.

Influence of the error current on the setting (example with $I_E> = 2 \cdot I_{error}$)

maximum error angle at $I_E = I_E>$ (important for detecting the direction)



maximum error magnitude I_E



$$\text{with } I_{error} = \frac{I_E>}{2};\ \sin\left(\frac{\varphi_{f.max}}{2}\right) = \frac{I_{error}/2}{I_E>}$$

$$\varphi_{f.max} = 2 \cdot \arcsin\left(\frac{I_{error}/2}{I_E>}\right) = 2 \cdot \arcsin\left(\frac{1}{2 \cdot 2}\right)$$

$$\varphi_{f.max} = 28.95\,\text{Grad}$$

The real (pickup-) earth current I_E can be between $I_{E.min}$ and $I_{E.max}$
$50\% \cdot I_E> \leq I_E \leq 150\% \cdot I_E>$

email: support.ic@siemens.com
Telefon: +49 (180) 524 8437
Fax : +49 (180) 524 2471

7UM6: Stator earth fault protection with cable type CT

Influence of the error current on the settings (example with $I_E> = 5 \cdot I_{error}$)
If the error current I_{error} amounts to only 20% of the setting value $I_E>$, the resulting error angle and error magnitude are naturally significantly smaller!

maximum error angle at $I_E = I_E>$
(important for detecting the direction)

$$\text{with } I_{error} = \frac{I_E>}{5};\ \sin\left(\frac{\varphi_{f.max}}{2}\right) = \frac{I_{error}/2}{I_E>}$$

$$\varphi_{f.max} = 2 \cdot \arcsin\left(\frac{I_{error}/2}{I_E>}\right) = 2 \cdot \arcsin\left(\frac{1}{5 \cdot 2}\right)$$

$$\varphi_{f.max} = 11.47 \text{ Grad}$$

maximum error magnitude I_E

The real (pickup-) earth current I_E can be between $I_{E.min}$ and $I_{E.max}$
$80\% \cdot I_E> \leq I_E \leq 120\% \cdot I_E>$

The specifications for the cable type CT are obtained based on the explanations given above:
When mounted correctly*) the load dependant error current must remain below a given threshold Ierror-max (refer to diagram). → improved design

Explanation:

convent.	Cable Type CT **not suitable** (for this application)
improved design	Cable Type CT suitable but badly mounted
improved design and centered	Cable Type CT suitable and correctly mounted

If the properties of a given Cable Type CT are not clearly defined (with regard to „improved design“) then the CT manufacturer must be contacted

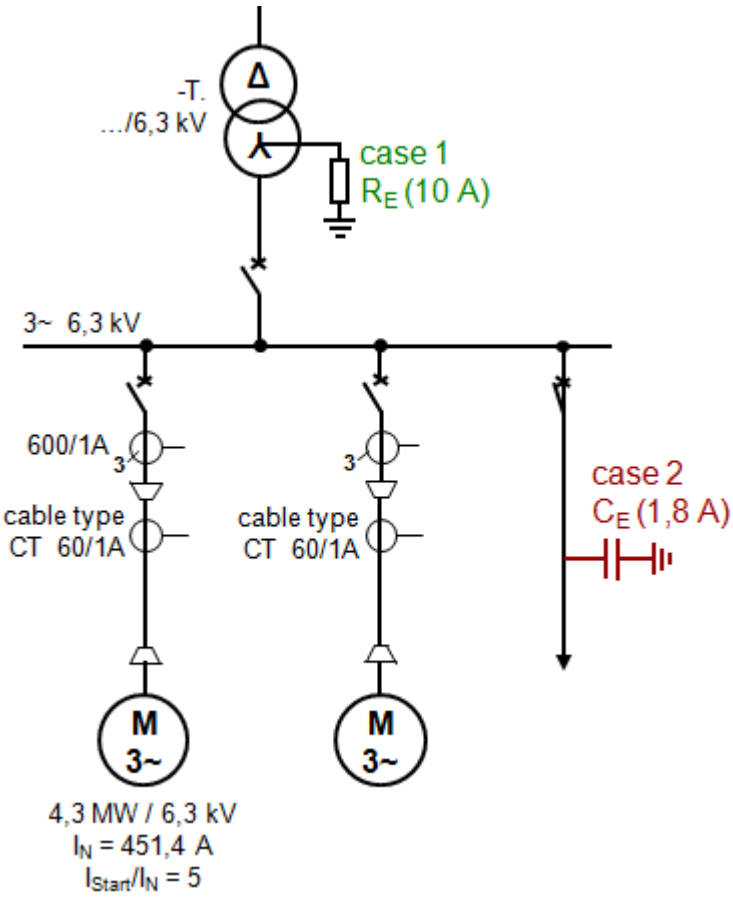
IC SG Energy Automation
Product Management
email: support.ic@siemens.com
Telefon: +49 (180) 524 8437
Fax : +49 (180) 524 2471

7UM6: Stator earth fault protection with cable type CT

***) Comments for mounting**:
1) Mounting instructions of the supplier must be observed

2) General comments
- conductors bundled and centered
- spacing maintained to other cables and parallel cable type CT
- feedback of the (isolated) cable earth
- burden within the permissible range

Application: (Motor) Stator Earth Fault protection with 90% protection coverage
Motor data: I_N = 451,4 A starting current $I_{Start} = 5 \cdot I_N$ = 2257 A



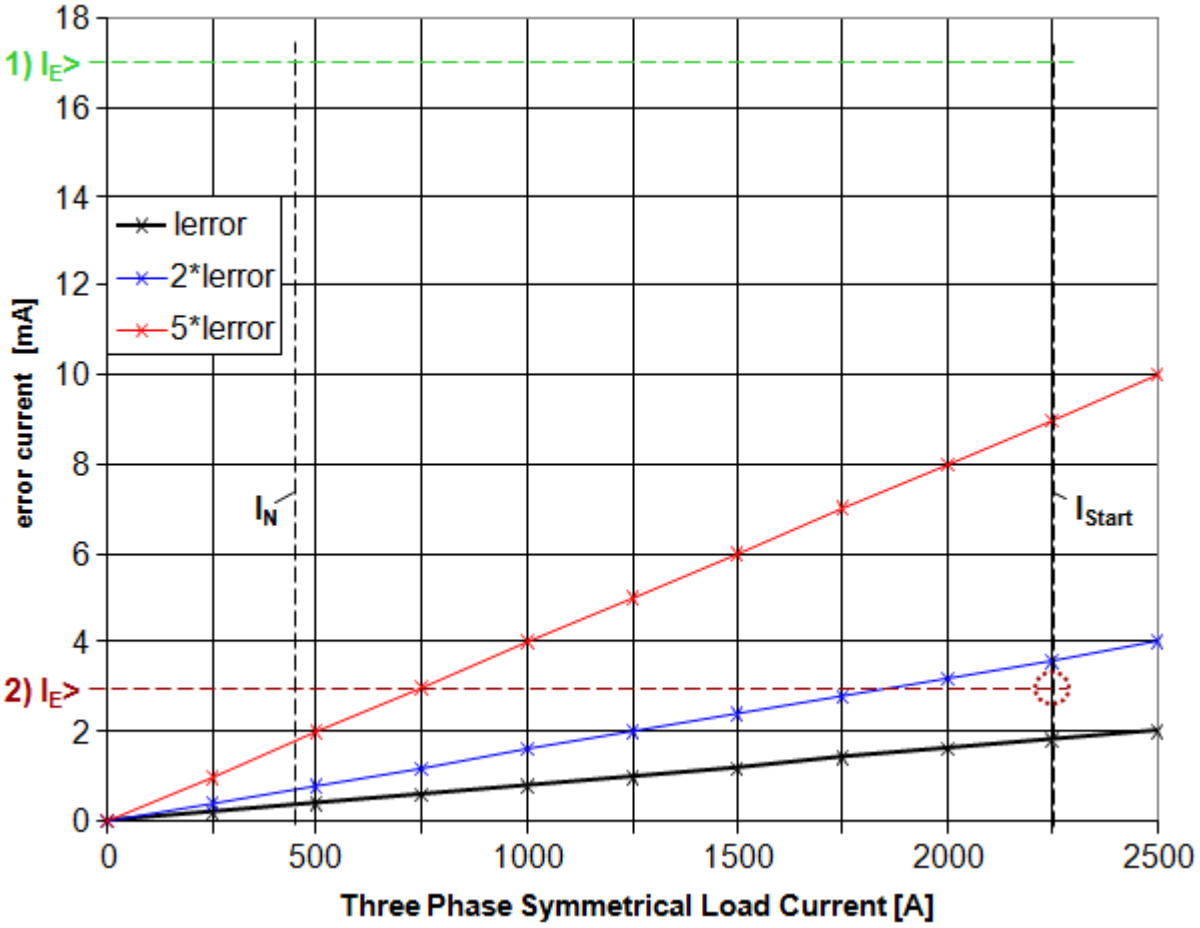
Case 1: Maximum earth fault current = 10 A resistive (via transformer neutral grounding resistor)
During earth fault (100%-90%) distant from motor star point: $I_E = (1\text{-}0{,}9) \cdot 10$ A = 1 A
The setting threshold is calculated on this basis for $I_E>$ = 1A/60 = 16,6 mA ≈ 17 mA

Case 2: maximum earth fault current = 1,8 A capacitive*)
(No transformer neutral grounding)
During earth fault (100%-90%) distant from motor star point:
$I_E = (1\text{-}0{,}9) \cdot 1{,}8$ A = 0,18 A The setting threshold is calculated on this basis for $I_E>$ = 0,18A/60 = 3 mA

*) The 1,8 A must always be obtained in the event of a solid earth fault. For the calculation only those plant items (cables/feeders) that are always/minimally in service may be considered.

IC SG Energy Automation
Product Management
email: support.ic@siemens.com
Telefon: +49 (180) 524 8437
Fax : +49 (180) 524 2471

7UM6: Stator earth fault protection with cable type CT



With the setting for Case 2, where I_E> = 3 mA, it is possible that the protection picks up during motor starts.

email: support.ic@siemens.com
Telefon: +49 (180) 524 8437
Fax : +49 (180) 524 2471