

**7UM6: Stator earth fault protection with cable type CT****Earth-Fault Protection with Cable Type CT's**

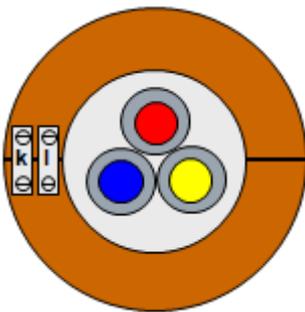
For **certain** earth-fault protection applications with cable type CT's, sensitive settings are required (e.g. directional or also non-directional stator earth-fault protection on generators and motors). Siprotec 4 devices always have a lowest possible setting value of 2 mA or in some cases 1 mA.

**Problem:**

Even in the case where the 3 conductors are centrally bundled, when passing through the cable type CT, an error current  $I_{\text{error}}$  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  $I_{\text{error}}$  may be substantially larger.

$I_{\text{error}}$  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.

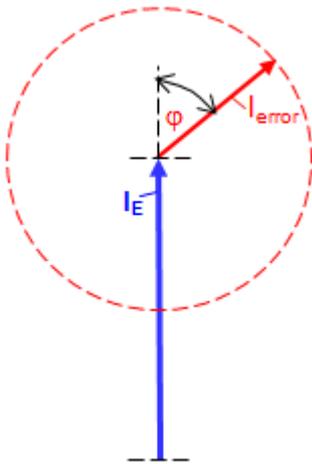
**The CT class does not state anything regarding the error current  $I_{\text{error}}$ .**

**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

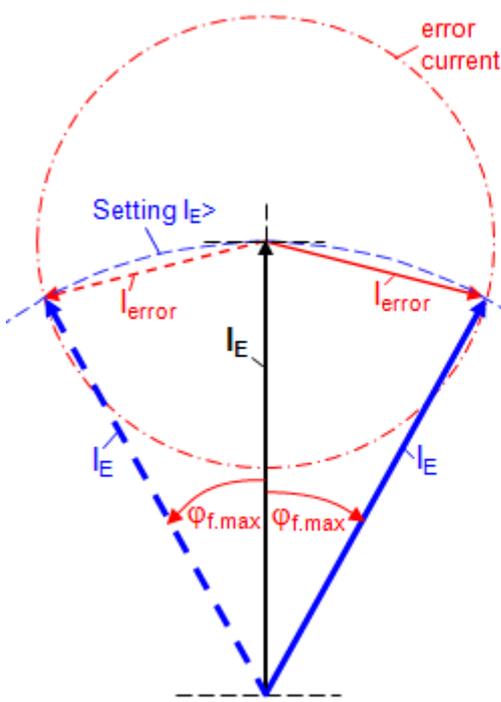
**7UM6: Stator earth fault protection with cable type CT**



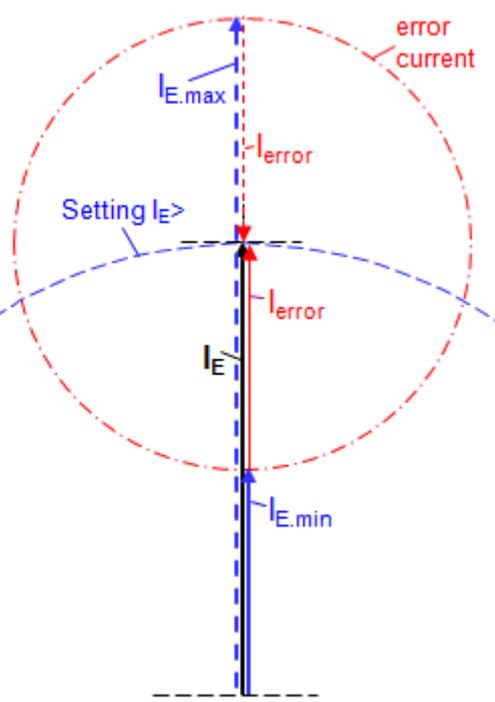
The angle ( $\varphi$ ) between the error current  $I_{error}$  and the actual earth fault current  $I_E$  may assume any value from 0 to 360 degrees. It may not even be assumed to remain constant in a particular application.

**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  $I_E$**



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  $I_{E,max}$   
 $50\% \cdot I_E > \leq I_E \leq 150\% \cdot I_E >$**

**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)**

$$\text{with } I_{error} = \frac{I_{E>}}{5}; \sin\left(\frac{\varphi_{t,max}}{2}\right) = \frac{I_{error}/2}{I_{E>}}$$

$$\varphi_{t,max} = 2 \cdot \arcsin\left(\frac{I_{error}/2}{I_{E>}}\right) = 2 \cdot \arcsin\left(\frac{1}{5 \cdot 2}\right)$$

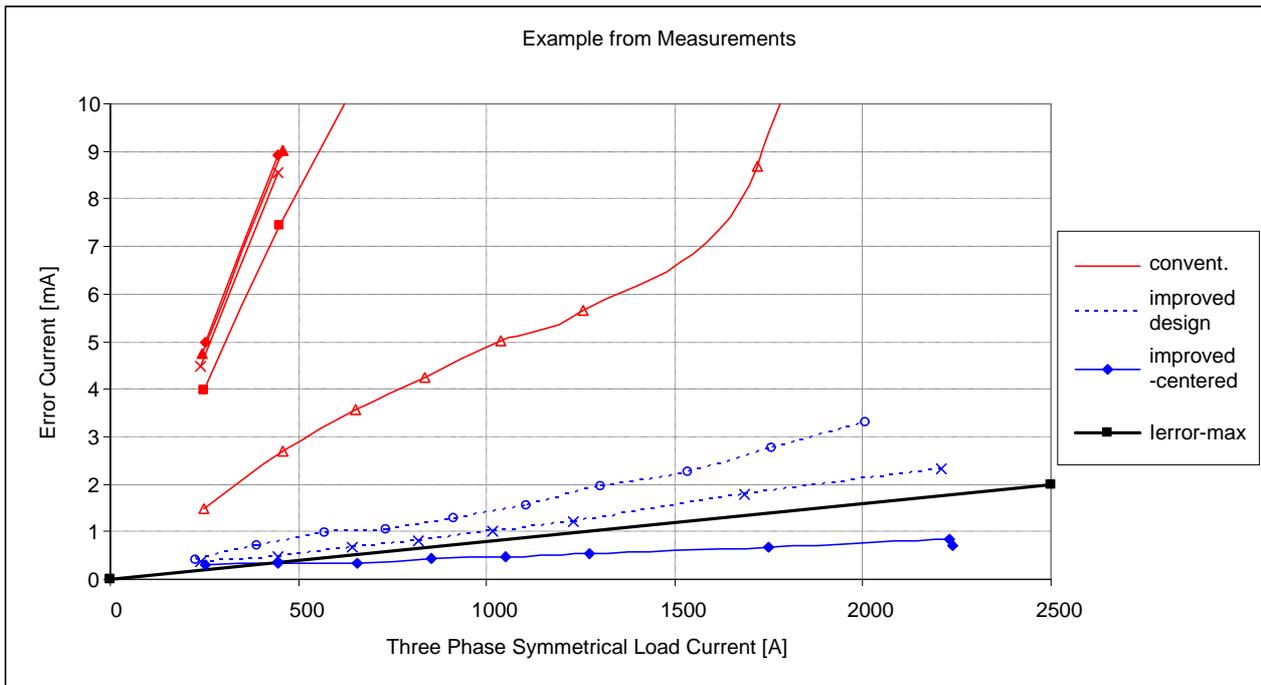
$$\varphi_{t,max} = 11.47 \text{ Grad}$$

**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 error-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**

**7UM6: Stator earth fault protection with cable type CT****\*) Comments for mounting:**

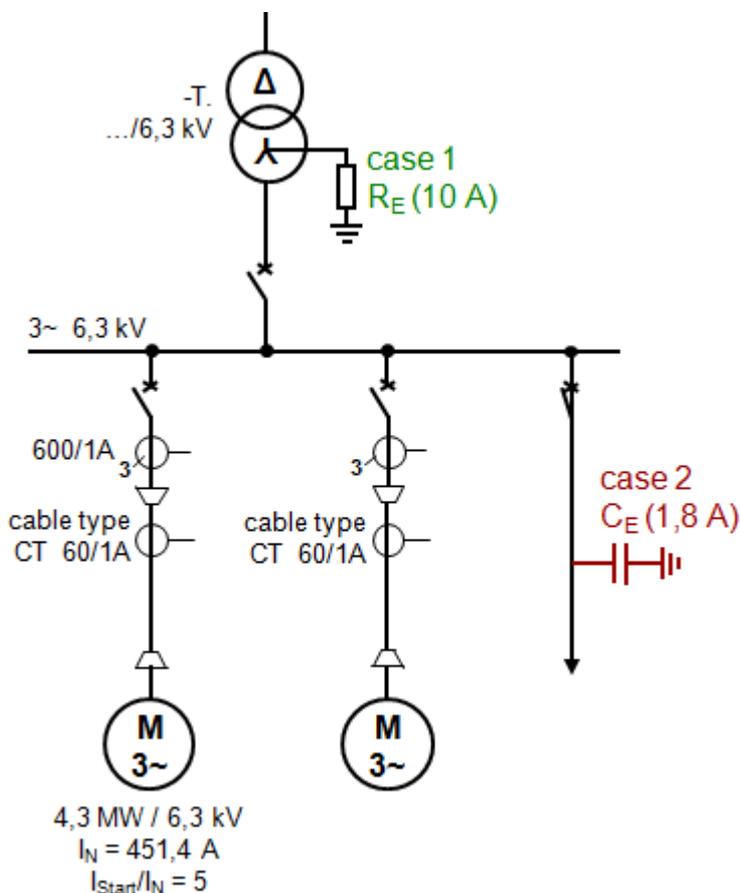
1) Mounting instructions of the supplier must be observed

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:  $I_N = 451,4 \text{ A}$  starting current  $I_{\text{start}} = 5 \cdot I_N = 2257 \text{ A}$



**Case 1: Maximum earth fault current = 10 A resistive** (via transformer neutral grounding resistor)

During earth fault (100%-90%) distant from motor star point:  $I_E = (1-0,9) \cdot 10 \text{ A} = 1 \text{ A}$

The setting threshold is calculated on this basis for  $I_{E>} = 1\text{A}/60 = 16,6 \text{ mA} \approx 17 \text{ mA}$

**Case 2: maximum earth fault current = 1,8 A capacitive\*)**

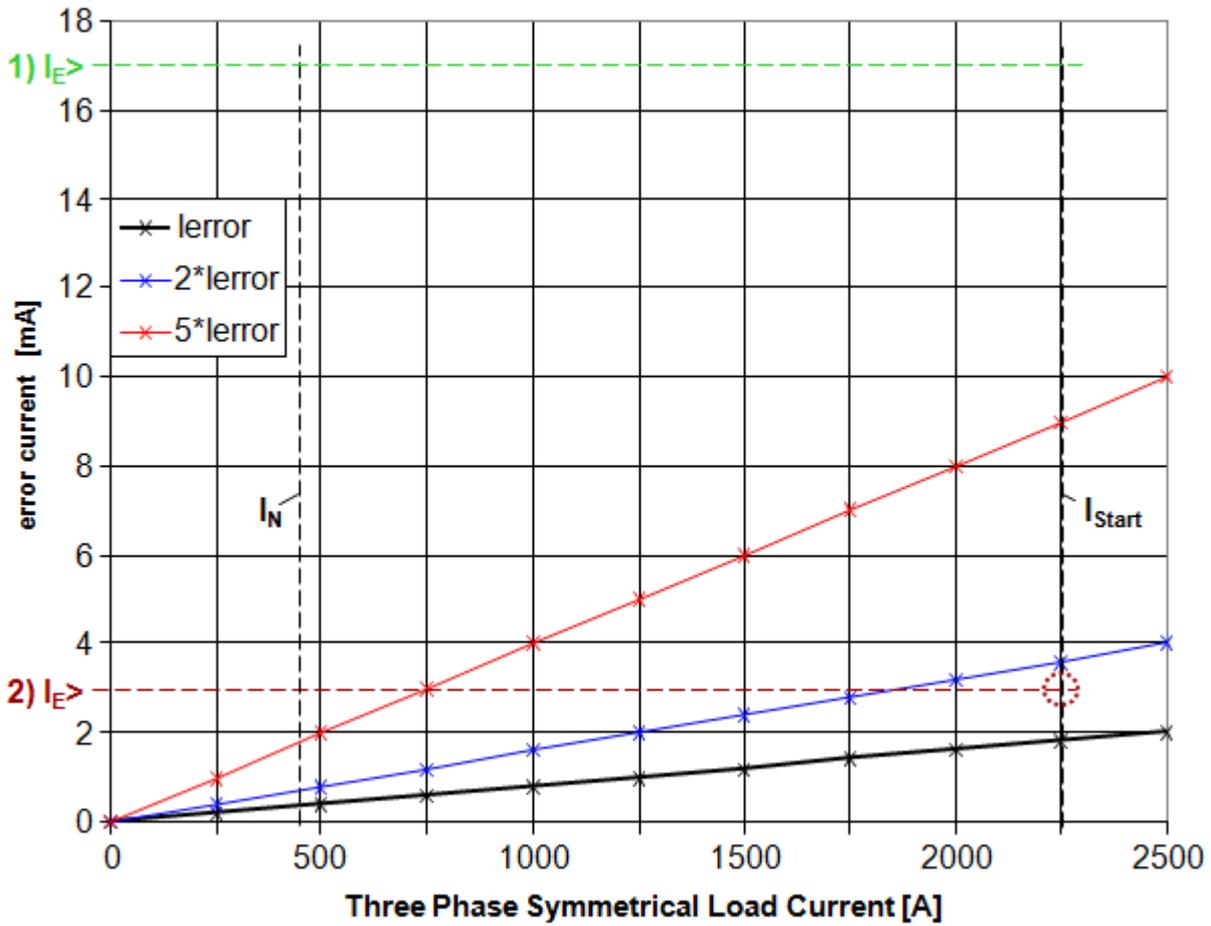
(No transformer neutral grounding)

During earth fault (100%-90%) distant from motor star point:

$I_E = (1-0,9) \cdot 1,8 \text{ A} = 0,18 \text{ A}$  The setting threshold is calculated on this basis for  $I_{E>} = 0,18\text{A}/60 = 3 \text{ mA}$

\*) 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.

7UM6: Stator earth fault protection with cable type CT



With the setting for Case 2, where  $I_{E>} = 3 \text{ mA}$ , it is possible that the protection picks up during motor starts.