

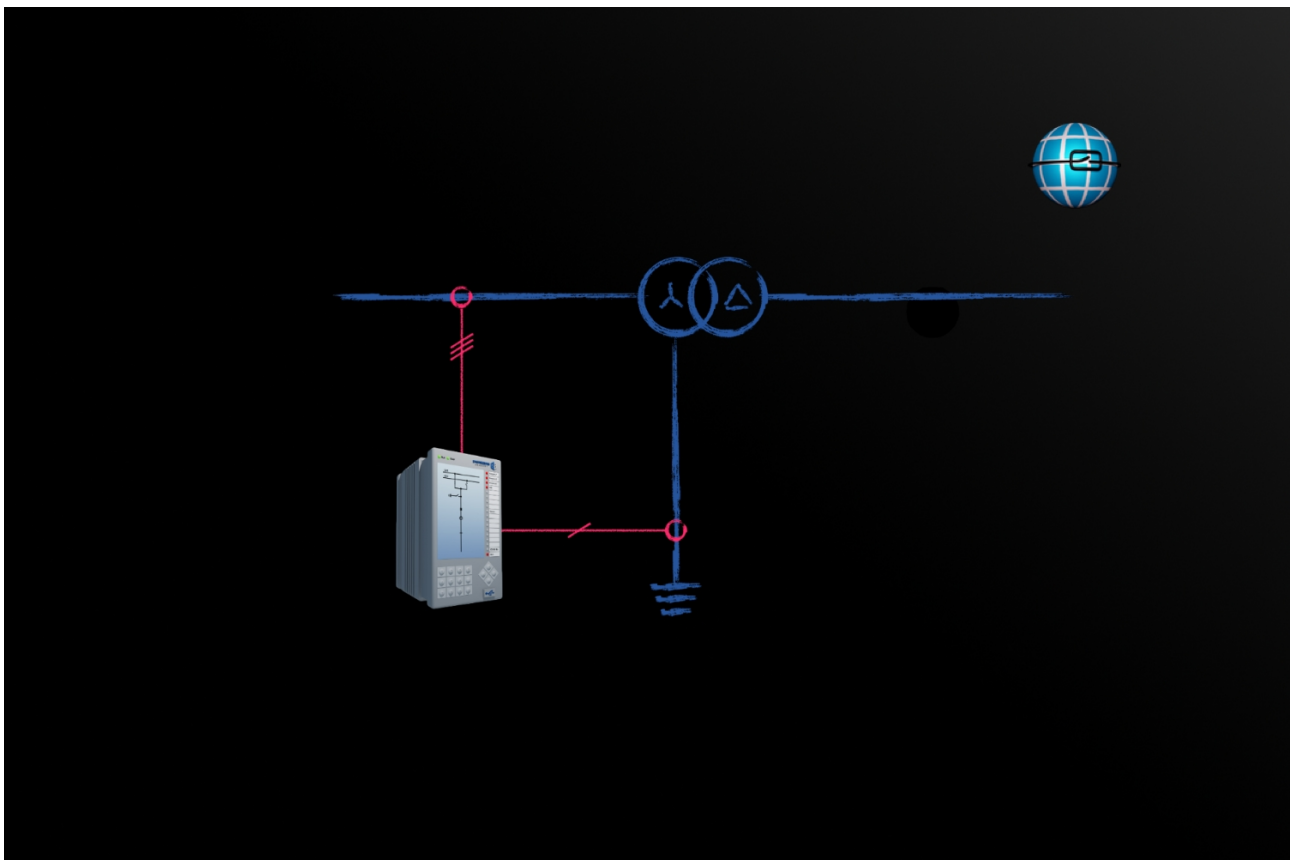
ELECTRICAL-ENGINEERING.ACADEMY

What is 87TE?

Restricted Earth Fault Protection - An Introduction

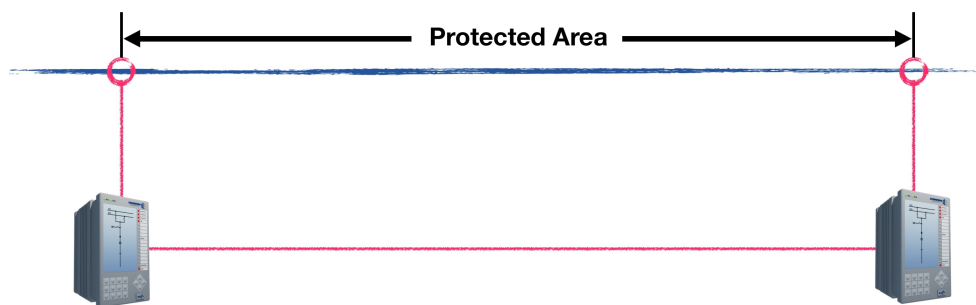
Welcome, dear friends of protection, control and electrical engineering. What is behind the function 87TE and why do you need something like that? In today's article, we present you with an actually quite old form of extension of the classic differential protection, which is still very rarely used in practice. Why?

Have fun while reading!

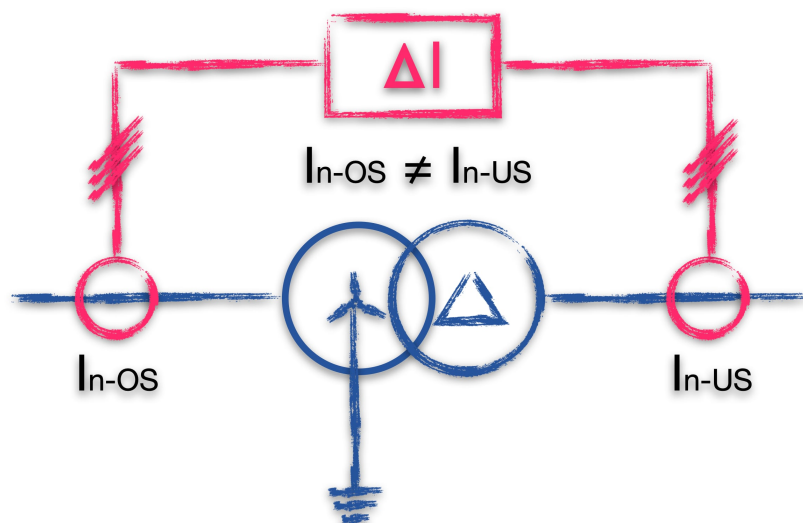


Introduction

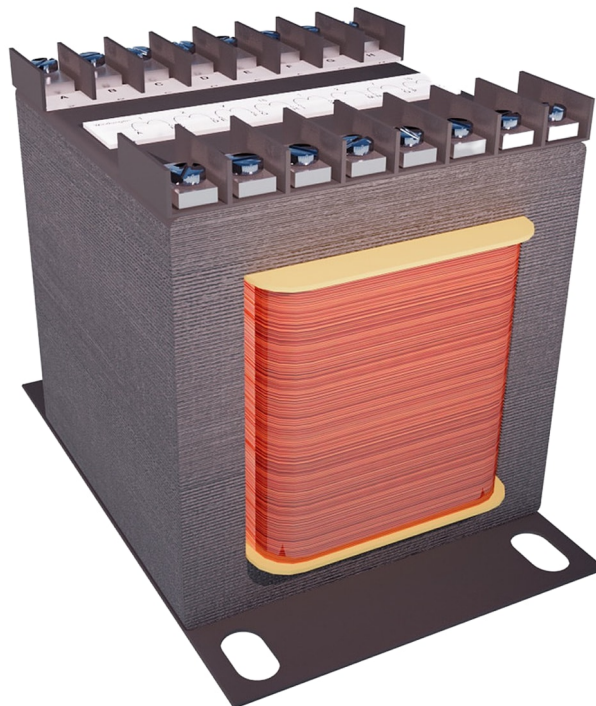
In order to grasp the essence and functionality of restricted earth fault protection, it is expedient to start with the function and the challenges of classic phase differential protection. The differential protection has the decisive advantage of absolute and definitive selectivity, since the protection area is determined by the installation locations of the current transformers.



One of its main challenges is the consideration of undesired residual currents, which can drive the algorithm into underfunctioning and, above all, into overfunctioning. In the case of generator and line differential protection, these are initially trivial mismatches due to typical CT errors and the CT ratios themselves. It gets really exciting when it comes to differential protection for transformers, since a few other aspects have to be taken into account here. In the case of a two-winding transformer, the transformer has two different voltage levels and correspondingly different nominal currents.



Accordingly, the transformation ratio of the transformer must be taken into account by the protection algorithm. Other undesired differential currents arise due to the vector group of the transformer, since the currents between the transformer sides are phase-shifted by 30° per group number. Before the advent of digital protection technology, the deviations mentioned were compensated for using so-called matching transformers.



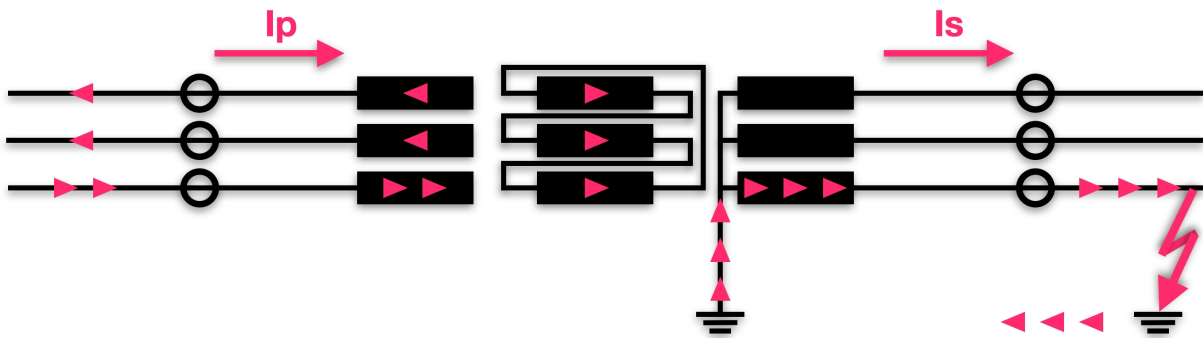
We gave an insight into the topic of matching transformers in our article: „Matching Transformers?“

Today's generation of protection relays works digitally and uses numerical calculation. A calculation is usually based on the rated current of transformer side 1, with the secondary measured currents being converted into primary currents. All other adjustments, such as vector group, transformer ratio, star point direction of the current transformer and the transformation ratio of the transformer, are taken into account numerically. But that's not

all, the different neutral point treatment between the high and low voltage sides is also of great relevance.

Residual Current Elimination

The figure below shows a transformer arrangement with a **Y yn d** group.



As soon as the star point of a transformer side is grounded and an external single-pole short circuit occurs, the classic differential protection system is no longer able to stabilize. The reason: The zero sequence system is not transferred to the other side of the transformer due to the existing compensation winding. The single-pole short circuit on the low-voltage side thus appears as a three-pole fault on the high-voltage side. Here the numerical residual current elimination is carried out by the protection algorithm. From the two vectors of the high and low voltage sides,

$$\underline{I}_p = \begin{bmatrix} -1 \\ -1 \\ +2 \end{bmatrix} \quad \underline{I}_s = \begin{bmatrix} 0 \\ 0 \\ +3 \end{bmatrix}$$

that the zero-sequence system of its own transformer side is subtracted from each phase current. The zero sequence system is generally calculated on the basis of the symmetrical components:

$$\underline{I}_0 = \frac{1}{3} (\underline{I}_{L1} + \underline{I}_{L2} + \underline{I}_{L3})$$

In our example, the zero-sequence current of the high-voltage side is $I_{p0} = 0$ and the zero-sequence current of the low-voltage side is $I_{s0} = 1$.

We now subtract the zero sequence current from the phase current vector. An unchanged vector results here for the primary side, since the zero sequence system on the high-voltage side simply does not exist or is zero.

$$\underline{I}'_p = \underline{I}_p - \underline{I}_{p0} = \begin{bmatrix} -1 \\ -1 \\ +2 \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -1 \\ -1 \\ +2 \end{bmatrix}$$

The "magic" now happens on the secondary side, we also get the vector of the high-voltage side, since the secondary zero sequence system has now been eliminated or numerically subtracted.

$$\underline{I}'_s = \underline{I}_s - \underline{I}_{s0} = \begin{bmatrix} 0 \\ 0 \\ +3 \end{bmatrix} - \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} -1 \\ -1 \\ +2 \end{bmatrix}$$

If the algorithm now calculates the differential and stabilization values, a stable system reappears in the event of an external single-pole fault. The zero current was eliminated numerically.

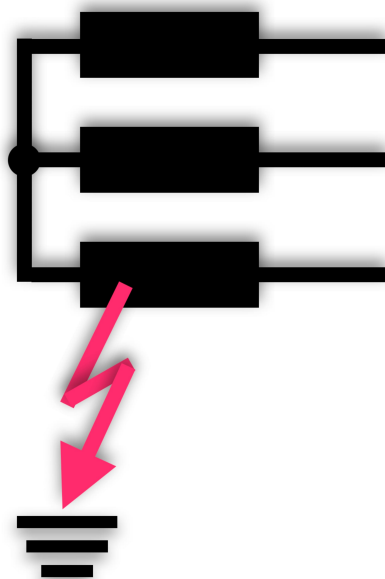
The elimination of the zero-sequence current was also carried out with appropriate matching transformers before digital technology was introduced. Today it is calculated in most cases. However, this calculation has a significant disadvantage:

"In the calculated zero-sequence current elimination, grounded-side internal single-phase faults are seen with 1/3 less sensitivity."

In order to counteract this phenomenon, it is also possible to measure the zero-sequence system by integrating an additional current transformer in the earth current path of the star point. The protection relay is thus able to divide the actually measured current in the earth path by 3 and subtract it from the phase currents.

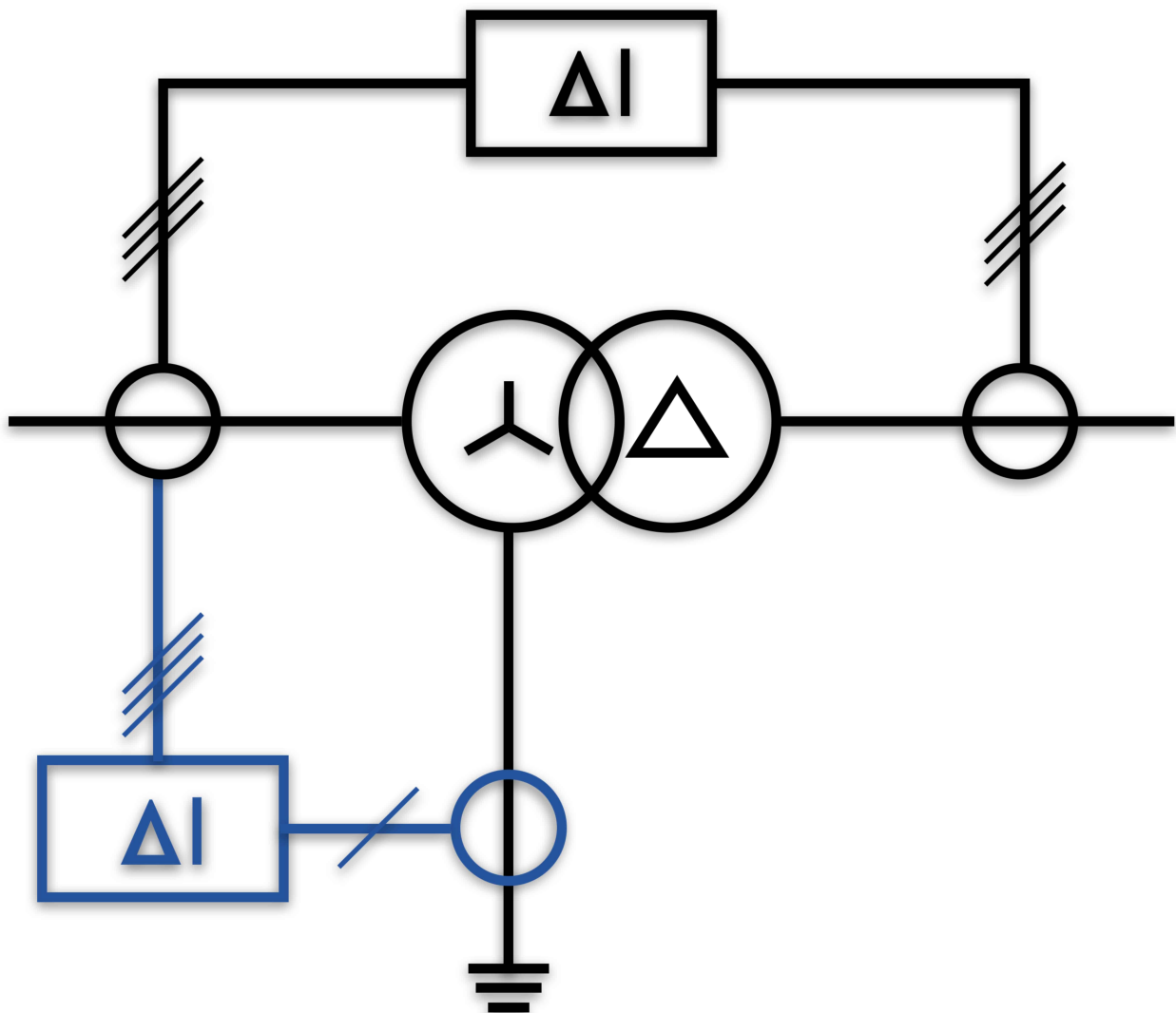
If we have an additional current transformer available in the earth path, we can counter this disadvantage of differential protection and thus come to restricted earth-fault protection, because it remains the same:

"Ground faults near the star point are generally difficult to detect."



Why restricted earth fault?

The figure below shows the basic structure of a ground-fault differential protection (see blue illustration).



As we can see, the protection function requires 4 analog current inputs. The measured current of the neutral point is compared with the calculated zero-sequence current of the 3 phase currents. We have shown the function here in blue and drawn it in as a separate

protection relay. In practice, the E-Diff function is combined with the classic phase differential protection in one device and a total of 7 current inputs are required.

The advantages of restricted earth fault protection are obvious: there is no tap changer, transformer ratio or vector group to be taken into account. The transformer-typical stabilization features are omitted. This allows increased sensitivity to be achieved and the grounded star winding is optimally protected in the event of ground faults. The residual current elimination of the phase differential protection can also be omitted.

For larger power transformers from 20 MVA upwards, the restricted earth fault protection should be mandatory by now. But he isn't.

Warm wishes

Your EEA-Team