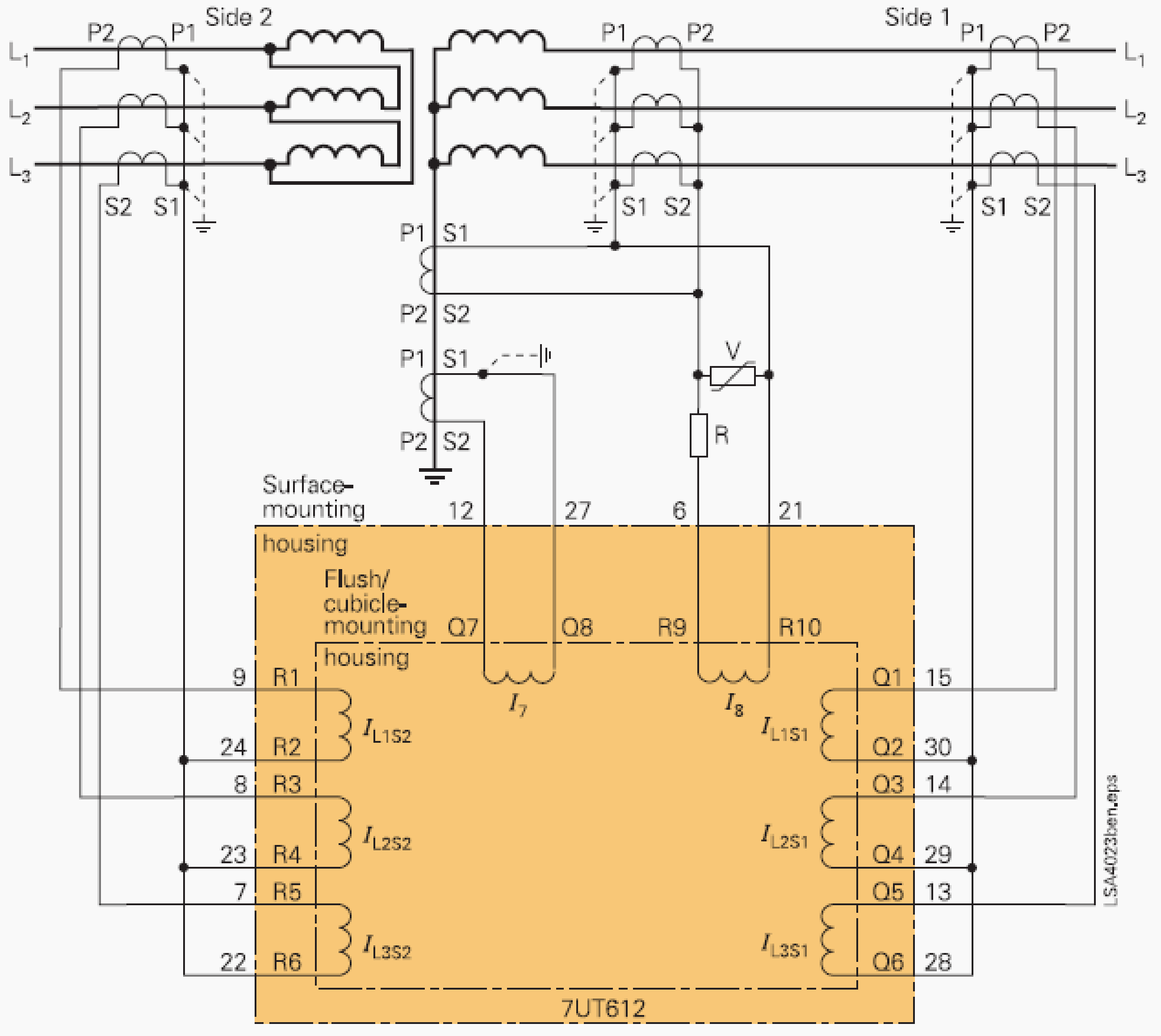
Transformer differential protection (ANSI code 87 T)



SIPROTEC 4 7UT6 Differential Protection Relay for Transformers - Connection of transformer differential protection with high impedance REF (I7) and neutral current measurement at I8

Introduction to ANSI code 87 T

Transformer differential protection protects against ***short-circuits*** between turns of a winding and between windings that correspond to phase-to-phase or three-phase type short-circuits.

If there is no earthing connection at the transformer location point, this protection can also be used to protect against earth faults. If the earth fault current is limited by an impedance, it is generally not possible to set the current threshold to a value less than the limiting current.

The protection must be then carried out by a ***high impedance differential protection***.

Transformer differential protection operates very quickly, roughly 30 ms, which allows any transformer deterioration in the event of a short-circuit between windings to be avoided.

Transformers cannot be differentially protected using high impedance differential protection for phase-to-phase short-circuit due to the natural differential currents that occur:

1. The transformer inrush currents. The operating speed required means that a time delay longer than the duration of this current cannot be used (*several tenths of a second*);
2. The action of the on-load tap changer causes a differential current.

The characteristics of transformer differential protection are related to the transformer specifications:

1. Transformation ratio between the current entering I_{in} and the current leaving I_{out} ;
2. Primary and secondary coupling method;
3. Inrush current;
4. Permanent magnetizing current.

The block diagram is shown in ***Figure 1*** below.

In order to prevent tripping upon

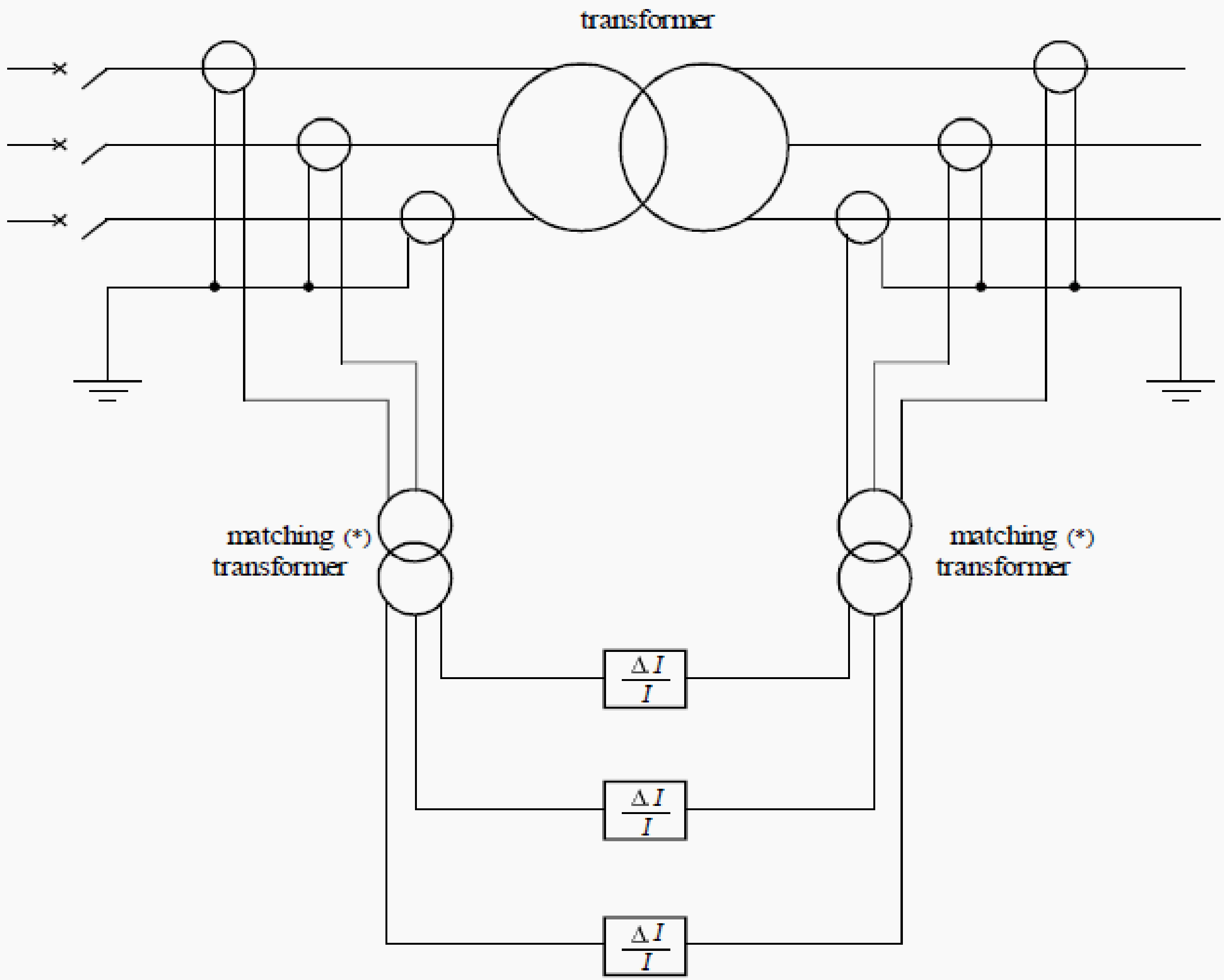


Figure 1 - Transformer differential protection block diagram

occurrence of high fault currents of external origin, biased differential protection devices are used.

This is because of:

- The differential current due to the on-load tap changer;
- The current transformer measurement errors, as for pilot wire differential protection for cables or lines.

Protection is activated when:

$I_{in} – I_{out} > K\ I_{in} + I_o$ (*see Figure 2*).

Problem relating to the transformation ratio and the coupling method

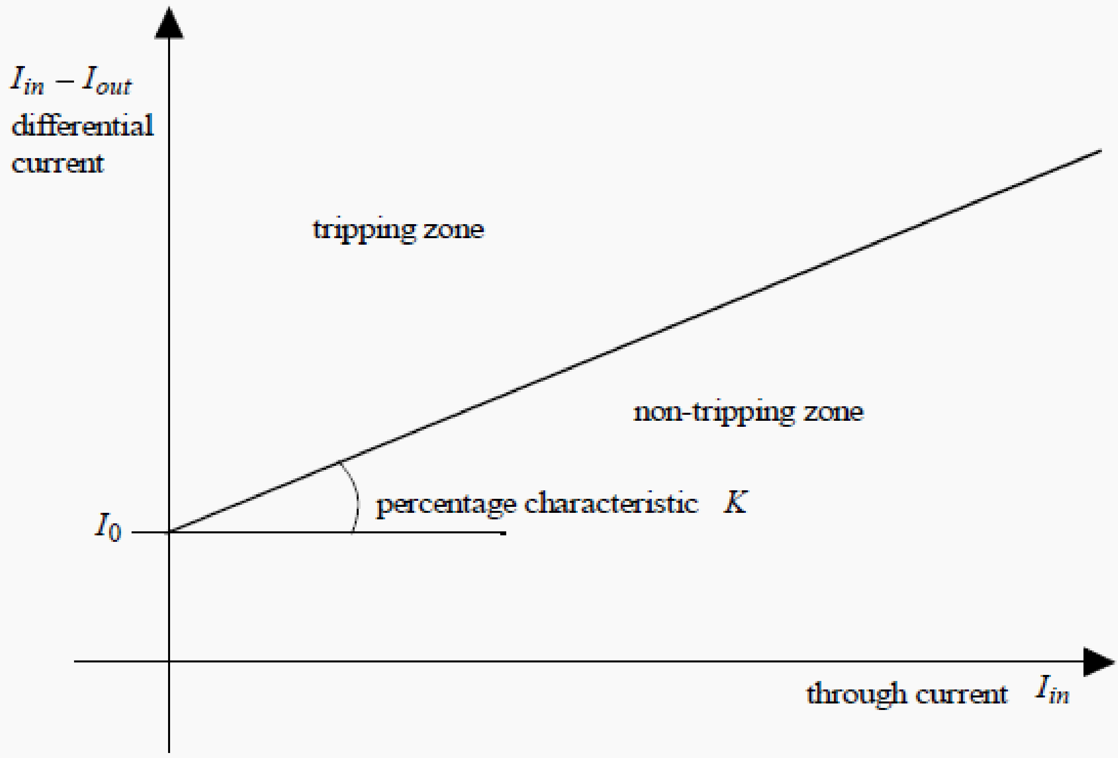


Figure 2 - Transformer differential protection tripping curve

The primary and secondary currents have different amplitudes owing to the transformation ratio and different phases depending on the coupling method (delta-star transformer makes a phase displacement of 30°). Therefore, the current values measured must be readjusted so that the signals compared are equal during normal operation.

*This is done using matching auxiliary transformers whose role is to **balance the amplitudes and phases**.*

When one side of the transformer is star-connected with an earthed neutral, the matching transformers located on this side are delta-connected, so that the residual currents that would be detected upon occurrence of an earth fault outside the transformer are cleared.

Problem relating to the transformer inrush current

Transformer switching causes a very high transient current (***from 8 to 15 I_n***), which only flows through the primary winding and lasts several tenths of a second.

It is thus detected by the protection as a differential current and it lasts far longer than the protection operating time (30 ms). Detection based only on the difference between the transformer primary and secondary currents would cause the protection to be activated. Therefore, the protection must be able to distinguish between a differential current due to a fault and a differential inrush current.

Experience has shown that the inrush current wave contains at least 20% of second harmonic components (*current at a frequency of 100 Hz*), while this percentage is never higher than 5% upon occurrence of an overcurrent due to a fault inside the transformer.

The protection must therefore simply be locked when the percentage of second harmonic component in relation to the fundamental harmonic component (current at 50 Hz) is higher than 15%, i.e. ***$I_2/I_1 > 15\%$***.

Problem relating to the magnetizing current upon occurrence of an overvoltage of external origin

The magnetizing current constitutes a difference between the transformer primary and secondary currents (see section 6.1.1). It is therefore detected as a fault current by the differential protection even though it is not due to a fault.

In normal operating conditions, this ***magnetizing current is very low*** and does not reach the protection operating threshold.

However, when an overvoltage occurs outside the transformer, the magnetic material saturates (in general the transformers are dimensioned to be able to operate at saturation limit for the nominal supply voltage), and the magnetizing current value greatly increases. The protection operating threshold can therefore be reached.

Experience has shown that the magnetizing current due to the magnetic saturation has a high rate of fifth harmonic components (current at a frequency of 250 Hz).

To prevent ***spurious tripping*** upon occurrence of an overvoltage of external origin, there are two solutions:

1. Detect a rise in voltage that locks the protection;
2. Detect saturation using the presence of fifth harmonic current that locks the protection.

Transformer differential protection therefore requires fairly complex functions as it must be able to measure second and fifth harmonic currents or, in order to avoid measuring fifth harmonic currents, it must be able to detect overvoltages of external origin.

Resource: *Protection of electrical networks - Christophe Prévé*