Info Letter No. 1

Measurement Transformers in three-phase networks (Part 1)

The direct connection of measuring devices into the network is limited for safety reasons to values below approximately 500 V to 800 V for voltages and ≤ 10 A for currents.

Inputs with higher operating values are adapted to the input range of the measuring equipment with transformers.

1.0 Transformer for alternating values

Transformers for alternating values are low-power transformers operating well below the saturation limit of the iron core. The high values of a grid value (primary values X_1) are accurately amplitude and phase mapped to lower values (secondary values X_2) by conversion and galvanic separation. The grid values can therefore be measured more easily and with less danger.

Nominal translation

The nominal values X_{1n}, the primary values and X_{2n} the secondary values and thus the nominal translation K_n determine the choice of the transformer.

$$K_\mathrm{n} = \frac{X_\mathrm{1n}}{X_\mathrm{2n}}$$

K_{nu} = Voltage transformer nominal translation
K_{ni} = Current transformer nominal translation

Example 1.1
Current transformer data:
X_{1n} = 1000 A, X_{2n} = 5 A

Nominal translation of the current transformer:
K_{ni} = 1000 A : 5 A = 200

Conversion of measured values of the power
The measured value of the power on the line side is the product of the measured value of the power in the secondary circuit and the nominal translation of the current and voltage transformers.

$$P_\mathrm{prim} = P_\mathrm{sek} \cdot K_\mathrm{nu} \cdot K_\mathrm{ni}$$

This correlation is the same for all types of network. In three-phase networks, the nominal translation of all voltage transformers and current transformers must be the same

Example 1.2
Network data: 300 MW, 110 kV
Measurement transformer:
K_{nu} = (110 kV / √3) : (100 V / √3) = $1.1 \cdot 10^3$
K_{ni} = 1200 A / 1 A = $1.2 \cdot 10^3$

Power value on the secondary side
P_{sek} = ($300 \cdot 10^6$ W) : ($1.0 \cdot 10^3 \cdot 1.2 \cdot 10^3$) = 300 : 1.2 = 250 W

1.1 Current transformer

A current transformer is a transformer that is whose secondary winding is almost short circuited. The secondary circuit must always be closed. Operation with an open current circuit (no load, open secondary winding), because of the non-existing mutual induction and the consequent multiplication of the iron losses, causes major heating of the transformer core, and in extreme cases, an explosion. Because of the large ratio of the primary to the secondary winding, in this case a high, dangerous voltage can result at the terminals of the secondary winding, which can also cause arcing between the windings. For these reasons, fuses must **not** be used in the secondary circuit.

Earthing of the secondary winding

For safety reasons, the secondary winding of a current transformer that is installed in a high-voltage grid is grounded on one side to prevent the endangerment of the operating personnel due to high voltage on a breakdown of the winding insulation. This requirement is defined in VDE 0100 for measurement transformers from series **3** (operating voltage 3 kV) upwards.

Earthing of the secondary winding is not required for the series **0.5** and **1**. Often, however, this is necessary for technical reasons, in order to create a defined reference point in a current circuit and dissipate interference voltages to earth.

Nominal value I_{2n}
The standardised nominal values of the secondary currents are:
1 A, 2 A and 5 A.

Accuracy classes of current transformers
Current transformers are produced in the classes 0.1; 0.2; 0.5; 1; 3; 5.

Current transformer terminal designations

In accordance with DIN 0414, the terminal designations for the primary winding are K and L and *k* and *l* for the secondary winding.

K on the generator side, and L on the consumer side.

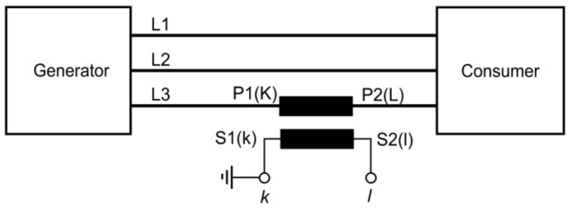

Figure 1.1:
Terminal designation in current transformers in accordance with DIN0414.

Table 1.1

Current connection	k	l
*I*1	Terminal 1	Terminal 3
*I*2	Terminal 4	Terminal 6
*I*3	Terminal 7	Terminal 9

1.2 Voltage transformer

Voltage transformers are transformers that operate with almost no load on their secondary windings. A shorted secondary winding can lead to the destruction of the voltage transformer (protection by fuses).

Types of voltage transformer

Voltage transformers are designed as single-phase or three-phase transformers. In the design of single-phase voltage transformers, a distinction is made between single-pole insulated and double-pole insulated voltage transformers. This term relates to the isolation of the connector pins of the primary winding to Earth. - Only single-pole insulated voltage transformers are used in medium and high-voltage networks.

Earthing of the secondary winding

As with current transformers, for safety reasons a terminal of the secondary winding should be earthed immediately with voltage transformers above series 3. Earthing of the secondary winding is not required for the series **0.5** and **1**. Often, however, this is necessary for technical reasons, in order to create a defined reference point in a current circuit and dissipate interference voltages to earth.

Voltage transformer terminal designation

The standard terminal designations in accordance with DIN0414 for single-pole and two-pole voltage transformers are shown in Figure 1.2. This terminal designation applies to measuring devices in the three-phase network according to DIN 43807.

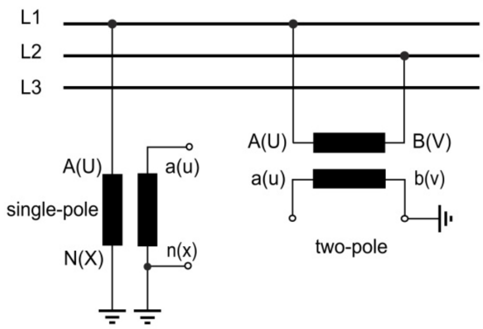

Figure 1.2:
Terminal designations for voltage transformers in accordance with DIN0414.

Table 1.2

L1	L2	L3	N
Terminal 2	Terminal 5	Terminal 8	Terminal 11

Indication of nominal translation in single-pole voltage transformers

With single-pole insulated voltage transformers, due to the prevailing use in three-phase networks the identification "External conductor voltage / √3“ is used for the nominal values U_{1n} of the primary winding and U_{2n} of the secondary windings. The usual notation for the nominal translation has the form

$$K_{nu} = \frac{U_{1n}}{\sqrt{3}} \div \frac{U_{2n}}{\sqrt{3}}$$

Example

$$K_{nu} = \frac{\frac{110\,\text{kV}}{\sqrt{3}}}{\frac{100\,\text{V}}{\sqrt{3}}} = \frac{110\,\text{kV}}{100\,\text{V}} = 1100$$

Nominal value U_{2n}

The nominal values of the secondary voltage are standardised. The values for the voltage between two external conductors are: 100 V; 110 V; 220 V (mainly in Europe) and 115 V; 120 V; 230 V.

For the measurement of external conductors to earth, there are the values of the top series of numbers divided by √3, thus 57.74 V; 63.51 V; 115.47 V and 66.40 V; 69.28 V; 132.79 V.

Accuracy classes of the voltage transformer

Voltage transformers are produced in the classes 0.1; 0.2; 0.5; 1; 3.

1.2.1 Voltage transformers in three-phase networks

Two two-pole insulated voltage transformers

With two of these voltage transformers, all of the delta voltages in the network can be measured. The star point is not accessible. This transformer configuration is used primarily for the two system-performance measurement (Aron circuit).

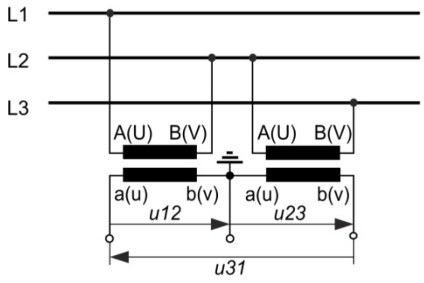

*Figure **1.3** Measurement of all delta voltages*

Three single-pole insulated voltage transformers

With three of these voltage transformers all of the delta voltages and all voltages reference to the earthing point (star point) can be measured.

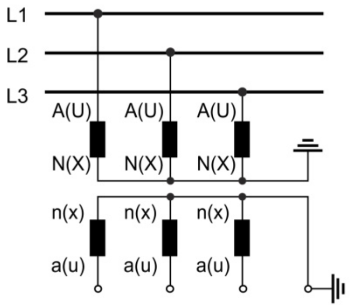

Figure 1.4 *Measurement of all delta voltages and all voltages with reference to the earthing point*

Cyclic commutation with current connections in other external conductors

Usually, for the power measurement in a three-phase network with a symmetric load the current is supplied from strand L1 of the measuring equipment (fig. 1.5)

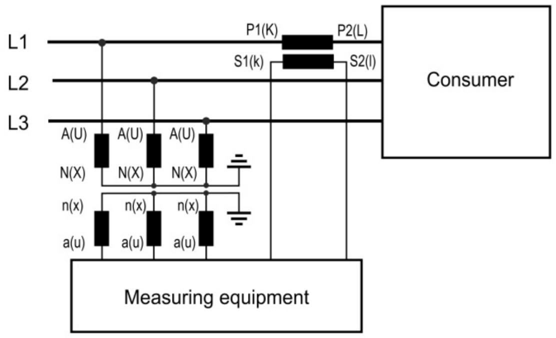

Figure 1.5 *Common connection of the current path*

The topic is continued in Part 2 / Info Letter No. 2

The series will be continued.
We will gladly supply missing Info Letters at any time!

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