# THE INSTRUMENT TRANSFORMER – A RACECAR WITH THE WRONG SETTINGS?

By Detlef Ebel, Gösta Hallgren and Peter Kurth

*At the Monaco Grand Prix, Ferrari set up Michael Schumacher's race car with the parameters of the Hockenheim race circuit. Despite Schumacher's obvious driving skills and many years of experience, he had no chance of winning.*

If we use this analogy for metering installations, why is it that the majority of utilities 'drive' their measuring instruments (meters) with the wrong overall parameters – and are then surprised by high network losses?

Utilities should be aware of the conditions under which instrument transformers have to be used. This paper mentions some common mistakes; the explanations are based on more than 50 years of industry experience with current and voltage transformers (CTs/VTs).

The connection of a measuring system comprising electricity meter, VT and CT is shown in Figure 1. This connection and other variations are common and have remained unaltered for many years. From the point of view of most users, no significant changes for VT and CT have occurred. The respective transformation ratios of the transformers are determined and the burden remains unchanged for a long time.

**MEASUREMENT**

It is obvious to any user that an incorrect transformer ratio leads to incorrect measurements – but the influence of the operating burden associated with the transformers (measuring devices and conductors) is rarely taken into consideration.

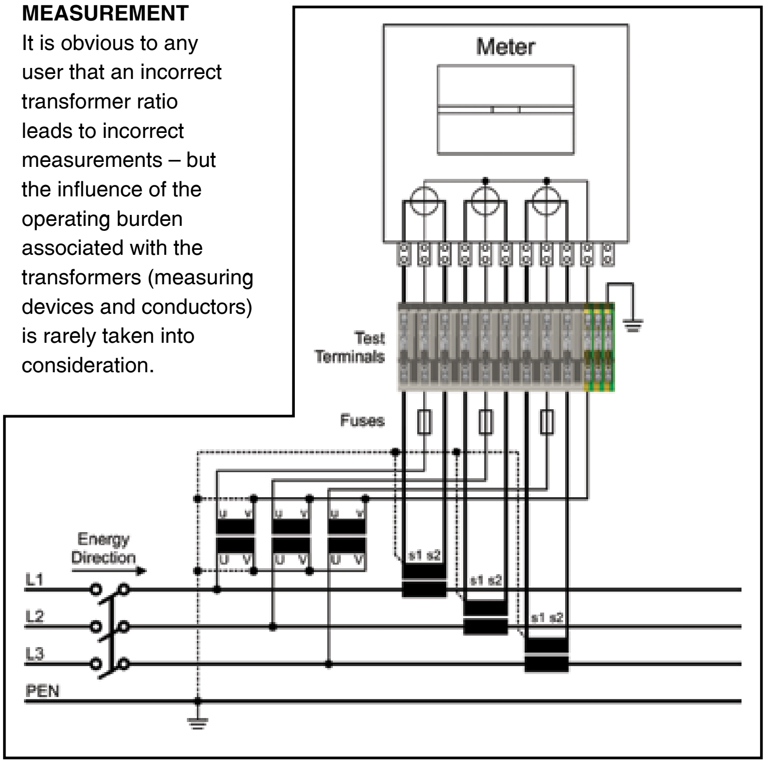



*Figure 1 – Connection diagram of a measuring system with VTs and CTs*

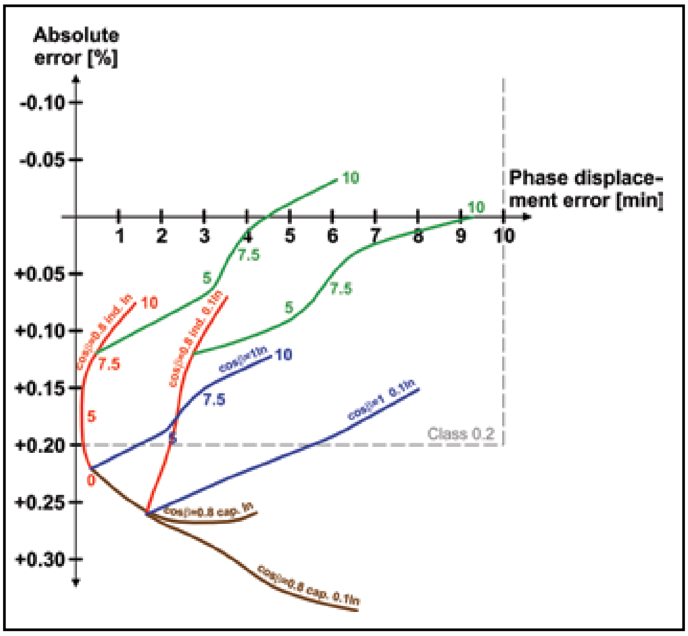



*Figure 2 – Error curve of a 10 VA CT*

**METERING INSTALLATION**

Installing new sophisticated measuring instruments can result in under-burdening, if the installation is not taken into account when deciding on the CT/VT or modernisation of the measuring system (i.e. CT/VT and meters). Today, sophisticated measuring devices replace sets of several instruments. They also have very low energy consumption, and the meter cabinets have become smaller and smaller, with very short cable lengths. All this results in a lower operating burden for the metering installation, and can result in the transformers operating in an under-burden mode.

The accuracy of instrument transformers is defined as ratio error and phase displacement error. It must be remembered that the phase displacement error has a substantial influence on power measurements with part-resistive network loads.

Figure 2 shows the typical error curves of a CT Cl. 0.2 with rated burden of 10VA, cos β = 0.8 and at: - different operation burdens with cos β = 0.8 ind. at 10% IN and 100 % IN (red curve for a Ferraris meter),
- cos β = 1 at 10% IN and 100 % IN (blue curve)
- cos β = 0.8 capacitive at 10% IN and 100% IN (brown curve).

This behaviour of CTs is typical for differently rated burdens. The green curves describe the characteristics if the transformer burden is adjusted to 7.5VA, cos β = 0.8 and the wires are not considered. The resulting curve shape is shown for different wire lengths that result in a burden of up to 10VA.

The error curves above clearly show that the operating burden should not only be within a range of 25 … 100% SN indicated on the CT, but also the cos β must be maintained 0.8.

From the load curves it can be seen that in the case of an incorrect burden – < 25% SN or an incorrect cos β – the absolute error exceeds the accuracy class in a positive direction, and the phase displacement becomes larger. But what influence does the phase angle have?

The additional error of the measuring system Fδi at different network loads cos φ and different phase displacement errors δ of a CT is displayed in Figure 3. It shows that an incorrect operating burden has a significant influence on the total accuracy of the measuring system.

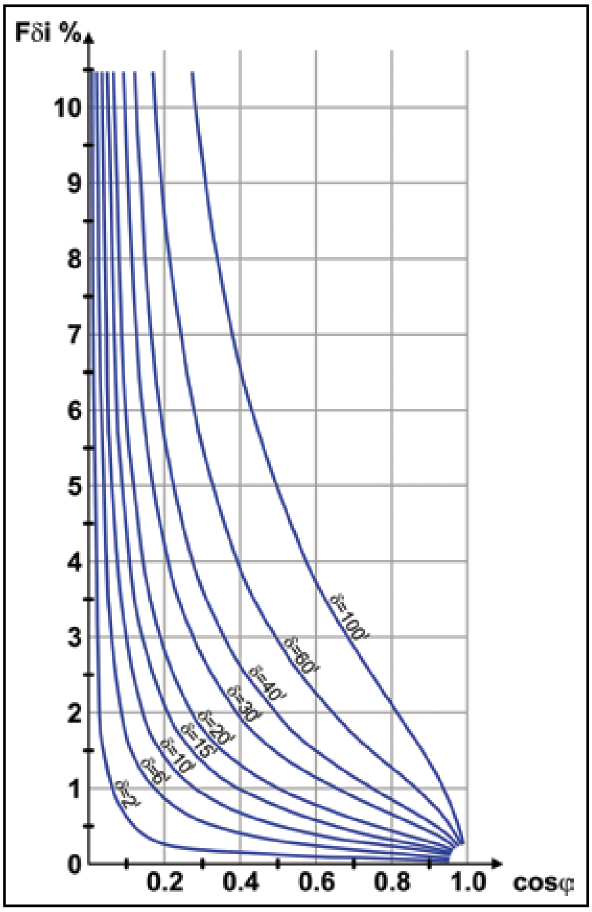


*Figure 3 – Influence of the phase displacement*

**MISTAKES IN USING CTs**

**Conductor cross-section.** The choice of wire cross-sections has a big influence on the operating burden. An over-burdened CT leads to significant negative additional error and reaches saturation. The risk of transformer overheating exists and, in the long run, damage or even destruction.

**Exchanging of meter.** The operating burden of a CT is considerably reduced if one or more Ferraris meters are replaced by an electronic meter. If the old installation has an 18VA operating burden; the new operating burden will be 3VA after changing to one new electronic meter. If the CT rated burden is 20 VA, the actual burden is 15% SN after replacing the meters. The burden is out of the range 25 and 100 % SN and an additional error arises.

**Phase shift in secondary circuit.** In general CTs are designed for a load in a secondary circuit of cos β = 0.8i, because this was the load caused by Ferraris meters. Today an electronic meter at the same CT results in cos β = 1. The graph in Figure 3 shows that errors may lie outside acceptable limits.

**Unbalanced load.** The CT should not be wired with a common neutral wire. The resulting unsymmetric current would flow through the common neutral wire and thus change the CT operating burden.

**Operation in capacitive range.** A capacitive CT operating burden results in the brown error curve in Figure 2. Ratio and phase error increase significantly.

**Short circuit in the network.** The lower CT operating burden results in higher secondary current in the event of network short circuit. The CT is designed to transform the primary current up to 120% IN with classified accuracy between 25% … 100% SN. Primary current above this limit results in transformer saturation. However, if the operating burden is too low, the secondary current of the CT may reach values that could damage or destroy the connected meter.

**Adjusting the operating burden.** There are different methods of changing the burden of a measuring device connected on site. If the CT is over-burdened, load resistance must be reduced. If it is under-burdened, load resistance must be increased.

**Measurement of the operating burden.** The precise determination of the operating burden of a CT is only possible after installation on site. The measuring instrument is connected directly to the CT output terminals, but if this is not possible it should be connected to the nearest clamping point. The burden for wire length and cross-section must be added.

The rated CT burden always relates to the rated secondary current. Therefore the actual burden must be calculated to this current.

**MISTAKES IN USING VTs**

**Secondary circuit voltage drop**. The wire cross-sections influence the measurement accuracy – i.e. the voltage drop on the conductor to the measuring instrument has a significant influence on the measurement accuracy.

**Example:**
A VT with secondary voltage 57 V and conductor length 150m. Since voltages always have a balanced system, the current in the common neutral wire is ≈ 0. The operating burden of the VT is 10 VA. Using copper conductors with cross-section 1.5 $mm^2$ the voltage drop is 312 mV. This voltage drop related to rated voltage 57V causes an additional measuring error of 0.5%. This means that the voltage drop leads to a measurement error larger than the accuracy class of the electricity meter.

**Exchanging of meters.** If one or more Ferraris meters is replaced by an electronic meter, the operating burden of the VT – which consists almost exclusively of the connected consumers/devices – decreases considerably.

**Phase shift in secondary circuit.** The same conditions apply here as explained for CTs.

***"Utilities should be aware of the conditions under which instrument transformers have to be used."***

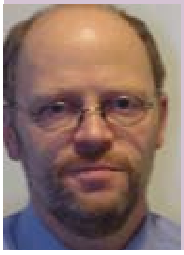
**Adjusting the operating burden.** There are different methods of changing the burden of a measuring device connected on site. If a VT is over-burdened, load resistance must be increased; if it is under-burdened, load resistance must be reduced.

**Measurement of the operating burden.** The correct determination of the operating burden of a VT is only possible after installation on site. The measuring instrument is connected directly to the output terminals of the VT to measure the operating burden. If this is not possible, it should be connected to the nearest possible clamping point. The rated VT burden relates to the rated secondary voltage, e.g. 57.7V, and the actual burden must therefore be calculated to this voltage.

## CONCLUSIONS

The operation of CT/VT outside the specified burden range leads to additional errors that may decrease the accuracy of the total measuring system. Replacing a Ferraris meter with an electronic meter with a higher accuracy class does not in all cases lead to higher measurement accuracy; it may even decrease the total accuracy of the measuring system.

In each case, a complete measurement of the parameters affecting the overall accuracy of the installation should be carried out. Simply adding the lab calibration error values of the meter and transformers does not result in the actual total measurement accuracy. MI



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**ABOUT THE COMPANIES: MTE Meter Test Equipment AG**, established in 1995, is located in Zug, Switzerland. The company is active worldwide in marketing and sales for stationary and portable measuring technology for electricity meters and power quality analysis, as well as for transformer monitoring systems.

**GH Teknik**, situated in Malmö, Sweden was founded in 2001. GH Teknik's main field is marketing and sales of MTE products in Sweden.

**EMH Energie-Messtechnik GmbH** was founded in 1984 and is located in Brackel, Germany. The main field of activities is R&D and manufacturing of stationary and portable measuring technology for electricity meters, CT, VT, power quality analysing systems, and gas in oil monitoring systems for power transformers.

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