Revolution in measuring techniques enables superior protection performance

Traditionally, magnetic instrument transformers have been used to measure currents and voltages in medium voltage switchgear. Their basic construction dates back to the early days of the electricity. The new measurement system based on current and voltage sensors, and the new protection and control IED (Intelligent Electrical Device) technology are superior to older techniques as regards functionality, environmental aspects and personnel safety. As sensor technology is gaining ground at the expense of conventional CTs and VTs, the manufacturers of test equipment for protection and control IEDs have already developed test equipment for sensor inputs. Equipment that can use the required accurate low signals received from a sensor have been available on the market for some years.

ABB´s REF 541/543/545 Feeder Terminals and KEVCD sensors combine the benefits of modern protection and control IED and sensor technologies

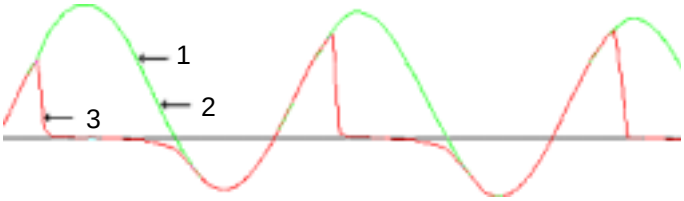
Rogowski technology as a basis

The current sensor is based on Rogowski technology. The Rogowski coil is a magnetic current transducer, where the iron core has been replaced by a non-magnetic material. The Rogowski coil was invented in 1912, but until now it has only been used in special, expensive laboratory equipment. Thanks to the introduction of the new protection technology, it is now possible to use Rogowski coils in standard switchgear. The signal produced by sensors can easily be verified by a normal, off-the-shelf multi-meter.

Wide dynamic current measurement range – no saturation effects

Current measurement based on Rogowski coils (sensors) offers clear advantages compared to iron-core CTs. Sensors have a wide dynamic measurement range, which enables high currents to be measured without causing saturation (see figure 1, next page). Sensor technology contributes to improving the performance of protection equipment in the whole current range, as the signal delivered by the sensor is linear to the primary current. Consequently, one standard coil can be used for a wide current range. When conventional CTs are used, the overcurrent protection will be affected by the

saturation of the instrument transformers. When saturated, an instrument transformer may distort the current signal, causing malfunction or delayed operation of the protection IED.



1. Non-symmetric primary current
2. Primary current measured by Rogowski coil
   (output voltage of coil is integrated numerically)
3. Secondary current of a conventional CT

Figure 1. Secondary current from a CT versus secondary current from a Rogowski sensor

Voltage measurement without saturation and ferroresonance

The technology of voltage sensors including impedance dividers, resistive and capacitive dividers is not new, but it was not until the introduction of microprocessor-based protection IEDs that it was possible to industrialize the basic idea of these low-power devices.

In voltage measurement, sensor technology provides the solution for eliminating the saturation problem: one sensor type can be used for a wide voltage range, i.e. from 7.2 kV to 24 kV. Another important advantage is the elimination of ferroresonance, which is the major problem in VTs. In addition, both CTs and VTs require specification of primary currents, voltages, accuracy classes and burdens, which in turn leads to time and labour consuming engineering and ordering processes, and order-specific products.

Combi sensors

Due to the small size of the sensing elements, combi-type sensors such as KEVCD sensor are possible. In this type of sensors, current and voltage measurement functions are integrated in the same compact cast resin part.

Sensor technology supports power quality measurement

Sensors have a high frequency bandwidth, which is ideal for power quality measurement. The modern protection IED technology allows the waveform of the signals measured by the sensors to be captured. The sensor technology provides an opportunity for more accurate monitoring and recording of harmonics and high-frequency disturbances in the network. The data recorded can be used for various disturbance analyses and for getting accurate information of the harmonics. When the network is isolated or high impedance earthed, the earth fault current is measured by a conventional cable current transformer. Of this reason, protection IEDs with sensor inputs are often provided with standard current inputs for CTs and VTs as well.

As the output signal from the sensor is linear, the short-circuit values obtained are much more accurate. In modern, microprocessor-based protection and control IEDs, the short-circuit current values are stored in the IED and used, for instance, for accurate fault location calculations, which can be graphically presented in a Distribution Management System.

Improved personnel safety

In conventional systems with CTs and VTs, the measured signals are hazardous to people. Appropriate safety precautions have to be taken, because the voltage levels of the signals from CTs and VTs are far beyond the level that the human body can withstand. Due to significantly lower measuring signals the use of sensors improves personnel safety in this environment. The signals received from the sensors are between 0 and 10 VAC, whereas signals received from CTs/VTs may reach several kilovolts**.** Rogowski sensors and voltage dividers can be connected and disconnected live without precautions taken to protect people or equipment.

Accidental short circuit of secondary terminals will destroy a VT. When secondary terminals of a CT are left open, voltages of several kVs will appear across the terminals, destroying the secondary circuit. However, there is no such effect on sensors.

Clear economical and environmental effects

Conventional instrument transformers produce high power in secondary circuits. In addition, they cause considerable losses. In one medium voltage switchgear unit with 15 cubicles, the difference in power comsumption will be 1.4 kW. The standard model for calculating the costs of energy losses results in savings of 4.2 kEUR in ten years. This example calculation is

based on the average energy price on the Finnish market. Remarkable is that this sum is just for one single switchgear unit. At utility level the savings would be significant.

In life cycle analyses, environmental calculations show, that the efficiency of sensors exceeds that of instrument transformers by more than 90%. The logistic process for sensors is short, since it does not involve order-specific actions: one sensor type covers a wide range of applications. The same sensor can be used at rated system voltages from 7.2 to 24 kV and feeder currents from 4 to 1250 A. The small physical size of the sensor contributes to additional savings. The size, in fact, affects the dimensions of the switchgear. The sensors can be used in future products as well as integrated into existing switchgear components.

Sophisticated condition monitoring of network equipment provides significant economical savings in both periodical and preventive maintenance. The condition of the objects in the network can be monitored and supervised by the protection and control IEDs connected. Thus the operators continually get accurate information about the condition of network equipment. Based on this information, the timing of equipment maintenance can be optimized. Some of the modern protection and control IEDs, e.g. REF 541/543/545, have functions dedicated for this. Circuit-breaker wear, for example, can be monitored by measuring the real short-circuit current at the breaking moment. When sensors are used, the measured current values will be more accurate. This, in turn, leads to more accurate circuit-breaker wear calculations. The same protection and control IED is also capable of providing an alarm signal, if the circuit breaker has been inactive for a long period. Thus the use of condition monitoring functions means less money spent on preventive maintenance.

Standards for sensors in progress

Considering the benefits of sensor technology, national and international organizations are preparing rules and standards for sensors. Two IEC Technical Committee 38 working groups (WG 23 and WG27) have prepared standards on the basis of the existing standards for Instrument Transformers, taking into account the special requirements of the new sensor technology (EMC etc.). The IEC standard 60044-7 for voltage sensors was issued in December 1999. A draft of the IEC standard 60044-8 for current sensors is under circulation. Both of the standards include specifications for analogue outputs for voltage and current sensors. IEC 60044-8 also includes a specification for a digital point-to-point link for up to seven current signals and up to five voltage signals. The IEEE Power System Relaying committee, too, have issued a proposal for a sensor standard.

As a conclusion it can be said that, sensors together with modern protection and control IEDs provide a safe and cost-effective solution, when you invest in new substations or refurnish old ones.

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