FAULT DETECTION USING NEW LOW-POWER SENSORS LEADS TO COSTS REDUCTION

Bruno Opitsch
Siemens AG – Germany
Bruno.opitsch@siemens.com

ABSTRACT

Outages in Distribution Grids are causing high maintenance costs. Integration of renewables requires a live monitoring of the instantaneous load situation for net operations and predictive maintenance.
Microprocessor based Fault Indicators can be used for both applications, however, sensors are expensive or lacking in accuracy. The new method introduced, uses a combination of Medium-Voltage currents and Low-Voltage voltages to calculate Live Monitoring values and to detect fault with directional information. This technology will reduce the costs for sensors and achieve the necessary accuracy for the Live Monitoring.

INITIAL SITUATION

Outages in Distribution Grids are causing high maintenance costs. Main reason is the time to identify the faulty section of the feeder before restoring the power supply.
In most of the Ring Main Units (RMU) mechanical or electromechanical fault passage indicators with no communication interface are used. To identify the faulty section of the distribution network the workforce has to drive along, checking every RMU whether the indicator shows alarm or not. This is very time consuming and costly reflecting the thereby caused maintenance costs.

Another driver to deploy monitoring into the Medium-Voltage Power Distribution Network is the integration of decentralized generation. Mainly renewable energy resources are used and their volatile infeed characteristic requires a live monitoring to avoid over load situations. These counts for medium-voltage and the low-voltage distribution with an additional focus there, to identify possible violations of the voltage limit given by EN 50160

Microprocessor based measuring units or fault indicators are available for deployment. Precise detection of the fault location and a continual monitoring of all electrical parameters will help to reduce operational cost in above described scenarios. But high cost for the necessary voltage transducers (VT) or the low accuracy of the capacitive output of the medium-voltage switchgear bushings retard the deployment of such microprocessor controlled measuring devices.

APPLICATION FAULT INDICATOR

There are two typical applications with electronic fault indicators due to the star point treatment. For direct and low resistive earthed networks short circuit and earth fault detection is just depending on the high current caused in both cases. All fault indicators upstream between fault and infeed detect this event and will indicate it to the control centre. Therefore, the fault location algorithm will show the faulty segment after the last fault indicator which has send an alarm. This principle is also known as fault passage indicator.

With decentralized generation this principle does not show a clear result any longer. It is necessary to have directional information to evaluate the fault location. Therefore, a voltage measurement is necessary.

The same applies in isolated and compensated distribution networks. To detect the fault location the current and voltage phase angle is used to indicate whether the fault location is forward or reward.
A phase shift of the transducer as small as possible across the whole measuring range is the base for a clear detection of the fault location, especially when the location is very close to the location where the measuring unit is placed.

APPLICATION MV MONITORING

For the monitoring of the medium-voltage distribution with reasonable validity 1% accuracy is necessary. This is a result of installed applications in various projects. For calculating load curves at a higher level this is the optimum of necessary liability and costs for deployment.
The alternative for expensive measuring fields used today, is the use of a fault indicator with integrated measuring unit.
The obvious advantage is the all-in-one functionality for fault locator and measuring. The monitoring can be done on a whole distribution line in each secondary substation because costs are low, compared with the total costs of ownership for a measuring field.

CURRENT MEASURING TRANSDUCER VERSUS SENSOR

Cost driver for measuring applications are the use of 1A or 5A current transducers (CT). There price is as high as the whole fault indicator or measuring unit itself. Another disadvantage is the size and weight of these transducers. Therefore the installation requires a solid mechanical mounting e.g. to the subplate. This makes the installation complex, depending on the space inside the cable compartment and the flexibility of the cable routing.

To avoid this started a check on alternative solutions. Some fault indicators products available in the market use proprietor sensors. Focus developing these sensors was to reduce costs. What they achieved was a reduction in weight and thereby a simpler installation. The but is, that the output of these sensors can only be used together with the single fault indicator it is made for. So looking at the live time of a switch gear a change of the fault indicator after 15 up to 20 years requires a complete new installation including the sensors.
Another circumstance to be considered for the monitoring purpose is the typically achieved accuracy of midrange single digit only.
Due to costs users accept this con and the additional disadvantage that the sensors cannot be used with other equipment. So in case of replacement or upgrade to e.g. protection functionality the whole installation has to be dismounted without any reuse.

VOLTAGE MEASURING CAPACITIVE VOLTAGE-TEST INTERFACE

To keep the cost low for fault locators the voltage is typically acquired from the capacitive voltage- and interface-tests in medium voltage switchgears at HR-interfaces (KSP HR 2) resp. at LRM interfaces (KSP LMR 2) at the bushings. This output is designed to be used by voltage detection systems to detect if voltage U<10% or U>45% is applied to the medium voltage switchgear in conformity with IEC 61243-5. For this purpose a specified accuracy is not necessary.
According to the norm these interfaces must not be connected to more than one device. To have a use of the signal for the monitoring some voltage detection systems provide an output signal to be used as an input for fault indicators.
Even wiring the capacitive voltage- and interface-tests to sockets for manual test, which would allow a use for a measuring unit, the design of the capacitive output is not adequate because of its signal accuracy. The isolation material is not a dielectric as it would be used for a capacitor. Therefore, the capacity of the output is varying depending on the environmental temperature and also aging will bring a deviation. In addition this is a non linear behavior so a adjustment of primary voltage to the input signal gained for measuring is necessary at the RMU if a single digit accuracy shall be achieved for the monitoring purpose. Feedback by users of this method is, that an adjustment to have at least 2% accuracy is necessary every second year.

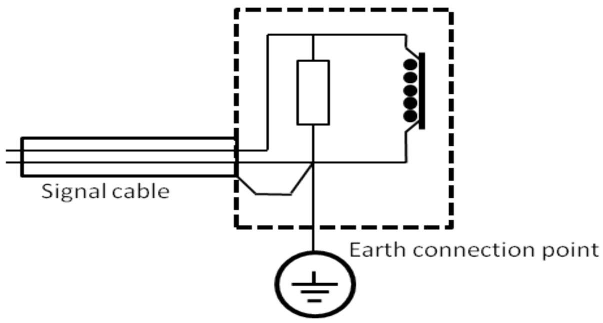
NORM CONFORM LOW-POWER SENSORS

More than 10 years ago the Norm IEC60044 Part 7 and Part 8 have been introduced to vendors and users. Its purpose was to specify interoperable electronic transducers for current and voltage measuring.
To achieve that goal measuring methods, test procedures and output signal levels have been defined.
Working group TC 38 decided to restructure the whole set of stand-alone Standards in the IEC 60044 series and transform it into a new set of standards composed of general requirements documents and specific requirements documents as IEC61869.

Such Low-Power Instrument Transformers have been developed for applications in medium-voltage systems as described above. Compared to the conventional current and voltage transformers they have technical, economical, application and logistical advantages. The main advantages are wide measuring range, high frequency bandwidth, lower weight and size and lower numbers of variances. At the end of the day this results in a lower price for the sensors.

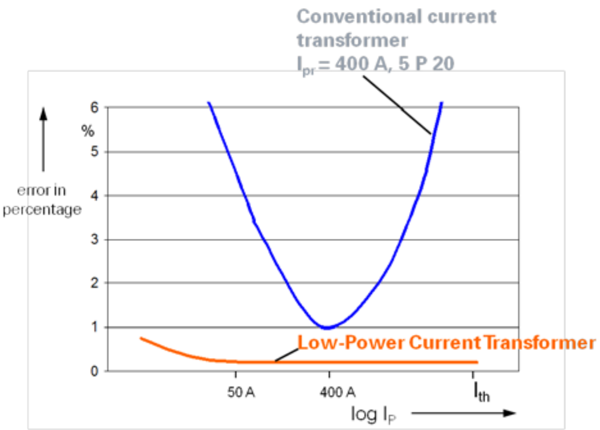
LOW-POWER CURRENT SENSORS

The main advantage of IEC60044-8 (IEC61869-8) conform sensors is their interoperability and clearly specified behavior. Manly two types of current sensors are available for deployment: Rogowski coil sensors and Low-Power Iron Core Current Sensors with a resistiv burden.



Picture1: Low-power current sensor principle

Both types give linearity for the Low-power-sensors to cover a vast range of primary current input. Inherent difference between the secondary current of conventional current transformers and the electronic current transformer it the output as a voltage signal.



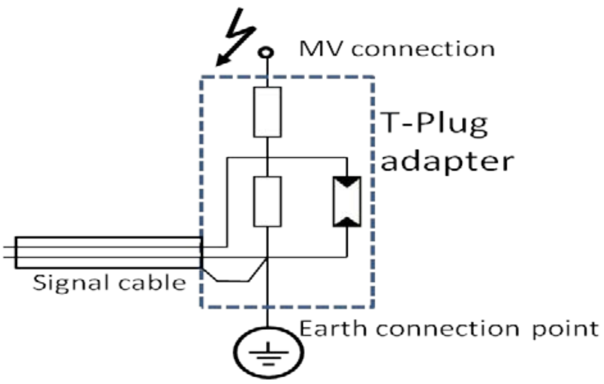
Picture 2: Comparison of Characteristic
Low-power sensor versus Transducer

This secondary voltage is related to a rated primary current. A typical value is e.g. 225 mV@300A for RMU applications. Instead of a burden defined in VA there is standardized a minimum input impedance of the secondary equipment in Ohms. A typical value is 20 kΩ.
In comparison of the two principles the air-core (Rogowski) solution has a minimum of weight and is very price efficient, but the iron-core solution with a winding short circuited by a shunt is focusing the magnetic field and produces a signal simpler to acquire in the electronic input.
For the solution described the system is based on low-power sensors with iron core and shunt due to the better concentration of the magnetic field of the measured phase and the lower influence cause by magnetic interference.

Low-power sensors allow the use of only one type for all secondary substations which reduces thereby the complexity in the supply chain and number of necessary spare parts.

LOW-POWER VOLTAGE SENSORS

Also for the voltage measurement sensors according to IEC60044-7 (IEC61869-7) are available.

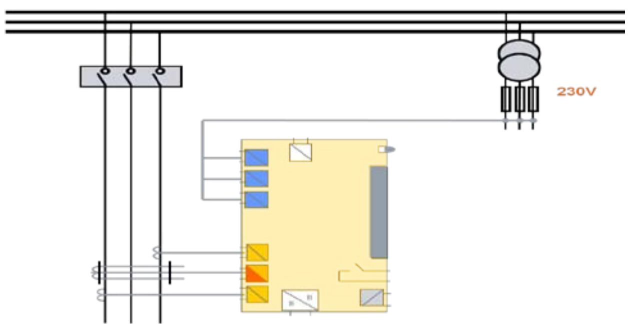


Picture3: Low-power voltage sensor principle

Especially for existing secondary substations the use of metal-thin-film resistors in a T-connector specific design can be used.
These measuring method using dividers give a true image of the primary signal of the voltage. The high accuracy is guaranteed in a wide range of voltage and accurate measurements are possible from DC to several kHz. In addition this makes it possible to measure harmonics in the network.
This frequency behavior is the biggest difference in the performance of the dividers compared to inductive or capacitive voltage transformers. Conventional Voltage transformers have typically resonance depending on their design at some hundreds of Hertz. They can only be used for measurement at the rated frequency or for a low harmonic order. The RC divider is designed to have a good accuracy up to high frequencies and be used to measure harmonics up to the 50th order with good accuracy.
The described voltage sensors for the t-connector in the medium-voltage cable compartment are easy to install and are saving moneys for the complete solution consisting of product, engineering and as well maintenance.

ALTERNATIVE LOW-VOLTAGE

A compromise in accuracy but with the lowest costs is the use of the low-voltage for the detection of the fault location and the medium-voltage measurement. In direct or low resistive earthed networks the fault location forward or reward can be derived by the low-voltage phase ankle based on the connection type of the distribution transformer.



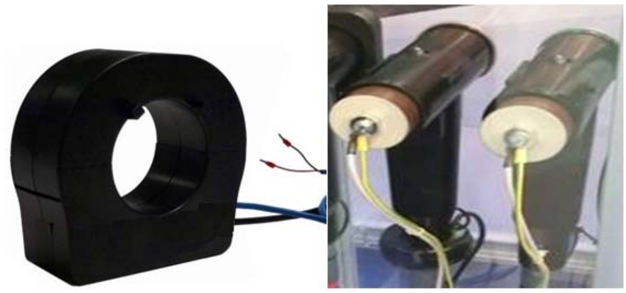
Picture3: Connection diagram for 230V input

This method uses the in any case existing low-voltage signal and only the wiring to the inputs of the fault locator and/or monitoring unit is necessary. Therefore, it's causing no additional cost for voltage sensors. Based on the distribution transformer ratio Z or a curve of the transformation ratio, which is depending on the operation point of the transformer, can be used to calculate the medium-voltage value.

To achieve reasonable results as the expected 1% accuracy this requires some engineering to parameterize the transformer ratio curve.
Is the main target a fault detection this is by far the best solution in costs and give resilient results.

DEPLOYMENT ON A LARGE SCALE

Integration of decentralized generation and new market demands controlled by spot market, virtual power plants and other Smart Grid applications results in a need of a detailed know how about current network load. This leads to the need of a monitoring of at least some secondary substation (RMUs) to have a basis for control centers for a reliable state estimation. Even better is a deployment of all ring main units with monitoring equipment to have precise information about the network status.
To accomplish this, a rollout of fault locators and monitoring units is necessary on a large scale. A simple state estimation and an updating of the switch status for the secondary substations at the control center are not sufficient any longer.



Picture4: Low-power sensors
Split core current sensor and T-connector voltage sensors

Feeder Condition Monitoring Devices like SICAM FCM using low-power current transducers and low-power voltage sensors fulfill all needs for clear fault location and provide a live value monitoring for all important measurands as there is U, I, P, Q, S; cosφ and frequenz.

RESUME

Independent of distribution network, communication and functional requirement the described measuring methods using low-power sensors and combined units for fault detection and condition monitoring is the best economical way for equipping ring main units.

The major benefits of using feeder condition monitoring result in:

- Reduced maintenance costs in case of faults due to the precise knowledge about the fault location
- Detection of overloaded network components gives the chance for counter measures e.g. in case of high infeed by decentralized power production
- Date acquisition for planning on true live values instead of given load profiles

Specific advantages by using the low-power sensor technology are:

- Cost efficient measuring compared with conventional transducers
- Easy to install solution for the current transducers because of the low weight
- Easy to install solution for the voltage sensors directly into the medium voltage cable t-connector
- No adjustment to the primary signal necessary
- Very low influence by temperature and aging

Comparing all this advantages in operations and for the installation of fault detection and monitoring devices a very quickly commercial advantage can be seen.
By the way, a deployment of such equipment helping to maintain voltage level according IEC50160 and reducing outage times will keep the image up of an utility at their customers.

REFERENCES

[1] IEC, 1999, CEI/IEC 60044-7:1999, IEC, Geneva, Switzerland
[2] IEC, 2002, CEI/IEC 60044-8:2002(E), IEC, Geneva, Switzerland
[3] Siemens, 2010, SIPROTEC 7SJ81 Manual, E50417-K1150-C462-A1, Siemens AG, Nürnberg, Germany