Measuring of „unreal“ DC-signals

One might imagine that no sophisicated power meters are required for measuring of DC-signals. Lots of units for measuring eighter DC voltage or DC current are on the market. Superficially this units offer a wide range of accuracy and might be sufficient. In practice most of the measured signals are no „real“ DC-signals. Many applications are afflicted with ripples or clock pulses.

In power electronics DC-signals are most common in applications like:

- DC-DC-converters
- DC-Output of switch mode power supplies
- DC-link circuits of frequency converters
- DC-Input of solar-converters

In any case conventional DC-power meters face the problems shown in this application note.

Bandwith

Most of a.m. applications show a voltage which is pretty steady. On the other hand the current comes with huge ripples due to clock pulses. In some cases the current is even rectangular.

It could now be argued that only signal components of the same frequency can cause active power (see ZES ZIMMER Application Report 105, "Power measurement and its theoretical background") and that it would therefore be sufficient to measure only the DC component of the current. In practice, however, a voltage source has a complex internal resistance (R and L). Solar cells in particular have a relatively large ohmic component and therefore a current ripple also leads to a ripple on the voltage. With these two equal-frequency signal components, you have all the prerequisites so that active power can also be converted at the clock frequency.

The clock frequencies of several 10 kHz that occur in practice exceed the bandwidth of conventional DC measuring devices by orders of magnitude. In addition, the phase relationships between current and voltage must now be taken into account, which is not possible with two independent devices. A multiplication of current and voltage therefore does not calculate the active power, but only the apparent power. In this case, only the use of high-quality power measuring devices can help.

The best way to estimate these high-frequency components is to use a practical example: The efficiency of modern solar inverters is in the range of 98% and more. However, these values can only be achieved if measurements are taken at an extremely

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clean voltage, which can only be generated with very high-quality DC sources. As soon as the voltage has a ripple, however, these efficiencies can no longer be achieved, as the MPP (Maximum Power Point) regulation then no longer works optimally. This can reduce the efficiency by up to one per cent. Subsequently increasing these efficiencies by 1% again is a challenge for the manufacturers of these inverters.

Measurement time

The more precise a measurement needs to be, the longer it needs to be. However, if, for example, highly dynamic processes such as a motor start-up are to be measured in a frequency inverter, short measurement times are essential. Modern power meters are able to deliver measured values every 50 ms without any gaps between the individual measurements. For conventional DC measuring devices, however, both the short measurement time and the lack of gaps can pose a problem.

Potential isolation

When measuring current on the DC link in a frequency converter, both lines usually have a considerable voltage to earth. Two problems can occur here, especially with DC current measuring devices:

- The insulation of the devices must be designed so that this measurement poses no danger to the user. This should be the least of the problems with modern multimeters.
- The devices could be operated with a common mode signal. Good common mode rejection is important here.

Both conditions are fulfilled by good power meters, as these are specially designed for this application: Measurement in the phases of a motor controlled by a frequency converter.

Display range

A typical application, which is usually referred to as "DC measurement", is a servomotor in a vehicle that is fed from a battery via a pulse-wide modulated semiconductor switch. Due to the motor inductance, the current to the motor consists of a DC component with superimposed ripple current. The current in the semiconductor switch and the voltage at the motor, on the other hand, are a superposition of a square-wave component and a DC component. Different measuring devices can display very different values here, depending on the setting. ::

- - For battery discharge: DC component (=DC value)
- - For the heating of the semiconductor switch: RMS value (with DC component)
- - For a filter capacitor: RMS value (without DC component)

Depending on the setting, multimeters often only display the DC component or the RMS value (without DC component). Only very few multimeters display the thermally effective total RMS value (with DC component). With DC measuring devices, it is also only possible to measure these values one after the other, which is prone to errors, and then calculate the total RMS value. A modern power meter from ZES ZIMMER, on the other hand, displays all values simultaneously.

Signal processing

A basic law of signal processing is that the DC characteristics of amplifiers deteriorate as their bandwidth increases. As bandwidths of several megahertz are state of the art nowadays, a few working principles will be explained here on how modern devices attempt to maintain high measurement accuracy even with DC.

Pure DC measuring devices can utilise several things to their advantage. Firstly, almost all disturbance variables can be eliminated using suitable filters. Noise can be countered with long measurement times, which do not interfere with "real" DC measurements: After all, the signal is constant, otherwise it wouldn't be DC! Furthermore, operational amplifiers optimised for DC with a narrow bandwidth can be used. And finally, it is also possible to separate the measurement signal internally, measure the DC generated by the measurement channel and calculate it out of the result. These measurement gaps do not play a role with "real" DC signals, as already shown.

With power meters, most of these points are realised differently depending on the application:

- - The bandwidth must be large and these high-frequency components must not be cut off
- - Operational amplifiers optimised for DC are therefore not possible
- For dynamic processes, the measurement time must be short so that the processes are finely resolved in time and do not disappear in an average value

There is only room for manoeuvre for detailed technical solutions in the measurement gaps, but these can have a major impact on the results:

Every operational amplifier causes a DC offset, which is interpreted as part of the measured value. The measuring device must compensate for this DC offset. There are two ways to do this:

The first is to artificially create gaps in the measurement, during which the measurement signal is internally separated from the signal processing and the DC offset is determined. This is then used to correct the measured values internally. This procedure is often used with simple devices. As long as these measurement gaps occur periodically, such a solution can still be acceptable, unless transient measured values are missed as a result. However, some devices only carry out this zero point adjustment when the measuring range is switched. This sounds extremely clever at first, as there is a measurement gap at this point anyway. The disadvantage, however, is that the manufacturer's specification is only valid for a relatively short time after a measuring range changeover. So if you switch on your appliance in the morning and switch to a certain area,

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preferably when the appliance is still cold, the DC is initially calibrated correctly. A few minutes later, however, when the appliance has warmed up, this calibration

value is no longer correct. If you continue to measure in this range without changing, the effects of inexpensive components are added (large drift, large temperature dependence, ...). In short, this type of measurement can be advantageous, but it can also be completely the opposite. The insidious thing about it is that this measurement error cannot be detected during calibration due to the system (although it is naturally present), as a measuring range is always set and measured shortly afterwards. Within the short time between calibration and measurement, the system shines with values that are completely unrealistic in practice.

Another disadvantage of DC compensation during operation is that it is not possible to detect all DC sources in the device: If, for example, thermal voltages occur at the connection terminals and the signal is only disconnected behind them (which is not possible otherwise, as you are not allowed to interrupt the customer's current!), these are not measured, nor are possible DC errors caused by the disconnection circuit itself.

Simple measuring devices must therefore insert gaps at some point in order to compensate for the effects of the low-cost components.

The second and better option is to permanently compensate for the DC offset by adjusting the device. This requires the use of high-quality components with low drift. This is the only way to guarantee adjustment intervals that are at least as long as the calibration intervals recommended by the manufacturer. However, only high-end devices offer this feature.

The measuring devices from ZES ZIMMER generally work without any gaps due to the use of high-quality components. The measurement uncertainties are in the range of devices that (hopefully) synchronise during operation, even though our specification is guaranteed for 1 year: If a device fails to meet the specification within one year of an adjustment, this would constitute a warranty claim.

Tuning the measuring devices beyond the manufacturer's specifications

For some very specialised measurement tasks, it may be necessary to get the last drop out of a measuring device. An example of this would be measuring the efficiency of a solar inverter, where every last bit of uncertainty needs to be removed. Here it can make sense to optimise the measuring devices despite the already low uncertainty, even though they are still well within the manufacturer's specification! This is of course particularly easy with DC signals, as you only need to short-circuit the open voltage inputs to see how large the DC error of the channels is. The short circuit is therefore the reference here; no expensive standards are required. In this case, longer-term effects such as drift are eliminated and only the short-term errors remain.

ZES ZIMMER offers two procedures for these special cases:

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Firstly, the zero points of the appliance can be temporarily rewritten via the operating menu after warming up. These new zero points are only saved until the device is switched off; the factory settings, which guarantee compliance with the specification, are not affected and are available again the next time the device is started. Of course, this calibration can only be carried out when the appliance is warm and requires all measurement signals to be disconnected from the appliance.

However, it generally offers the optimum reduction in uncertainties, as it must/can be repeated each time the device is switched on (or before each measurement).

On the other hand, customers can use special calibration software to overwrite the factory settings of the zero point values. If a customer carries out such an adjustment incorrectly (e.g. with applied signals instead of short-circuited inputs), the device will of course measure incorrectly on a permanent basis. In this case, ZES ZIMMER can no longer guarantee compliance with the specification. This procedure is recommended if the last reserve does not need to be extracted from the device or if it is too inconvenient to readjust the device every time it is switched on.

Fazit

Various measuring devices are available for measuring DC components in signals. It has been clearly shown why conventional DC measuring devices can cause problems with power measurements.

But even with specialised power meters, you have to separate the wheat from the chaff: When it comes to DC uncertainty data, it is not enough to just look at the pure numerical values; the boundary conditions are almost more important:

- A good numerical value that results from the assumption of unrealistic conditions can be associated with a large error in practice if the signal processing is solved in a clumsy manner.
- A device that fulfils the specification without restrictions will often have a lower measurement uncertainty in practice.

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