ZES ZIMMER
Precision Power Measurement

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.

Bandwidth

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 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

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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 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. Which Which value is the correct one depends on what you need it for:

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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 suitables filters. Noise can be countered with long measurement times, which do not interfere with "real" DC measurements: After all, the signals 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 seperate 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 ate finley resolved in time and do not disappear in an average value

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mit Werten, die in der Praxis völlig unrealistisch sind.
Ein weiterer Nachteil der DC-Kompensation im Betrieb ist, dass man nicht alle DC-Quellen im Gerät erfassen kann: Treten z.B. an den Anschluss–klemmen Thermospannungen auf und das Signal wird erst dahinter abgeklemmt (was nicht anders Möglich ist, da man nicht den Strom des Kunden unterbrechen darf!), so werden diese nicht mit gemessen, ebenso wenig mögliche DC-Fehler durch die Abklemm-Schaltung selbst.
Einfache Messgeräte müssen also irgendwann Lücken einfügen, um die Effekte der kostengünstigen Bauteile wieder kompensieren zu können.
Die zweite und bessere Möglichkeit ist, den DC-Offset dauerhaft durch Justierung des Gerätes zu kompensieren. Dies erfordert die Verwendung hochwertiger Komponenten mit geringer Drift. Nur so können Justierungsintervalle gewähr–leistet werden, die mindestens so lang sind, wie die vom Hersteller empfohlenen Kalibrierintervalle. Dieses Feature bieten jedoch nur Geräte im High-End-Bereich.
Die Messgeräte von ZES ZIMMER® arbeiten prinzipiell lückenlos, bedingt durch die Verwendung hochwertiger Bauteile. Die Messunsicherheiten liegen im Bereich von Geräten, die sich im Betrieb (hoffentlich) abgleichen und das, obwohl unsere Spezifikation für 1 Jahr garantiert wird: Sollte ein Gerät innerhalb eines Jahres nach einer Justierung die Spezifikation nicht einhalten, würde ein Garantiefall vorliegen.

Tunen der Messgeräte über die Herstellerspezifikation hinaus

Bei einigen sehr speziellen Messaufgaben kann es notwendig sein, das letzte aus einem Messgerät heraus zu hohlen. Ein Beispiel wäre die Messung des Wirkungsgrades eines Solarwechsel–richters, bei der auch noch der letzte Hauch Unsicherheit beseitigt werden müsste. Hier kann es sinnvoll sein, die Messgeräte trotz der ohnehin schon geringen Unsicherheit optimal abzugleichen, obwohl sie noch weit innerhalb der Hersteller-Spezifikation liegen! Das ist bei DC-Signalen natürlich besonders einfach, da man nur die offenen Spannungseingänge kurzschließen muss, um zu sehen, wie groß der DC-Fehler der Kanäle ist. Der Kurzschluss ist hier also die Referenz, man braucht keine teuren Normale. In diesem Fall werden längerfristige Effekte wie Drift eliminiert und es bleiben nur noch die Kurzzeitfehler übrig.
ZES ZIMMER® bietet für diese speziellen Fälle zwei Verfahren an:
Zum einen kann man per Bedienmenü die Nullpunkte des Gerätes nach dem Warm–laufen temporär neu schreiben. Diese neuen Nullpunkte bleiben nur bis zum Ausschalten des Gerätes gespeichert, die Werkseinstellungen, welche die Einhaltung der Spezifikation garantieren, werden dabei nicht angetastet und stehen beim nächsten Start wieder zur Verfügung. Dieser Abgleich kann natürlich erst bei warmem Gerät durchgeführt werden und bedingt, dass alle Messsignale vom Gerät getrennt werden.
Er bietet aber in der Regel die optimale Reduzierung der Unsicherheiten, da er bei jedem Einschalten (oder auch vor jeder Messung) wiederholt werden muss/kann.
Zum anderen können Kunden mit einer speziellen Abgleichsoftware die Werks–einstellungen der Nullpunktwerte überschreiben. Führt ein Kunde einen solchen Abgleich fehlerhaft durch (z.B. mit angelegten Signalen statt mit kurz–

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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.

Resumee

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.

Verfasser

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