不同测试系统的对比测试

（对谐波测试仪及低频功率放大器进行的测试）

几年前的一项调查发现，当进行 EN61000-3-2 标准测试时，不同测试系统的测量结果存在着巨大的偏差。虽然标准规定测量精确度为 5%，但实际的测试设备竟然会出现 100%的巨大偏差。

基于这一原因，德国电工委员会（DKE）成立了一个“测量不确定性”工作组，以调查此问题。工作组成员同意进行一个实验室之间的对比测试，从而找出测量结果偏差的原因。多家测试实验室及公司参与了此次实验室之间的对比测试。

此次测试的所有参与者收到了两种不同的整流器电路板，每种电路板上的元器件都经过精密而准确的测量。每一位参与都依据标准 EN61000-3-2 进行了一系列的测量。

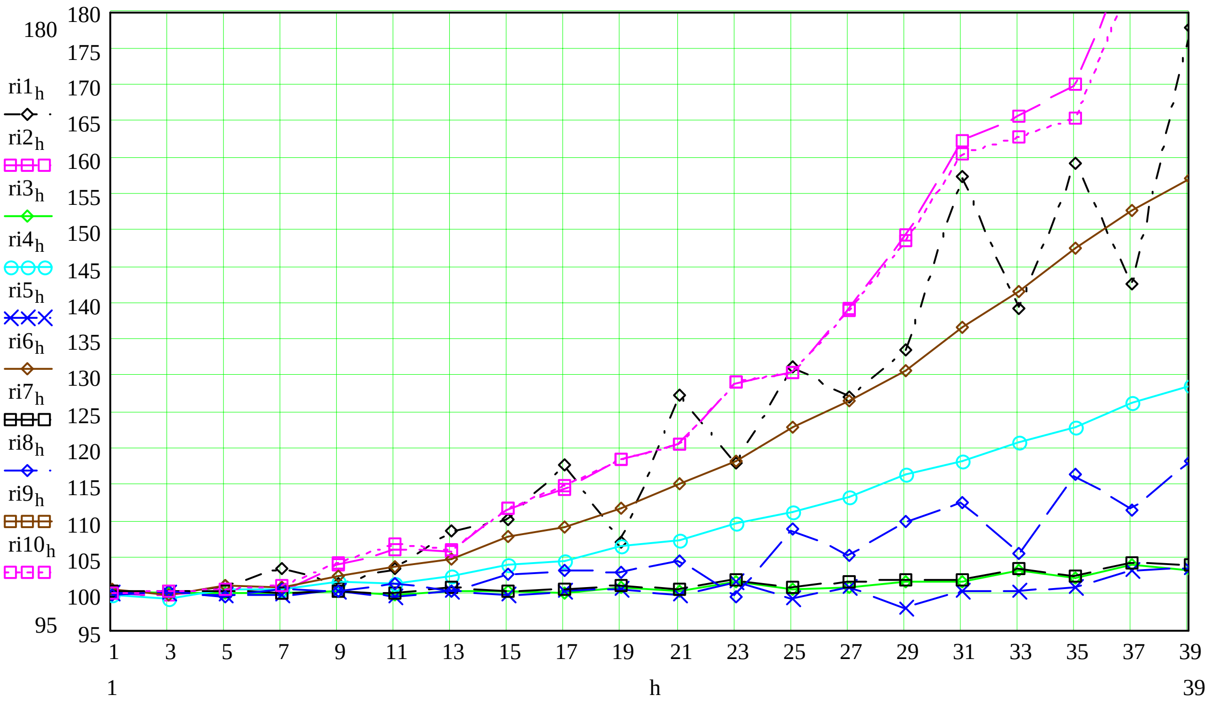
测试结果确认了不同的测试仪器（谐波测试仪）确实会产生不同的测试结果。对比测试结果显示：不同的功率放大器所产生的测试结果千差万别。

目前，通过多种模拟方法可以再现出经过精确调试后的测试样品的理论性能参数。因此，借助计算和使用 PSpice 软件可以作出一个精确的 FFT 分析。从而，可以确定这些预选测试样品的理论性能参数。通过比较理论数据与测试所得数据之间的偏差，可以发现某些偏差会高达 70%或 80%。甚至有一家厂商的测试数据偏差高达 90%

第二次室验室间的对比测试开始了。将所测试样品（整流器）的第 13 次至第 39 次范围内的谐波分量范围内调整到 Class A 的 d 等级。另外，在第二次测试对比中，也对各种实际的测试样品（如电视机，各种灯具等）进行测试比较。仍然根据标准 EN61000-3-2 进行测试。在两次室内测试中，大部分的实验室都测试了电压谐波（测试结果见图 2 和图 3）

通过分析电压谐波数据，会发现，即使是测试结果与理论数据最接近的的谐波测试仪也会产生极小的电压谐波。标准要求的偏差范围在 5%之内，而最好的谐波测试仪的实际测试结果是在 4%的偏差范围之内的。这些测试结果最好的谐波测试仪有两台，一台是为德国电气工程协会（VDE）所拥有。这些仪器是完全由德国 SPS 公司设计并生产的。另一台一直用于 SPS 公司的生产工厂。其它公司的一些测试系统（这些公司测试系统的功率放大器部份是由 SPS 提供，而测试部分是其它厂商提供），其功率放大器部分的使用时间有的已经超过 20 年，但与其他公司的功率放大器所产生的偏差相比，其所产生的微小偏差是可以接受的。

图一　谐波电流偏差（对比理论值，理论值=100%）



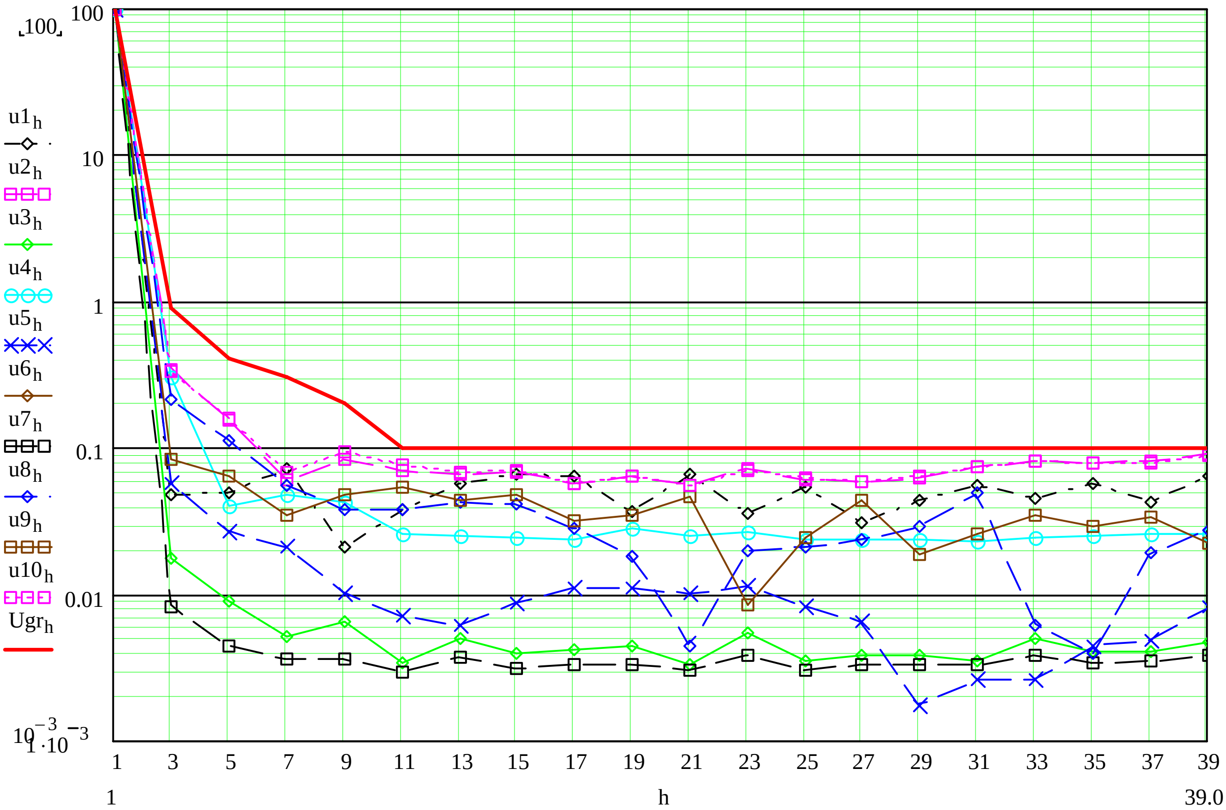
ri1 - ri10 = 各实验室的测试序列 / h = 各谐波数据序列号

只有测试序列 ri7 (德国电气工程协会 VDE 所拥有的 SPS 系统 PAS10000)

和 ri3 (SPS PAS 5000) 均在标准要求的<5%范围内.

依据据标准 EN 61000-3-2，谐波测量仪的功率放大器或电源的电压谐波必须在控制制在规定限值以内。但显而易见的是：图中所列不同仪器测试出的电压谐波差异巨大。

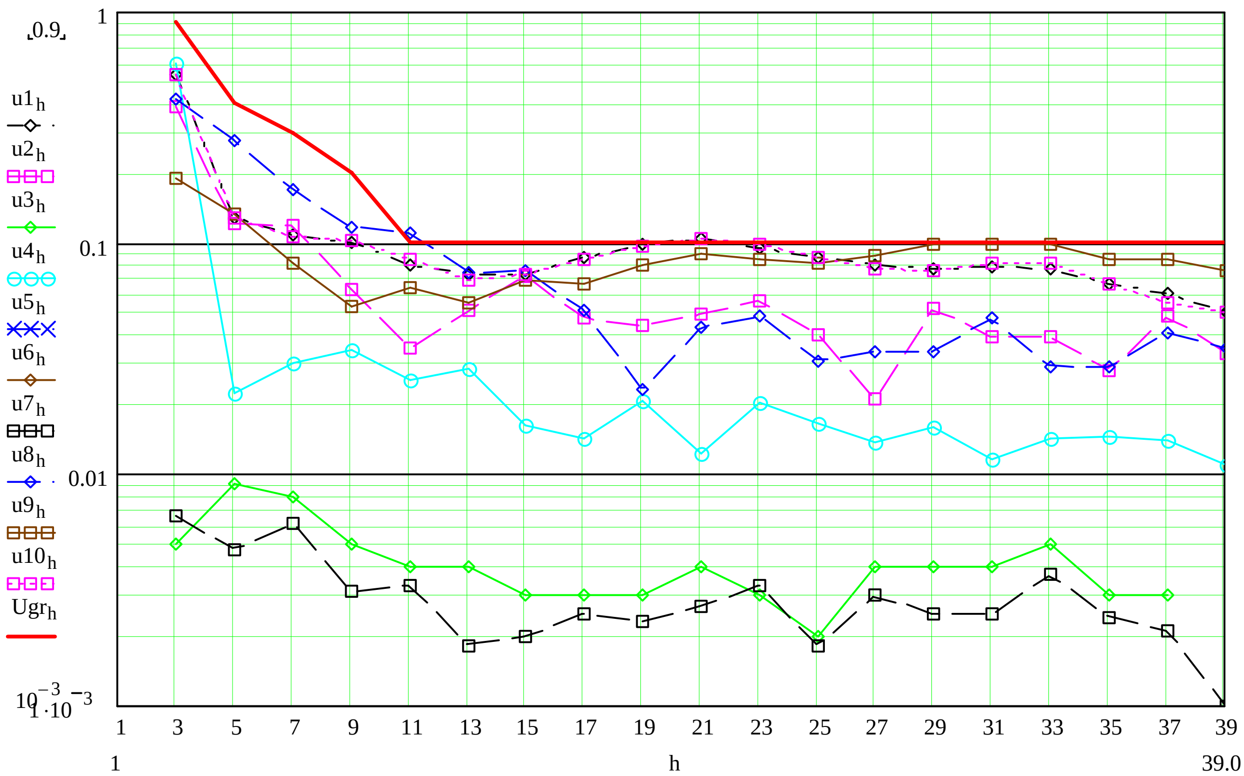
图二 对 600W 样品进行的谐波电压测试



u7h 和 u3h (VDE and SPS)设备产生的电压谐波一直较小

至此，与理论值最接近的测试设备所产生的谐波因子一直非常小。（图 2 和图 3）

图三 对 44W 样品进行的谐波电压测试

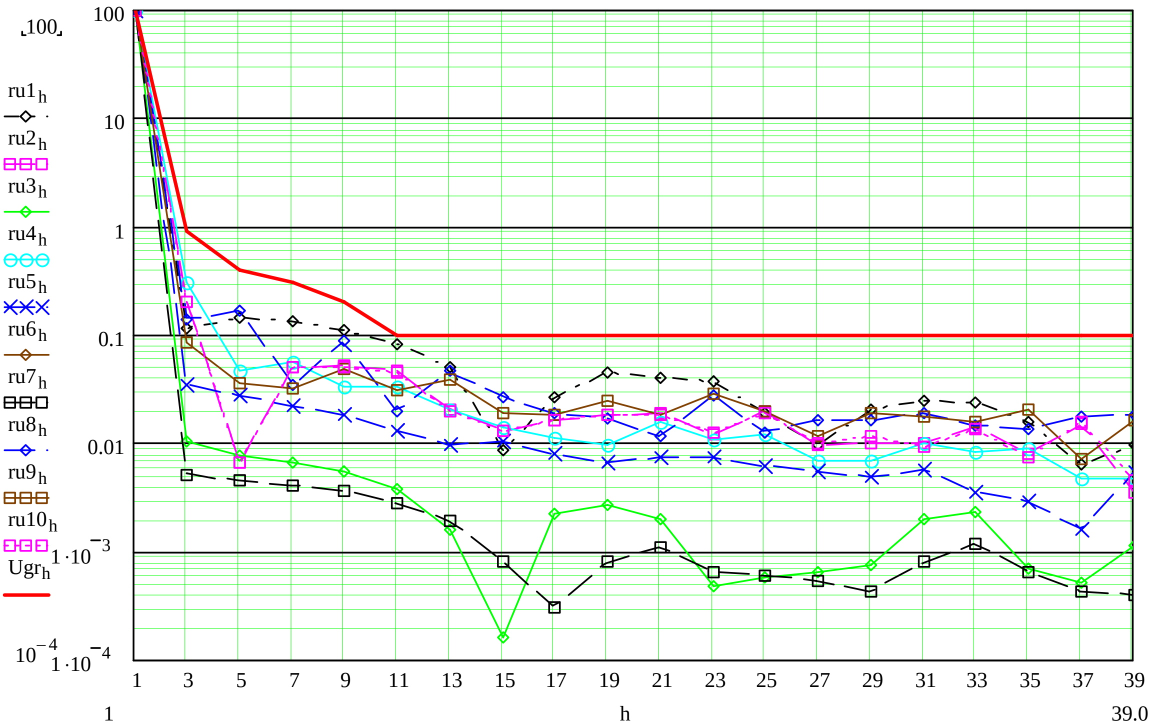


虽然测试样品功率很小 (44W)，但有些功率放大器还是超出限值。

而 u7h 和 u3h (VDE and SPS)，PAS 系列功率放大器的偏差只有标准值 1/30。

通常，SPS-功率放大器（型号 PAS）谐波性能要好于标准要求的 30-100 倍。SPS 其它的测试性能也情况也类似。（见图 4）

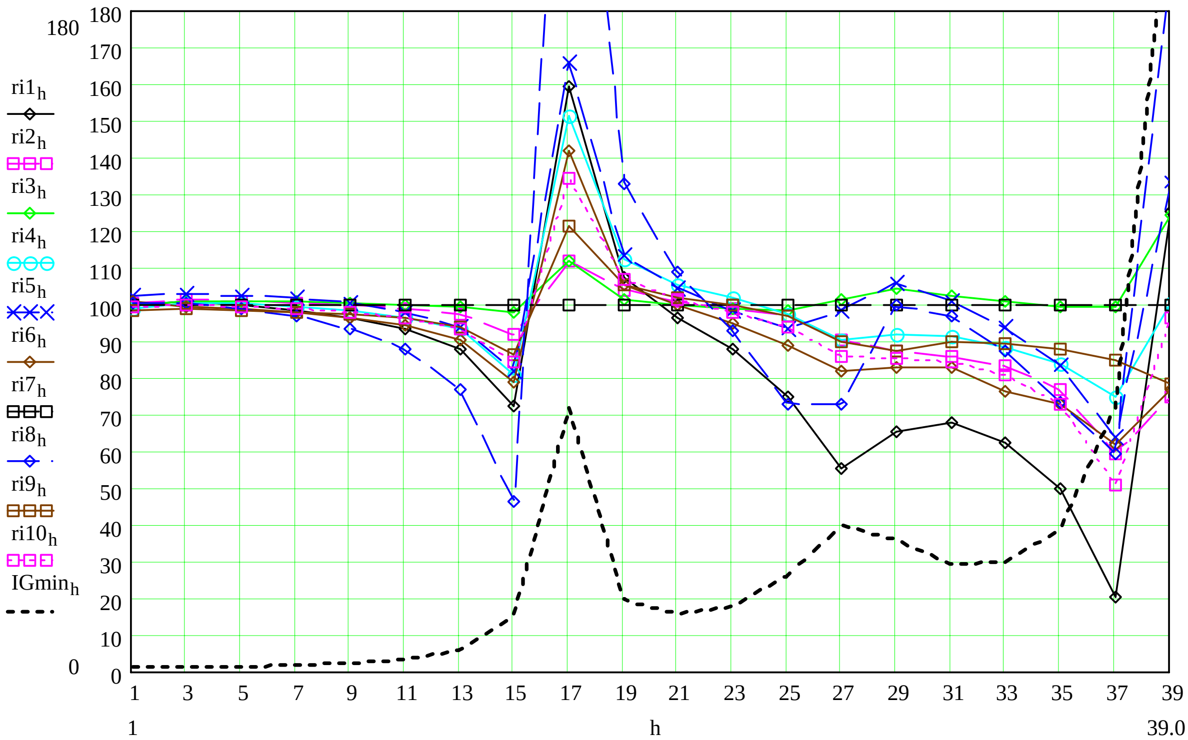
图 4 对电视机样品进行的谐波电压测试



u7h 和 u3h (VDE and SPS)型号为 PAS 的 SPS 的功率放大器所产生的谐波也非常小

将低谐波的功率放大器 ru7 (VDE-PAS)作为参考,下图所示是测试的不稳定性：

图 5 对同一个电视机进行测试时所产生的电流谐波



各测试设备的电流偏差明显变大，一些厂商的测试设备当 **h>35** 时的完全不能满足标准要求

结 论

不同测试系统的对比结果和对三个标准测试样品的测试结果表明: 在使用不同的功率放大器时, 不同的谐波测试仪会差异巨大的偏差。

只有在使用 **SPS** 生产的 **PAS** 系列的四象限功率放大器的测试系统时, 其误差才可以保持在标准规定的 **5%** 限值内。

在多数情况下，使用不适合的功率放大器不仅会产生多余的谐波，甚至还会产生相反的测试结果，从而导致错误的结论。

与交流直接转换的功率放大器相比，某些功率放大器 (如开关电源类型的)会产生极大的误差。

依据标准而进行的这一对比测试的目的是为了弄清如何可以获得具有精确性和重复性的测试结果。

不精确的测试结果不仅会导致产品制造成本的大幅提高，和增加产品开发周期, 而且还将会因此而导致 **CE-mark** 认证的失败!

Comparison Measurement of various Measurement Systems

Some years ago, it was found that there was a great variation in the measurement results obtained from various test systems when performing tests in accordance with the standard EN 61000-3-2. Deviations of up to 100% were apparent, although the standard defines a measurement accuracy of 5%.

As a direct result, the German national (DKE) founded the "measurement uncertainty" working group to investigate this problem. The members of the working group agreed to commence an inter-laboratory test, with the aim of establishing the reason for the variation in the measurement results. Several measurement laboratories, and companies, participated in the inter-laboratory test.

The participants received two different rectifier circuits, each of which was assembled from very precise and accurately measured components. Each participant then carried out a series of measurements in accordance with the standard EN 61000-3-2.

The results confirmed that the measuring devices (harmonic analyser) produced more or less acceptable measurement results. Comparison showed that the various sources (amplifiers) caused the greatest deviations.

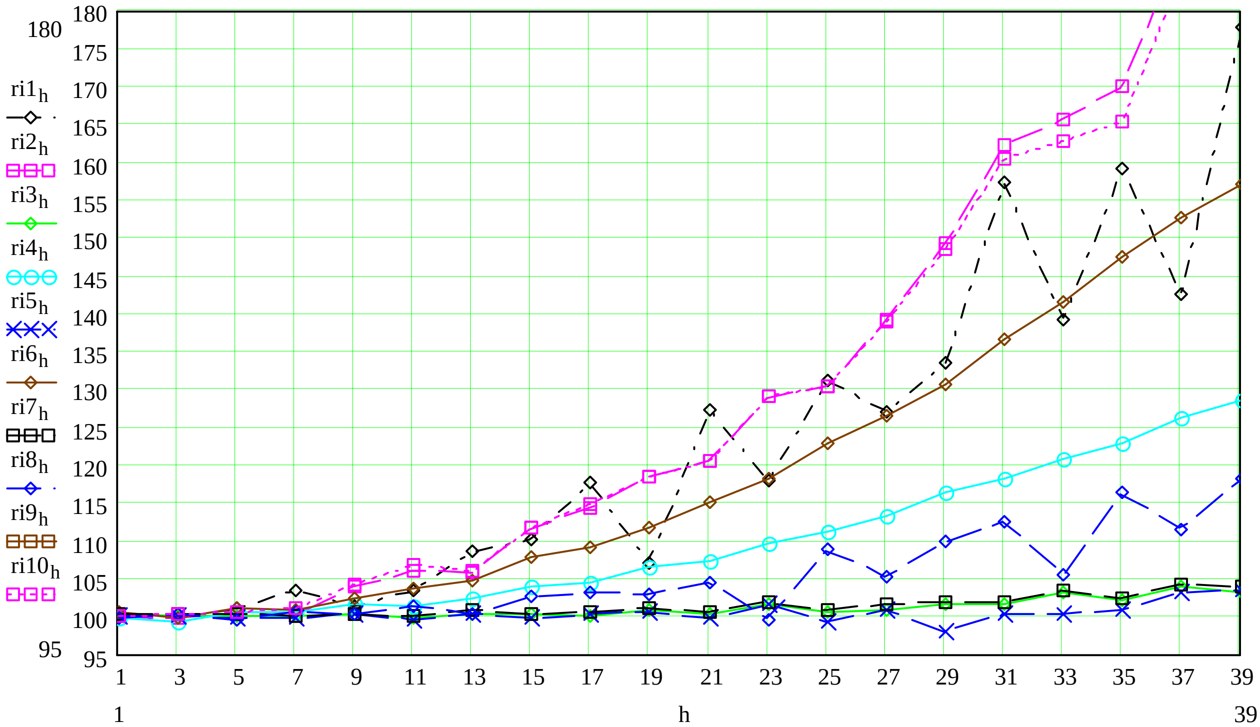
Now, the behaviour of these precisely constructed and measured test specimens could also be characterised by various simulation methods. Therefore an exact FFT analysis was conducted, by way of calculation, utilising PSpice. As a result, the precise behaviour of these test specimen candidates was thus defined. Actual comparison of the theoretical data with the measured data resulted in deviations of up to 70% and 80% being observed (see picture 1). A source of from another manufacturer, which was placed at our disposal, resulted in a deviation up to 90%.

A second inter-laboratory test was started. The harmonics of the supplied test specimen were adjusted to the result of class A in the range of approx. 13th up to 39th harmonic. Furthermore, various real-life test specimens (e.g. a TV-set, various lamps etc.) were also measured in the second test for comparison for comparison purposes. Again, the measurements were performed according to the standard EN 61000-3-2. During both the first and second inter-laboratory tests,

most of the laboratories also measured the harmonics of the voltage (see pictures 2 and 3).

Analysing the voltage harmonic data, it was noticeable that the test equipment that had produced measurement results that had the closest correlation to the simulation analysis also exhibited the smallest voltage harmonics. Comparing the simulation data with the actual measurement data of these test equipments showed that the measurement results of these devices were within the 5% limit (actual was within approx. 4%). These devices were a test system owned by VDE, which had been completely designed and manufactured by Spitzenberger + Spies, and a test system used at the production plant of Spitzenberger + Spies. Some other test systems including those with a source made by Spitzenberger + Spies (but with measurement devices from other manufacturers), as well as those with test sources older than 15 – 20 years, turned out to have slight deviations but to be acceptable compared to other sources.

Picture 1 Deviation of the harmonic currents from the reference value (reference value = 100%)

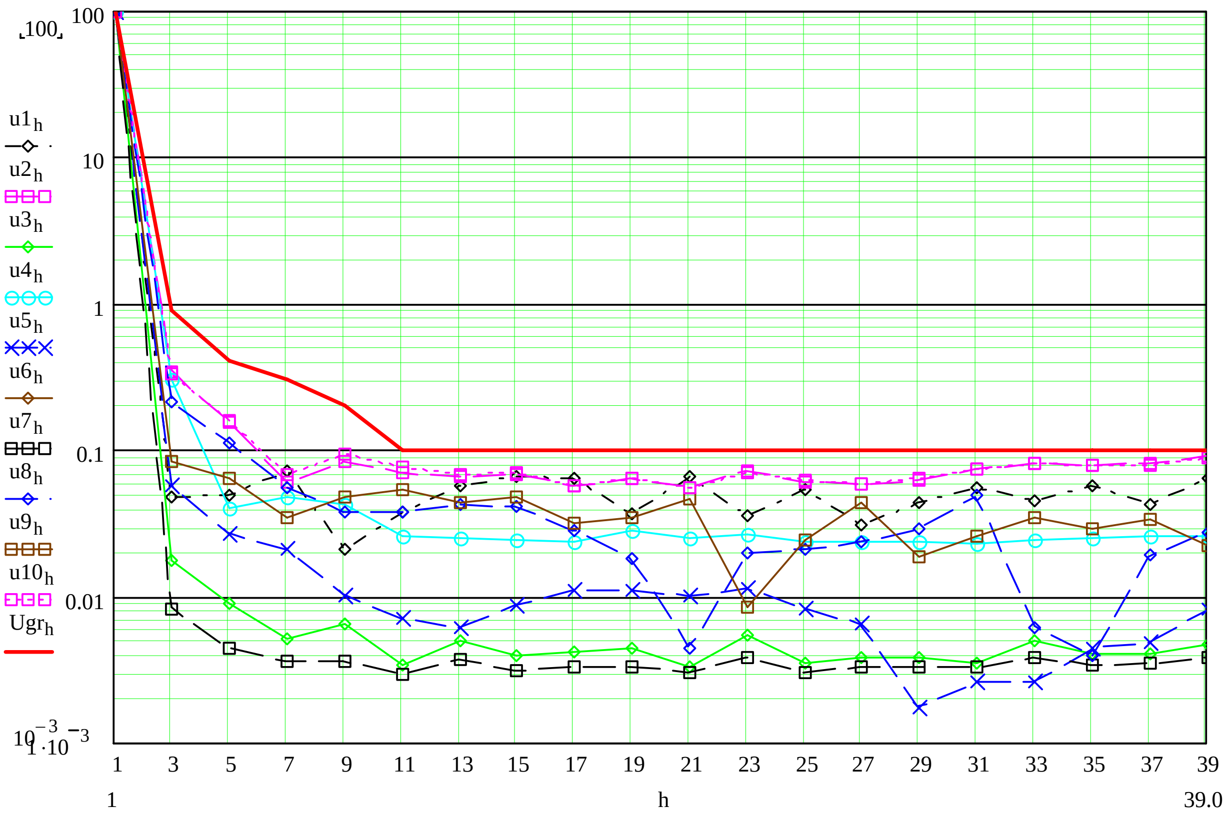


ri1 - ri10 = test series of the participating laboratories / h = ordinal number of the harmonics

Only test series ri7 (VDE Offenbach with SPS-system 3 x PAS 10000) and ri3 (SPS PAS 5000) are within <5%.

The harmonics of the voltage were generally within the permissible limits, according to standard EN 61000-3-2. However it was noticeable that the harmonics of the voltages were very different.

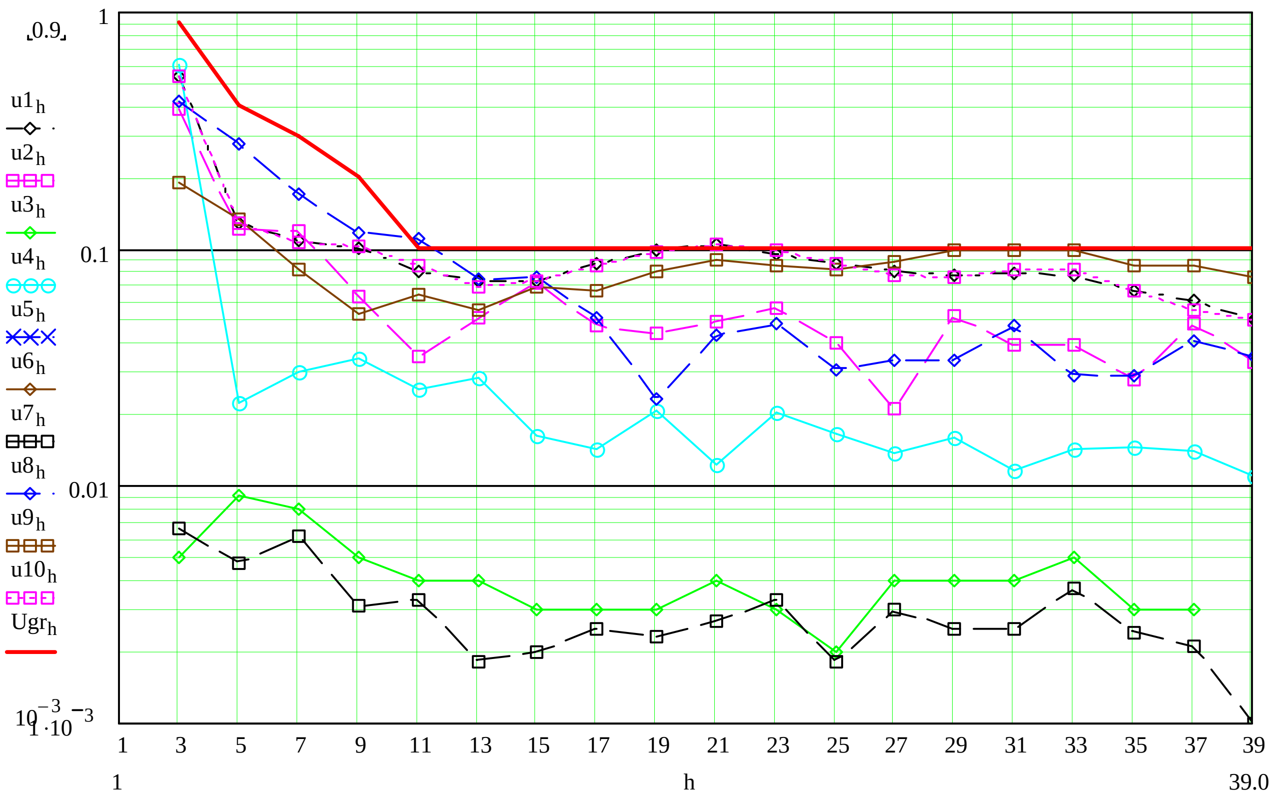
Picture 2   Harmonics of the source voltage caused by the 600W test specimen



u7h and u3h (VDE and SPS) always have less harmonics of the voltage

Devices with the best correlation to the simulation analysis also had the smallest harmonic factors by far (see pictures 2 and 3).

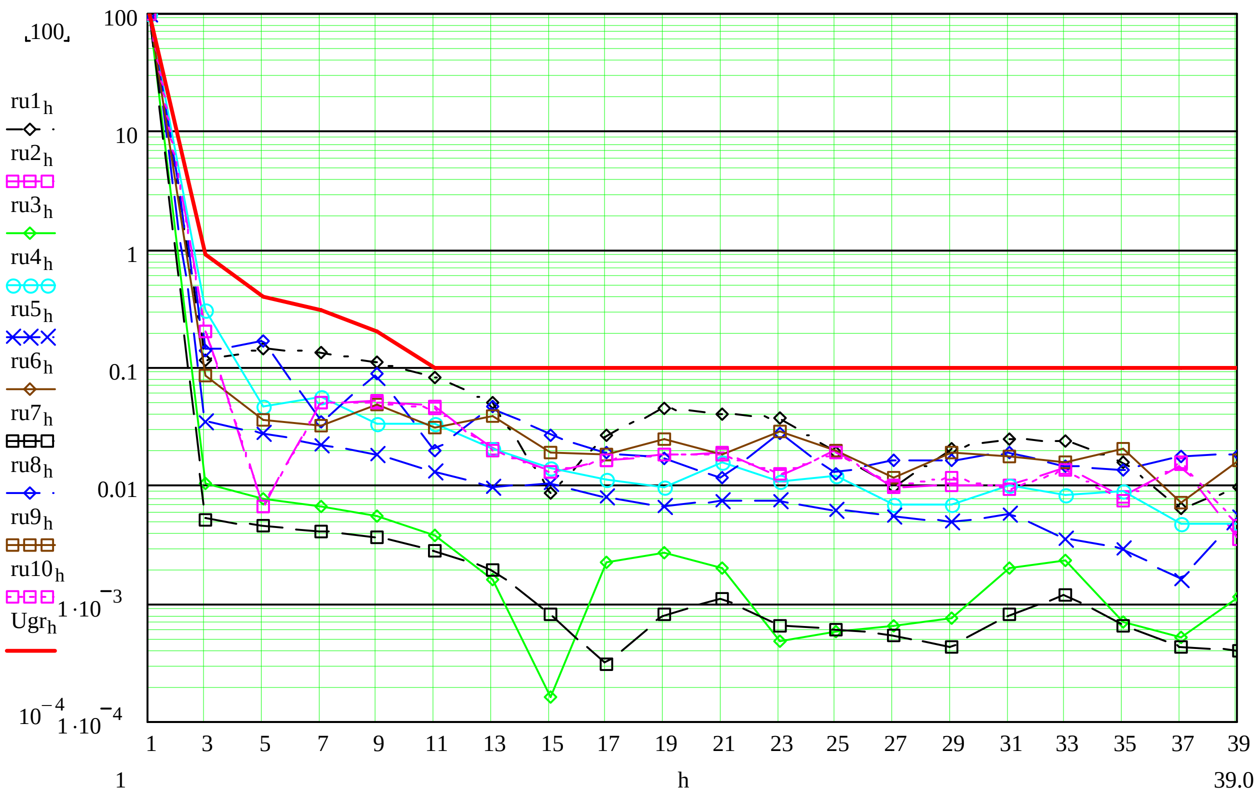
Picture 3 Harmonics of the voltages of the 44Watt test specimen



Despite the small power (44W) some of the sources are pushing the limits. The PAS-sources only approx. 1/30.

Generally, the harmonic performance of the SPS-sources (type PAS) is approx. 30-100 times better than that required by the standard. Other measurements show a similar view (see picture 4).

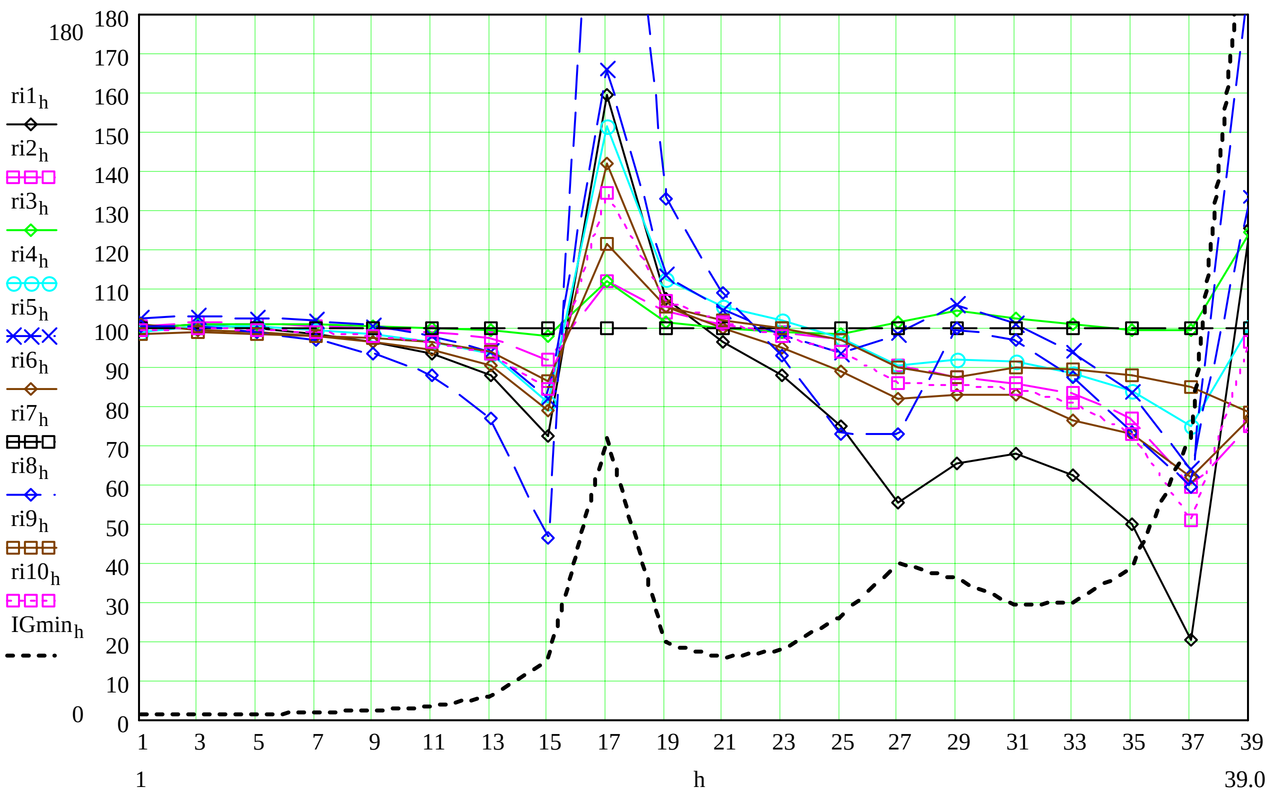
Picture 4 Harmonics of the voltage of a TV set



Here, the harmonics of the voltage of the sources type PAS are much smaller as well.

Taking the source with the lowest harmonics ru7 (VDE-PAS) as a reference, the following picture of the measurement uncertainty appears:

Picture 5 Harmonics of the currents of the TV set above



Considerable deviations of the currents. Values with h>35 are below the minimum.

Summary

The comparison measurement with various measurement systems and three verifiable reference test specimen each showed that there are very high deviations when using various sources.

Only the test systems utilising PAS-series sources (4-quadrant-amplifiers) from Spitzenberger + Spies are able to keep within the defined 5% limits.

In most of the other cases, the use of unsuitable sources is generating additional harmonics. However, the opposite result is possible. This causes incorrect measurement results.

Specific sources (e.g. switching amplifiers) cause extremely large errors; comparison measurements conducted directly from the utility AC supply hardly resulted in worse values.

The aim of conducting tests in accordance to a published standard is to obtain accurate and repeatable measurement results.

Inaccurate measurement results may result in very high costs - once as a result of over-engineering and again by the loss of the CE-mark!