Phase Shift Correction: The key for Power Analysis of GaN or SiC switching devices

Improving power efficiency of motor drive systems for electric vehicles or DC-DC power supplies means a continuous increase of switching speeds in the inverters. At the same time the inductive behavior of current sensors always causes a phase shift between voltage and current when measuring AC power at higher frequencies. Ignoring this can have a big effect on your measurement results.

The good news is that phase shift is nothing you have to worry about too much if the frequencies in your switching device stay below 10kHz. The bad news is that you have to consider harmonics as well in power analysis because high speed switching systems generate high-order harmonics. So just looking at the switching frequency is not enough.

Lets use a SiC-MOSFET switching element with a switching frequency of just 20kHz as an example. Very likely you will know plenty of applications based on SiC technology with switching frequencies much higher than 20kHz, but we want to show you that phase shift has a measurable effect even at that level.

Measuring harmonics up to the 50th order of the basic switching frequency is standard for today's power analyzers. Of course the impact of the 50th harmonics to the measurement result won't be dramatic - but now we are looking at MHz frequencies and at those frequencies phase shift is certainly an effect to consider.

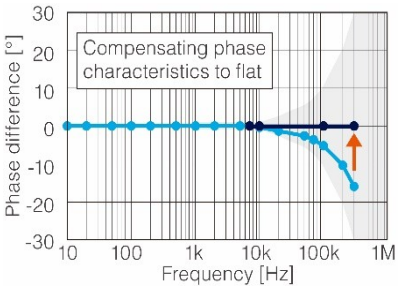

Figure 1: Phase error with and without compensation

When a power analyzer is used in a high precision power measurement application, it is typical to use sensors to measure currents. One of the reasons for this is because a direct input measurement with shunts wouldn't provide the required accuracy when measuring high currents at higher frequencies.

However, every current sensor in the world exhibits a gradually increasing phase error in the high-frequency region due to the inductive characteristics of the sensor's magnetic core and circuitry. Furthermore, differences in the design of various sensor models cause the magnitude of this error to vary.

HIOKI is the only manufacturer of power analysis solutions offering a true phase correction feature. This is because only HIOKI designs and makes both the power analyzers as well as the sensors allowing the analyzer to detect the sensor and working based on its characteristics.

Figure 2: HIOKI PW6001 power analyzer

The HIOKI power analyzers PW6001 and PW3390 can both use the current sensor-specific phase error information to correct this error, thereby improving phase characteristics in the high frequency region and reducing power measurement error.

To show you the effect that phase shift correction has on your measurement results we have done a comparison doing the same measurement once using the phase shift correction feature and once without. We have chosen one of the

most common inverter setups: One DC phase going into an inverter and three AC phases on the output side. The inverter is based on the SiC-MOSFET switching element mentioned before and it's operating at a switching frequency of just 20kHz.

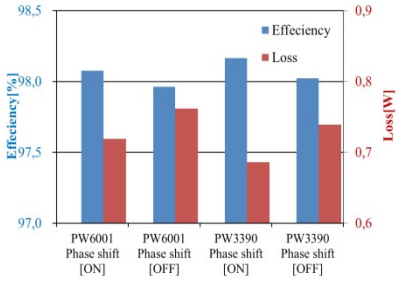

Figure 3: Comparison of inverter efficiency and loss

Looking at the measured inverter efficiency and the loss of power in the inverter you can see in figure 3 the positive impact phase shift correction has on your measurement results as the measured loss is lower and the measured efficiency is higher.

Utilizing phase shift correction and reducing the error caused by this physical phenomenon of phase shift increases the output of an inverter even at this low switching frequency by 0.1% to 0.15%. While this value doesn't look like a lot every engineer working on improving the efficiency of inverters will tell you that this is a significant number. It's easy to imagine the difference in efficiency results when performing the same measurement with an inverter that runs on higher switching frequencies.

Deep dive:
http://bit.ly/PhaseShiftError

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