APPLICATION NOTE 32
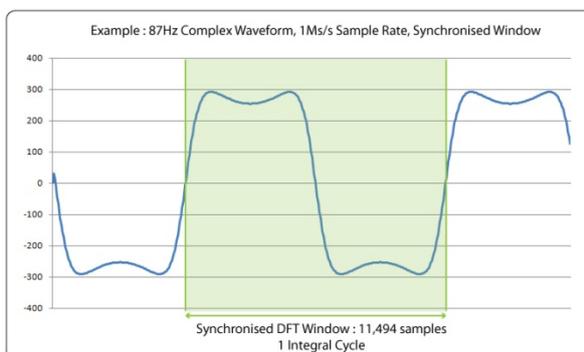## Efficiency Measurement of Traction Motors

Efficiency measurements of DC-AC converters is a key part of the EV traction system development process, accurate and reliable measurement is a key priority for any test and development engineer. This article discusses important aspects of efficiency measurement that a power analyzer will need to address.
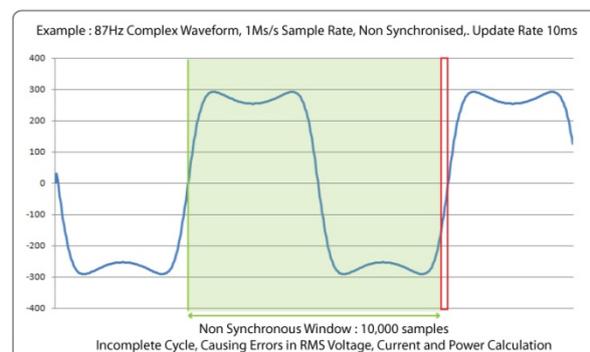
Synchronisation

Traction system analysis involves DC Bus to AC Inverter electrical efficiency measurement along with electrical to mechanical efficiency between DC input/AC output and output shaft. Synchronisation of these measurements is vitally important, so that the instantaneous efficiency is correctly calculated. Some power analyzers will not synchronise the measurement acquisition window of the input and the output power. In this application, synchronisation can be defined as the common start and end time of the data acquisition window across all phases of the measurement instrument. This ensures that the instantaneous efficiency calculated using P_{out} (AC output power) and P_{in} (DC Input Power) utilise data points from a time synchronised acquisition window, where the start time and end time match respectively.

Windowing

It is common for a power analyzer to use the nominal update rate set by the user (eg. 500ms) as its internal data acquisition window size, regardless of the motor frequency of the motor drive unit being evaluated. However, optimum measurement requires synchronisation of the measurement window to the fundamental time period or "motor frequency" (with respect to time). If the measurement window is correctly sized to a single or even multiple fundamental time periods, RMS calculations of Voltage, Current and Power will be correctly computed. If the acquisition window does not contain an exact integer number of cycles, this will cause significant measurement error when update rates approach the time period of the motor frequency, figure 1 illustrates the issue.

Example : 87Hz Complex Waveform, 1Ms/s Sample Rate, Synchronised Window

Synchronised DFT Window : 11,494 samples
1 Integral Cycle

N4L Proprietary Dynamic Synchronous Windowing

Example : 87Hz Complex Waveform, 1Ms/s Sample Rate, Non Synchronised,. Update Rate 10ms

Non Synchronous Window : 10,000 samples
Incomplete Cycle, Causing Errors in RMS Voltage, Current and Power Calculation

Non-Synchronous Traditional Windowing

N4L power analyzers utilise a proprietary windowing algorithm based upon the discrete Fourier transform (DFT) as well as dual FPGA/DSP signal processing techniques to adjust the acquisition window size proportional to the fundamental time period of the power waveform. For example, if a

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1 second update rate is selected by the user, N4L power analyzers are capable of adjusting the acquisition window size in 500ns steps (1 sample point) around the 1 second selected update rate in order to ensure that complete cycles are captured. This is preferred to simply "chopping" off part of the final cycle in a particular window to achieve a given update rate, this improves accuracy for both power measurement and harmonic measurement.

One or Two Instrument chassis' for 4 phase measurements?

There are pro's and con's when selecting a single 4 phase instrument chassis for measurement of DC Bus to 3 Phase Output power of an inverter module. The advantages are that only a single instrument needs to be queried by software, simplifying programming and system integration time. Another advantage is size, as an example the N4L PPA3500 is a 2U high, high accuracy multi-channel power analyzer supporting up to 6 phase (12 channel) analysis within a single chassis.

This occupies minimum space within a test system, leaving space for other equipment while still

PPA3500 1 to 6 Phase Power Analyzer

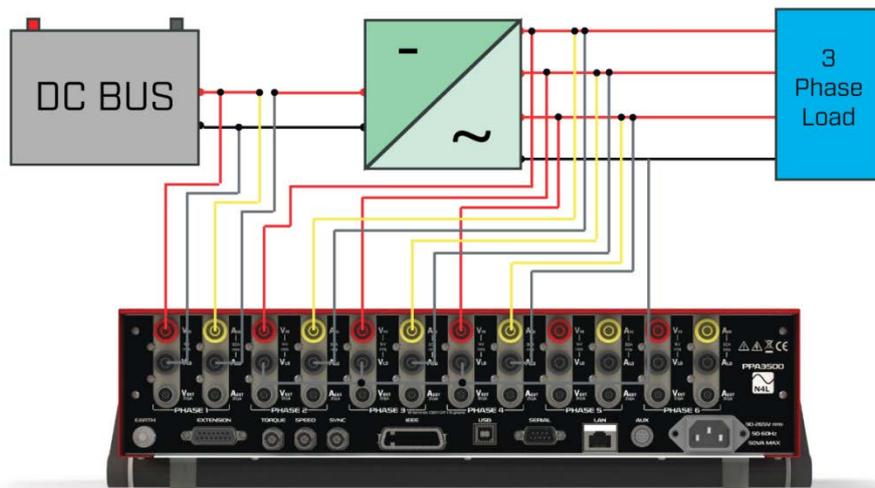providing market leading 0.03% nominal accuracy. A second option is to utilise two separate instruments, a single phase unit to measure the DC bus and a 3 Phase unit to measure the output power of the inverter. An advantage of this setup is flexibility, since the instruments can be separated at any time and used in separate applications. Furthermore, the high specification hardware required to analyse PWM waveforms is not necessary to measure DC bus power, therefore cost savings can be made on selection of DC bus instrumentation. The disadvantages of a 4 phase analysis system comprising 2 instruments is greater complexity with regards to software programming, as well as greater rack space requirements.

Whilst making the choice between a four phase instrument and two separate instruments is important, engineers should ensure best practice synchronisation techniques and integer cycle windowing are carried out to avoid waveform "chopping". N4L Power Analyzers perform all of the above to ensure optimum measurement in demanding applications.

Example 4 Phase measurement using N4L PPA3560

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