Application Note No. 0001

Optimising Phase Measurement with the ITA-1

Introduction

The ITA-1 has been designed such that it produces data enabling standard phase measurements to be carried out. It is important, however, to understand some of the relationships between the data acquired and the resulting phase value. This will enable the user to set up his system correctly and minimise any inaccuracies.

Measuring Phase

First, let us look at how phase is measured using spectral techniques.

To obtain consistent phase readings, we have to ensure that the phase of the waveform we are measuring does not vary over the sampling period, even when the speed of the machine we are monitoring is varying in speed. In simple terms, we need to start and stop the measurement process at the same relative instants regardless of shaft speed. We achieve this by using external trigger to provide a consistent start point, and phase-lock-loop to ensure a uniform sample period, and therefore consistent end point.

Let's look at this in more detail.

To synchronise to shaft rotation, **we must use an external trigger for our data acquisition**. Data is gathered in the time domain and phase is calculated from the Fast Fourier Transform (FFT) by taking the arctan of the real part over the imaginary part. In any spectral process, windowing (typically a Hanning window) has to be applied to the incoming data to prevent smearing of the resulting spectrum caused by a non-integer number of cycles being gathered. Any amplitude or phase deviation caused by the Hanning window is negligible for all practical purposes, but the error in the phase calculation caused by free running data sampling from the trigger point is very significant. **Therefore, when measuring phase, it is necessary always to use the phase-lock-loop function (or “orders”) to ensure an integer number of cycles in the time data.** Without this, the number of cycles and part-cycles will vary as shaft speed varies, and so lead to erroneous phase. On a rotating shaft, a once-per-rev synchronising trigger together with orders mode ensures that a whole number of revolutions of the shaft is always measured. Let us call this whole (or “integer”) number of revolutions N.

Now let's look at some of the numerical relationships using orders.

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In a time record, the number of integer revolutions N of a rotating shaft is given by the formula:

N =no of spectral lines / no of orders (1)

For example, a 400 line spectrum gathered with 16 orders defined will result in 25 revolutions of data being gathered. For accurate phase calculation, N should be a whole number. In other words**, the number of spectral lines must be divisible by the number of orders**. For example, with a 400 line spectrum, a selection of 10 orders is good whereas 12 orders should not be used.

The sample rate at which this data is gathered is dependent on the rotational speed of the machine and the number of orders defined. The sample rate (SR) is given by:

SR = speed (in Hz) x N x 2.56 (2)

Knowing the speed range of the machine being monitored, it is possible to calculate the sample rate range for a given number of orders. For example, a machine rotating at 1800RPM (30Hz) with 16 orders selected will result in a sample rate of 1.229kHz. The sample rate range of the ITA-1 is 15Hz to 51.2kHz. If the sample rate required is outside this range, an error code is produced by the system protocol.

Minimising Phase Deviation

To fully understand how to optimise phase measurement, it is important to appreciate how the sample rate for data conversion is generated in the ITA node. Basically, a clock is loaded with a count, and this counter value CVAL is given by:

CVAL = 409600 / SR (3)
or
CVAL = 409600 / (speed x N x 2.56)

For this exercise, the number produced is not important, but it should be appreciated that CVAL is a whole number with discrete steps. The ITA node calculates the ideal value of CVAL (which depends solely on the machine speed as the other numbers are constants) and rounds this to the nearest integer. This rounding can cause the number of cycles in the time record not to be an exact number (although it will be very close). This is equivalent to a tiny shift in the time record across the period of the record (depending on the amount of rounding of CVAL), and this can be manifested as a small phase shift. To minimise this effect, the number of cycles in the time record should be reduced (since, the fewer the cycles, the less any shift will be as a proportion of a cycle). Referring back to equation 1, this is achieved by increasing the value of N. Therefore**, phase deviation can be minimised by making the number of orders as large as possible**. It should be noted that the rounding error, and therefore phase deviation, will increase with speed.

In practical terms, the number of orders N selected for phase measurement when using 400 or 800 spectral lines should always be greater than 10. A number of 16 or 20 is ideal.

In summary, to ensure stable phase measurement using the ITA-1, the following conditions should be adhered to:

1. Always use an external trigger source;
2. Always use the orders (or “phase-lock-loop”) function;
3. Ensure that the number of spectral lines divided by the number of orders selected is a whole number;
4. Select a high number of orders to minimise phase deviation.

The above techniques apply to a number of other systems that provide phase measurement.