

4.4 Guidance on narrow-band measurements

Transformer sound is characterised by tones at double the power frequency and at even harmonics of the power frequency (assuming sinusoidal excitation and no DC bias). Therefore noise at other frequencies can be suppressed by applying narrow-band measurements. The term “narrow-band” is here used to describe a measurement where a frequency analysis of the sound is made and thereafter only the frequency bands containing the characteristic transformer tones are used in the evaluation. A more exact description would be “band selective analysis”. This method is applicable for sound pressure and sound intensity measurements, and can be used to calculate sound power levels. The method cannot eliminate the effects of reflections described by the environmental correction K .

The application of the band selective narrow-band measurement method is subject to agreement between manufacturer and purchaser. Cooling equipment and oil circulating pumps do not produce sound characterised only by tones at fixed frequencies but produces sound at many different frequencies, in other words they are a “broad-band” noise source. Therefore band-selective narrow –band measurements are not permitted when cooling equipment and oil-circulating pumps are in operation.

The required frequency analysis may be achieved by using either the parallel real-time analysis method, which results in logarithmic frequency resolution (1/1 octave, 1/3 octave, 1/12 octave etc.) or the FFT method. FFT (Fast Fourier Transformation) transforms the digitised measured sound pressure amplitudes vs time records into amplitudes vs frequency records (spectra) by a mathematical algorithm. The bandwidth of the spectra thus obtained depends on the sampling rate of the analog to digital converter. A frequency analysis by the FFT method results in a constant bandwidth resolution (x Hz).

Band selective analysis can be used in principle also for very wide bands such as 1/3 octave but the background attenuation becomes more effective if a narrower bandwidth is chosen. If the power supply frequency generates a higher harmonic frequency which falls outside the chosen bandwidth (Δf), a different (neighbouring) band for that harmonic or a wider bandwidth should be selected.

Measurements are made as usual except that, instead of measuring single A-weighted values, the levels are measured over frequency bands containing frequencies equal to twice the rated frequency and multiples thereof. The A-weighted sound pressure level or sound intensity level at each measurement position can then be calculated by the following equation:

$$L_{Ai} = 10 \lg \left(\sum_{n=1}^{n_{\max}} 10^{0,1L_{An}} \right) \quad \dots 6$$

where

- L_{Ai} is the A-weighted sound pressure level (or sound intensity level) at rated voltage and rated frequency;
- L_{An} is the A-weighted sound pressure level (or sound intensity level) measured over the chosen bandwidth, Δf , containing a frequency equal to $2fn$, at rated voltage and rated frequency. The A-weighting may be accomplished in two ways:
- by using an analogous filter on the front end of the measurement system such that all measured values are A-weighted from the start.

- b) if the measurement is linear: apply A-weighting digitally on the measured level in each frequency band. Values of the A-weighting for each harmonic frequency may be taken from table 1 below.

f is the rated frequency;

n is the sequence number (1, 2, 3, etc.) of multiples of the even harmonics of the rated frequency;

$n_{\max} = 10$.

| Lower frequency limit > Hz | Upper frequency limit ≤ Hz | A-weighting value dB |
|-------------------------------|-------------------------------|-------------------------|
| 28 | 36 | -39,4 |
| 36 | 45 | -34,6 |
| 45 | 56 | -30,2 |
| 56 | 71 | -26,2 |
| 71 | 90 | -22,5 |
| 90 | 112 | -19,1 |
| 112 | 141 | -16,1 |
| 141 | 179 | -13,4 |
| 179 | 224 | -10,9 |
| 224 | 281 | -8,6 |
| 281 | 355 | -6,6 |
| 355 | 447 | -4,8 |
| 447 | 561 | -3,2 |
| 561 | 710 | -1,9 |
| 710 | 895 | -0,8 |
| 895 | 1120 | 0,0 |
| 1120 | 1410 | +0,6 |
| 1410 | 1790 | +1,0 |
| 1790 | 2240 | +1,2 |
| 2240 | 2810 | +1,3 |

Table 1 – Values of A-weighting as a function of frequency

4.4.1 Frequency analysis by the real-time method

It is recommended that the analyzer bandwidth, Δf , is chosen to 1/10 octave or narrower. In the evaluation the frequency bands that contain transformer sound must be selected manually such that the first 10 harmonic components of the sound are included. The frequency bands will not be centred on the harmonic components but each harmonic will be measured with sufficient accuracy if it is contained within a band.

4.4.2 Frequency analysis by the FFT method

It is recommended that the analyzer bandwidth, Δf , is chosen to 10 Hz, 5 Hz or 2.5 Hz. It is recommended that the “Flat-top” time window of the instrument is used. This window gives maximum accuracy in the measured amplitudes of each harmonic also if a harmonic frequency falls on the limit of a frequency band. A result of the “Flat-top” window is that the pure sound at 100 Hz which is correctly measured in the 100 Hz frequency band also will give a high level in the 95 Hz and the 105 Hz bands. This so-

called "leakage" causes no problem in a band selective analysis but must be considered when all frequency bands are added as in case of measurements with cooling equipment in service. A "Flat-top" window gives an effective bandwidth of approximately 3,8 times Δf whereas the commonly used "Hanning" window has an effective bandwidth of approximately 1,5 times Δf , but gives a possible error of up to 1,4 dB on the measured amplitudes for a harmonic that is not centred. Please consult the specification of the FFT instrument for exact data about the effective bandwidth and amplitude accuracy.