Detecting partial discharge with ultrasonic measurement

Ultrasonic measure to detect partial discharge corona, arcing and tracking has become a viable means used for electrical equipment. Author Lee Wai Meng discusses the considerations in this new method.

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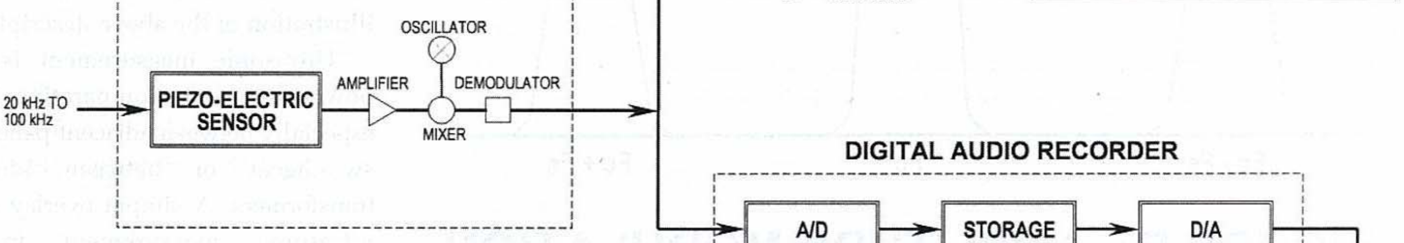

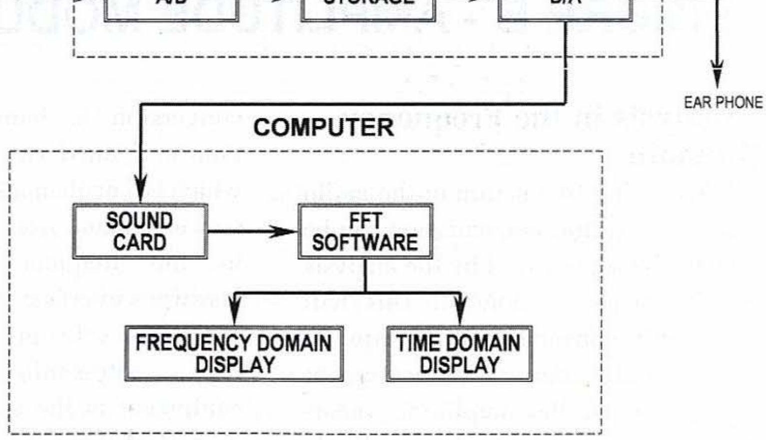

FIGURE A - BLOCK DIAGRAM

Introduction to ultrasound and its meaurement

Firstly, ultrasound waves are sound waves of frequencies 20KHz to 100KHz, and outside the frequency response of the human ear. Ultrasound waves are produced by electrical problems like partial discharge, tracking, corona, and arcing. Typically the frequencies of the ultrasound produced are:

- Partial discharge - 20kHz to 30kHz
- Corona, arcing, tracking - 40kHz

Ultrasound waves are able to penetrate small openings, seals, door seams and air vents. The ultrasound is perceived as crackling sound by the human ear. The ultrasonic measurement used is on-line and non-intrusive. Therefore measurements can be done on energised electrical equipment without the need to remove protective covers. By maintaining the insulation integrity of the electrical equipment being tested, this method has already been employed in common applications such as cable terminations, switchgears, busbars and transformers.

Ultrasonic Measurement Equipment

Figure A is the basic block diagram for ultrasonic measurement. The ultrasound is detected by the piezoelectric sensor, which converts pressure energy from the ultrasound striking the sensor into electrical energy. Quartz is a common material for such piezoelectric sensors. Typically, the electrical signal is very small and will have to be amplified. The resulting electrical signal is in high frequency and thereafter, this high frequency electrical signal is shifted down to the audio frequency range by amplitude modulation. This is done by mixing the electrical signal with a carrier frequency from a local oscillator.

If we assign the electrical signal be Fs, and the carrier frequency be Fc. The three output signals from the amplitude modulation will have frequencies Fc, (Fc + Fs) and (Fc - Fs). Refer to Figure B.

Only the output signal with frequency (Fc - Fs) will fall into the audio range of the human ear. The demodulator extracts the signal and a connection to a loudspeaker or earphone will produce the crackling sound should the measured electrical equipment have partial discharge, corona, tracking or arcing.

One major disadvantage of using the human ear to hear the crackling sound is the difference in perception and sensitivity of various people.

An obviously crackling sound to one person may not be obvious to another person. Hence to solely rely on the audio analysis of the measured ultrasonic emission will not be accurate.

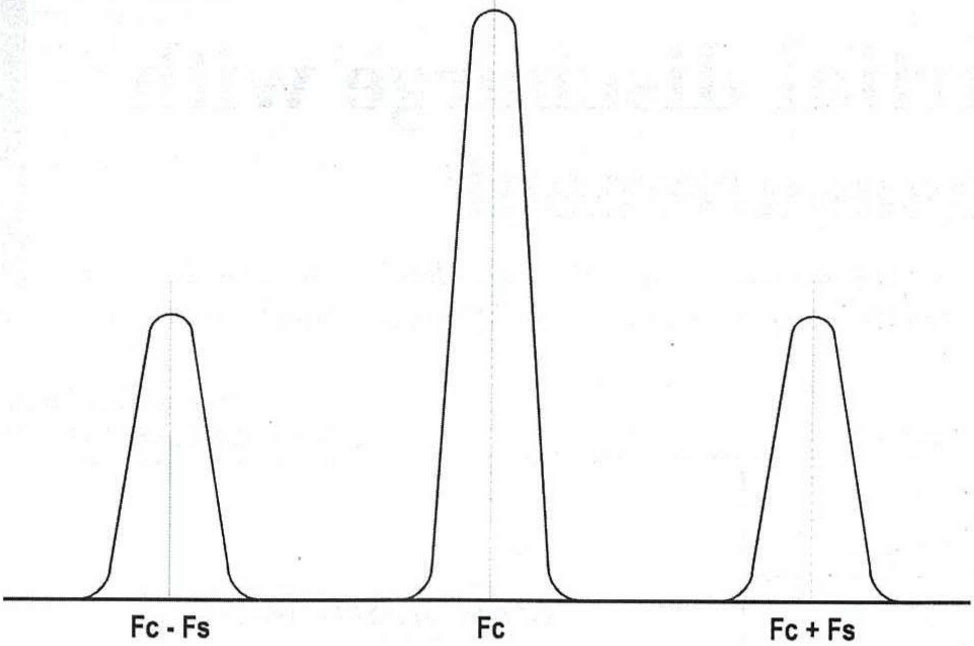

FIGURE B - AMPLITUDE MODULATION

Analysis in the Frequency Domain

The subjective nature of the audio analysis of ultrasonic emission can be significantly improved by the analysis in the frequency domain. This will require the conversion of the output of the ultrasonic measurement equipment in the amplitude versus time representation to the amplitude versus frequency representation. This conversion is handled by a Fast Fourier Transform (FFT) software, which is a mathematical algorithm that converts signal from the time domain to the frequency domain. The hardware interface between the input of the FFT software and the output of the ultrasonic measurement equipment is the sound card, which does an analogue to digital conversion of the audio signal. The 16 bit sound card commonly used on personal computer will work well with audio frequency analysis using FFT.

Partial discharge, corona and arcing in electrical equipment have signature characteristics when viewed in the frequency domain. Invariably, amplitude spikes will appear at the fundamental frequency of the electrical supply (50 hertz in Singapore), and integer number of the fundamental frequency. Figure C is an illustration of the above description.

Ultrasonic measurement is most powerful on a comparative basis, especially between adjacent panels of a switchgear or between identical transformers. A simple overlay of the ultrasonic measurement in the frequency domain will show up differences and indicate the source of the ultrasonic emission. The directional nature of ultrasonic emission makes it possible to confirm the location of the ultrasonic emission. This is easily done by removing a bolt of the protective panel to the electrical equipment and measuring the escaping ultrasonic emission from the created opening.

FFT Software

Any commercially available FFT software will work well with the output electrical signal of the ultrasonic measurement set. This is because the output electrical signal is in the audio frequency range and both the hardware and software requirement are not stringent, unlike high frequency measurements, storage, processing and analysis. In using a FFT software, the following are the very important parameters;

- Sampling rate
- FFT size

Sampling Rate

The sampling rate determines the number of times a second the analogue input signal is digitized by the sound card. The larger the sampling rate the more accurate the representation of the analogue signal in the digital form. An

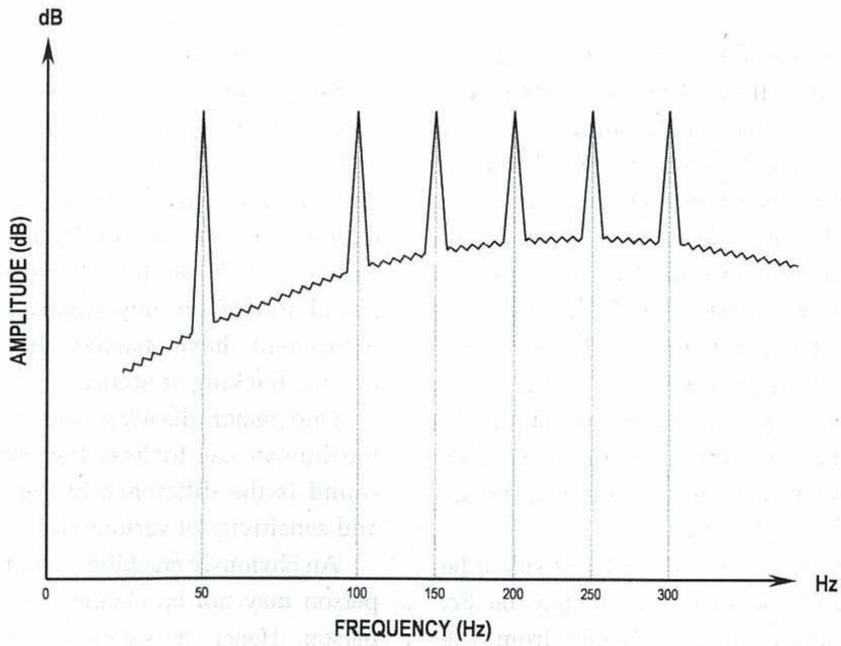

FIGURE C - SIGNATURE OF ELECTRICAL PROBLEMS