In industry, there is increasing use of motors with variable rotation speeds.

The need to control this feature led to the invention of variable speed drives. Initially, the speed variation was proportional to the voltage supplied to the DC motor, but maintenance of this type of system proved too complex. In addition, the components used were affected by electrical disturbances linked to the network.

Nowadays, variable frequency speed drives are the most widely used, with the most well-known being PWM (Pulse Wave Modulation) speed drives. PWM speed drives help to limit voltage drops when the motor starts up, because the variable speed drive causes the rotation speed to vary gradually. In addition, the speed is controlled precisely and the life span of the equipment is extended.

We are going to study the signal waveforms with an oscilloscope and, more particularly, the SCOPIX IV portable oscilloscope with isolated channels.
A bit of theory

PWM variable speed drives

This type of variable speed drive is divided into several functions:

- The rectifier, which serves to convert the AC voltage into a DC voltage while smoothing the voltage.
- The UPS (Uninterruptible Power Supply), which can be used to convert from a DC voltage to an AC voltage whatever the latter’s frequency.
- The command and intermediate circuits, which are used, respectively, to command the variable speed drive, filter the signals, store the energy values and smooth the signals.

Tip
At the output from a rectifier, two characteristics of the output voltage are crucial:

THE FORM FACTOR
This represents the quality of the rectification. The closer it is to 1, the better the rectification. It is calculated as follows:

\[
\text{form factor} = \frac{U_{\text{rms}}}{U_{\text{average}}}
\]

THE RIPPLE FACTOR
After filtering of the variable speed drive's output voltage, the voltage is smoothed and the quality of the smoothing is symbolized by the ripple factor. To calculate this, you must use the following formula:

\[
\text{ripple factor} = \frac{U_{\text{max}} - U_{\text{min}}}{U_{\text{average}}}
\]

A PWM variable speed drive is based on the principle of applying a constant (often nominal) voltage during defined periods of time to reach the required speed.

Here is an example of the sort of signal which a PWM drive may transmit (measured using a SCOPIX IV oscilloscope):

As you can see, the pulses are transmitted successively to cause an acceleration. The peaks all have the same amplitude to provide the required average value as a function of time, in the high status of the signal.

There are constraints regarding the use of these variable speed drives, however, as these instruments are the source of a lot of disturbance on the electrical network. Indeed, one of the consequences of using this type of equipment is the appearance of harmonics on the electrical network. Filtering is sometimes needed to remove these impurities.

To detect these anomalies, you need specific equipment to correctly identify any problems which may occur. For this type of situation the Scopix IV is ideal because it is equipped with Probix probes. It is quite capable of measuring the different signals emitted by the variable speed drive on different channels isolated from one another and from the earth.

Several measurements are essential for correct operation of the variable speed drive and the equipment present in its environment, such as motors:

- The variable speed drive’s output voltage is very important because, if it is not suitable, it may damage the receivers connected to the variable speed drive.
- The disturbances present on the output voltage. It is crucial to know whether the signal is too disturbed, because it means the filter is not sufficiently effective or there is a dysfunction in the global setup.

Above: use of envelope selection in OSCILLOSCOPE mode to view the shape of the pulses.
In three-phase systems, you often need to measure the RMS value of each phase to check the balancing. If the phases do not have the same characteristics, a dysfunction may occur. As explained earlier, variable speed drives can cause disturbances which may make the measurements incorrect if too significant. For this type of problem, the Scopix IV offers a harmonic analyser and FFT analysis which can be used to detect whether a signal is disturbed and diagnose the frequencies to be eliminated.

In addition, the oscilloscope possesses digital filters directly accessible from the touch screen. This means the disturbed signal can be modified to remove some of the disturbances. It is possible to filter at 5 kHz, 1.5 MHz or 15 MHz in Oscilloscope mode, and at 625 Hz or 5 kHz in Multimeter mode.

Other filters can be used with the Scopix IV, however: the analogue filters. For example, the HX0093 3rd-order low-pass filter, whose cut-off frequency is located at 300 Hz. This probe has been developed to filter the voltage because it attenuates the signal by 60 dB (i.e. a factor of 1,000) for signals below 300 Hz.

Reminder concerning PWM drives

The Scopix IV is a genuinely effective tool for this type of measurements because not only can it measure RMS values very quickly in Multimeter mode, but it also allows users to view all the signals with the Oscilloscope mode. This makes it very simple to detect a dysfunction or anomaly in the signals delivered by the variable speed drive.

The signal output by a variable speed drive is unusual, as it comprises several peaks over different time intervals. This is PWM (Pulse Width Modulation), or square-wave voltage control. The "slots" in the square wave are determined by the switching frequency, which can be deduced by using the FFT decomposition.
To demonstrate the functions of the Scopix IV enabling you to view the disturbances generated by a variable speed drive, this operation was performed on a drive powering an asynchronous motor (coupled in a star configuration) bearing a load with a generator powering a resistor.*

Thanks to the multiple modes available on the Scopix IV, it was possible to carry out a thorough analysis. A power factor was measured in Multimeter mode and observations were made on the signal transmitted by the variable speed drive.

After filtering at 5 kHz, these signals already become more comprehensible and the instrument can perform a few automatic measurements. Here, an HX0093 filter should be added to make the signal "cleaner" (noise elimination).

With perfect filtering, the voltage and current received by the motor should have the waveform opposite.

The use of variable speed drives is essential in major industries because they enable potential energy savings of approximately 42%. They therefore play a crucial role in the process of rational, responsible use of energy with the aim of saving on resources.

Nevertheless, the switching devices incorporated in variable speed drives represent a non-linear load which generates harmonics leading to dropouts and disturbances on the electrical network. This is why it is necessary to view and monitor the waveforms (current and voltage) from the variable speed drive.

In the case of the operation above, the Scopix IV oscilloscope is particularly suitable for this application due to its various functions, including signal filtering and harmonic analysis.

*The operation was carried out at the IIT in Annecy-le-Vieux, France, in the context of practical exercises.