STUDY OF A VARIABLE SPEED DRIVE WITH THE **SCOPIX IV**

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.

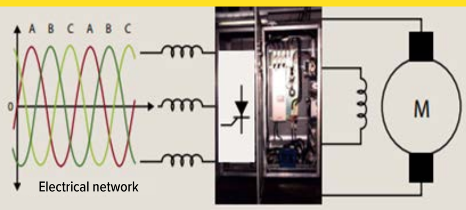
We are going to study the signal waveforms with an oscilloscope and, more particularly, the SCOPIX IV portable oscilloscope with isolated channels.

Oscilloscope with isolated channels

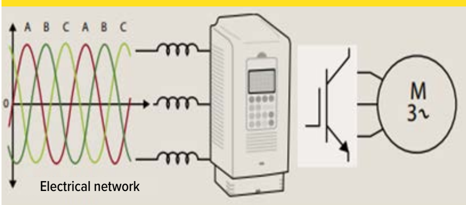
PWM filters

Harmonic analyses

DC variable speed drive



Variable frequency speed drive

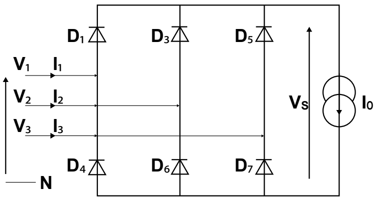


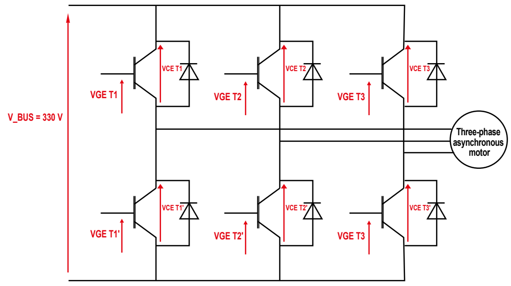
Measure up

A bit of theory

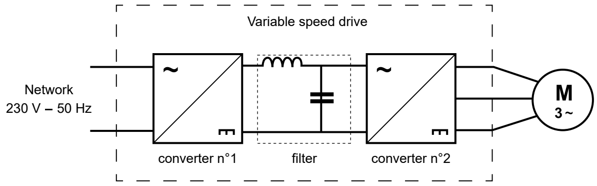
PWM variable speed drives

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 RECTIFIER

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

$$\frac{U_{rms}}{U_{average}}$$

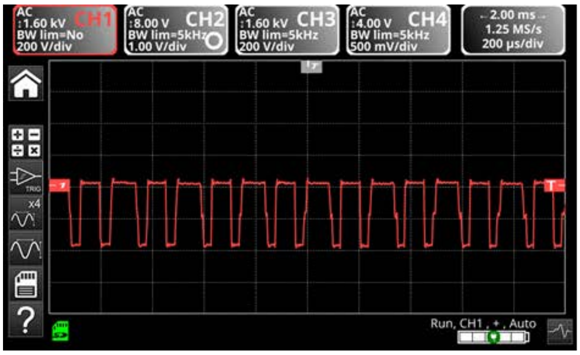
THE RIPPLE FACTOR UPS

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:

$$\frac{U_{max} - U_{min}}{U_{average}}$$

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.

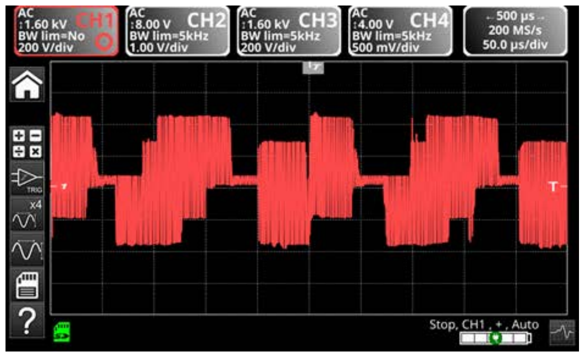
Here is an example of the sort of signal which a PWM drive may transmit (measured using a SCOPIX IV oscilloscope):



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 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.**

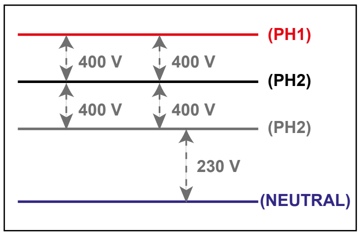


Above: use of envelope selection in **OSCILLOSCOPE mode** to view the shape of the pulses.

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.

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.



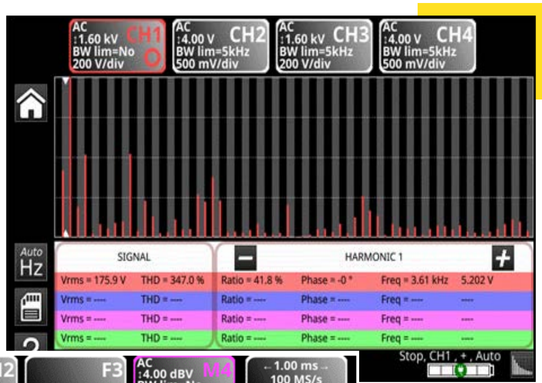
HX0093

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.

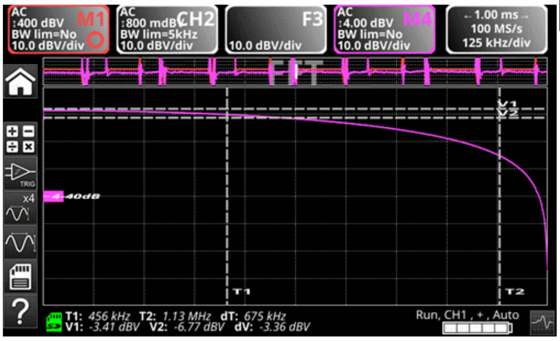
Opposite, you can see use of the **SCOPIX HARMONICS mode** for harmonic analysis on a slightly disturbed network. There are a few harmonics present in addition to the 50 Hz signal, but their amplitude is quite low. They have a negligible impact on the signal that you see in Oscilloscope mode.

Even if the harmonics disturbing the signal are visually negligible, they are problematic for the automatic measurements by the oscilloscope. They therefore have to be eliminated using the means provided on the oscilloscope.



In addition to harmonic analysis in **OSCILLOSCOPE mode**, FFT (Fast Fourier Transform) analysis is also available on the oscilloscope. Indeed, it is possible to perform FFT analysis so that you can detect the disturbances and, more particularly, their exact frequencies. This will enable you to choose the precise filters to be assigned for the optimum effect.

Opposite, you can see the gain curve and a view of the signal received at the top of the screen, By using the cursors, it is possible to identify the important frequencies.



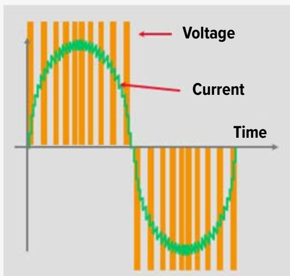
This first measurement was performed <u>without filters</u>, as can be seen with the frequency 7.8 kHz which is not the frequency of the variable speed drive. This means the power factor is wrong. There are several ways of solving this problem:

PRECAUTIONS Use an HX0093 filter to leave only the frequencies below 300 Hz, but with a x 1000 attenuation on the signal's amplitude. On high voltages, this filter is acceptable, but beware: if the signal is too weak, the automatic measurements cannot be performed.

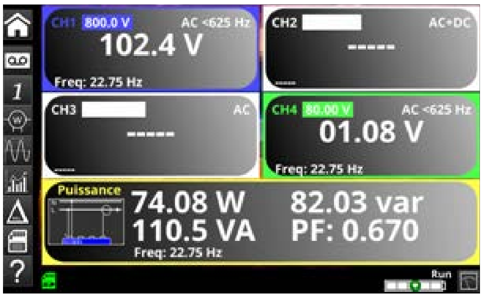
The second solution is to use a digital filter present on the oscilloscope. You can filter at 5 kHz or 625 Hz, depending on the situation. In our case, you will have to filter at 625 Hz because the frequency delivered by the variable speed drive is close to 20 Hz (frequency chosen arbitrarily).

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.



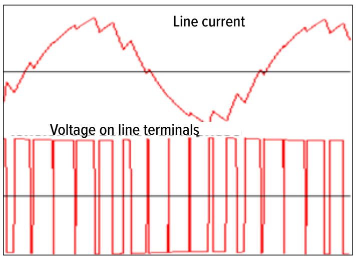
Opposite, you can see a single-phase power measurement with filtering at 625 Hz. It is clear that the frequency is the one provided by our variable speed drive, so our power factor is correct. The measurements were not performed in exactly the same conditions, which is why the current and voltage are different.

Here are two screenshots. The first shows a voltage and a current to which no filter has been applied. We can see that this type of signal cannot be processed manually or automatically by the instrument.

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.

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.

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 IUT in Annecy-le-Vieux, France, in the context of practical exercises.*

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