Harmonics and the Meter Test Bench

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Introduction

Electromechanical meters are relatively simple devices, with voltage coils and current coils that together produce torque in an aluminum disc. The disc rotates at a speed proportional to the product of the applied voltage and current (within a defined range). The coils are linear loads and they draw sinusoidal currents from the voltage and current sources of the test bench. The burden presented by the meter coils are inductive, typically 2-10VA for a voltage coil and 1-5VA for a current coil. The connections between the Test Set sources, Reference Standard, and Meter are shown in Figure 1.

The test bench voltage and current sources do not need a high frequency response, as neither their output voltage nor current contain harmonics. Similarly, the voltage source output impedances Zs do not have to be very low, as the loads presented by the coils are assumed to be constant once a voltage is set, for the duration of a particular test.

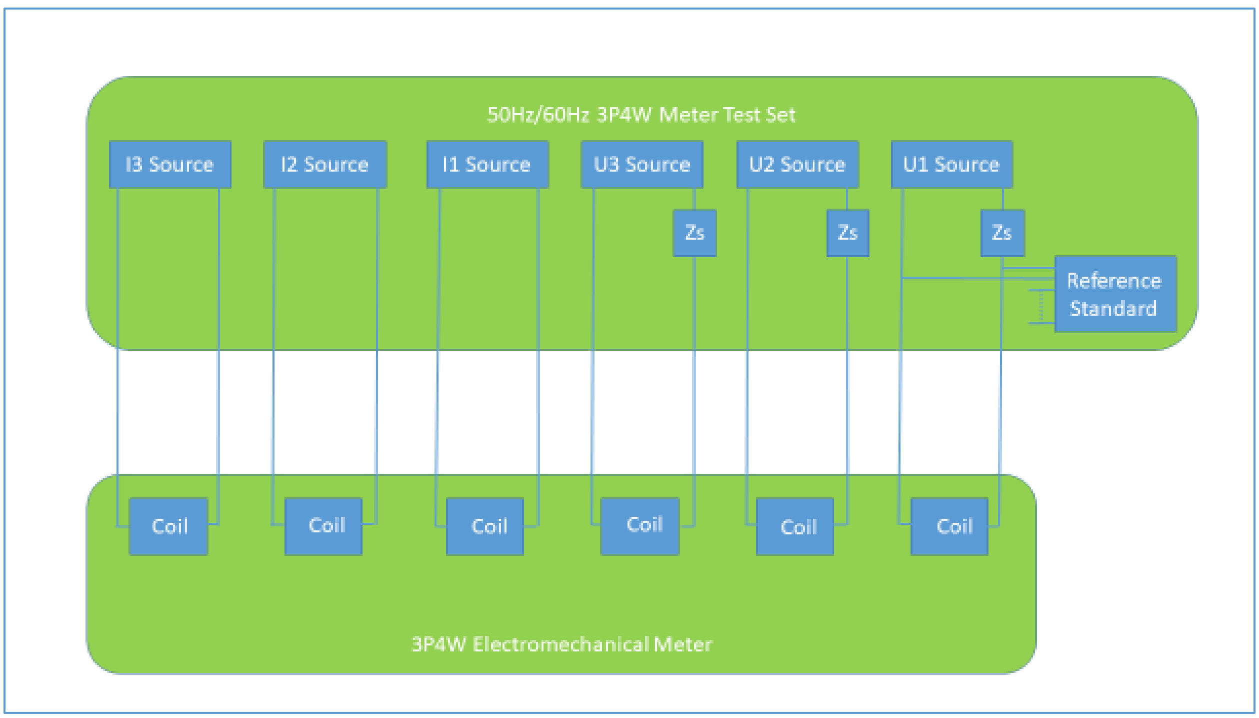

Figure 1 – Electromechanical 3P4W Meter and Test Set

Modern Electronic Meters

Early electronic meters designed for large loads (for example the Landis & Gyr ZMS meter in 1977) replaced the coils with internal CTs and VTs and separate terminal for an auxiliary supply to power the meter electronics. This was acceptable as these were high-end meters typically installed in a substation or enclosure with an auxiliary supply available. These meters presented a much lower burden to the test bench than the electromechanical meters did, usually less than 1VA per input circuit. This burden was still linear, and posed no additional requirements to the meter test bench.

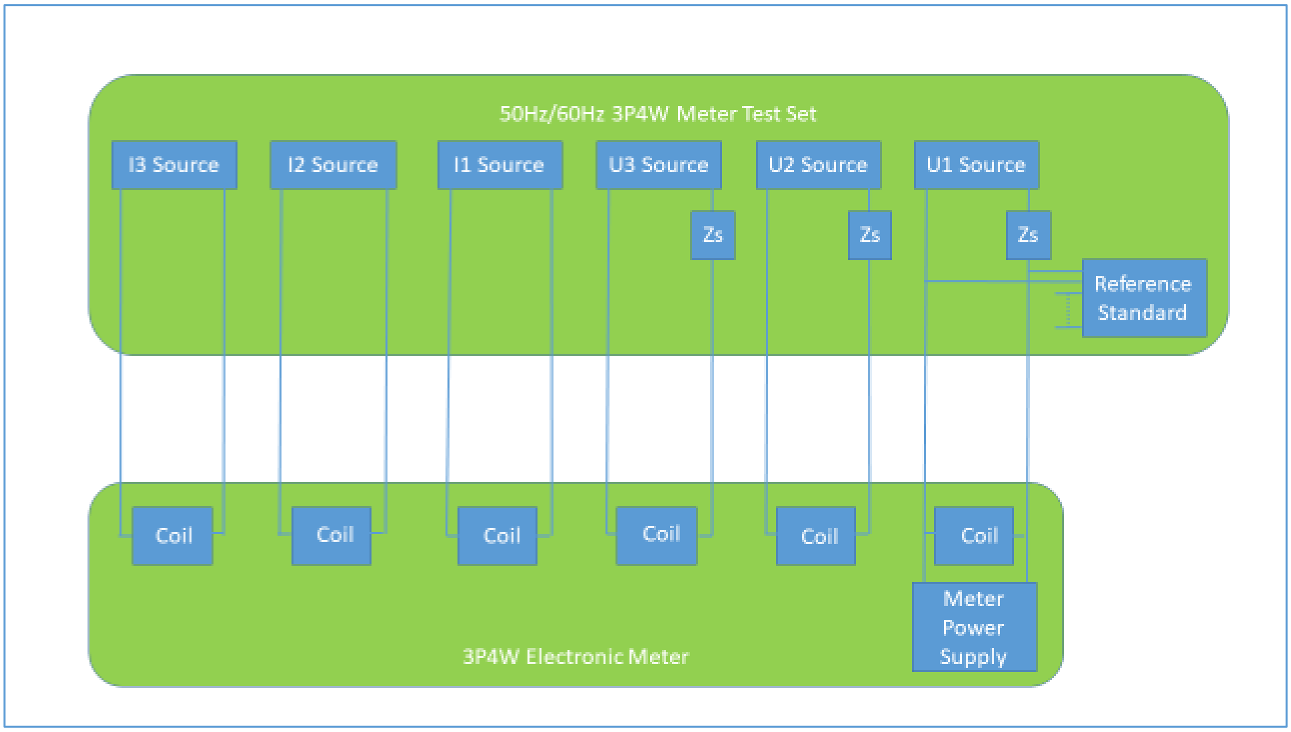

Figure 2 – Electronic 3P4W Meter and Test Set

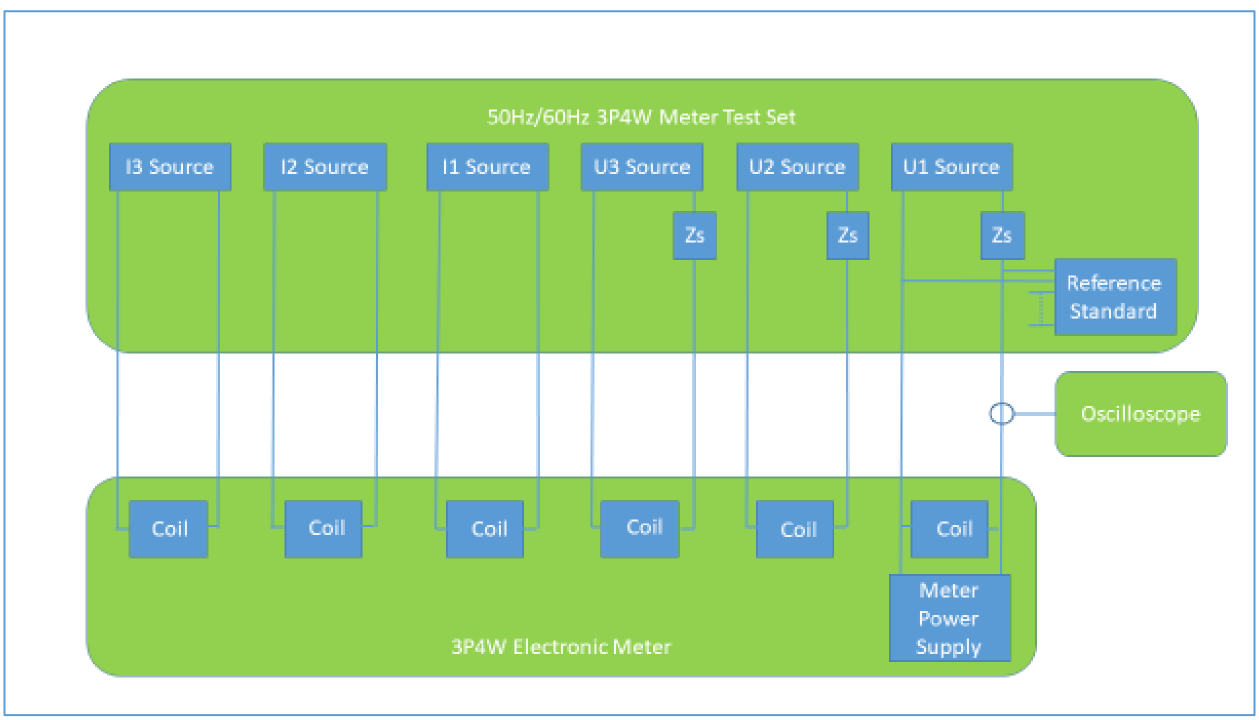

Figure 3 – Electronic 3P4W Meter and Test Set with Osciloscope

Electronic meters became cheaper and eventually replaced electromechanical meters that had no auxiliary supply capability. The meter's internal power was taken from one (or more) of the voltage input circuits. The additional load on the phase voltage circuit can be seen in Figure 2. The voltage circuit(s) now presented a non-linear load to the test bench, generating harmonic currents. This means that the non-zero source impedance of the test bench will develop harmonic volt drops and present a distorted voltage signal to the meter. The waveform of the voltage circuit's current can be monitored (Figure 3) with an oscilloscope. Figure 4 shows the current waveform of the voltage circuit for a Vision HIP 3P4W meter. The harmonic spectrum of the current waveform is shown in Figure 5, with significant components at the odd harmonics from 3rd to 19th.

The current pulse has a peak of only 20mA, which would be insignificant if the meter was installed in the field. However, when supplied by a meter test set voltage source expecting a sinusoidal load current, this could be a problem.

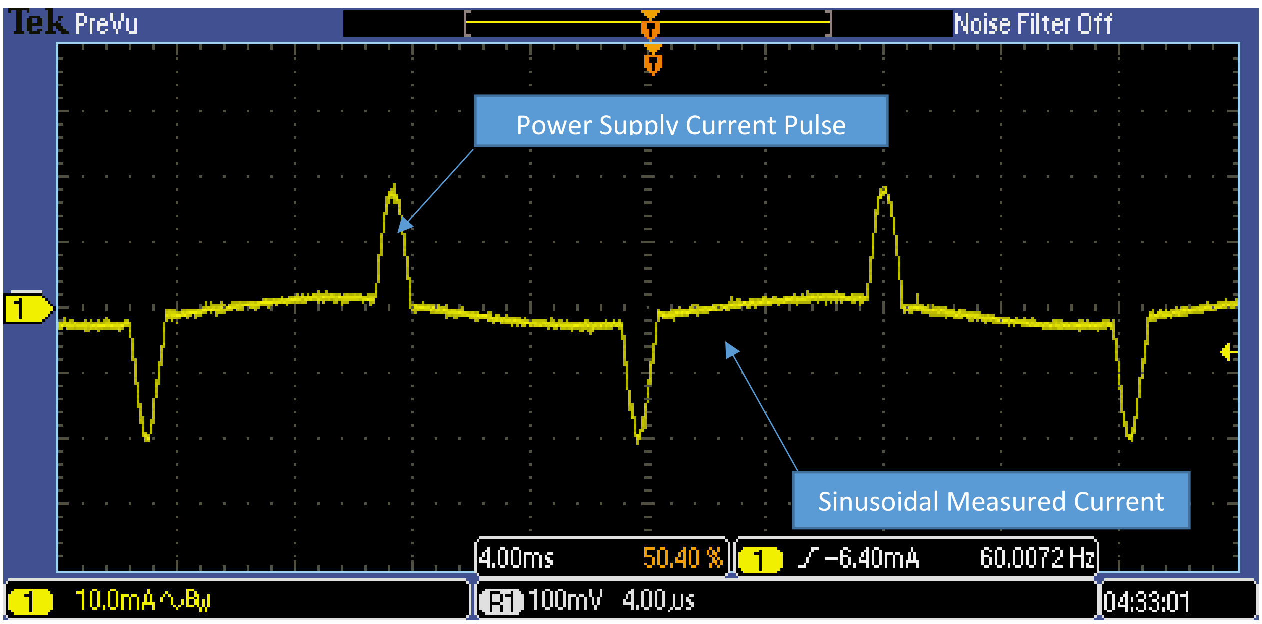

Figure 4 – Current Waveform of Phase 1 Voltage Circuit of Vision HIP 3P4W Meter

The degree to which this distorted current drawn from the test set voltage source affects the voltage waveform depends on the source impedance and frequency response of the source generator. Older test sets, designed for the linear loads presented by electromechanical meters, are more likely to be adversely affected. The current pulse could result in voltage distortion and, if significant, produce harmonic power flow to be registered in a harmonic-responsive meter or harmonic-responsive reference standard. The author has a Calmet TS33 meter test set, which is a modern design and less influenced by this issue than many older designs.

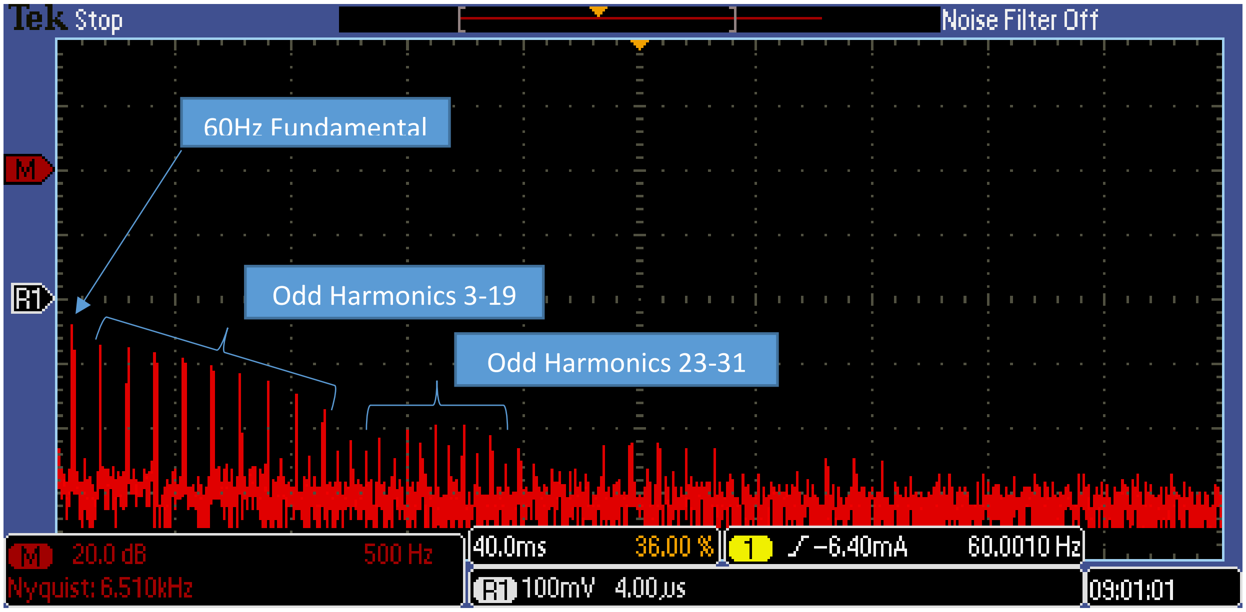

Figure 5 – Harmonic Spectrum of Phase 1 Voltage Circuit Current of Vision HIP 3P4W Meter

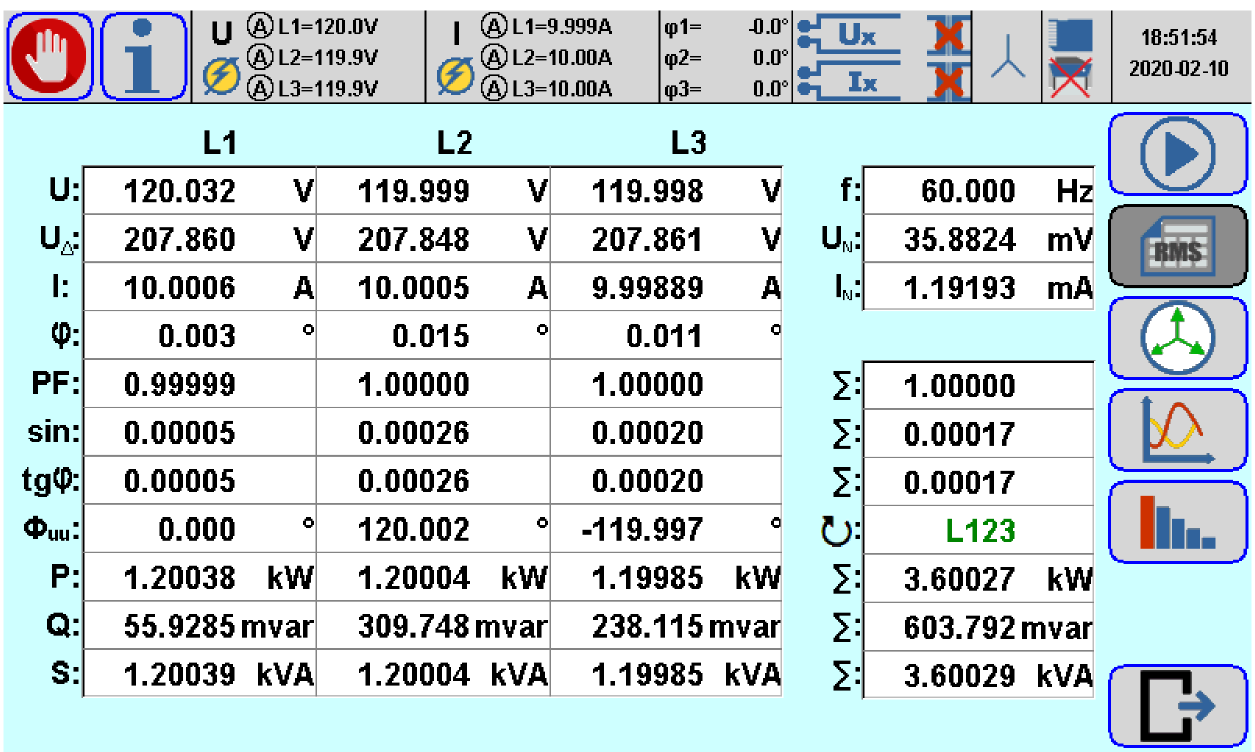

Figure 6 – TS33 RMS Measurement Table for Vision HIP 3P4W Meter

The only evidence of the power supply load on the RMS Measurement screen of the TS33 test set is the neutral voltage U_N of 35mV which is the unbalanced volt drop, and neutral current I_N of 1.2mA which is the unbalanced current. We know that the unbalanced load is the power supply attached to the Phase 1 voltage circuit.

The voltage and current waveforms generated and measured by the TS33 are shown in Figure 7. If one looks carefully at the peaks of the Phase 1 Voltage (red) one will notice a slight deformation or flattening of the peaks. This is the effect of the relatively large current pulses drawn by the meter's power supply at these times as seen in Figure 4.

Figure 8 shows the harmonic spectrum of the voltage output to the meter's phase 1 voltage circuit. This contains harmonic components at the same frequencies (3rd to 19th and 23rd to 31st) as the current harmonics generated by the meter's power supply in Figure 2. These components do not appear in the other phase voltage circuits (Figure 9) or current circuits (Figure 10).

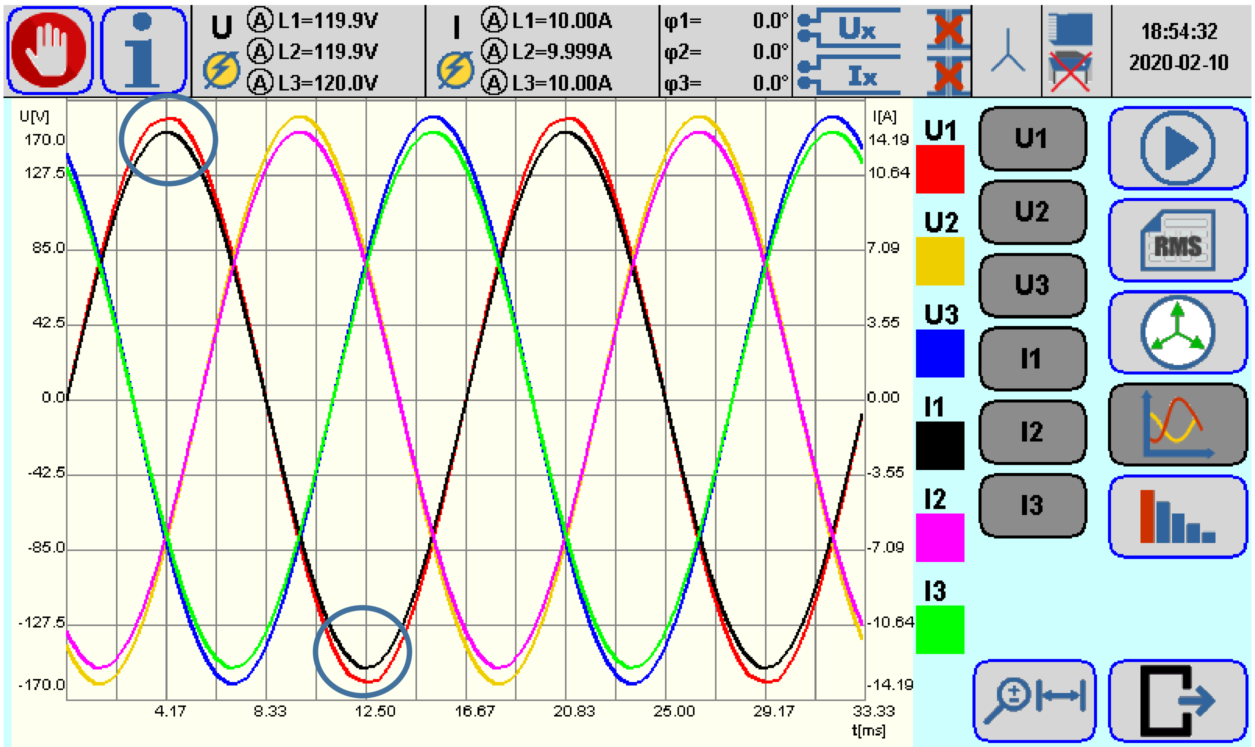

Figure 7 – The Voltage and Current Waveforms Generated and Measured by the TS33.

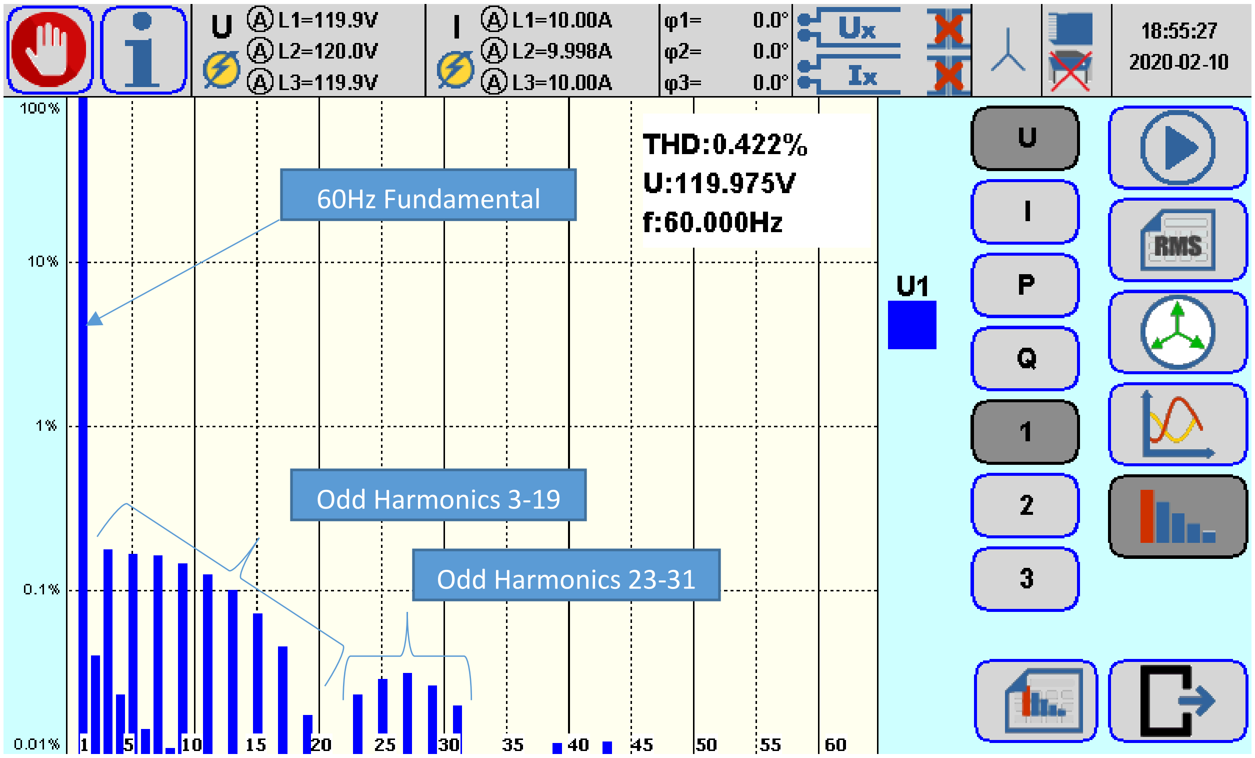

Figure 8 – Harmonic Spectrum of Phase 1 Voltage Circuit Voltage of Vision HIP 3P4W Meter

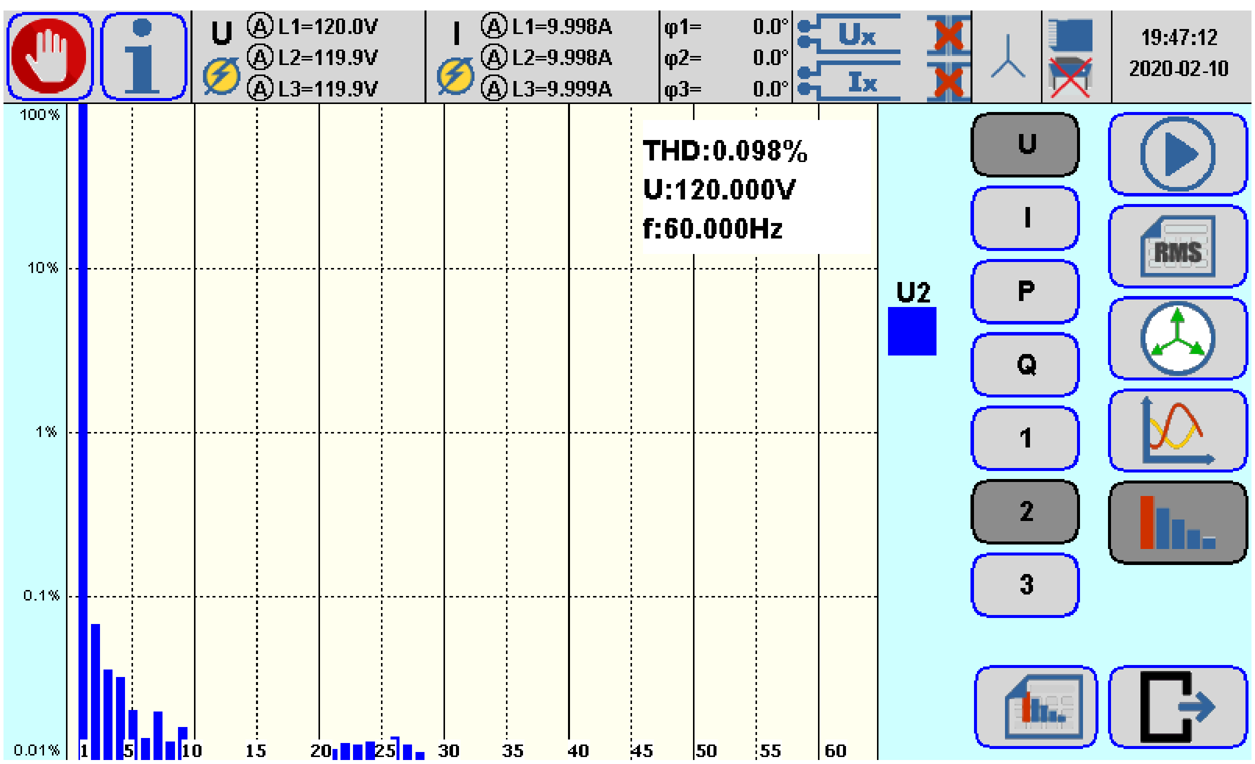

Figure 9 – Harmonic Spectrum of Phase 2 Voltage Circuit Voltage of Vision HIP 3P4W Meter

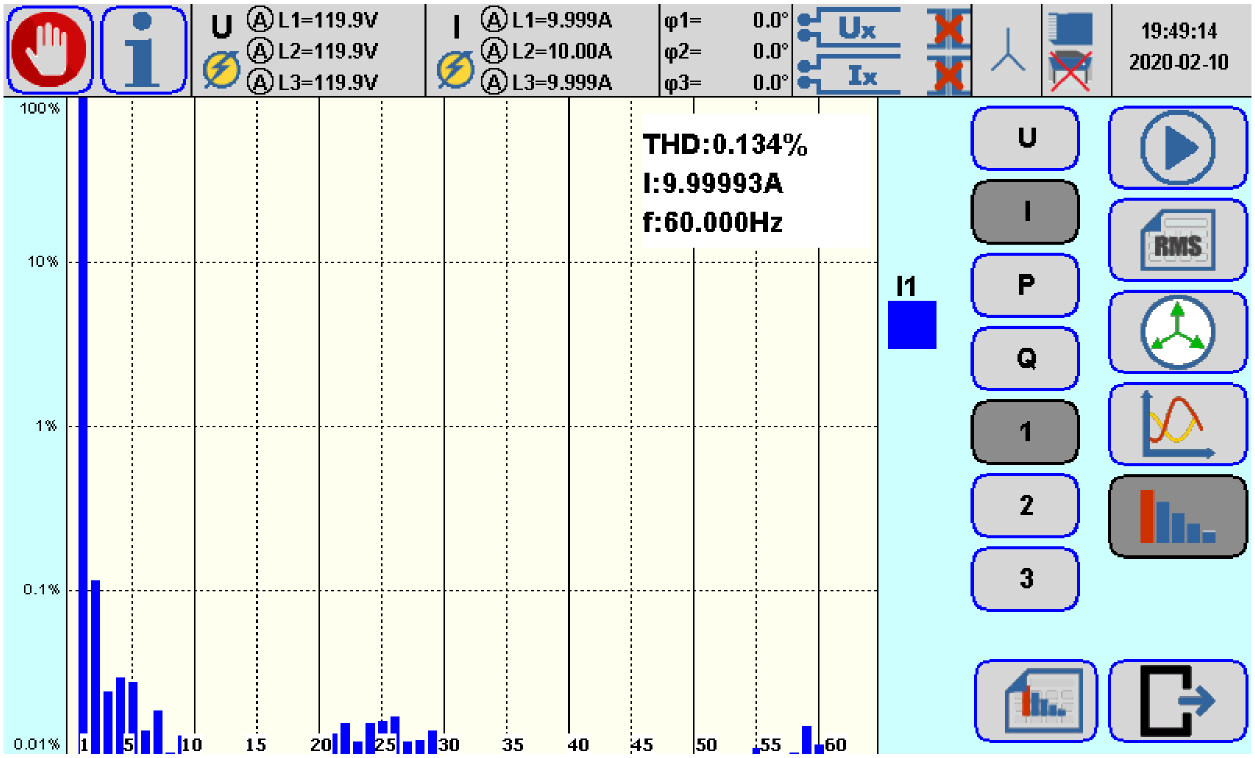

Figure 10 – Harmonic Spectrum of Phase 1 Current Circuit Current of Vision HIP 3P4W Meter

The harmonic currents generated by the meter's power supply result in additional harmonic distortion on the phase 1 voltage, increasing the THD from a background level of about 0.1% to about 0.4% for the Vision meter on the TS33 test set. This impact would vary with each meter type and each meter test set. Meters that use PLC communication technology will inject additional distortion into the voltage circuit as a PLC signal. The PLC signals are known to cause unacceptable levels of distortion on the voltage sourced from some meter test sets.

Impact on Meter Accuracy

This article illustrates the impact of a meter's nonlinear power supply load on the voltage waveform supplied by a meter test set source. In the case shown here, the impact on meter energy measurement accuracy is negligible, but for meters with larger internal power supplies and/or PLC communications, or test sets with higher source impedances, the impact may affect the accuracy of the energy measurement.