Vibro-acoustic method applied to voltage regulator

Tested apparatus: COOPER VR-32 voltage regulator with CL-5C Control

Test instrument: ZENSOL Tap Changer Analyzer, the TAP-4

Location: British Columbia (CANADA).

Goal: To know what kind of voltage regulator signature we obtain and see if we can use the TAP-4 as a diagnostic instrument as it is commonly used for on load tap changers in transformers. Indeed, voltage regulators have a tap changer and with the vibration method tests, we can see how it behaves.

- **Voltage regulator:**

The pictures below show the voltage regulator tested:

- **Test instrument, TAP-4:**

The pictures below show the test instrument, the TAP-4:

In order to perform the measures, we use an accelerometer and a current clamp.

- **Accelerometer:**

The accelerometer allows to record a vibration signal that is related to the noise made by the tap operation. Here below, there is a picture of the accelerometer used during the tests:

PCB Accelerometer (Voltage sensitivity: around 100mV/G)

- **Current clamp:**

The current clamp allows to record the tap changer motor current. It also allows to get the good time frame during the tests. Here below, there is a picture of the current clamp used during the tests:

AC Current Clamp (Voltage sensitivity: 100 mV/A AC)

The next pictures show the locations where the accelerometer and the current clamp were respectively glued and connected:

Accelerometer location

Current clamp location

- **Tests:**

The tests have been performed with the tap changer analyser, the TAP-4. To help analyze and interpret raw vibro-acoustic signals, Hydro-Quebec has developed a mathematical method that transforms the raw data into intuitive signal envelopes that are more stable and easy to compare. The following pictures show the results obtained for a single operation under the shape of raw data (on the left), and envelopes (on the right):

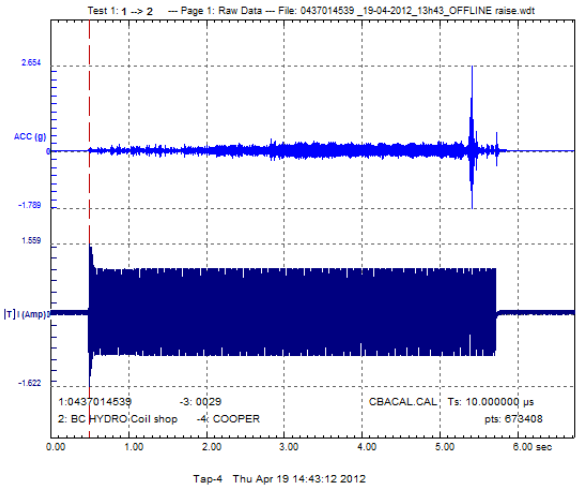


Fig. 1: Raw data

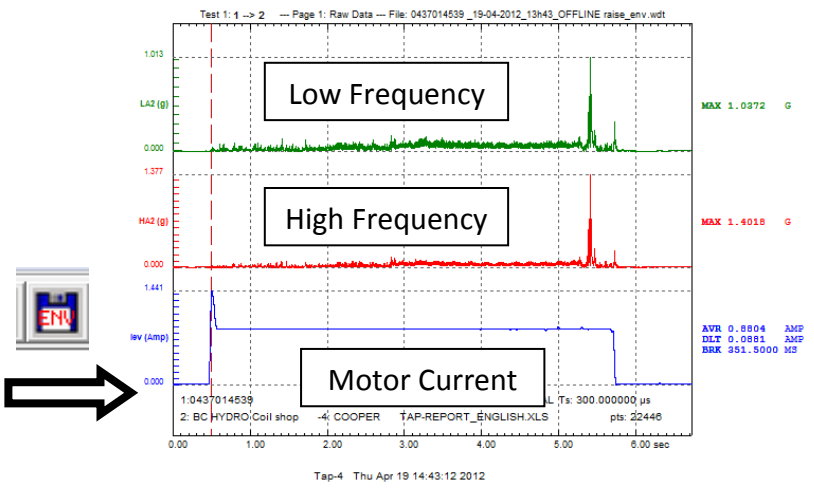


Fig.2 : Signal envelopes

These envelopes represent, starting from the bottom, the motor current curve, the HF signal and the LF signal.

Step 1: GENERAL OBSERVATION:

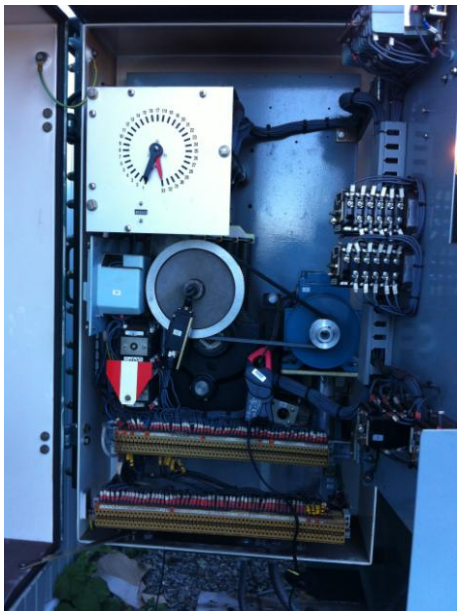
As mentioned above, the TAP-4 is commonly used on transformer's OLTC. Below, a comparison between a voltage regulator OLTC and a transformer's OLTC is reported.

VOLTAGE REGULATOR'S OLTC

Current clamp and accelerometer:

TRANSFORMER'S OLTC

Current clamp and accelerometer:



VOLTAGE REGULATOR'S OLTC

Tap configuration:

Raw data results:

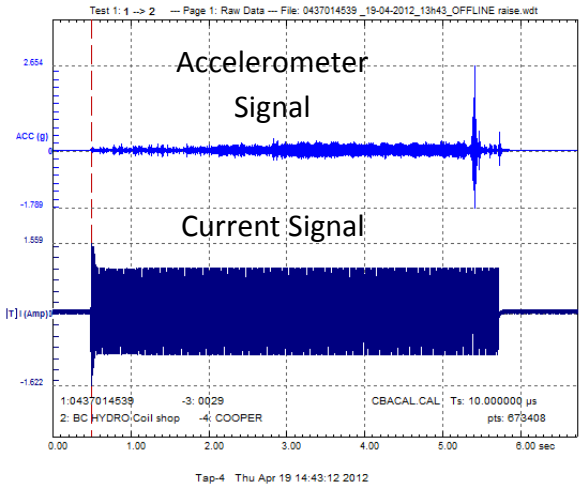


Fig. 3: OLTC voltage regulator's raw data

Envelopes:

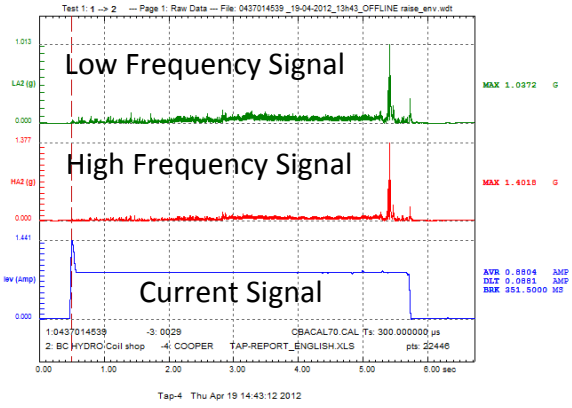
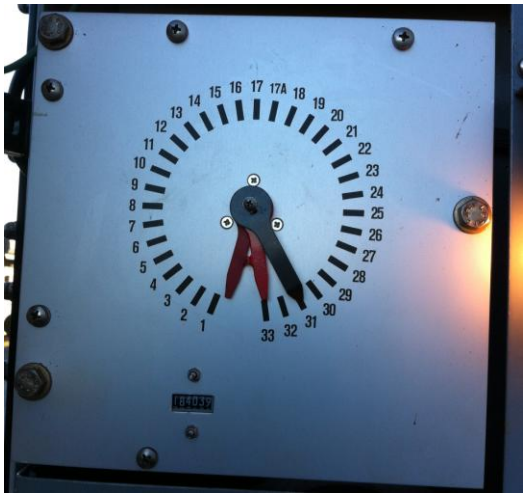


Fig. 4: OLTC voltage regulator's envelopes

TRANSFORMER'S OLTC

Tap configuration:



Raw data results:

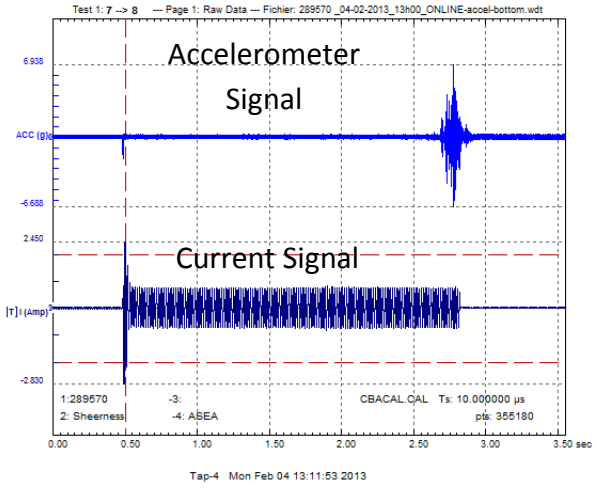


Fig. 5: OLTC transformer's raw data

Envelopes:

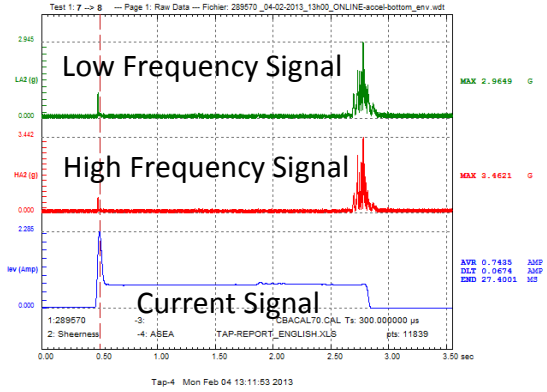


Fig. 6: OLTC transformer's envelopes

As we can see, the principles are the same, either we are testing an OLTC in a voltage regulator or in a transformer.

Step2: CURRENT SIGNATURE

In the case of a voltage regulator, we can compare current between each other to see if there is any difference. The figure 7 shows the current curve related to test 1.

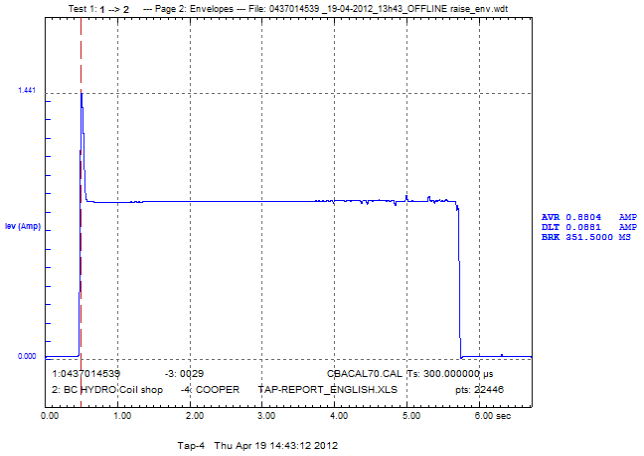


Fig. 7: Current curve of test 1

The software OpenZen-TAP allows to display simultaneously several curves belonging to different tests. The example reported in figure 8 shows the current curves related to different TAP positions. The average operation length associated to this voltage regulator is around 4700 milliseconds. Lastly, the figure 9 shows the superposition of the aforementioned signals pointing out the absence of anomalies.

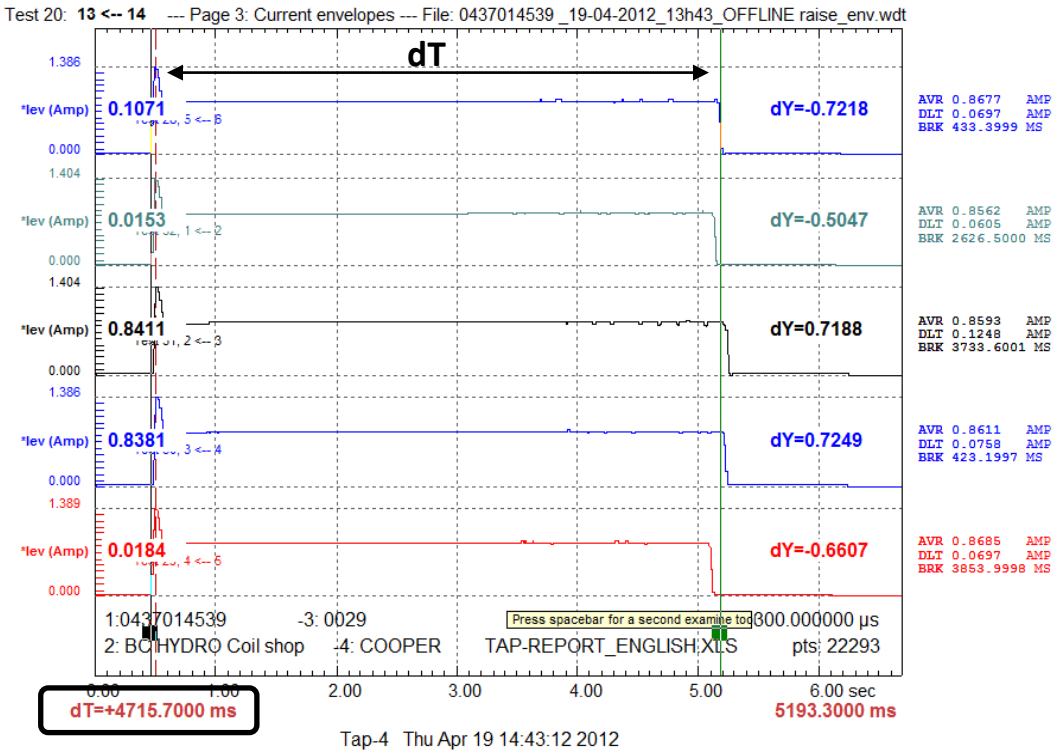


Fig. 8: Operation Time: 4700 milliseconds

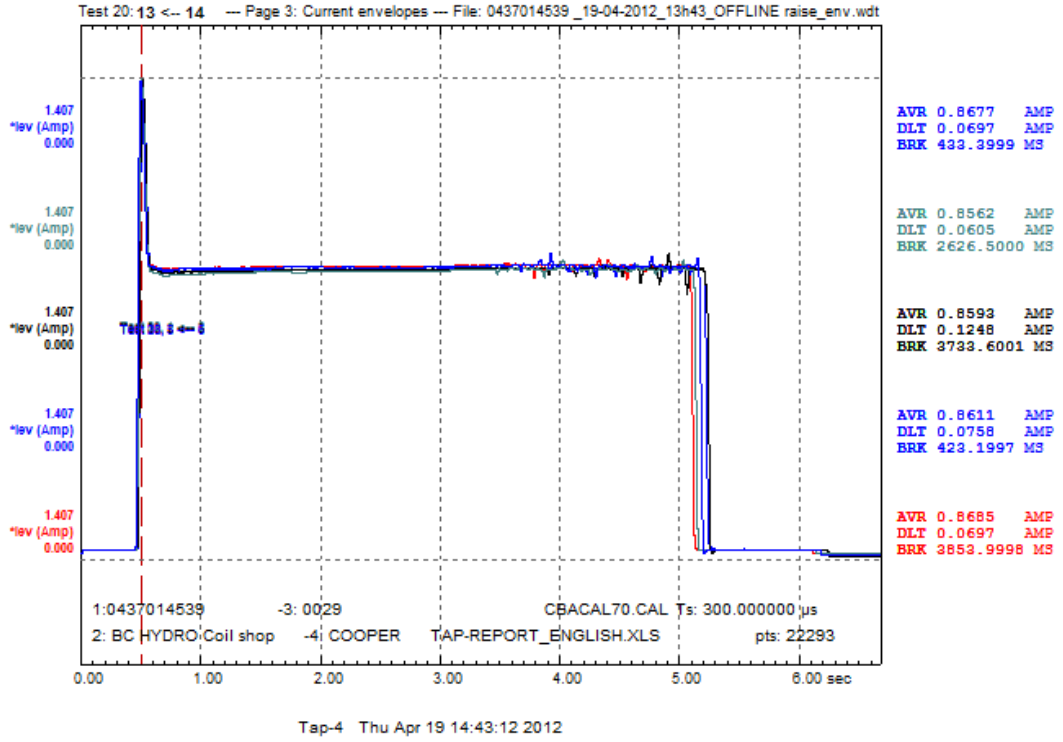


Fig. 9: Superposition of several motor current signals.

Step 3: VIBRATION SIGNATURE

As we did for the current, let's see the vibration's signatures that we obtained during the tests. With the support of the software, it is possible to compare HF and LF in order to point out differences between the two envelopes. The superposition is shown in the picture on the right:

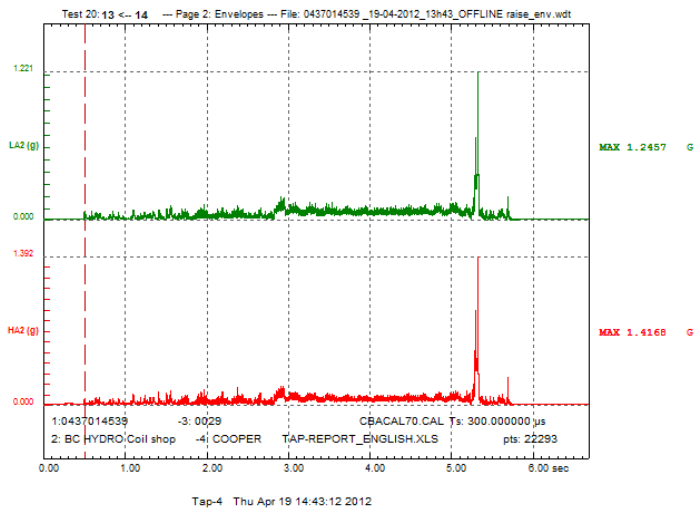


Fig. 10: HF and LF signals

High (red) and Low (green) Frequencies

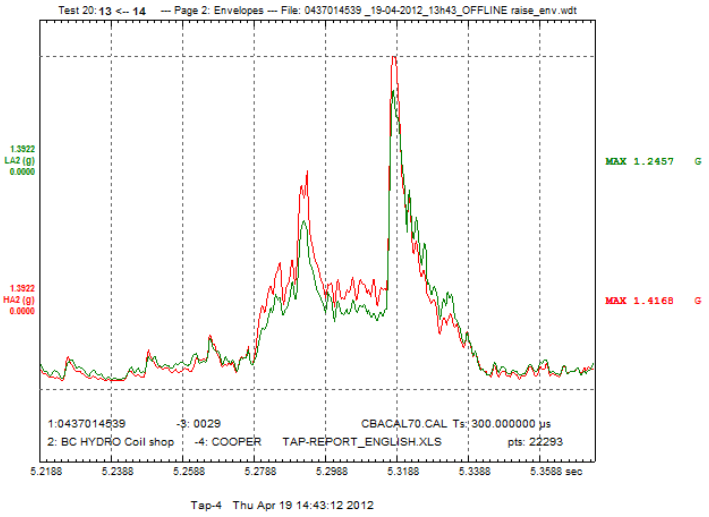


Fig. 11: HF and LF superposition

Superposition of both frequencies and amplification of the main impact.

Other observations can be made using comparison between even and odd taps, upward and downward movement, OFF-LINE test and ON-LINE test, and so on.

Conclusions:

-Given the low amplitude of the signal (1.5 G), it is recommended to use a more precise accelerometer with a measurement range of ± 10G limitations instead of ± 50Gs.

-The voltage regulators are commonly subjected to quality control checks every 10 years. This operation requires the voltage regulator to be disconnected from the network and hence, it would be beneficial to increase this frequency to 12-15 years. The use of the TAP-4 on a yearly basis is highly recommended since it can help the technician to do a trending analysis and identify which voltage regulator is eligible for quality control checks.