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VIBRATIONS MEASUREMENT DURING HYDROGENERATOR TESTING

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Abstract – This paper presents the results of vibration measurement during several specific tests of 35 MVA hydro-generator.

Keywords: vibration measurement, generator, test

1. INTRODUCTION

The extended testing of hydro-generator (rated 35 MVA) was made because the generators working age expired and was going to be replaced with new one. This was the perfect opportunity to do some specific and not usual testing.

The complicated testing plan was designed in order to enable recording as much relevant data as possible (electrical, electromechanical, mechanical). Therefore in some phases of testing, 44 quantities were measured simultaneously.

During this extended testing, vibration measurement also took place among all other measurements. The results of vibration measurements and comparison between two vibration measurement systems are presented in this paper.

2. MESUREMENT SYSTEM DESCRIPTION

The measurement system was based on data acquisition unit (MUSYCS + PC) with 128 channels.

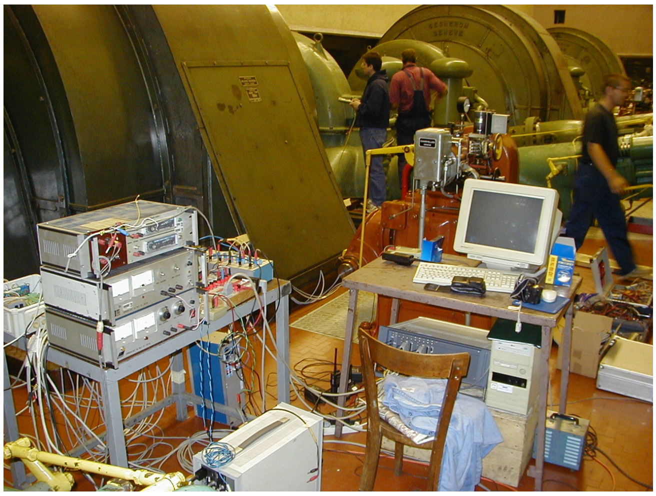
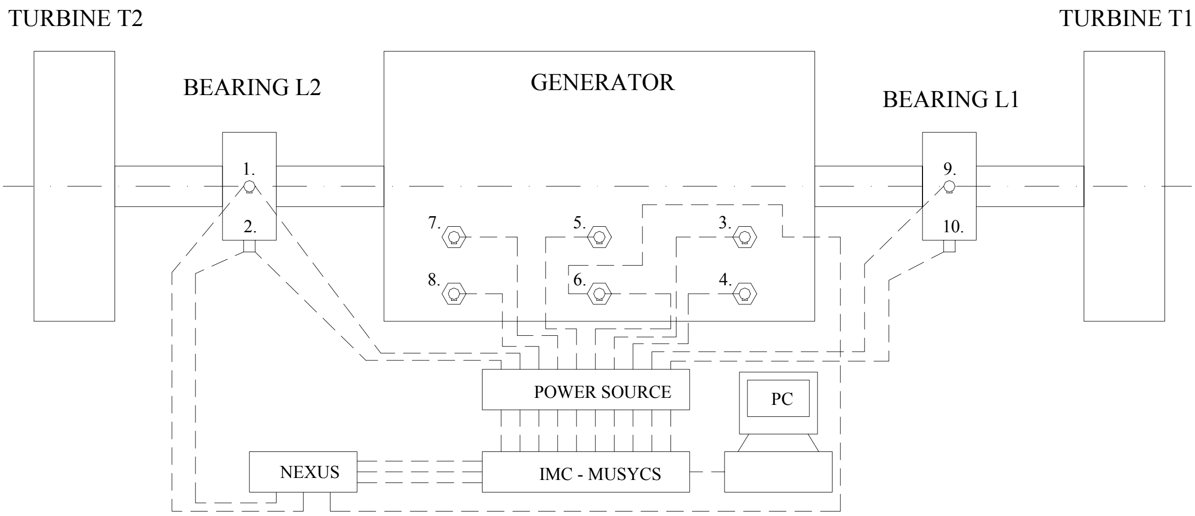


Figure 1: Vibration measurement system

Vibrations were recorded with two independent systems. The first measurement system was Bruel&Kjaer's vibration measurement system with three sensors (DELTA Tron) and amplifier (NEXUS).

The DELTA Trons were placed on one bearing (Figure 2), in horizontal and vertical direction (NexL1H, NexL1V are the data acquisition channel names) and on footing



1. ACC (VibL2V) + (NexL2V)
2. ACC (VibL2H) + (NexL2H)
3. F. SCREW 3 - ACC (VibTV3)
4. F. SCREW 4 - ACC (VibTV4)
5. F. SCREW 5 - ACC (VibTV5)
6. F. SCREW 6 - ACC (VibTV6) + (NexTV6)
7. F. SCREW 7 - ACC (VibTV7)
8. F. SCREW 8 - ACC (VibTV8)
9. ACC (VibL1V)
10. ACC (VibL1H)

Figure 2: Vibration measurement system

screw No. 6 (NexTV6). DELTA Trons were connected to signal conditioner and amplifier (NEXUS). NEXUS outputs are voltage signals.

The second measurement system was custom made with accelerometers AUC40Ex and powered by standard voltage source. Output is voltage signal.

The AUC40Ex were placed on both bearings in horizontal and vertical directions (VibL1H, VibL1V, VibL2H and VibL2V). Also the AUC40Ex were placed on each footing screw on one side of generator stator (VibTV3, VibTV4, VibTV5, VibTV6, VibTV7 and VibTV8). Such arrangement of accelerometers has elements of modal analysis.

The signals from both vibration measurement systems were connected to data acquisition unit based on IMCs MUSYCS and PC. The sample rate for every signal and measurement was 200μs and duration of data acquisition was 20 seconds.

This allows us to capture and record vibrations within frequency range from 0.5 Hz to 250 Hz if we set the following limits:

- at least 10 periods recorded
- at least 20 samples per period

3. GENERATOR TESTS

The generator tests, that took place, can roughly be divided into rest and de-energized, and one with generator rotation. For vibration measurement, rotation (movement) is essential so such tests will be described here.

The presented data were recorded during following tests:

- sudden 3-pole short circuit
- wrong synchronization (several types)
- asynchronous operation

4. RESULTS

Here are some measurements that took place during 3-pole short circuit. On Figures 3 and 4, line voltage and line current can be seen.

Figure 5 shows vibration acceleration in time domain recorded with Delta Tron accelerometer placed on footing screw 6. On this signal, FFT was applied and the result is presented in Figure 6.

The vibration acceleration in time domain was then integrated in order to produce vibration speed in time domain. The result of application of FFT on vibration speed in time domain is shown in Figure 7.

Finally, the vibration speed in time domain was integrated and the result was vibration displacement in time domain. After FFT of vibration displacement in time domain, the vibration displacement in frequency domain was produced and can be seen on Figure 8.

Figures 6 to 8 shows that vibration harmonic around 50 Hz is dominant. This is the result of current. The current in 3-pole short circuit produces dominant forces and that results with vibrations.

Very interesting is also asynchronous operation. This is very unstable and dangerous regime because it can result with severe damage. As it can be seen on Figure 9 during asynchronous operation, generator speed rises until reaction of the protection. The line current (Figure 10) responds to speed rise. Major vibrations starts after 11th second (Figure 11).

Figures 12 to 14 show vibration acceleration, speed and displacement in frequency domain. The same procedure was applied as in 3-pole short circuit.

Another interesting test was wrong synchronization (there was a phase shift between distribution network and generator voltage before switch closing). Figure 15 shows line current during this test. Figures 16 to 19 show vibration acceleration, speed and displacement.

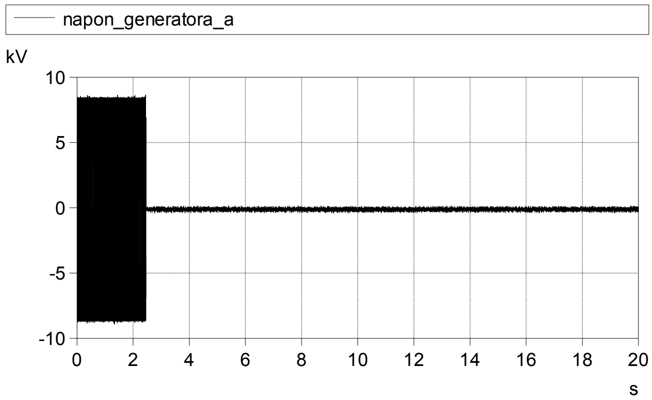


Figure 3: Line voltage during 3-pole short circuit test

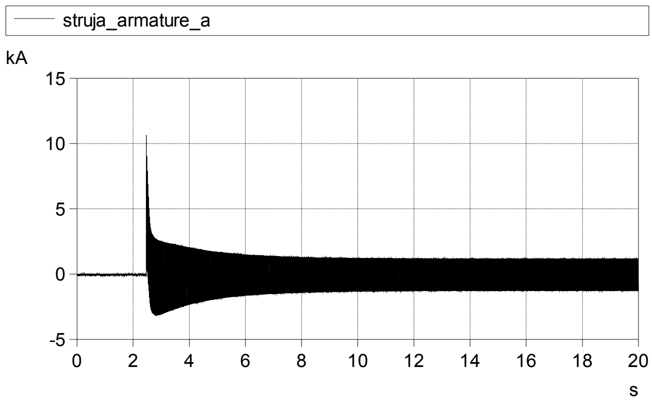


Figure 4: Line current during 3-pole short circuit test

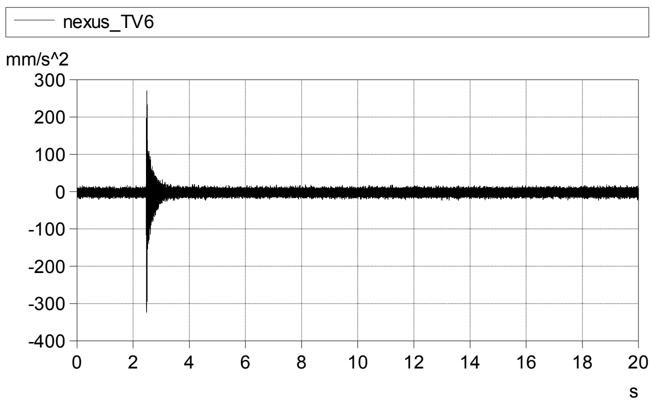


Figure 5: Vibration acceleration in time domain recorded on footing screw 6 during 3-pole short circuit test

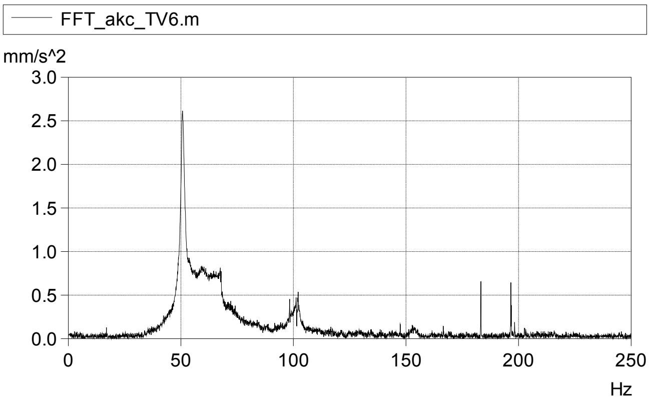


Figure 6: Vibration acceleration in frequency domain (after FFT)

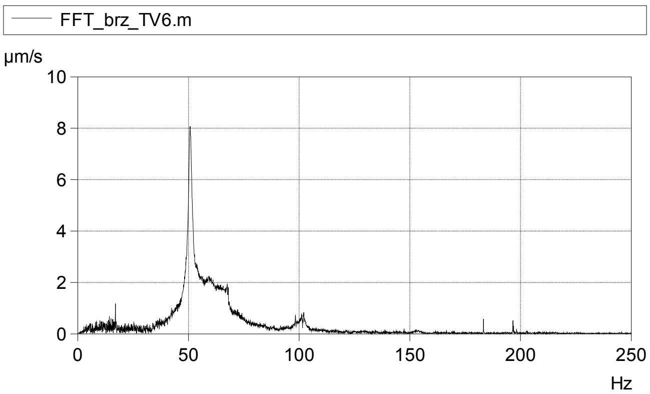


Figure 7: Vibration speed in frequency domain (after FFT)

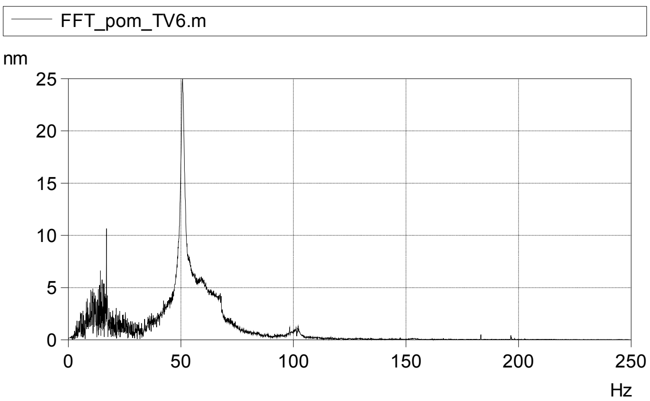


Figure 8: Vibration displacement in frequency domain (after FFT)

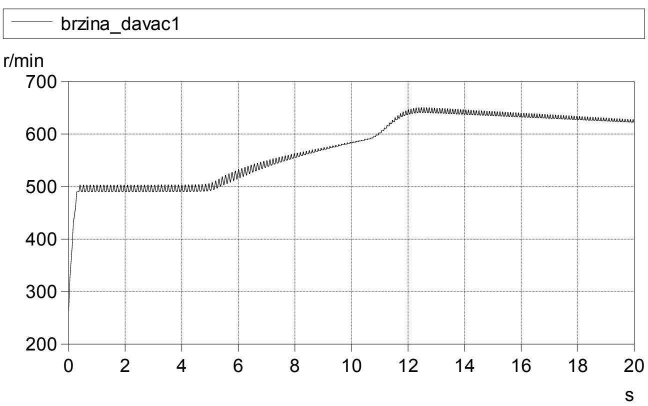


Figure 9: Speed recorded during asynchronous operation

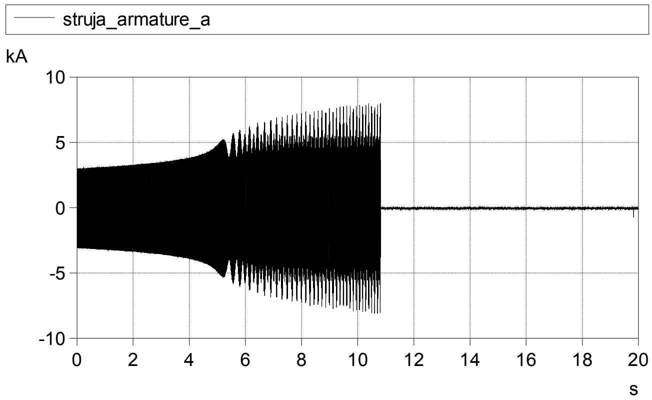


Figure 10: Line current recorded during asynchronous operation

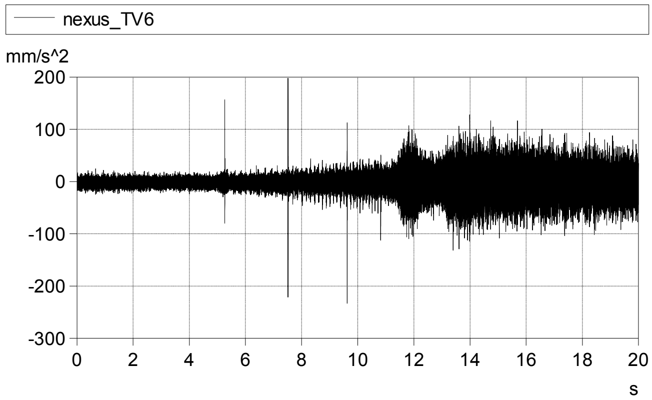


Figure 11: Vibration acceleration in time domain recorded on footing screw 6 during asynchronous operation

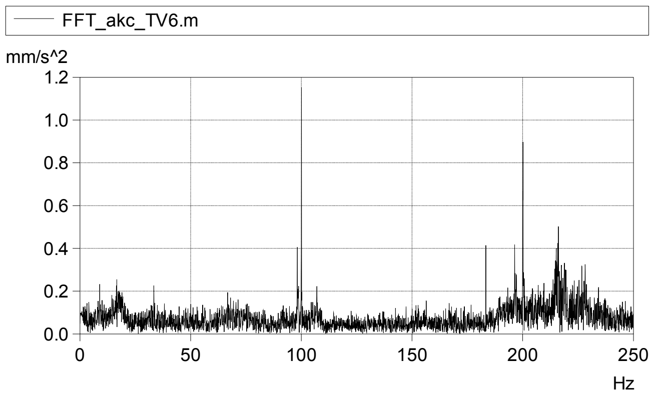


Figure 12: Vibration acceleration in frequency domain recorded during asynchronous operation

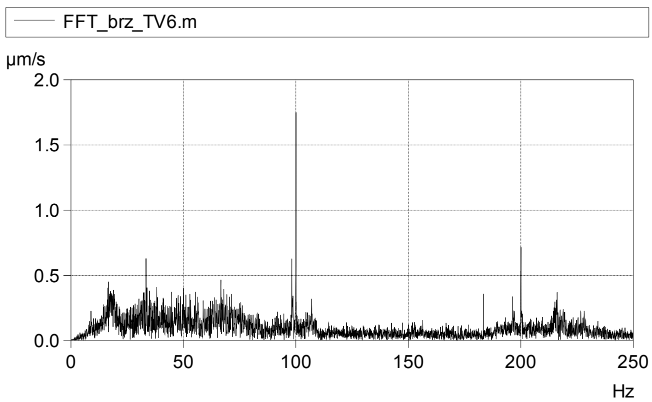


Figure 13: Vibration speed in frequency domain recorded during asynchronous operation

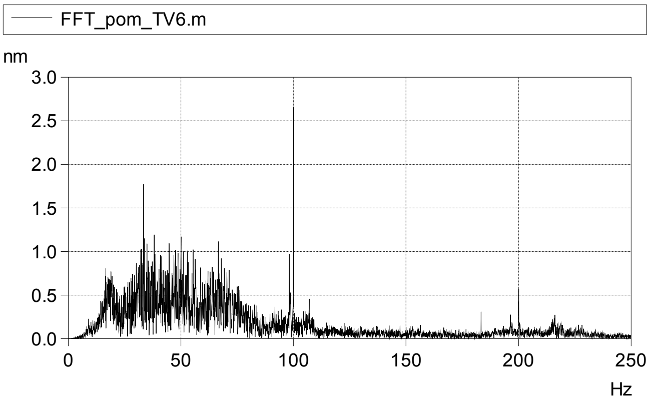


Figure 14: Vibration displacement in frequency domain recorded during asynchronous operation

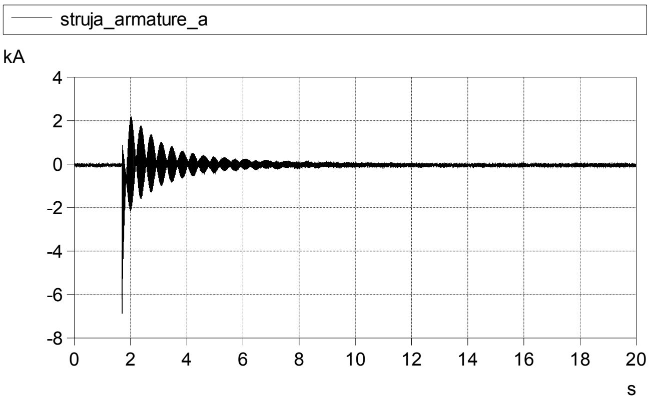


Figure 15: Line current in time domain recorded during wrong synchronization

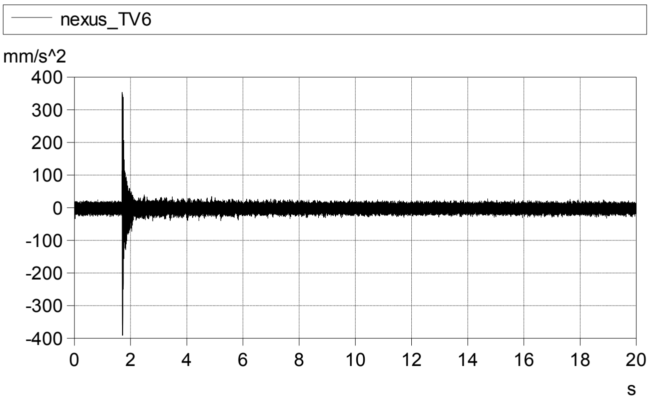


Figure 16: Vibration acceleration in time domain recorded during wrong synchronization

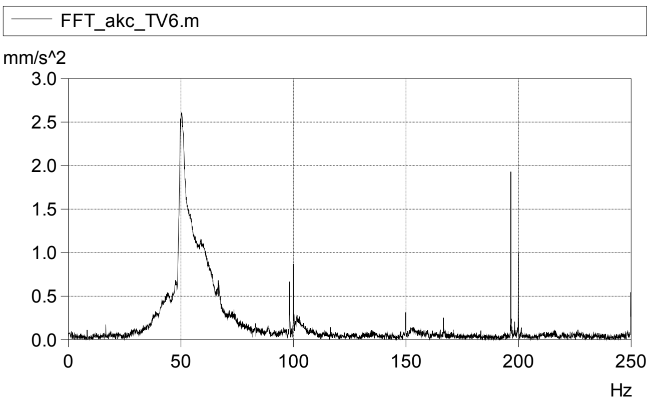


Figure 17: Vibration acceleration in frequency domain recorded during wrong synchronization

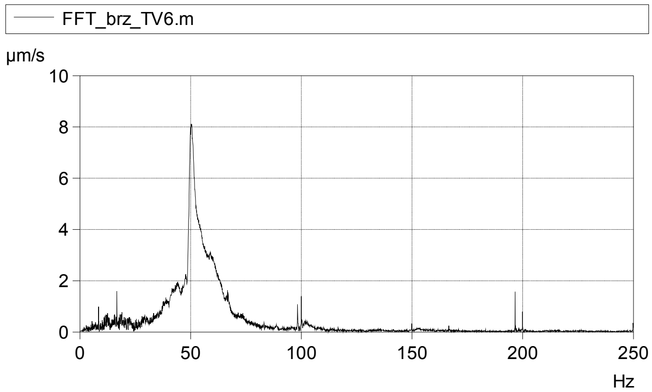


Figure 18: Vibration speed in frequency domain recorded during wrong synchronization

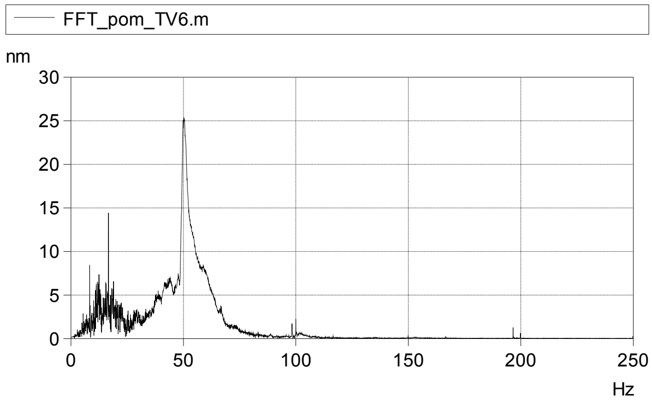


Figure 19: Vibration displacement in frequency domain recorded during wrong synchronization

5. MEASUREMENT SYSTEM COMPARISON

The vibrations were measured with two independent measurement systems, and the signals were recorded with unique acquisition unit. The comparison, of vibrations measured on footing screw during 3-pole short circuit, are shown on Figures 20.

The measured signals are practically the same, only the custom made system had a little bit more disturbances than the one measured with Bruel&Kjaer measurement system.

The Figure 21 shows comparison between vibration accelerations in frequency domain. The disturbance influence can also be seen when FFT is applied on recorded signals shown on Figure 20.

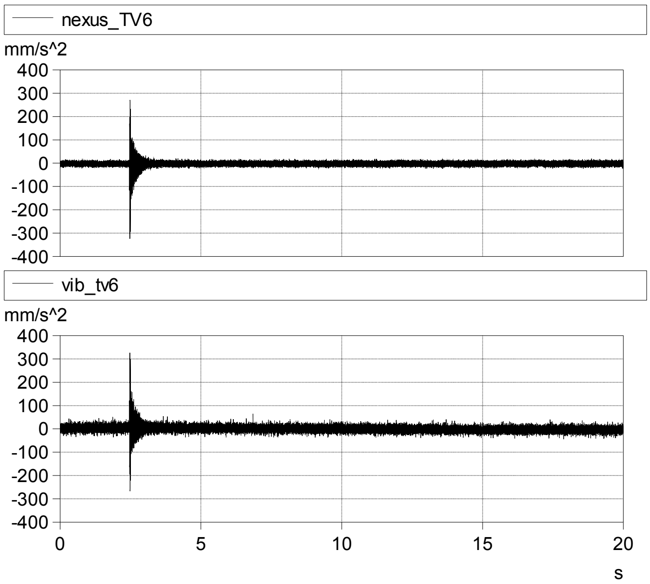


Figure 20: Comparison between vibration acceleration in time domain recorded with Bruel&Kjaer (nexus_TV6) and custom made system (vib_tv6) during 3-pole short circuit

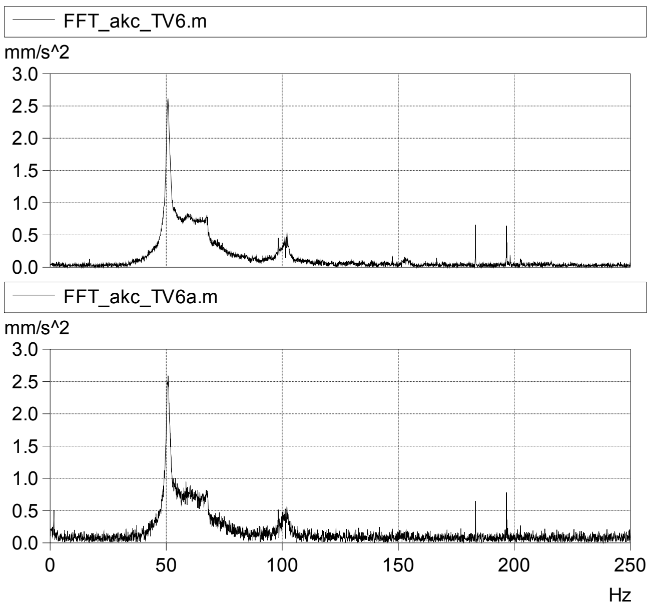


Figure 21: Comparison between vibration acceleration in frequency domain recorded with Bruel&Kjaer (nexus_TV6) and custom made system (vib_tv6) during 3-pole short circuit

6. CONCLUSIONS

From comparison of the two vibration measurement systems, following conclusion can be drawn. The custom made system is very good, and its application in such cases where electromagnetic disturbances are present, is satisfactory. It is also very accurate.

Custom measurement system can, of course, be improved (by filtering, with additional shielding, etc).

From the results that are presented in this paper the following can be concluded. Considering vibrations (and strains) on footing screw 6 (Table 1), the worst regime is wrong synchronization (vibration displacement of 25.5 nm at 50 Hz). The sudden 3-pole short circuit is better (vibration displacement of 24.5 nm at 50 Hz). Surprisingly, the asynchronous operation was the best regime considering vibrations (vibration displacement of 2.7 nm at 100 Hz).

Table 1: Vibration amplitudes (in frequency domain)

3-pole short circuit	50 Hz	100 Hz	195 Hz
ACC. [mm/s^2]	2.7	0.5	0.7
SPEED [mm/s]	8	0.7	0.6
DISPL. [nm]	24.5	2	1
Asynchronous operation	50 Hz	100 Hz	200 Hz
ACC. [mm/s^2]	0.1	1.18	0.9
SPEED [mm/s]	0.4	1.75	0.7
DISPL. [nm]	1.2	2.7	0.55
Wrong synchronization	50 Hz	100 Hz	195 Hz
ACC. [mm/s^2]	2.6	0.85	1.95
SPEED [mm/s]	8	1.2	1.6
DISPL. [nm]	25.5	0.25	0.1

Based on measurements that took place and analysis of collected data, the conclusion can be drawn, that this kind of non-standard testing on old hydro-generators are very useful. During such measurements some testing is more risky than usual (the users are not allow such tests in normal circumstances), but that doesn't mean that such cases couldn't occur in normal exploitation.

Tasting and measurements like this are very useful in science also, because they can confirm numerical models.

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