Master Thesis Proposal
Calibration of Vibration sensors – Evaluation and Effectivization

Summary
Focus of this Master thesis is to find methods and algorithms that shorten the time it takes to calibrate an INFRA Vibration Instrument without losing any accuracy.

Background
The calibration of an INFRA vibration sensor is quite time consuming and has the potential of effectivization. Thus, by investigating and changing the calibration process, time can possibly be saved. This must though be made without losing any accuracy of the calibration. An initial step is therefore to analyze the statistical deviations between units and occurrences of the calibration process of today to find measures of its quality level (accuracy of the calibrated parameters).

In the calibration, the main frequencies of interest are 16 Hz and 80 Hz, where the accuracy of the gain has toughest demands/limits. Also, the frequencies below 10Hz are important, because we need to estimate the parameters $a_1$ and $a_2$ in the dynamic model

$$G(s) = K \frac{s^2}{s^2 + a_1 s + a_2}$$

These parameters correspond directly to the eigen frequency and damping of the geophone (nominal values are 4.5Hz and 0.7, respectively).

The current method to estimate $a_1$ and $a_2$ is

1. run one frequency at the time (frequencies between 1 and 10 Hz). Up to 10 seconds of data are recorded for each frequency.
2. for each data file, FFT is used to find the amplitude factor for each frequency.
3. least square minimization (curve fitting) is used to find eigen frequency and damping.

Some months ago, we got the idea to investigate whether classical System Identification can be used to estimate $a_1$ and $a_2$. This should probably save a lot of time in the calibration. Another idea is to investigate the quality of the impulse response to see whether this can be used.

Methods etc.
- Can the test pulse (impulse) be used to find $a_1$ and $a_2$ or to use it as a validation in any form?
- How can the input signal be changed? (Multi-tones, other wave-forms etc.)
- Is classical System Identification possible to use? Is its quality good enough in comparison with the current calibration method?
- Can the so called live-values (= maximum-absolute value of the signal over an interval, e.g. one second) be used instead of the more time consuming “store time series, then do FFT”?
- Investigate how unwanted excitation (noise) from the shaker affects the parameter estimation.

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1 The factor between ADC-codes (=input) and velocity (=output)
2 For example, Prediction error method or Least-squares method.
   See book: System Identification – theory for the user (Lennart Ljung)
Expected results
Answers of the questions:

- What are the accuracy requirements of $a_1$ and $a_2$ (i.e. damping and eigen frequency)?
- Is the calibration process of today accurate enough?
- Regarding customer demands (and possible legislation requirements), how many and which singular frequencies are necessary to be used in the calibration, and presented in the calibration protocol? Can some frequencies of the current method be removed without losing any estimation accuracy?
- Is it possible to change the calibration routine and method so that time can be saved?
- Give a measure how well the phase response is estimated.

Time plan

- Study and describe the calibration process of today and its requirements, with focus on the time consuming parts. (1 week)
- Perform some mathematical analyses to get measures of possible statistical deviations and their implications. E.g. if estimation error of the eigen frequency is X% how does this affect the vibration monitoring for the customer (1 week)
- Investigate whether some frequencies can be removed from the current calibration process without losing any accuracy (2 weeks)
- Find other ways to speed up the calibration process without losing estimation accuracy (6-9 weeks)
- Implement (or specify what to implement) in the real calibration system (4-7 weeks)
- Finalize the report (3 weeks)

It is supposed that report writing is made continuously during the work.