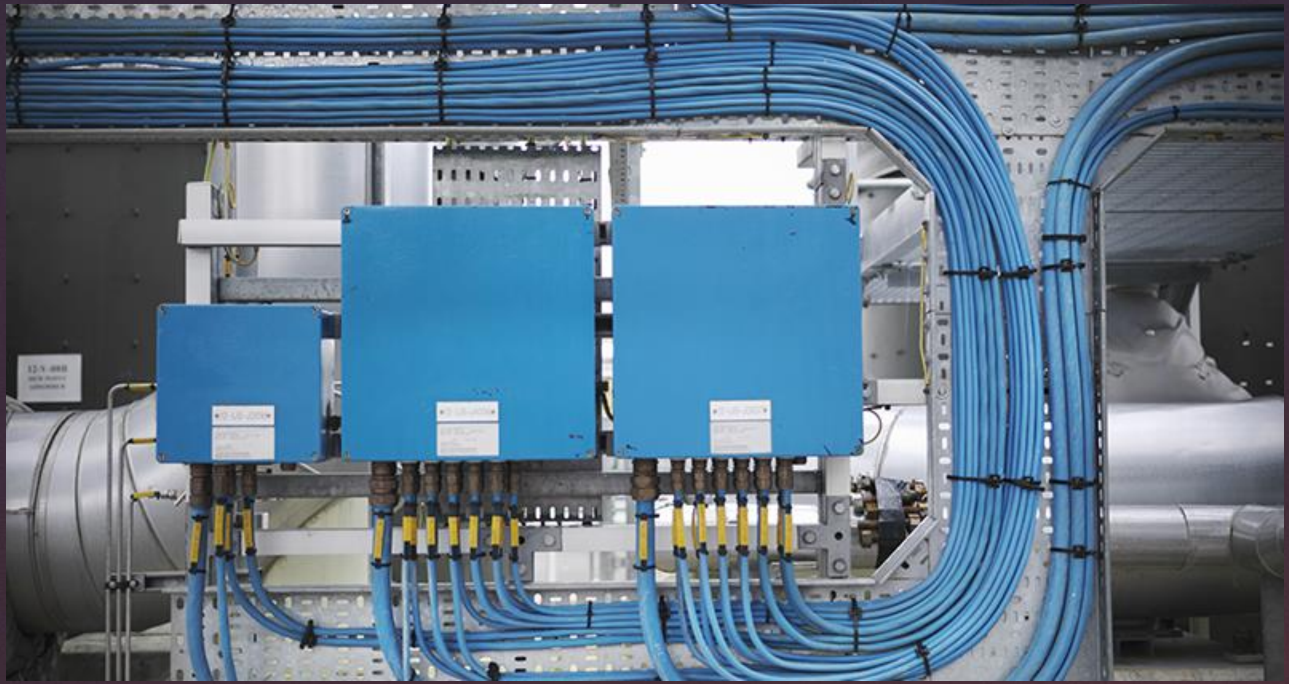

# VIBRATION MEASUREMENT PITFALLS

## PROJECT KKU52450 at Energiforsk

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Åsa

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# About Efterklang®

We have provided advice on acoustics, noise and vibration control since 1956 when Ingemansson Technology was founded in Sweden. In 2006 AFRY acquired Ingemansson and today Efterklang is a leading acoustic consultancy.

We are represented in Denmark, Norway, Sweden and Switzerland. Our team consists of 130+ dedicated acousticians and sound designers.

Vibration Measurement Pitfalls 2021-803 | (energiforsk.se)

# Objective

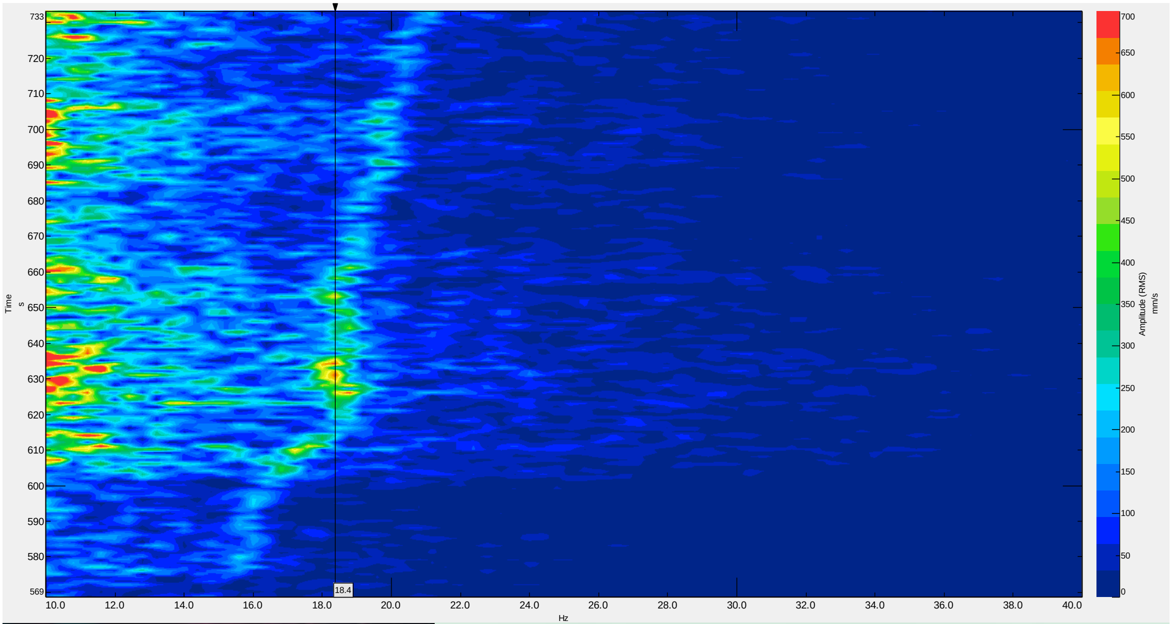
The objective is to assemble knowledge and experience in the area of vibration measurement pitfalls.

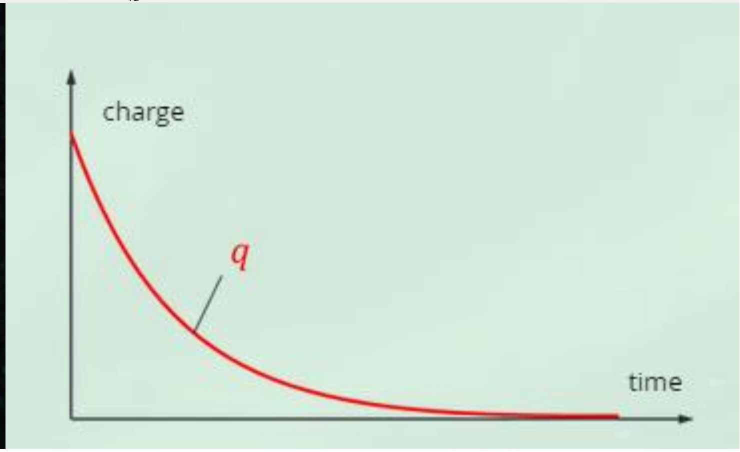
Summarized experience are collected by interviews from the Nordic nuclear power plants together with Efterklang's own experiences within the field.

The assembled information can be used to increase awareness of which pitfalls one might encounter doing vibration measurements and how to best avoid them when working with maintenance and quality assurance in a LTO perspective

# Content

1. Questionnaire - Interviews
2. NPP Vibration measurement pitfalls – Some shared experience in short
3. Examples of 5 pitfalls
4. Summary





# 3. NPP Vibration Measurement Pitfalls

Questionnaire

1. Measure response vibrations on a machine/pipe/foundation etc.
2. Measure reference signals (s) from force input.
3. Preparation of measurements
4. Validation of measurement chain – Transducers
5. Validation of measurement chain – Signal
6. Validation of measurement chain – Connections and cables between transducers
7. Validation of measurement chain – Frontend and intermediate boxes
8. Validation of measurement chain – Applied software and firmware
9. Validation of measurement chain – Book keeping
10. Selection of measurement points
11. Validation of results

Interviews

Performed with each NPP via digital meeting

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## 2 Measure reference signal (s) from force input

When performing modal analysis testing one or more source outputs is required to sufficiently exite the structure in the correct frequency range. Also the state and boundary conditions of the structure to be measured shall be the same as during operation. The temperature may be an issue.

a) For impact measurement there are different sizes of hammers. Which modal impact hammer (s) are your site using. Specify model and weight of hammer.
b) Do you have any rule of thumb for how much load the impact hammer you use can excite?
c) Have you notice any problem with the connector and cables when using the impact hammer? If yes how did you observe the error and how did you fix it?
d) Have you had any problem with unsufficent excitation force to the structure w.r.t. magnitude or frequency. How did you find out that the excitation was the problem and how did you solve it?
e) Have you had any problems with finding the correct trigger settings and window settings? If yes how did you observe that this was the problem?
f) Do you have experience with different force sensors of charge mode type and ICP type. Known problems that you have identified wrt polarity, disturbances, cables, connectors etc.
g) Fixed hammer/Rowing hammer excitation techniques. When do you find them usful?
h) Lessons learned from shaker tests
i) What kind of problems or pitfalls are in your experience most common wrt force reference signals and impact testing? Please define at least three examples that has been identified.
j) What is in your experience the most important factors to consider to avoid measurement pitfalls and to ensure good measurement and data quality?

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## 3 Preparation of measurements

A good planning of the testing is considered as very important and it can be very time consuming and costly if some factors are missed in the preparation phase. Many times a vibration specialist gets a request for a vibration test but needs to interprete what actually needs to be performed. Additionally there are circumstances for the place of concern which may influence the measurement and finally interpretion of the result.

a) A problem can be the state of the system that the component shall be measured under. How do you cope with full power/reduced power measurements? Any known misplannings and how did you solve it (calculation/remeasure etc)?
b) How do you prepare for unexpected temperature, humidity, radiation or other environmental factors? Have you experience of failures of environmental factors that you better could have planned for?
c) People and work in the same area may induce vibrations that disturb the measurements, especially for modal testing. Have you any experience in this field and what do you do in order to avoid these pitfalls?
d) Protection of the measurement chain as people may step on cables. How do you prepare for having a good measurement chain. Any lessons leard which can be useful when you prepare a new test campagne?
e) What kind of pitfalls have you experiences wrt preparation of measurements? What have the results/consequences been of the different pitfalls.

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## 6 Validation of measurement chain – Connections and cables between transducers

Cable and connections are important in the measurement chain. Often a site are using the same cables and connectors for several years if they still "look" good. Additionally, cables are used in different environments (radiation, temperature gradients, electrical disturbances etc) during their life span.

a) What kind of different cables and connectors do you use?
b) What is, in your experience the pros and cons between the different cable and connector types?
c) What parameters is important to consider/take into account, when choosing cable and connector for each different measurement application?
   a. Please specify examples for different applications and measurement environments that are applicable to your site.
d) Typical issues and pitfalls regarding cables and connectors
   a. Please specify at least five examples
   b. Please specify how you usually mitigate these issues described above.
e) Do you have any routine or best practice regarding life-span of cables and connectors and how to document, follow up and check? Please specify.
f) What kind of pitfalls have you experiences wrt validation of measurement chain? What have the results/consequences been of the different pitfalls.

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## 10 Selection of measurement points

Questions below concerns following:

2. Parts to be measured
   - Location of response transducer
   - Location of reference points ( modal)
   - Direction of the measurement

a) How do you usually select measurement points/positions?
b) How do you select an adequate co-ordinate system for your structure?
c) What is best practise in your organisation regarding measurement point selection and co-ordinate system?
d) What is, in your experience the most common mistakes/pitfalls made?
e) What is uncommon mistakes/pitfalls that still might be considered important to avoid?
f) How do you avoid these pitfalls?
g) How do you validate that the points selected are relevant/correct for the current measurement?
h) What kind of pitfalls have you experiences wrt selection of measurement points? What have the results/consequences been of the different pitfalls.

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# 3.1 NPP Vibration measurement pitfalls fields - Some shared experiences in short

**RINGHALS**

**OKG**

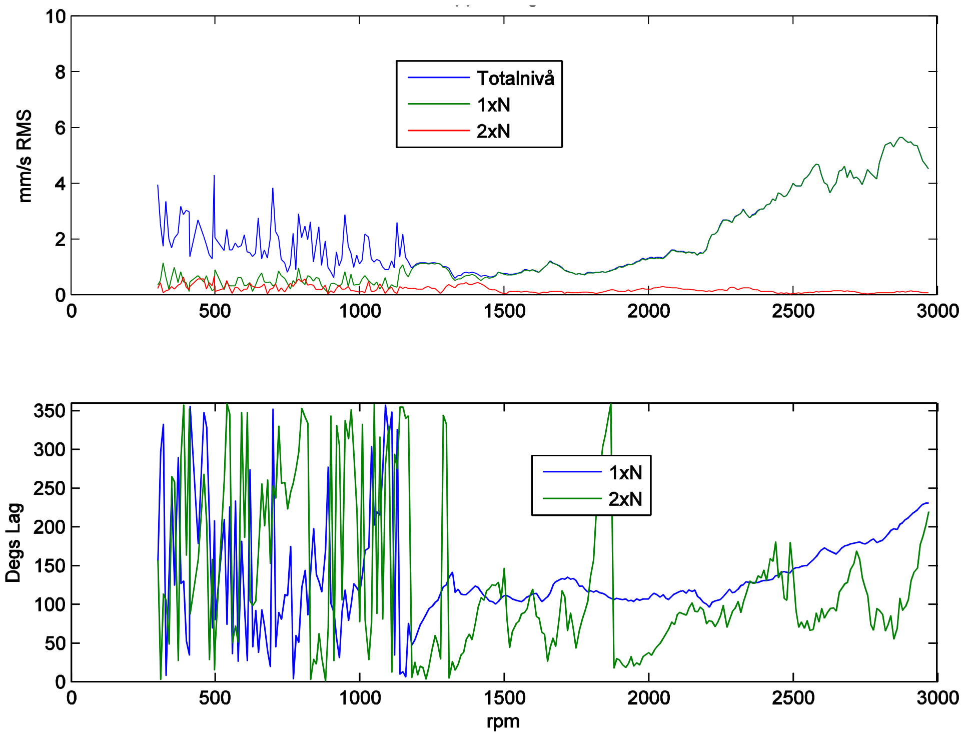
**FORSMARK**

**TVO**

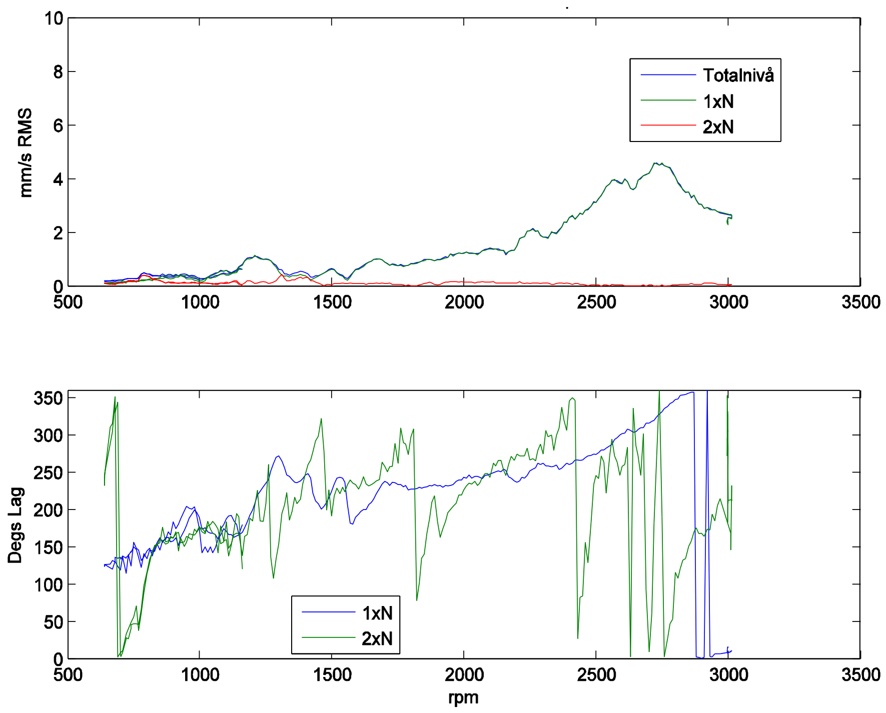
**FORTUM**

- Cables, connectors and sensor pitfalls
- Pitfalls due to inexperience and lack of training of personnel
- Pitfalls due to selection of measurement positions and insufficient preparation of measurements
- Pitfalls using ICP sensors on steam turbines
- Pitfalls due to communication/documentation mistakes. Eg structural changes of a rebuild/modification affecting not communicated with vibration specialists --> longer investigation time of problem, making wrong conclusions etc.
- Boundary condition issues when doing steam turbine modal measurements. The BC are never the same as during operation.
- Turbine testing with eddy current sensors
- Pitfalls due to lack of bookkeeping/documentation eg. Previous measurement positions, sensors used, levels measured that results in comparison of non-comparative results

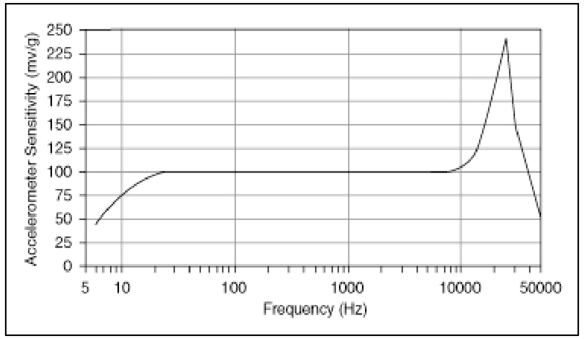
# EXAMPLE PITFALL 1: TURBINE ROLL-UP WHEN THROTTLED WET STEAM FLOW




**Accelerometers**

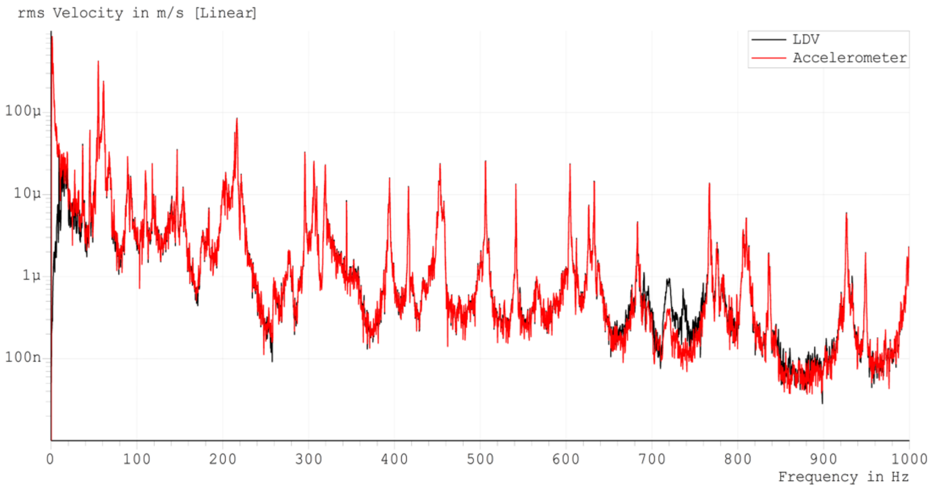



**Velocity sensors**




- Wet steam excites high frequency tones i.e. above f=10 kHz.

# EXAMPLE PITFALL 2: LOW-FREQUENCY SKI-SLOPE



Laser Doppler Vibrometer, LDV
Accelerometer ICP

- Transients from the pump
- The vibration must be “quicker” than the relaxation of the signal.

# Example Pitfall 3: Unexpected phase shift from peripherical devices measuring current I and voltage V

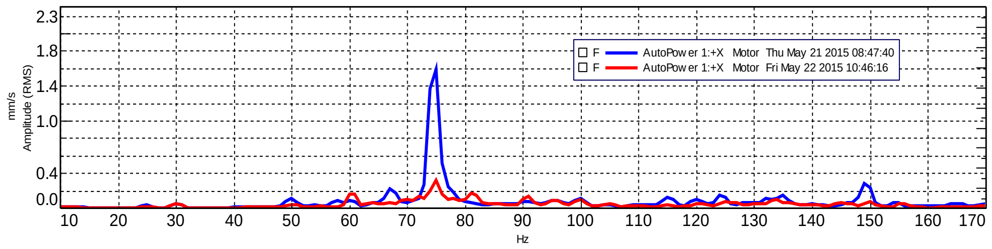

AmpFlex current sensors

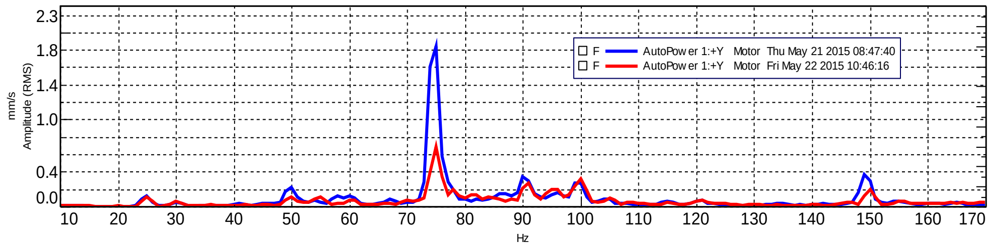
After a complementary verification of the current sensor, the  phase shift ended up to be 24˚ @ 2.4 A instead of the specified at data sheet 20˚ @ 10 A at f=50 Hz.

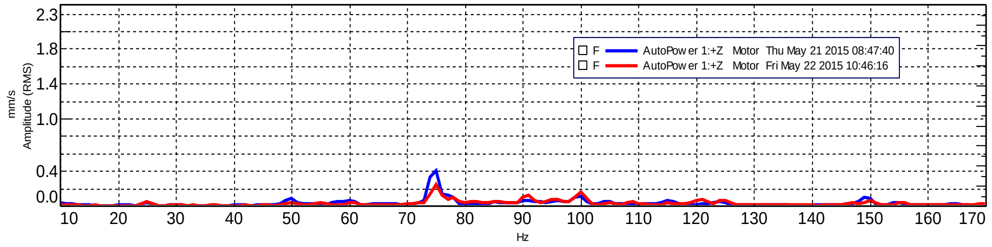
Analog isolation amplifier used to transform voltage 110.0 V on terminal to 5.47 V range suitable for measurement system

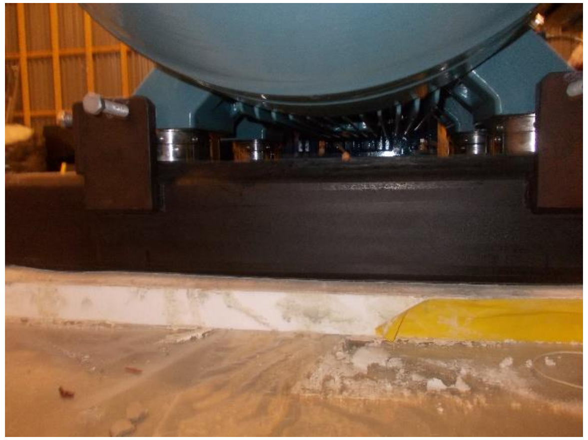
Upon phase verification it was verified that each input module of the isolator amplifier add a phase shift of approximately 17˚ @ 50 Hz during the prevailing circumstances

# Example Pitfall 4: Unexpected amplitude of motor component



- All components were aligned to meet at least 0.05 mm parallelism and 0.05 mm/100 mm in angle alignments.
- Use of self-adjusting Vibracon foot for angle error
- Grease in cup holder

## Example Pitfall 5: Missed and non-synchronized project information

Design of new pump foundation.

- Lack of communication between project experts pipe engineers and foundation design engineer.
- Missed the dynamic influence of strong constraints had on the discharge and suction pipes to the pump



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# Summary

- When you work in a group with a mixture of different project disciplines, suppliers and/or change of instrumentation nothing should be taken for granted.
- Often a tight timetable and/or lack of resources requires a longer and extensive pre-investigation before project start-up to achieve reliable measurement information when the project is running.

| Found fault | Possible pitfall 1 | Possible pitfall 2 | Possible pifall 3 | Possible pifall 4 | Possible pifall 5 | Possible pifall 6 | Possible pifall 7 |
|---|---|---|---|---|---|---|---|
| Unexpected DC component/ski-slope | ICP accelerometer, section 3.1.5-3.1.6 | High frequency overload, section 3.2.2 | Steam pipe meas urement Section 5.1 and 2.3 | Section 2.1.2, 2.3. Eg. Faulty cables, wrong sensors, temperature and radiation sensitivity | Integration issues section 2.4 and 3.1.5 | | |
| Unexpected 50 Hz component or other disturbances | Impact testing, section 3.1.4 | Interfering potent ials, Section 5.2 | 2.2 impact testing during parallel work | 2.3 and 5.2 Grounding issues. Transients due to cabling section 2.3 | Not galvanically sepa rated channels section 2.6 | | |
| Unexpected vibration magnitude/ frequency | Sensor malfunctioning, section 3.2.1 | Selection of measurement points, Section 4.3 | Inconsistent alignment, Section 4.4 | Section 2.1 Standards and Vibration criteria's, alarm levels | Section 2.1.1 Fixture points and resonances of fixtures | 2.1.1 and 2.3 using filters and amplifiers. And attachment of sensors | Sensor sensitivity, section 2.3 |
| Unexpected phase shift | Disturbance of high frequency vibration, section 5.1 | Amplifiers, section 6.2 and 2. 3 and 2.6 | Operating over long cables ( > 30m) with ICP sensors, Section 6.3 | Bookkeeping and selection of points sections 2.8 and 2.9 | | | |
| Missing project information | No rotor-dynamic model available, section 4.2 | Preparation, se ction 7.1, Section 2.1.2 | Section 2.1.1 and 2.1.2 Unable to access before or during meas. | Underestimation of construction changes Section 2.1.2 | Bookkeeping section 2.8 | | |
| Malfunctioning Equipment or poor signal quality | Sensitivity to radiation sectio n 2.1.1 and 2.3 and 6.3 | Using wrong Filters and sensors, eg se ction 2.3 | Poor/wrong attachment section 2.3 | Cabling and connection, section 2.3 | | | |
| Something breaks but root cause is hard to find. | Section 2.1.1 Not enough measurement time to find actual issue | | | | | | |


Thank you!
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