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UL RENEWABLES

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Performance of Test Bench testing for the evaluation of grid compliance of Wind and Solar generating units

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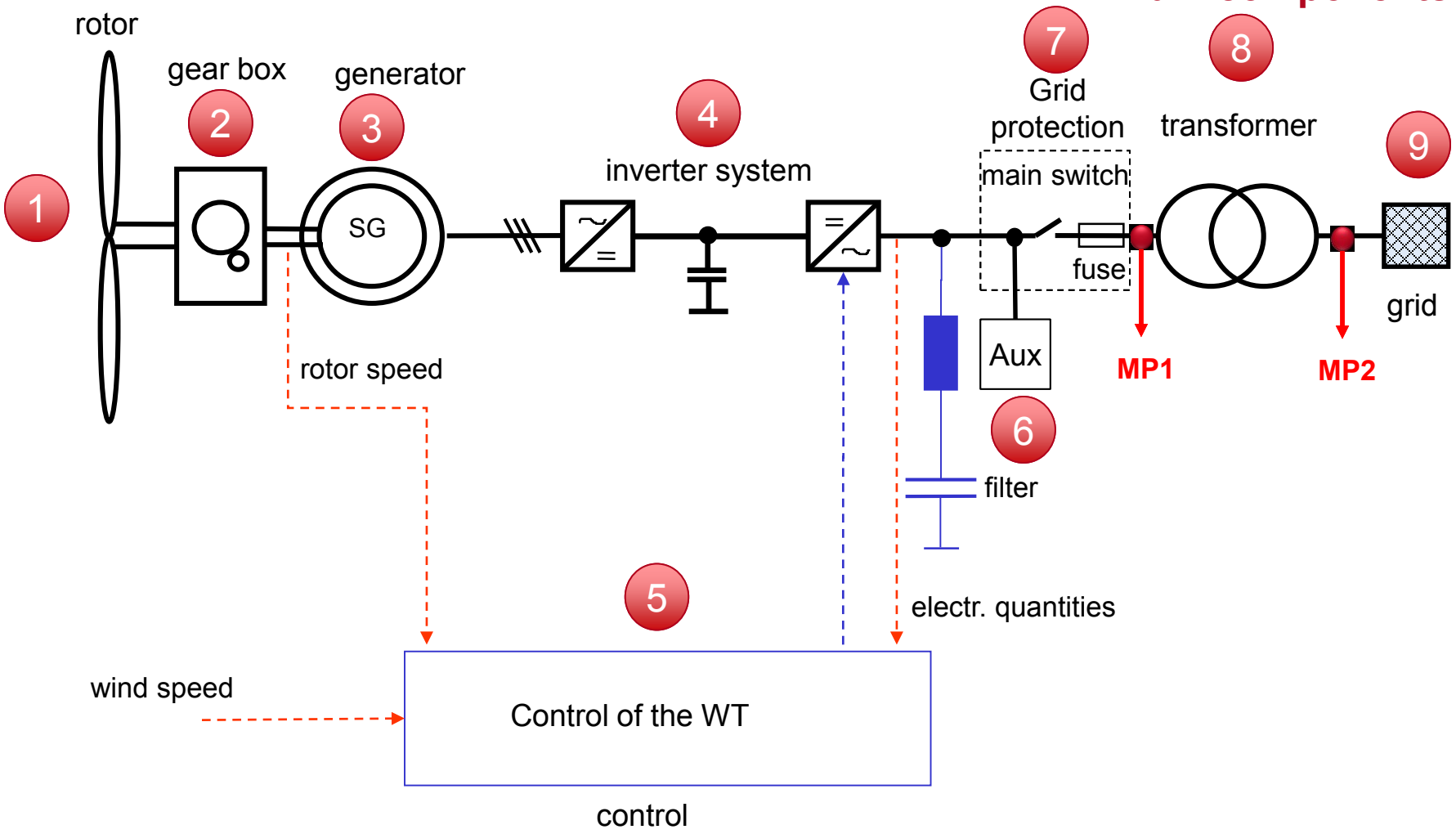
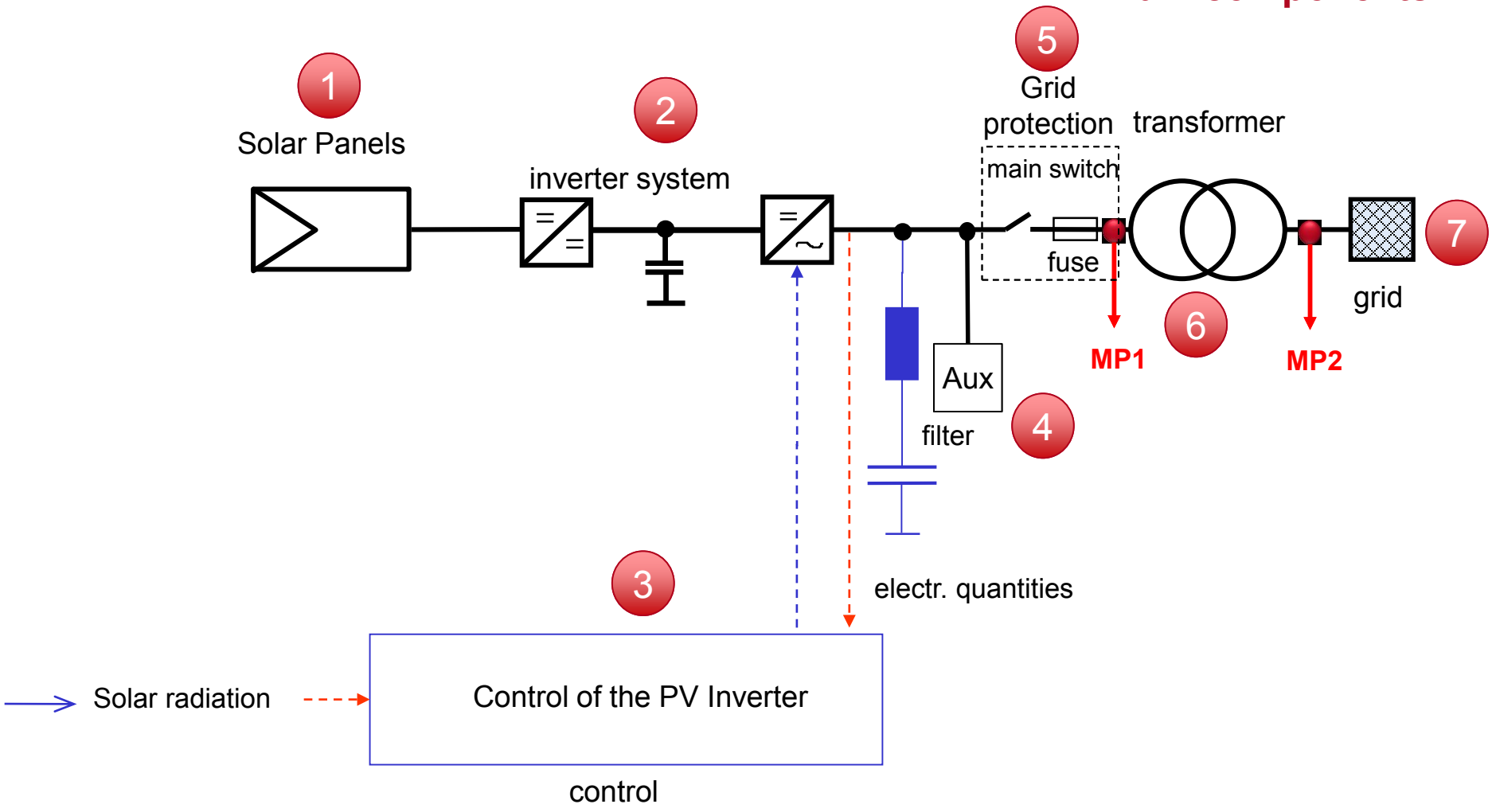
WHAT IS TEST BENCH TESTING?

Example 1: Wind Turbine main components



WHAT IS TEST BENCH TESTING?

Example 2: Solar station main components



STATE OF THE ART ON TEST BENCH TESTING

Available Standards and ongoing research work

- **IEC 61400-21-1**, Ed.1 (2019-05) — Measurement and assessment of electrical characteristics – Wind turbines
- **German Guideline FGW-TR3, Rev.25** — Technical Guidelines for Power Generating Units and Systems - Part 3
- **IEC 61400-21-4** — Measurement and assessment of electrical characteristics – Wind turbine components and subsystems

Technical Specification under development within IEC-TC88 Working Group (2019).

- **Research Project CertBench** – "Systematic validation of system test benches based on the type testing of wind turbines", Project funded by the German Federal Ministry of Economic Affairs and Energy, June 2017 – November 2019.

STATE OF THE ART ON TEST BENCH TESTING

IEC 61400-21-1 (2019): Suggested minimum levels for wind turbine testing

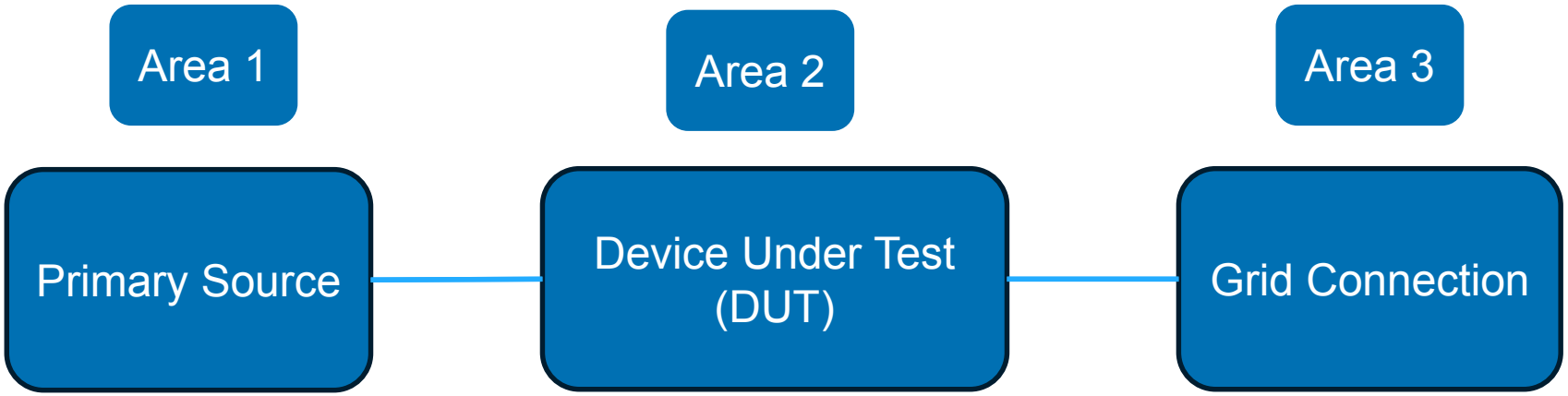
Wind Turbine Level (Field measurement)	Subsystem Level	Component Level
Flicker in continuous operation	Reactive power characteristic (Q=0)	Grid protection
Switching operations	Reactive power capability	Rate of change of frequency (RoCoF)
Harmonics	Voltage dependency of PQ diagram	
Maximum power	Unbalance factor	
Active power control	Frequency Control	
Active power ramp rate limitation	Reactive power control	
Synthetic Inertia		
Fault ride through capability		
Reconnection time		

TEST BENCH TESTING OF ELECTRICAL CHARACTERISTICS

Open points:

- Which electrical characteristic parameters can be reliably tested at a test bench and which are the restrictions?
- Which tests are imperative to be performed in the field?
- How does the test bench characteristics (grid emulator specifications and performance) influence the performance of the tested units?
- How can we draw conclusions for the performance of the complete unit based on the subsystem or component testing?

CLASSIFICATION OF TEST BENCHES (1/4)



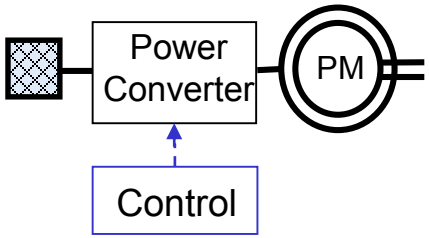
- Primary source to simulate the primary energy (e.g. wind speed or solar radiation)
- DUT behavior in the investigated characteristics to be equivalent to the behavior in the field
- A grid or a grid model is always necessary but special grid characteristics need to be taken into account for some points

CLASSIFICATION OF TEST BENCHES (2/4)

Area 1
Primary Source

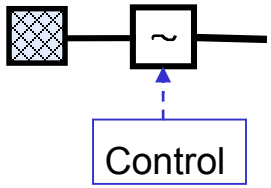
Variant 1

Prime Mover



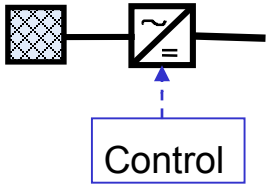
Variant 2

AC Source



Variant 3

DC Source



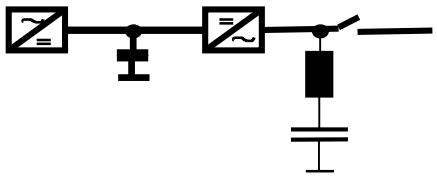
CLASSIFICATION OF TEST BENCHES (3/4)

Area 2
Device Under Test
(DUT)

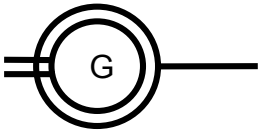
Component Testing

Variant 1

Converter system



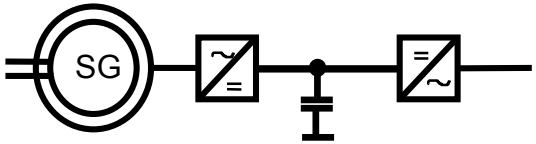
Generator



Transformer

Variant 2

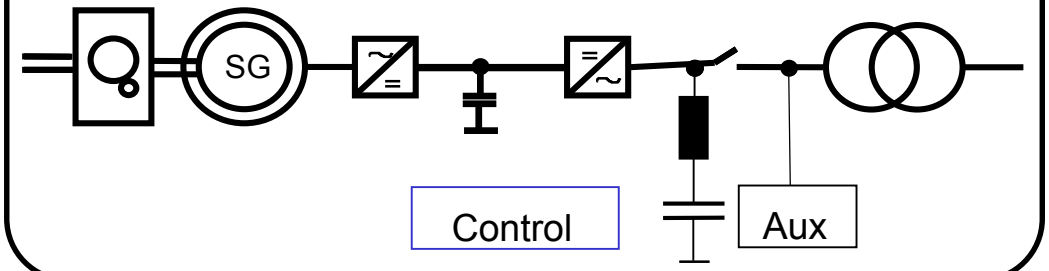
System



Control

Variant 3

Nacelle

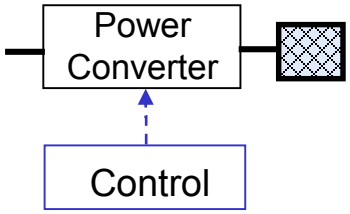


CLASSIFICATION OF TEST BENCHES (4/4)

Area 3
Grid Connection

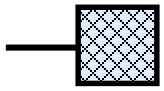
Variant 1

Grid Emulator



Variant 2

Direct grid connection

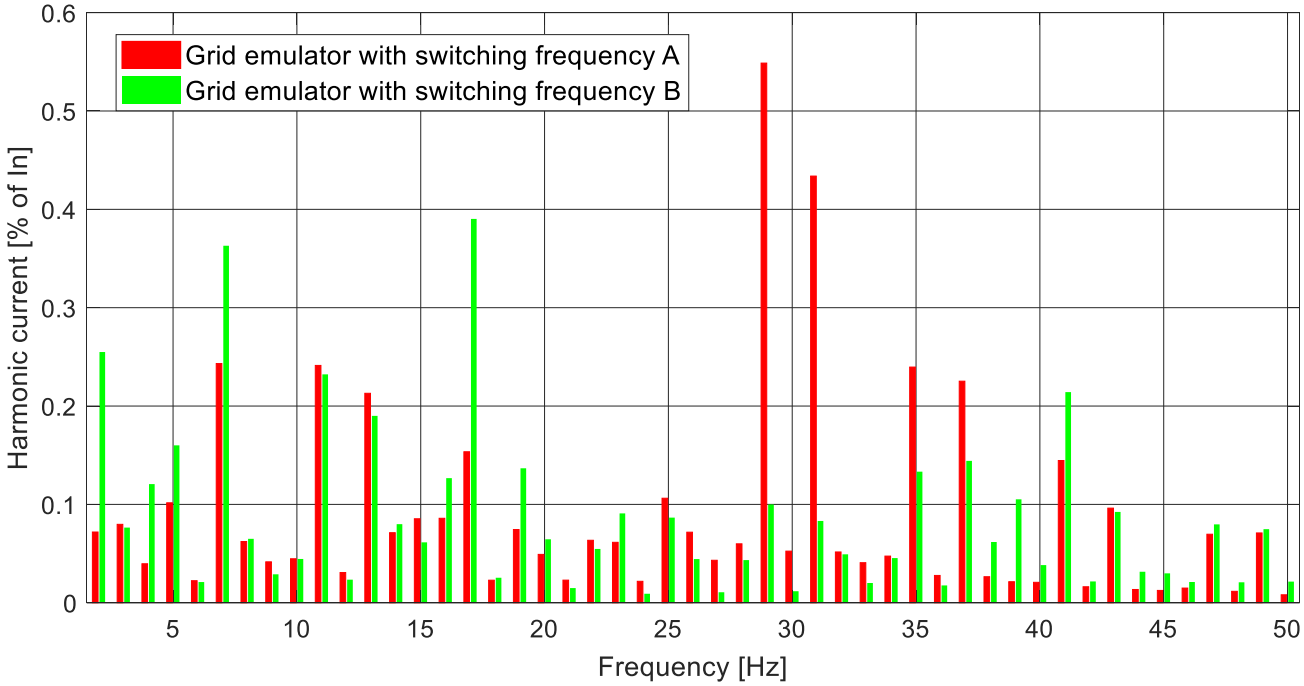


It is important to define the interfaces between the Primary Source, the DUT test and the grid.

In real operation the DUT may have sensors and actuators, which are not available at the test bench but their influence should be considered at the test bench operation.

PRACTICAL EXPERIENCE FROM TEST BENCH TESTING

Example: Influence of the grid emulator control on the performance of the tested DUT



- background harmonic distortion
- grid emulator harmonic impedance
- control etc.

➢ Systematic comparison between field measurements and measurements at test benches is ongoing within Certbench Research Project in Germany

SUGGESTED LEVELS FOR TESTING OF THE MAIN ELECTRICAL CHARACTERISTICS OF WIND TURBINES

Parameter	Suggestion
Flicker, Maximum Active power	• Testing in free field only • Additional tests for flicker mitigation can be performed at test bench
Harmonics	• Can be tested at test benches • harmonic voltage emission and impedance of the grid emulator must be considered
Reactive power (Q-Capability, PQ-U, setpoint control)	• Can be tested at test benches • All components of the WT affecting reactive power must be included in the tests
Active power control (set point / ramp rate limitation)	• Due to the influence of the rotor and of the drive train of the WT it is suggested to do the tests at free field

SUGGESTED LEVELS FOR TESTING OF THE MAIN ELECTRICAL CHARACTERISTICS OF WIND TURBINES

Parameter	Suggestion
Frequency control	• Can be tested at test benches.
Synthetic Inertia	• Can be tested at test benches, but the prime mover must emulate the behavior of a real rotor of the WT
FRT Capability	• Full scale free field testing is suggested, because the complete WT with all components must be tested • Additional tests with different settings (e.g. reactive power/currents) may be performed at test benches.
Grid protection	• Can be tested at test benches on component level

CONCLUSIONS

1. The electrical behavior of PV inverters can be tested at test benches

2. The electrical behavior of Wind Turbines cannot be tested purely at test benches – Several Electrical Characteristics have to be tested in the field

3. Additional test bench tests can be performed if necessary for model validation purposes or for the further investigation of alternative control parameters (e.g. flicker mitigation).

4. Still many open points have to be investigated e.g. influence of the harmonic impedance of the grid emulator, background grid distortion influence, variation of the primary source etc.

In general if a test can be carried out on-site, then it is recommended to be done

Thank you!

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