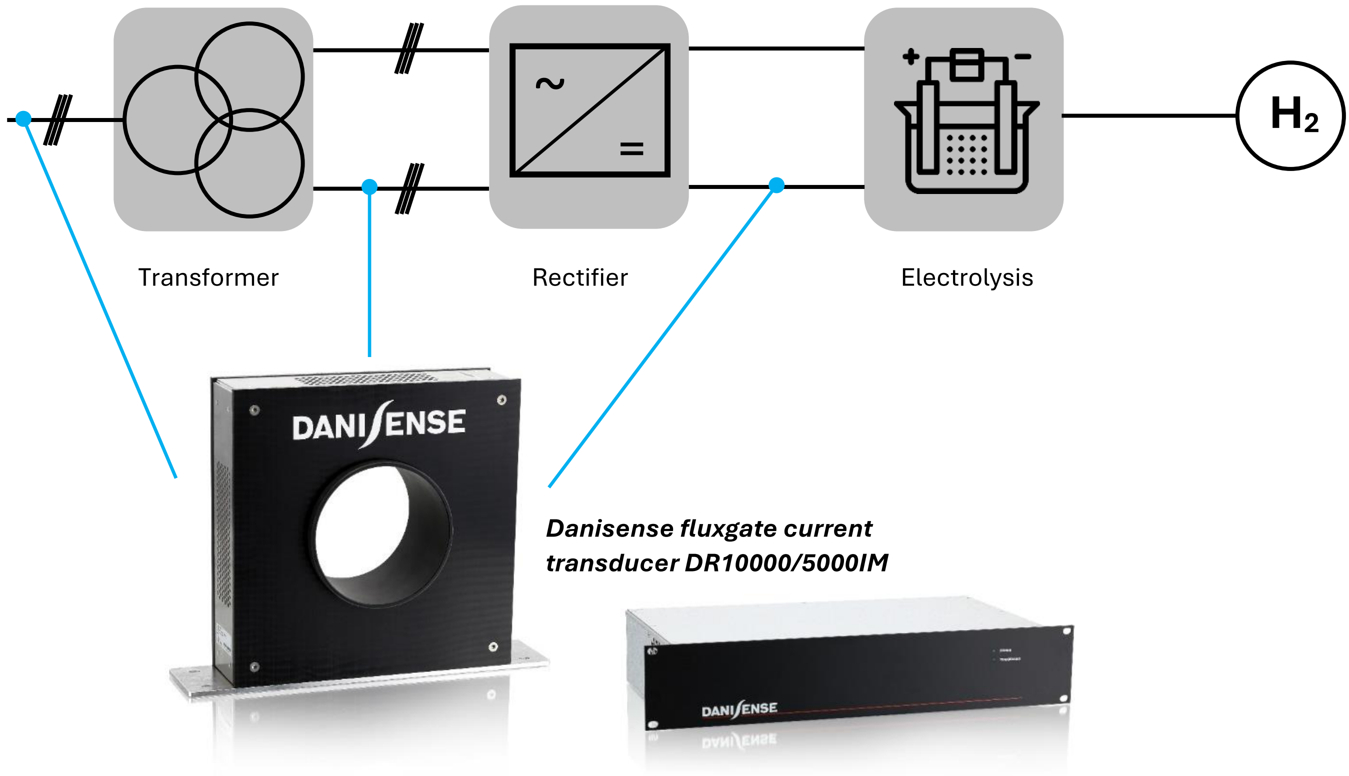
Current measurements in electrolysis applications



Danisense fluxgate current transducer DR10000/5000IM

Introduction

Hydrogen technology is considered a key element for a successful energy transition. It makes it possible to significantly reduce carbon dioxide emissions, particularly in the industrial and transportation sectors. Hydrogen can be stored and transported as an energy source and used for energy conversion. This is made possible by the process of electrolysis. This involves the use of electrolysers, which use electricity to split water into its component parts hydrogen (H_2) and oxygen (O) ("Power-to-Gas" or "Power-to-X").

Electrolysers are used wherever hydrogen production is appropriate from a logistical and energy perspective – for example, at large photovoltaic plants or wind farms. There, the renewable energy can be used for water electrolysis directly on site. The hydrogen can then be converted back into electricity by using fuel cells.

The use of electrolysers is also suitable for producing hydrogen that is fed into the natural gas grid. Up to 10% hydrogen can be fed directly into the natural gas grid. Alternatively, it can also be converted into natural gas by methanation.

In addition, hydrogen can replace fossil fuels in some CO_2-intensive industrial processes, such as in the steel or chemical sector, thus helping to reduce greenhouse gas emissions and further strengthen global competitiveness.

The efficiency of an electrolyser can be defined on the basis of the electrical energy required to produce one cubic meter of hydrogen under standard conditions: in a modern high-pressure electrolyser, this requirement is less than 4.8 kWh per m^3 (standard volume) at a pressure of 12 bar. This corresponds to an efficiency of 62.5% (based on the lower heating value of hydrogen).

The efficiency of the electrolysis systems is the decisive technical and economic factor in the electrochemical production of hydrogen using renewable energies.

The relatively high cost of electricity today is a major factor in the hydrogen production costs, along with the operating hours and the depreciation of the plant. From a technical point of view, these costs can only be reduced by increasing the overall efficiency of the system.

Efficiency measurements and their special aspects

Especially for efficiency measurements the overall accuracy of the measurement chain must be very precise. Even small ratio errors can lead to major deviations when determining efficiencies and losses. This is because losses cannot be measured directly and can only be calculated as the difference between the input power and the output power.

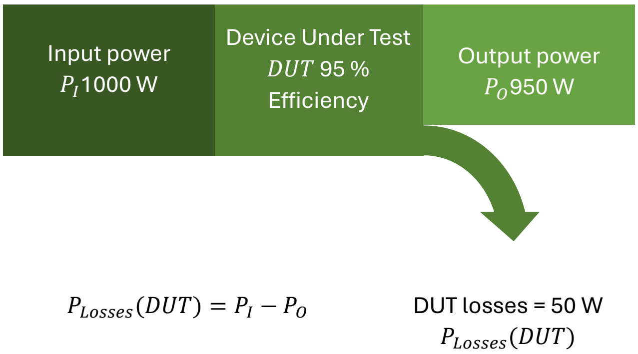


Figure 1: DUT - Determining the efficiency as the difference between input and output power

With the power values used in the figure above, an example calculation for current transducers with the ratio accuracy of 0.1% can now be performed. In the worst-case scenario, the measured value of the input power is increased by 0.1% and at the same time the measured value of the output power is decreased by 0.1%. This results in the largest possible error in the calculation of the power loss.

$$P_I + 0.001 \times P_I = 1001\ W$$

$$P_O - 0.001 \times P_O = 949.05\ W$$

$$P_{Losses}(DUT) = 51.95\ W$$

Percentage error of the power loss:

$$\frac{(51.95 - 50)W}{50\ W} \times 100 = 3.9\ \%$$

If current transducers with an accuracy of 0.1% are used to measure the input and output power, the calculated power loss of the test device, such as a frequency converter, can deviate from the true value by 3.9% in the worst case. All the other necessary components like voltage dividers and the power analyser itself are assumed to be ideal without any error.

The following figure 2 shows the effects of various ratio errors in current measurement on the percentage deviations in the loss calculation.

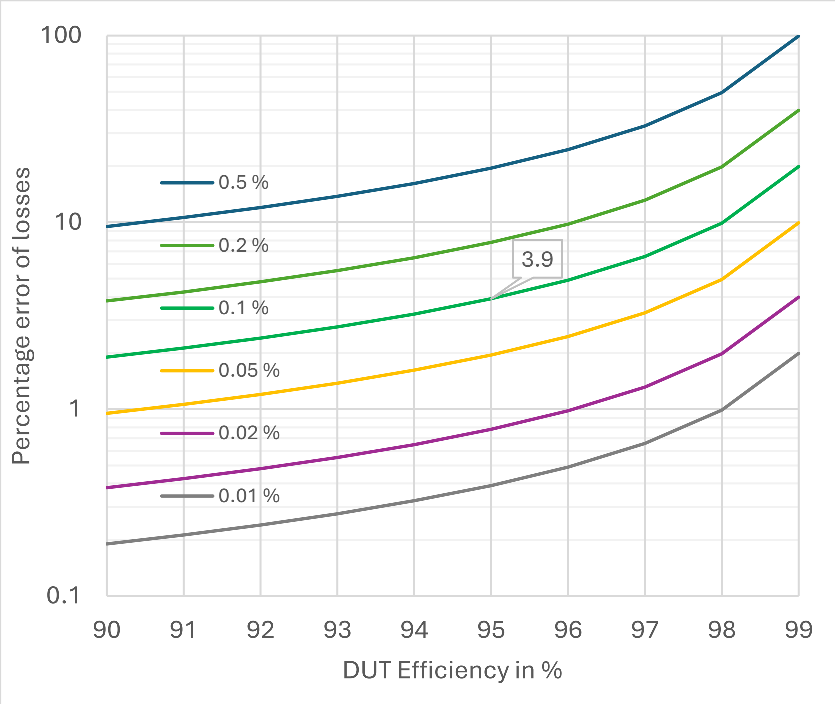


Figure 2: Accuracy of the loss measurement as a function of efficiency and current measurement error for the worst-case scenario

The measurement errors of the power analyser or the voltage sensors must also be considered in practice. The calculated value of 3.9% is marked on the green line for the accuracy of 0.1%. The percentage error in the loss calculation increases as the efficiency of the device under test increases.

To keep the error as low as possible, even for high-efficiency rectifiers, current transducers with an amplitude error in the ppm range are needed.

Efficiency measurements in the hydrogen generation

Various efficiency analyses can be carried out in hydrogen production. In order to evaluate the electrical components, the following efficiency measurements are usually carried out.

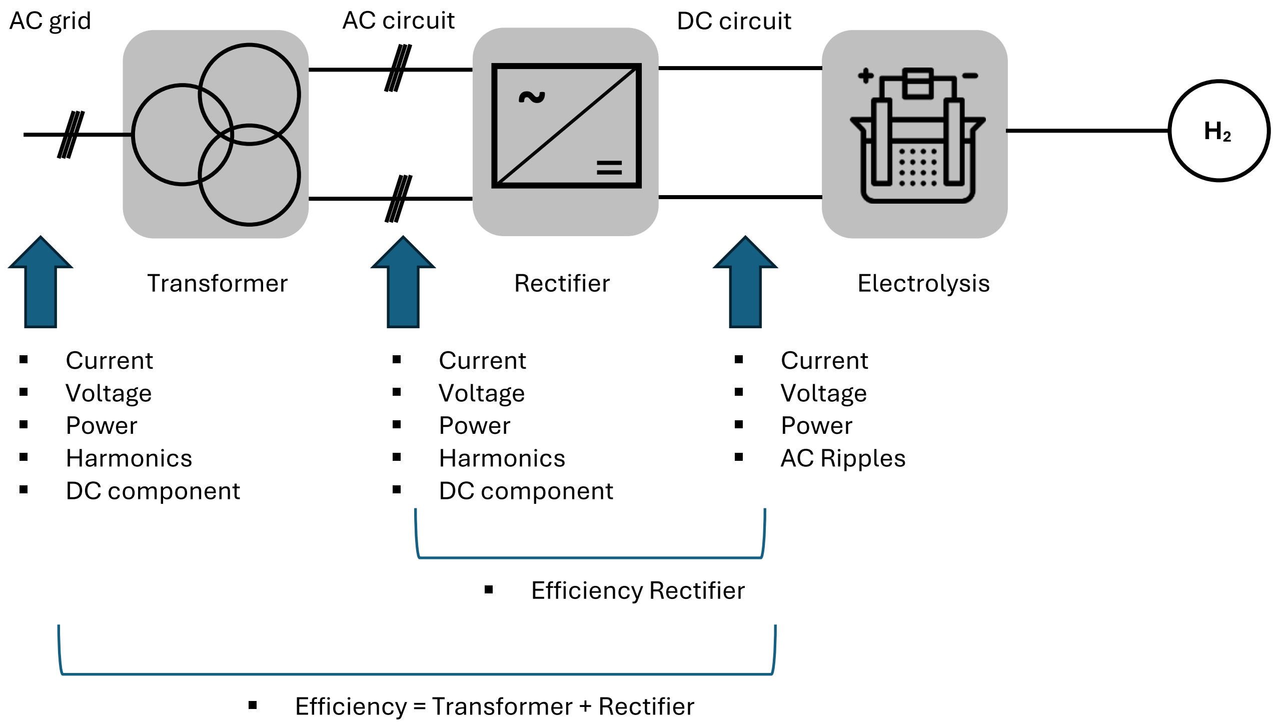


Figure 3: Usual efficiency measurements in hydrogen production

The DC currents are often in the double-digit kA range. Danisense offers current sensors in its standard portfolio that can continuously measure up to 10 kA DC. If the values are higher than this, many customers decide to interconnect current transducers in the respective current input channels of the power analyser. The following figure shows a schematic diagram of the measurement setup in the DC circuit.

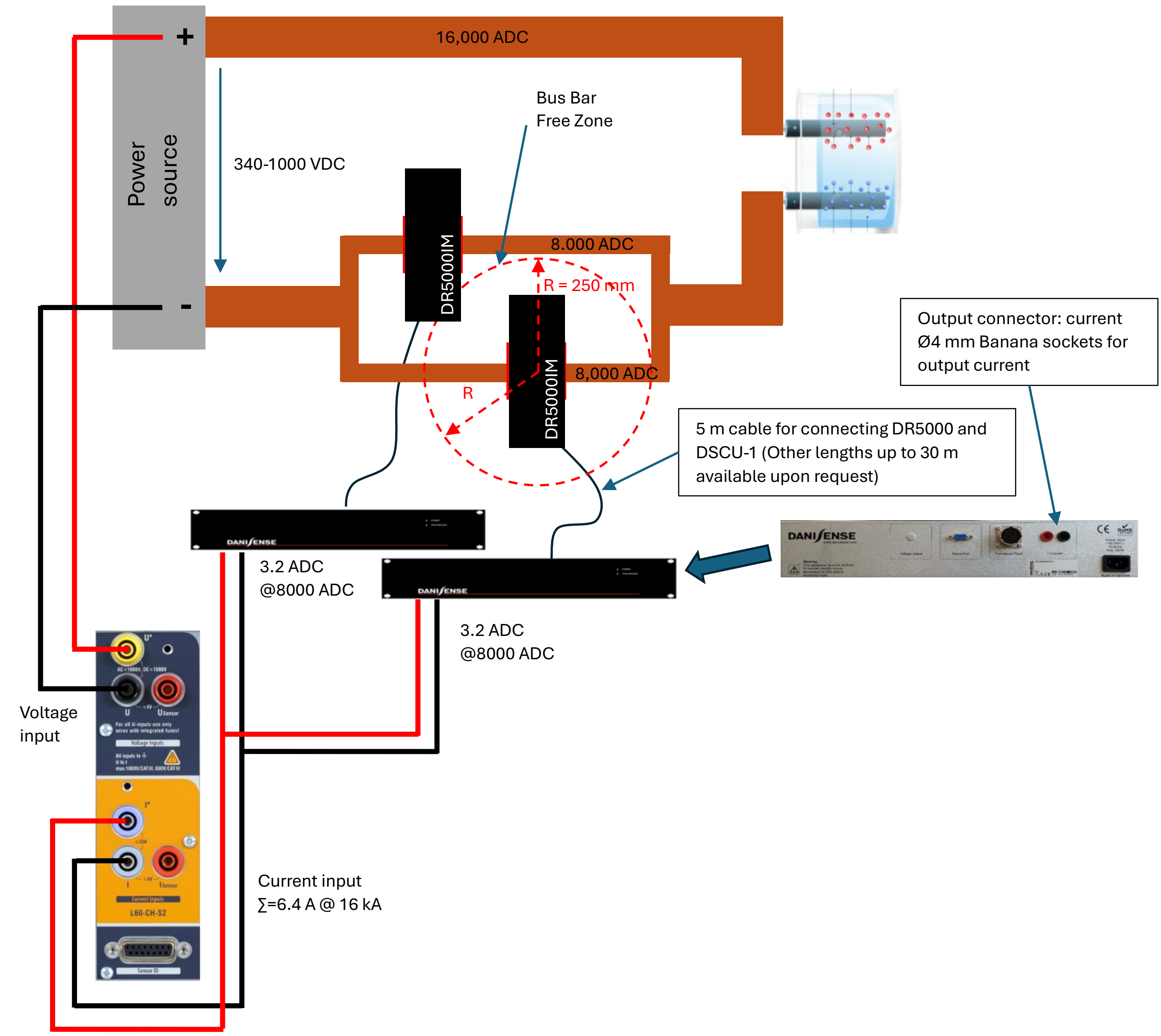


Figure 4: Schematic measurement setup for measuring high DC currents up to 16 kA with two DR5000IM

This method not only doubles the measuring range. The tolerance of the current measurement is also doubled. However, due to the unbeatable accuracy of fluxgate current transducers, the overall tolerance is always well below the customer specification. The following diagram shows the accuracy of the frequently used DR5000IM.

If the measuring device can compensate* (e.g. zero adjustment function at the ZES ZIMMER LMG600 series) the DC offset of the current transducer, very high accuracies can be achieved even at small primary currents.

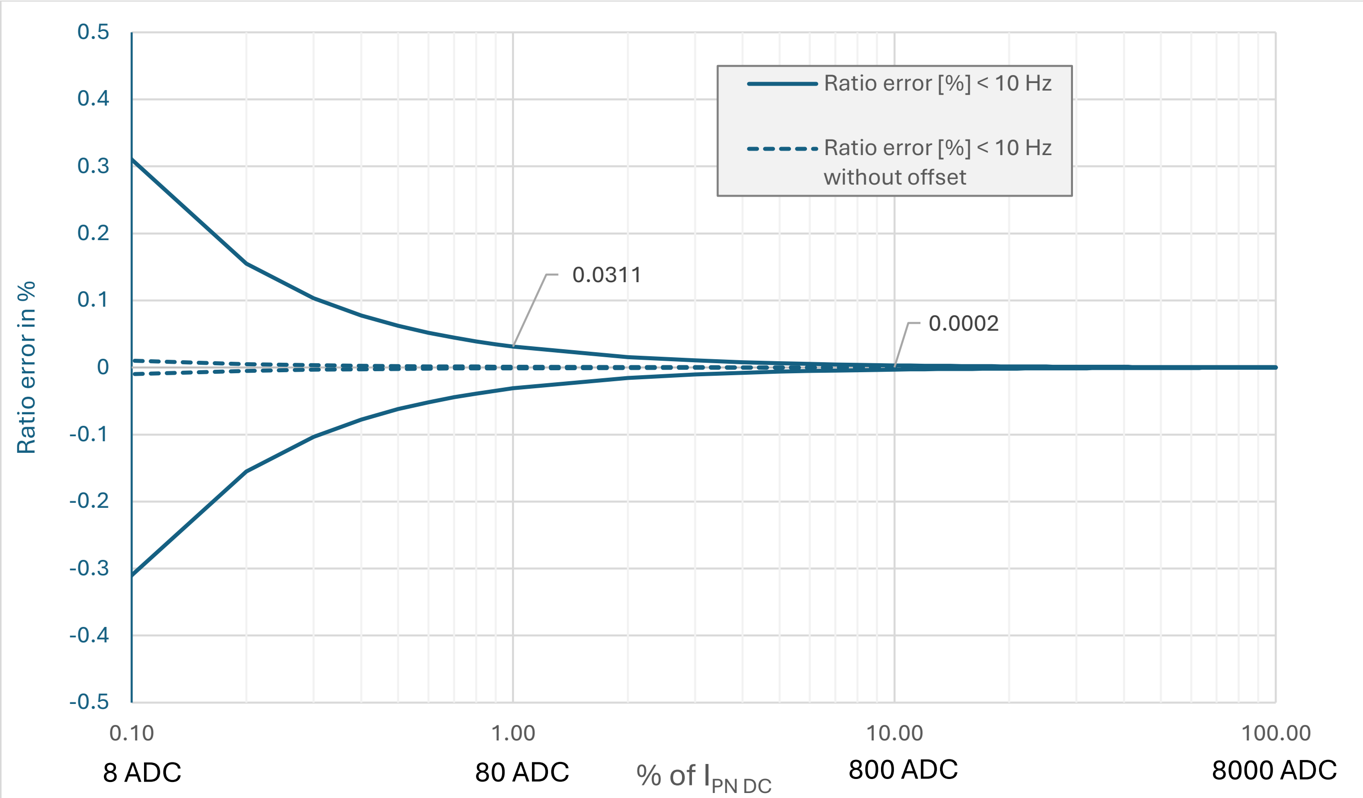
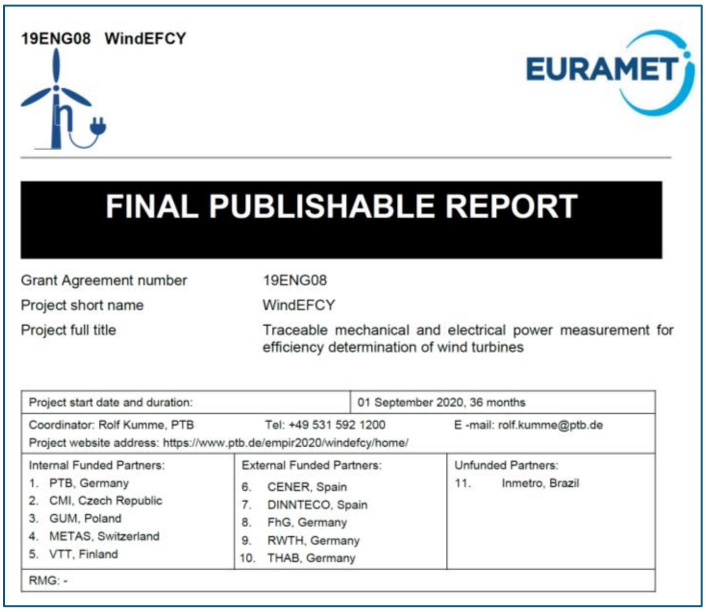


Figure 5: Ratio error of the DR5000IM < 10 Hz

References and Conclusion

Danisense current transducers have been used and recommended in many projects in combination with ZES ZIMMER power analyzers of the LMG600 series. The customer can therefore use proven technology in a new and challenging technical sector. The LMG600 from ZES ZIMMER not only measures high precisely the TRMS values of the measurement signal, but also displays the AC and DC components individually. Thanks to the very high resolution of 18 bits, it is possible to identify and analyze very small AC components (e.g. ripple components caused by the rectifier) on the DC signal. In combination with the Danisense precision current transducers, which offer outstanding DC and AC accuracy, you have the perfect analysis system at your disposal.

The following figure shows a recent European project on efficiency measurements in wind turbines. The final report is freely accessible via the link provided.


19ENG08 WindEFCY

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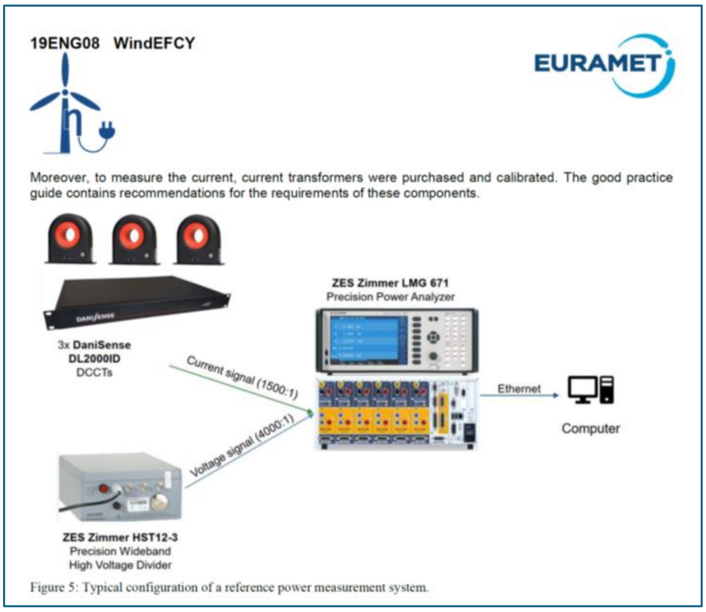
FINAL PUBLISHABLE REPORT

Grant Agreement number	19ENG08
Project short name	WindEFCY
Project full title	Traceable mechanical and electrical power measurement for efficiency determination of wind turbines

Project start date and duration:	01 September 2020, 36 months	
Coordinator: Rolf Kumme, PTB	Tel: +49 531 592 1200	E -mail: rolf.kumme@ptb.de
Project website address: https://www.ptb.de/empir2020/windefcy/home/		
Internal Funded Partners:	External Funded Partners:	Unfunded Partners:
1. PTB, Germany 2. CMI, Czech Republic 3. GUM, Poland 4. METAS, Switzerland 5. VTT, Finland	6. CENER, Spain 7. DINNTECO, Spain 8. FhG, Germany 9. RWTH, Germany 10. THAB, Germany	11. Inmetro, Brazil
RMG: -		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Moreover, to measure the current, current transformers were purchased and calibrated. The good practice guide contains recommendations for the requirements of these components.

Figure 5: Typical configuration of a reference power measurement system.

Source: https://www.euramet.org/european-metrology-networks/clean-energy/activities-impact/projects/project-details/project/traceable-mechanical-and-electrical-power-measurement-for-efficiency-determination-of-wind-turbines

Figure 6: European project: Traceable mechanical and electrical power measurement for efficiency determination of wind turbines

Authors:

Roland Buerger – Danisense A/S

Timothy Hertstein – ZES ZIMMER