A NEW INSTRUMENT APPROACH FOR LOAD FLEXIBILIZATION OF THERMAL POWER PLANTS

UN NOU INSTRUMENT PENTRU ABORDAREA FLEXIBILITĂŢII CENTRALELOR TERMOELECTRCE

Stefan KRANZ[1]

Abstract: The energy transition is taking its toll, tighter environmental limits, higher efficiencies and more flexible loads are creating new challenges for the power generation sector. What does this mean for the process design, its control and the measurement of energy flows and GHG equivalents?This paper addresses the changing requirements for grid stabilizing thermal power plants at the example of the main steam temperature control with a new flow measurement approach.

Keywords: The flexibility of power plants, steam temperature control, measuring.

Rezumat: Tranziția energetică implică realizarea unor limitele de mediu mai stricte, eficiența în utilizarea energiei mai mare iar prezenţa unor sarcini variabile creează noi provocări pentru sectorul de producere a energiei electrice. Ce înseamnă aceasta pentru proiectarea procesului, controlul acestuia și măsurarea fluxurilor de energie și a cmponentelor GES? În lucrare sunt abordate aspecte privind cerințele în schimbare pentru centralele termoelectrice privind capacitatea de a asigura stabilitatea sistemului electric, luând ca exemplu controlului principal al temperaturii aburului cu o nouă abordare de măsurare a debitului.

Cuvinte cheie: Flexibilitatea centralelor termoelectrice, controlul temperaturii aburului, măsurare

1. Introduction

Some European countries started in the 2000's by adding wind and later on PV as renewable sources for electricity generation to the grid. A rapidly increasing number of grid stability events made first measures for stabilization necessary in 2003 compensating the uneven power input of renewables. With the "Transmission Code 2007" [1] Germany introduced first rules for generators feeding electricity to the grid. In the following years unified rules for generators RfG have been developed in EUROPE on basis of the German

[1] KROHNE Group, s.kranz@krohne.com

regulation. The most cost-effective way to enhance plant flexibility is to optimize the I&C system [2] which strengthens the flexible operation and reduces the risk of increased thermal stress on the steam generator. Modern control strategies [3] together with new instrument technologies can help to increase load flexibility and efficiency by maintaining the thermal stress in its limits. With the example of a new measurement method for attemperation water it should be demonstrated how modern instrumentation can help to improve grid stability by maintaining plant availability.

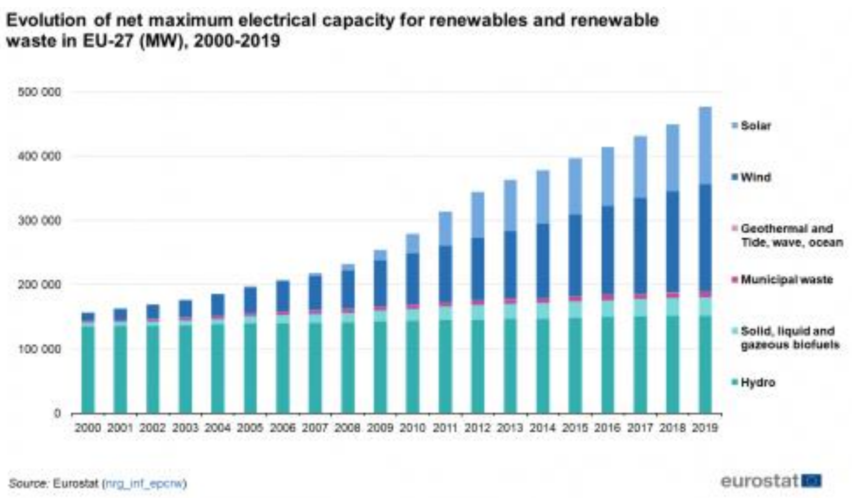


Figure 1. The structure of primary sources for the production of electricity

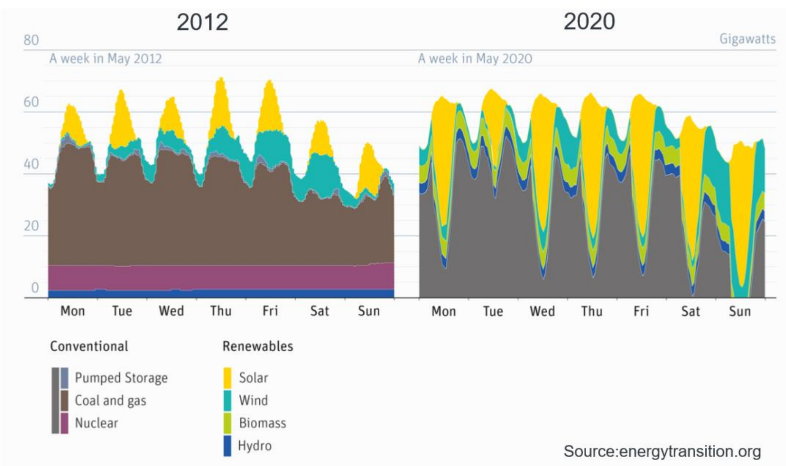
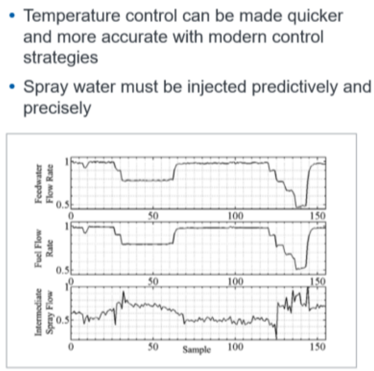


Figure 2. The weekly production of electricity in 2012 and in 2020

2. Main

The main steam temperature is affected by several variables such as feedwater, steam, and fuel flow rates, where controlling the flow rate of water spray through the attemperators is a unique useful method that can be used to regulate the final steam temperature. Moreover, elevating the steam variables and declining the reliability and performance of aged thermal power plants could potentially increase the complexity of control systems. [3] The control behaviour of the flow control valve as well as the characteristics of the attemperator nozzle will change over time. Modern feedback forward control strategies help to reduce temperature deviations and overswing and subsequently overfiring/ underfiring.



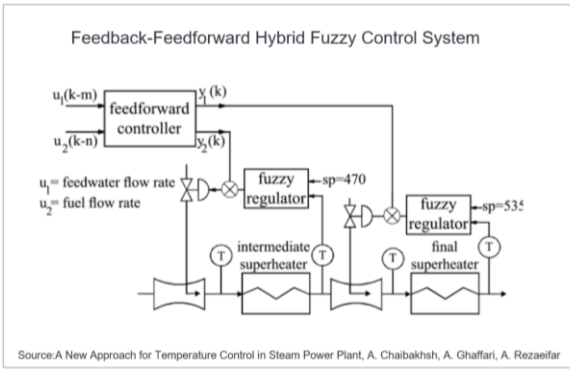


Figure 3. Size variation thermal circuit Figure 4 - Thermal circuit control scheme

A long-term stable flowmeter as a reference covering the big dynamic range of the attemperation water flow helps to improve the control quality further.

Ultrasonic flowmeters have matured over decades with the development and affordability of high-speed digital signal processing. The majority of ultrasonic flowmeters applied today work according to the transit time principle. They have established a fixed role for many applications in process control, for example for the custody transfer of natural gas according to MI-002, AGA9 or OIML R137 or heat in district heating according to MI-004, OIML R75 and for measurements in industrial processes.

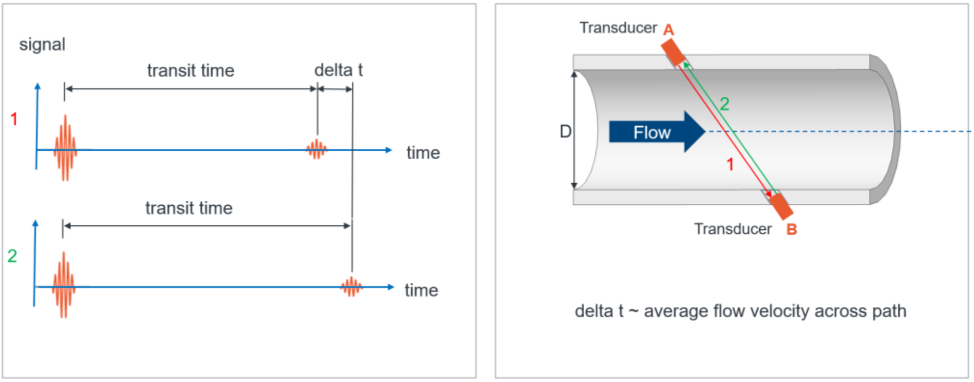


Figure 5. The principle of fluid velocity measurement with flowmeters

The majority of ultrasonic flowmeters work on the ultrasonic transit-time principle. Delta T, the time difference of upstream signal and the downstream signal is proportional to the average flow velocity across the signal path.

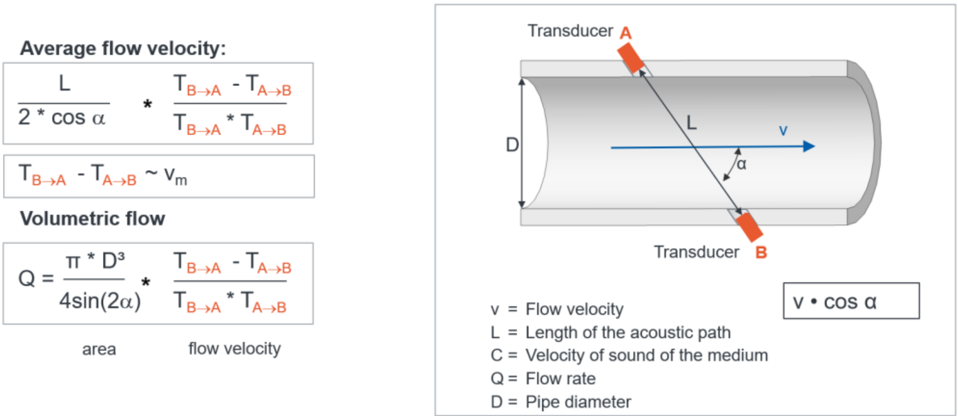


Figure 6. Determination of the velocity and volumetric flow of the fluid with flowmeters

The sound velocity mainly depends on the fluid, its temperature and pressure. It influences both signal directions in the same way and have no effect on the measurement. The measuring effect is linear proportional to the flow velocity.

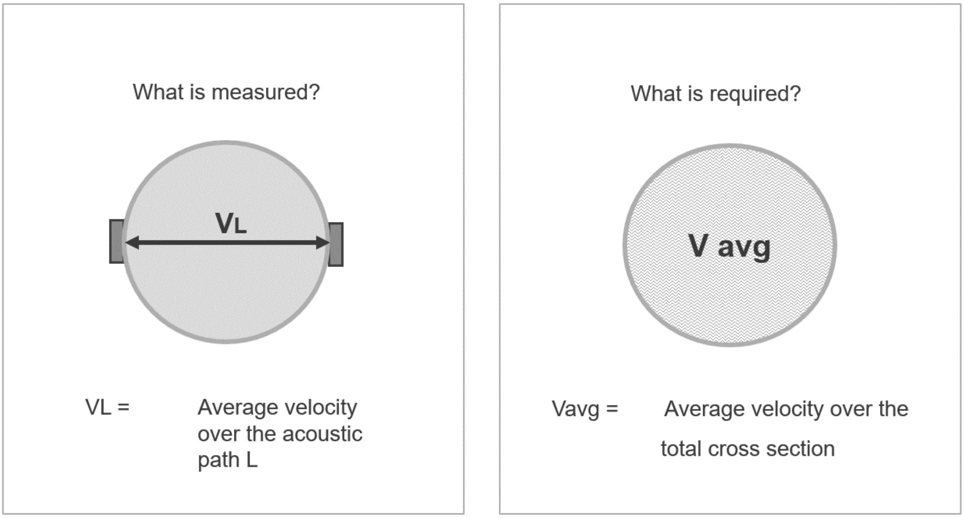


Figure 7. Fluid velocity measurement

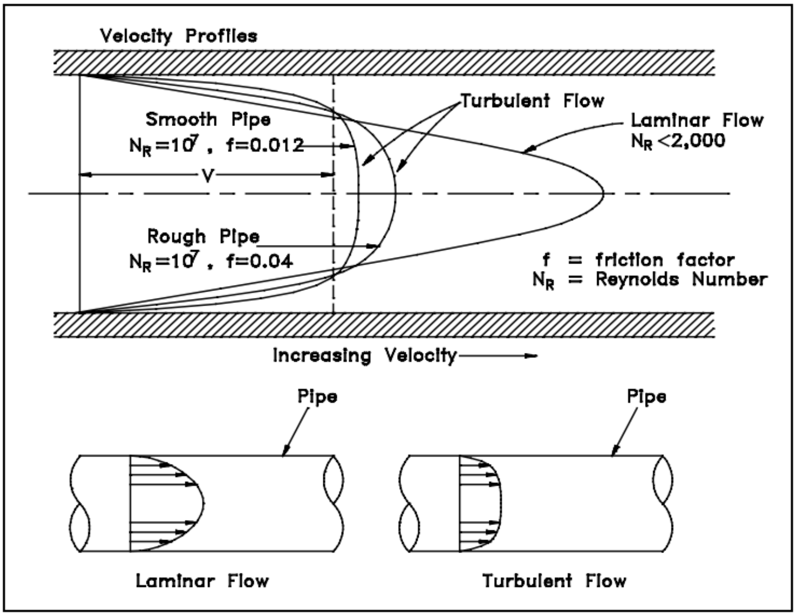


Figure 8. Flow velocity profiles for straight pipes
depending on Reynolds number and pipewall roughness [6]

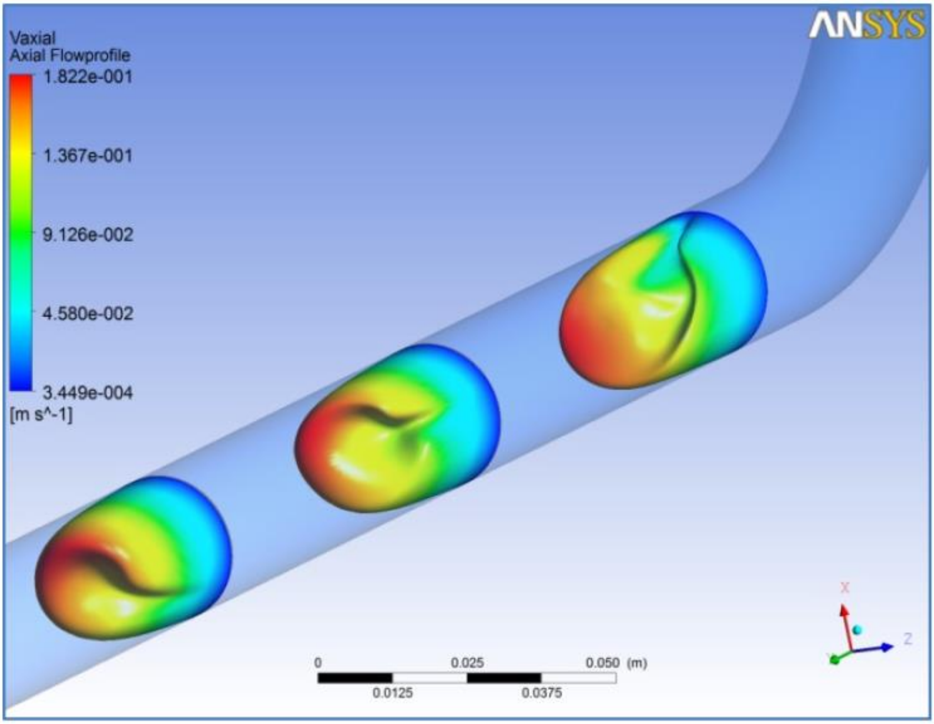


Figure 9. CFD - Flow velocity distribution behind double bend in 2 planes[7]

The flow velocity distribution for straight pipes mainly depends on the Reynolds number and the pipe-wall roughness. Bends, valves and other installations disturb the rotary symmetric profile and lead to flow disturbances which are complex to define. One can see from the above figures the influence of these factors. In order to achieve an accurate flow measurement under these conditions the flow profile can be conditioned by a flow conditioner and/ or a sufficiently long upstream piperun. Another countermeasure is a flowmeter which captures more information about the flow velocity distribution in the relevant pipe section. With an increasing number of ultrasonic signal paths and the optimized arrangement in the flow profile the accuracy and independence of flow profile disturbances and velocity profiles of the flowmeter can be improved. A chordal (off-center) location of the ultrasonic signal path in the outer area of the lowest flow velocity change at the changeover from laminar to turbulent flow is advantageous to make the meter insensitive against Reynolds number changes. The utilization of more ultrasonic signal paths capturing more flow velocity information generally improves the flowmeter accuracy [9].

Finally the calibration of the spoolpiece or even better a longer metering section (meter run) at comparable conditions with the same Reynolds number range will help to achieve best possible accuracies in service [8].

3. High temperature and high-pressure ultrasonic flow measurement

In the water steam cycle of power plants ultrasonic flowmeters could have been only found in applications with limited temperatures and pressures for example for condensate flows. The temperature limits of Ultrasonic flowmeters have been dictated by the curie temperatures of the piezo transducer element and the piezoelectric efficiency at elevated temperatures [4]. The useful temperature range of the directly coupled ultrasonic flowmeters is therefore limited to a temperature in the region of approximately 225 to 250 °C. With the development of ultrasonic waveguides [5] the piezo elements could be separated from the exposure of high process temperatures and the application limits for temperatures could have been significantly increased.

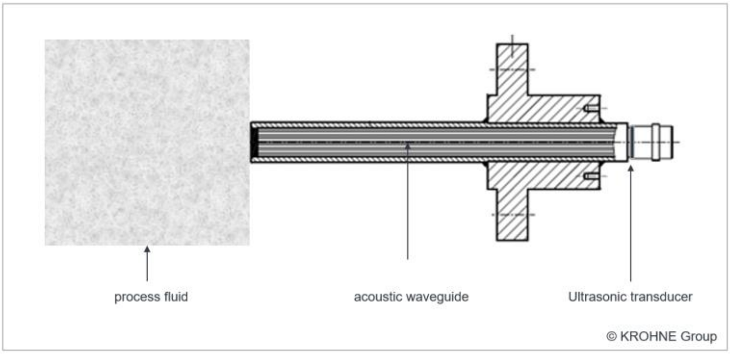


Figure 10. Ultrasonic transducer with Waveguide

A waveguide can be utilized to separate the piezo-ceramic transducer from the high process temperatures and pressures. It must be designed in a way, that it conducts the ultrasonic signals at the relevant wavelength with the required efficiencies. The ultrasonic travel time in the waveguide depends on the temperature distribution in the material and must be well compensated for an accurate measurement. The associated converter electronics is using an adapted signal processing and evaluates the signal reflection at the interface of the transducer window to the process. By this the total signal travel time can be corrected by the travel time in the waveguide so that measurements can be carried out with similar accuracies as with transducers without waveguides.

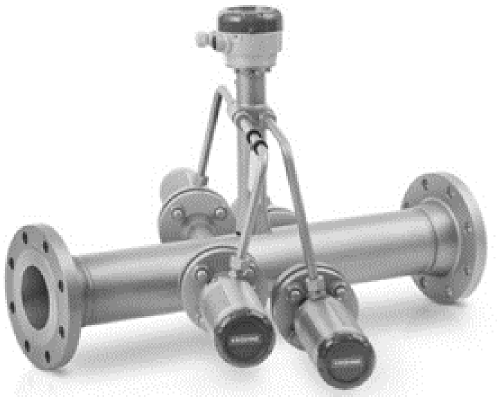


Figure 11. Ultrasonic flowmeter with integrated waveguide transducers for high temperature flow measurement of feedwater, injection water and similar applications

The transducers with the waveguides can be fitted into spoolpieces in different path configurations in order to meet specific requirements. The spoolpieces can be flow calibrated on a suitable flow rig where similar Reynolds numbers like in the field application can be covered by the calibration facility.

4. Attemperation water flow measurement

Attemperation water is injected for the temperature control of the main steam. Depending on the process, attemperation water can reach pressures of 320 bar(g) and temperatures of 250°C or even more. It is injected over a wide flow range requiring a flow turndown of 20:1. In the absence of other technologies attemperation water was usually measured by DP flow.

Figure 12. High pressure, high temperature Ultrasonic Steam temperature flowmeter for steam temperature water

Figure 13. The structure of the measurement system

With the application of high temperature, high pressure Ultrasonic flowmeters for the flow measurement of attemperation water, The control quality and control speed of the main steam temperature control can be improved by utilizing modern feedback forward control strategies using the flow measurement as an important reference. By this the load flexibility of the power plant can be improved and overfiring/ under firing can be reduced.

5. Conclusion

With the development of high temperature and high pressure inline Ultrasonic flowmeters attemperator water and boiler feedwater can now be measured over a big dynamic flow range. The application at several retrofit and newbuild projects has shown the suitability of this technology for applications in the water-steam cycle. Based on the ultrasonic transit time measurement, the flowmeters are drift free over long periods of time. The execution as inline flowmeter enable the calibration of the flowmeter spoolpiece or of longer metering sections like they are applied according to ASME PTC 6. [8]. The inline design further enables a chordal (off-center) arrangement of the ultrasonic path through the flow profile which improves the meter linearity over a big Reynolds number range. The wetted ultrasonic transducers with integrated waveguides [5] thermally decouple the piezo ceramics from the process and enable a precise compensation of the travel time of the acoustic signal in the waveguide.

Beside attemperation water measurement to improve load flexibility like in this example, the primary boiler feedwater flow as well as steam flows can be measured with this technology. Meters can be designed as meter runs with redundant converters so that common power generation requirements are met.

R E F E R E N C E S

[1] TransmissionCode 2007, Network and System Rules of the German Transmission System Operators, 08/2007 Verband der Netzbetreiber

[2] FLEXIBLE OPERATION OF THERMAL POWER PLANT FOR INTEGRATION OF RENEWABLE GENERATION Sewa Bhawan, Sector 1, R K Puram, New Delhi – 110066, January 20149

[3] A new approach for temperature control in steam power plant Conference Paper · July 2008 DOI: 10.1109/MED.2008.4601994 · Source: IEEE Xplore

[4] Effect of Temperature on The Main Piezoelectric Parameters of A Soft PZT Ceramic, ROMANIAN JOURNAL OF INFORMATION SCIENCE AND TECHNOLOGY Volume 10, Number 3, 2007, 243–250

[5] ULTRASONIC WAVEGUIDE, United States Patent (10) Patent No.: US 6,400,648 B1, Krohne A.G. (CH), EP1098295A2

[6] U.S. Department of Energy, THERMODYNAMICS, HEAT TRANSFER, AND FLUID FLOW. DOE Fundamentals Handbook, Volume 1, 2 and 3. June 1992

[7] CFD study of flow disturbances downstream bends; influence upon the measurement accuracy, KROHNE 05/2013
[8] ASME PTC 6-2004 (R2014) Steam Turbines, Performance Test Codes
[9] How Accurate are Ultrasonic Flowmeters in Practical Conditions; Jankees Hogendoorn, Herman Hofstede, Peter van Brakel and André Boer. NFOGM 2011
[10] Using Precise Flow Measurements to Increase Efficiency in Power Plants „Power Plants – Technology in Dialogue“ 24. April 2008, Hannover
[11] IEC 60953-2 Revision 1.0, December 1990 Rules for steam turbine thermal acceptance Tests Part 2: Method B - Wide range of accuracy for various types and sizes of turbines
[12] Calibration of an ultrasonic flow meter for hot water: KarstenTawackoliana, OliverBüker, Jankees Hogendoorn, ThomasLederer, Science Direct Flow Measurement and Instrumentation, Volume 30, April 2013
[13] 23rd International North Sea Flow Measurement Workshop: Flow Disturbances and Flow Conditioners: The Effect on Multi-beam Ultrasonic Flowmeters Jankees Hogendoorn, André Boer, Dick Laan