Long-term validation of a new modular approach for CO-λ-optimization

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AREA 5.3
Automation and Control

Introduction

The residual oxygen content of the flue gas (short: oxygen content) significantly influences the CO-emissions and the efficiency of biomass boilers, see Fig. 1.

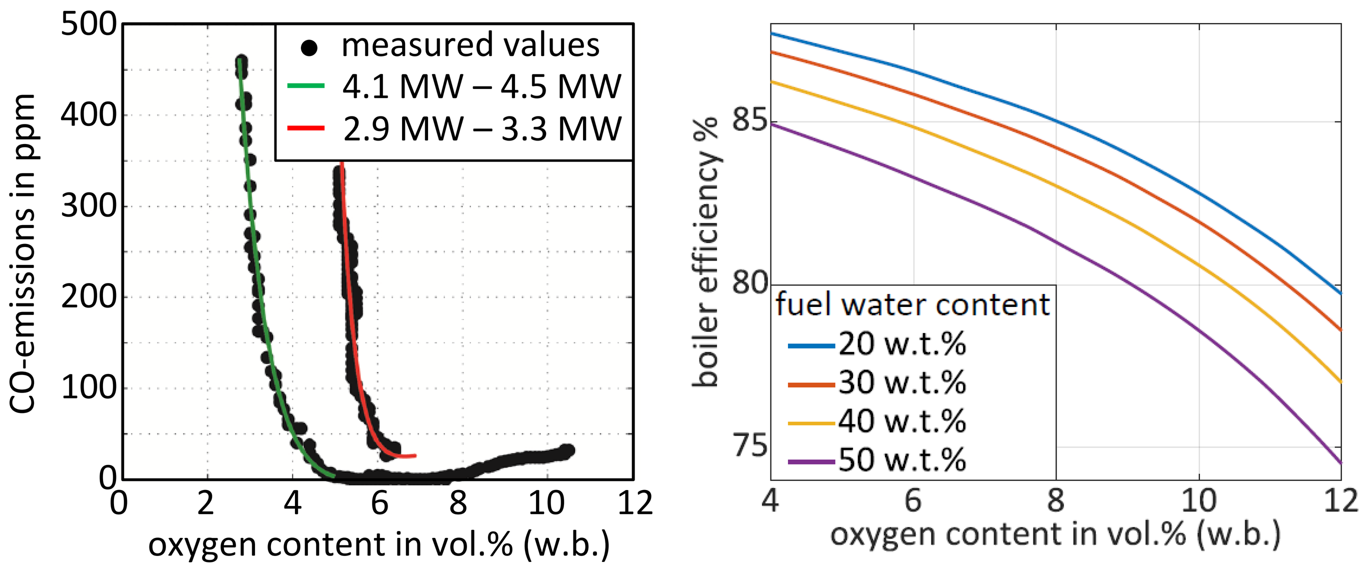

Fig. 1: Influence of the oxygen content on the CO-emissions (left) and the boiler efficiency (right).

CO-λ-optimization is the operation of biomass boilers with an optimal oxygen content which minimizes the CO-emissions and maximizes the boiler efficiency. The optimal oxygen content needs to be determined during the operation of the biomass boiler as the CO-λ-characteristics changes with the thermal output and the fuel properties. State-of-the-art approaches for CO-λ-optimization are not capable of detecting these changes sufficiently quick and lack robustness for a wide-spread practical application.

New modular approach for CO-λ-optimization

The new approach for CO-λ-optimization utilizes a mathematical model of the CO-λ-characteristic in combination with advanced methods from control engineering (Extended Kalman Filter) to quickly and robustly identify the biomass boiler's CO-λ-characteristics. This new approach determines the optimal oxygen content from the identified CO-λ-characteristics and then defines it as a desired value for the biomass boiler's existing oxygen control. This makes this new approach entirely modular.

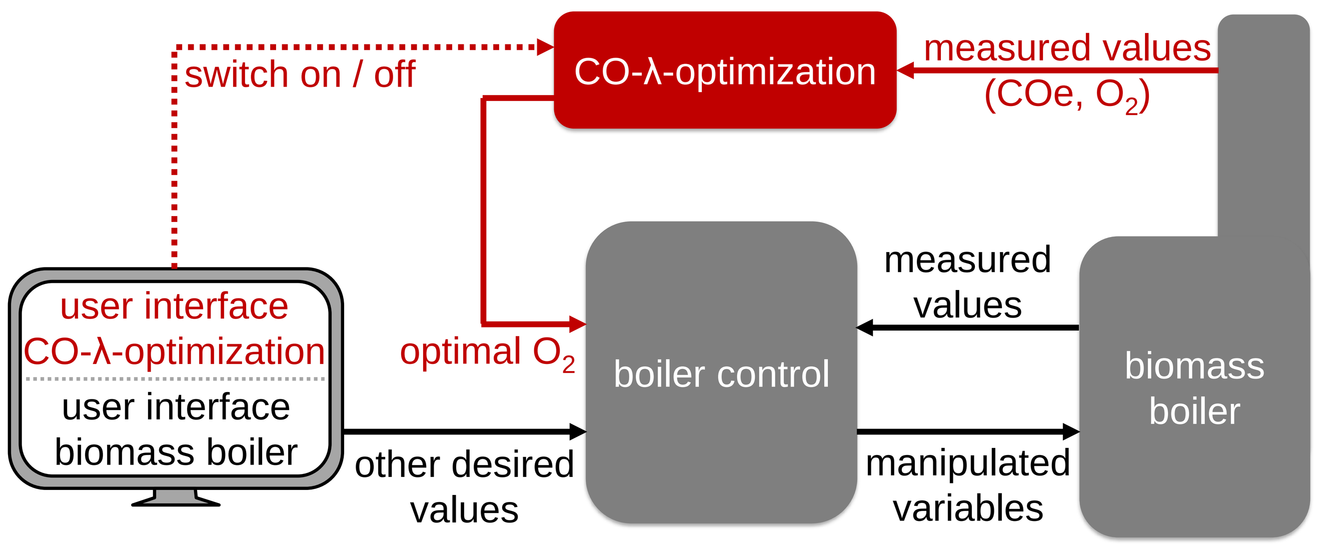

Fig. 2: Schematic illustration of the new modular approach for CO-λ-optimization.

Long-term validation

The new modular approach for CO-λ-optimization was validated at a medium-scale fixed-bed biomass boiler with air staging from November 2018 to March 2019 (5 months). This biomass boiler has a nominal capacity of 2.5 MW and is part of a district heating plant which supplies approximately 175 customers with heat.

During this long-term validation, the biomass boiler was alternately operated with the CO-λ-optimization activated and deactivated. When the CO-λ-optimization was activated (in total 1155 hours) the biomass boiler was operated with the optimal oxygen content determined by the modular CO-λ-optimization. When it was deactivated, the biomass boiler was operated with a constant value of the oxygen content of 11 vol.% (w.b.).

Results of the long-term validation

The application of the CO-λ-optimization led to a significant improvement in the biomass boiler's operating behavior. **The new modular CO-λ-optimization reduced the fuel consumption necessary for the production of the same amount of heat by -3.8% (see Table 1).**

Table 1: Key results from the long-term verification.

activated CO-λ-optimization	31462	cycles	...stoker cycles
	1154.8	h	...operating hours
	2814.7	MWh	...total delivered heat
	2.44	MW	...mean thermal output
	11.18	**cycles / MWh**	
deactivated CO-λ-optimization	36651	cycles	...stoker cycles
	1310.6	h	...operating hours
	3154.0	MWh	...total delivered heat
	2.41	MW	...mean thermal output
	11.62	**cycles / MWh**	

3.81% fewer cycles per MWh needed with the CO-λ-optimisation

In a measurement campaign conducted over the course of one week during the long-term validation the CO-emissions were measured by a flue gas analyzer (ABB AO2020) and total dust emissions were measured discontinuously according to VDI 2066 . During this measurement campaign the new modular CO-λ-optimization decreased the **CO-emissions on average (median) by -200 mg/m³ (standard conditions, 13 vol.% O2 d.b.), see Fig. 3.**

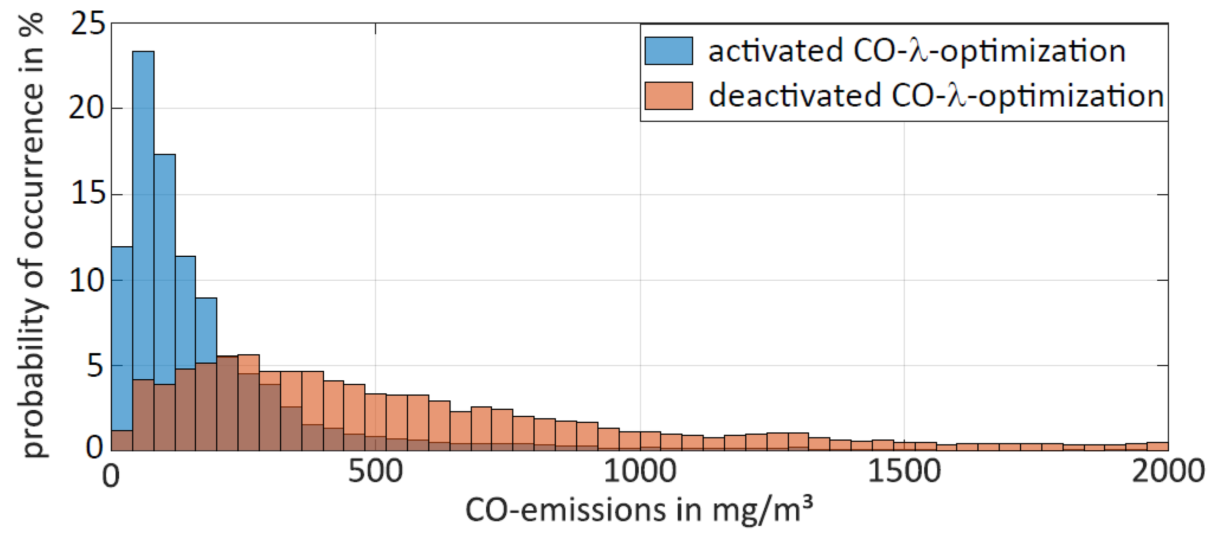

Fig. 3: Distribution of the CO-emissions with activated and deactivated CO-λ-optimization.

The **total dust emissions were reduced on average by -19%** when the CO-λ-optimization was activated during the measurement campaign, see Fig. 4.

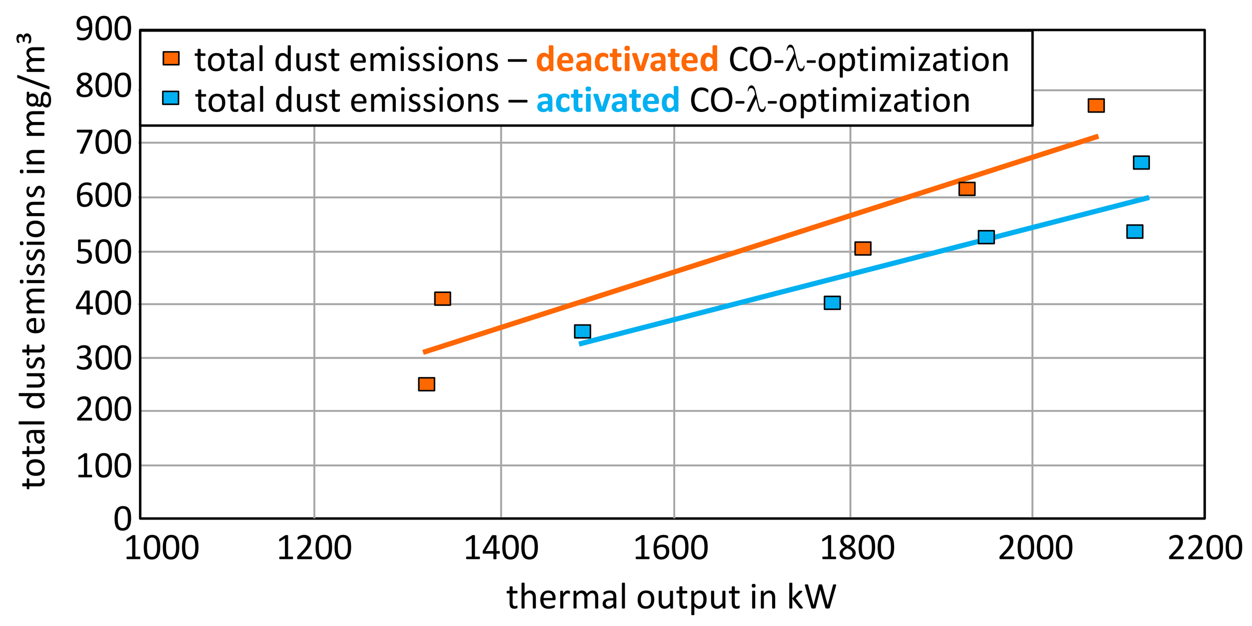

Fig. 4: Total dust emissions with activated and deactivated CO-λ-optimization.

Conclusion

The results clearly demonstrate that the new modular approach for CO-λ-optimization is capable of substantially improving the operational behavior of biomass boilers. It increases the boiler's efficiency while simultaneously decreasing its pollutant emissions. Due to the robust approach and the ability to quickly detect changing CO-λ-characteristics it can easily be implemented at new biomass boilers, enabling a wide-spread application.

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